No. 141, Original

In the

SUPREME COURT OF THE UNITED STATES

STATE OF TEXAS,

Plaintiff,

v.

STATE OF NEW MEXICO and
STATE OF COLORADO,

Defendants.

OFFICE OF THE SPECIAL MASTER

APPENDIX OF EVIDENCE IN SUPPORT OF STATE OF TEXAS'S NOTICE OF MOTION AND MOTION FOR PARTIAL SUMMARY JUDGMENT; MEMORANDUM OF POINTS AND AUTHORITIES IN SUPPORT THEREOF FEDERAL RULE OF CIVIL PROCEDURE 56

Stuart L. Somach, Esq.*
Andrew M. Hitchings, Esq.
Robert B. Hoffman, Esq.
Francis M. Goldsberry II, Esq.
Theresa C. Barfield, Esq.
Sarah A. Klahn, Esq.
Brittany K. Johnson, Esq.
Richard S. Deitchman, Esq.
SOMACH SIMMONS & DUNN, PC
500 Capitol Mall, Suite 1000
Sacramento, CA 95814
Telephone: 916-446-7979
ssomach@somachlaw.com
**Counsel of Record*

APPENDIX OF EVIDENCE

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1	Declaration of Robert Brandes, P.E., Ph.D., and Attachments 1-3	TX_MSJ_000001	TX_MSJ_000016
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3	**Attachment 2:** National Resources Committee, Regional Planning: Part VI-The Rio Grande Joint Investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and Texas 1936-1937, published in February 1938 (JIR)	TX_MSJ_000022	TX_MSJ_000600
4	**Attachment 3:** 2001 Report of the Rio Grande Compact Commission	TX_MSJ_000601	TX_MSJ_000656
5	Declaration of William R. Hutchison, Ph.D., P.E., P.G., and Attachments 1-4	TX_MSJ_000657	TX_MSJ_000669
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9	**Attachment 4:** DataAnn sheet of Excel file named Ferguson Rebuttal_revised 9-15-20	TX_MSJ_000693	TX_MSJ_000695
10	Declaration of Staffan W. Schorr and Attachment 1	TX_MSJ_000696	TX_MSJ_000699
11	**Attachment 1:** Resume	TX_MSJ_000700	TX_MSJ_000703
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17	Exhibit 3 to John D'Antonio Deposition 6/25/2020: Active Water Resources Management in the Lower Rio Grande (8/19/2005)	TX_MSJ_000813	TX_MSJ_000833
18	Deposition Excerpts of John D'Antonio, 6/26/2020	TX_MSJ_000834	TX_MSJ_000853
19	Deposition Excerpts of John D'Antonio, 8/14/2020	TX_MSJ_000854	TX_MSJ_000887
20	Deposition Excerpts of Peggy Barroll, 2/5/2020	TX_MSJ_000888	TX_MSJ_000925
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37	Deposition Excerpts of Adrienne Widmer, 2/5/2019	TX_MSJ_001424	TX_MSJ_001453
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51	Figure 11: Schematic of Rio Grande and Groundwater System Interaction After Development of Groundwater Pumping in Rincon and Mesilla basins	TX_MSJ_001584	TX_MSJ_001584
52	Declaration of Scott Miltenberger, Ph.D., and Attachments 1-2 **Attachment 1:** Resume **Attachment 2:** Library of Documents Referenced in Scott A. Miltenberger Declaration (*Documents in the Library are hyperlinked in footnotes*)	TX_MSJ_001585	TX_MSJ_006491

Dated: November 5, 2020

Respectfully submitted,

s/ Stuart L. Somach

STUART L. SOMACH, ESQ.*
ANDREW M. HITCHINGS, ESQ.
ROBERT B. HOFFMAN, ESQ.
FRANCIS M. GOLDSBERRY II, ESQ.
THERESA C. BARFIELD, ESQ.
SARAH A. KLAHN, ESQ.
BRITTANY K. JOHNSON, ESQ.
RICHARD S. DEITCHMAN, ESQ.
SOMACH SIMMONS & DUNN, PC
500 Capitol Mall, Suite 1000
Sacramento, CA 95814
Telephone: 916-446-7979
ssomach@somachlaw.com

**Counsel of Record*

Tab 34

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

****

ORAL DEPOSITION OF
CHERYL THACKER
APRIL 18, 2019

****

ORAL DEPOSITION of CHERYL THACKER, produced as a witness at the instance of the Plaintiff State of Texas, and duly sworn, was taken in the above-styled and numbered cause on April 18, 2019, from 11:04 a.m. to 3:38 p.m., before Heather L. Garza, CSR, RPR, in and for the State of Texas, recorded by machine shorthand, at the HOTEL ENCANTO DE LAS CRUCES, 705 S. Telshor, Las Cruces, New Mexico, pursuant to the Federal Rules of Civil Procedure and the provisions stated on the record or attached hereto; that the deposition shall be read and signed.

A P P E A R A N C E S

FOR THE PLAINTIFF STATE OF TEXAS:
Ms. Sarah A. Klahn
SOMACH SIMMONS & DUNN
2701 Lawrence Street, Suite 113
Denver, Colorado 80205
(720) 279-7868
sklahn@somachlaw.com

-and-

Mr. Francis M. Goldsberry II
SOMACH SIMMONS & DUNN, PC
500 Capitol Mall, Suite 1000
Sacramento, California 95814
(916) 446-7979
mgoldsberry@somachlaw.com

FOR THE DEFENDANT STATE OF COLORADO:

Mr. Chad Wallace (via telephone)
COLORADO DEPARTMENT OF LAW
1300 Broadway, 7th Floor
Denver, Colorado 80203
(720) 508-6281
chad.wallace@coag.gov

FOR THE DEFENDANT STATE OF NEW MEXICO:

Ms. Lisa M. Thompson
TROUT RALEY
1120 Lincoln Street, Suite 1600
Denver, Colorado 80203
(303) 861-1963
lthompson@troutlaw.com
-and-
Mr. L. Christopher Lindeen
ATTORNEY AT LAW
Post Office Box 2508
Santa Fe, New Mexico 87504

FOR THE UNITED STATES:
Ms. Judith E. Coleman
U.S. Department of Justice
Post Office Box 7611
Washington, DC 20044
(202) 514-3553
judith.coleman@usdoj.gov

-and-

Mr. Christopher B. Rich
U.S. DEPARTMENT OF THE INTERIOR
125 South State Street, Suite 6201
Salt Lake City, Utah 84138
(801) 524-5677

FOR ELEPHANT BUTTE IRRIGATION DISTRICT:
Ms. Samantha R. Barncastle
BARNCASTLE LAW FIRM, LLC
1100 South Main, Suite 20
Las Cruces, New Mexico 88005
(575) 636-2377
samantha@h2o-legal.com

ALSO PRESENT:

Ms. Andrea Mendoza
Mr. Erek Fuchs

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CHERYL THACKER,
having been first duly sworn, testified as follows:
E X A M I N A T I O N
BY MS. KLAHN:
Q. Good morning, Ms. Thacker.
A. Good morning.
Q. My name is Sarah Klahn. I'm here today representing the State of Texas.
A. Hi.
Q. You're here for your deposition. Have you ever had your deposition taken before?
A. I have.
Q. Okay. So you know the rules. Speak audibly. If you don't hear a question, ask me to repeat it. If you don't understand a question, ask me to rephrase it. If you'd like to correct or rephrase an earlier answer, just say so. You'll be allowed to do that. If you need to take a break, just let me know. Of course, you can't take a break if there's a question pending. You may consult with legal counsel, but only after you've answered the questions pending on the table. If you don't know or you don't remember, just say so, but if you do answer a question, I'm going to assume that you believe you do know the answer.
A. Okay.

Q. Do you understand?
A. I do.
Q. Okay. What did you do to prepare for this deposition?
A. Just spoke with our team of attorneys.
Q. Okay. Did you review any documents?
A. I did look at Ryan Serrano's initial deposition.
Q. Okay. Did you look at any other deposition transcripts?
A. I did not.
Q. Okay. Now, you indicated you've been deposed before. Do you remember what cases you've been deposed in?
A. Yes. One was for the City of Sunland Park, an aggrieved permit.
Q. Okay.
A. One was for an application filed by the town of Chamberino.
Q. How do you spell that?
A. C-H-A-M-B-E-R-I-N-O. I think that's right.
Q. Where's that?
A. It is south of Mesilla.
Q. Oh.
A. It's kind of a little town off the beaten

path.
Q. Was that another aggrieved permit?
A. It was a protested application.
Q. Okay. Anything else?
A. There were a couple more, but I don't recall the actual applications, what the deal was. But, of course, the Copper Flat.
Q. Okay. Yeah. And in -- have you ever testified in an administrative hearing?
A. Yes.
Q. Have you ever testified at trial?
A. I have.
Q. Okay. So in an administrative hearing context, that's what my question is limited to right now.
A. Okay.
Q. Did you testify as an expert witness?
A. I did.
Q. Do you remember what areas you were qualified in?
A. Water right administration.
Q. Okay. And the hearings that you were qualified as an expert in, were they the City of Sunland or the town of Chamberino?
A. Actually, it's the City of Sunland Park that

was the hearing.
Q. Oh, okay. All right.
A. And it's Chamberino.
Q. Chamberino. Okay. Sorry.
A. Not that it matters.
Q. Okay. So you were an expert in the City of Sunland Park?
A. The hearing, yes.
Q. Any other hearings that you can recall?
A. Just the trial for the Copper Flat.
Q. Okay.
A. So no other hearings.
Q. Okay. Trial for Copper Flats. Have you ever testified at a hearing or at trial when you were not qualified as an expert witness?
A. No.
Q. Would you take a look at Exhibit 111, and this is the State of New Mexico's initial disclosures, which as I explained during Mr. Hangen's deposition, is a document that parties in a lawsuit have to disclose information to people and documents initially early in the litigation, so people -- folks have a chance to exchange information. If you'd turn to Page 4 -- or 5, sorry, Page 5, you'll see that your name is listed in the middle of the page, Cheryl Thacker, LRG

basin supervisor. Is that you?
A. That is.
Q. Okay. Water resource allocation program water rights division. Is that your program, as well?
A. That's correct.
Q. And then in the right-hand column, it lists you as someone knowledgeable in water rights and administration. Would you agree with that?
A. Yes.
Q. Did you know that you'd been listed in this document?
A. No.
Q. That's why you're here. Have you had any conversations with individuals from the State of New Mexico who are not legal counsel involved in this lawsuit about potentially being a witness in this case?
A. Not legal counsel, you say?
Q. Uh-huh.
A. I think just speaking with my supervisor, Andrea Mendoza, and just more housekeeping, when -- when we're going and just kind of casual conversation.
Q. When you're going where?
A. Oh, for the depositions.
Q. Oh, okay.

A. Yes.
Q. But, I mean, as far as in the future, if there's a trial in this case, has there been any discussion about you being a witness in a -- in a trial in this case, Texas versus New Mexico?
A. No.
MS. THOMPSON: I'll object just to privilege. So you can answer to the extent you haven't either had those discussions or been directed by legal counsel.
MS. KLAHN: My apologies.
MS. THOMPSON: Just to be clear.
MS. KLAHN: I intended it to be limited to discussions not involving lawyers.
MS. THOMPSON: Absolutely.
A. No. It's always been with attorneys.
Q. (BY MS. KLAHN) Okay. What is your educational background?
A. I have a bachelor's degree in metallurgical engineering from Montana Tech in Butte, Montana.
Q. Any graduate work?
A. No.
Q. How long have you been with the Office of the State Engineer?
A. 16-and-a-half years.

Q. When did you get your metallurgical engineering degree?
A. May of 1992.
Q. So after your degree and before you came to work for the Office of the State Engineer, what was your professional employment history?
A. I worked from '95 to -- pardon me, from '92 to '95, as a process engineer for a copper smelter in Silver City, New Mexico, and then from '95 to '97, I was a -- also a metallurgical engineer -- engineer at -- it's Stillwater Mine. It's a platinum smelter in Columbus, Montana.
Q. Okay.
A. And then from '98 to 2000, I was a metallurgical engineer at the solvent extraction electrowinning plant.
Q. How do you spell that?
A. E-L-E-T-R-O-W-I-N-N-I-N-G.
Q. Winning?
A. Yes.
Q. Electrowinning?
A. Yes.
Q. Like, winning the lottery?
A. If you're into copper, it is.
Q. Okay. And then after 2000?

is the WRAB, water --

Q. Database?

A. Correct. And what they do is they input it. So we've got that placeholder that I mentioned this waters, just tells us, okay, that's the application. Then once we take our action, that information will be completed, entered into the waters database, and imaged so when you go on the waters database now, you can see the application, see the permit as aware of the conditions and all the evaluation that's been taken.

Q. So does the waters database entry happen in your office, too?

A. It's -- it is in our office. It's -- it's all one big building, but their office is kind of a suite down the --

Q. Okay.

A. -- down the hall.

Q. As a data entry staff?

A. That's correct. Yes.

Q. Okay. Does every district under the OSE have its own data entry staff for waters?

A. I don't know. The only thing I do know is there's a WRA B waters group in Albuquerque. Who they handle, I don't know.

Q. Okay.
A. Yeah.
Q. Okay. So you mentioned a step in the buckslip where the water resource specialist, I think you said will write -- write a review is the -- is the term you used. What do you mean by that? They write a review of what was asked -- what was requested by the applicant?
A. That's correct, actually. It's formally called a memorandum of recommendation, and so what they'll do is summarize what the applicant is requesting, all the elements of the water right, for instance, the point of diversion, the locations, if we're talking about an irrigation water right, the place of use, and so that's delineated, and then what's proposed, if it's a replacement well, for instance, and then through -- through the discussion in the -- the memorandum of recommendation, they establish whether there's a water right or the extent of the water rights. They talk about the hydrographic survey, and then eventually, they make a recommendation saying, yes, the water right is valid, I recommend that this point of diversion be -- or application to change location of well, for instance, be approved, and then there's the conditions of

approval that are attached to that recommending the point of diversion, the place of use that's approved, and all other conditions attached to that, and that attached to the application makes it a permit.

Q. I see. Okay.

MS. KLAHN: Could we have Exhibit 69?

THE REPORTER: Uh-huh.

Q. (BY MS. KLAHN) So this is Exhibit 69, which was marked in Mr. Serrano's first day of his deposition. It's Mesilla Valley Administrative Area Guidelines For Review of Water Right Applications. Have you seen these guidelines before?

A. Uh-huh.

Q. I figured you had. Just take a look at it and make sure it's complete. I believe it is, but just take a look and make sure.

A. It looks like it, and the weight of the document seems to confirm that.

Q. Okay. So generally -- I have some questions about these guidelines, but so generally, can you describe -- let's stick with the hypothetical example we were talking about in change of place of diversion for a well. How did these guidelines play into your evaluation of an application? Let's say Ms. Mendoza has referred it to you because it's more complicated.

How does this play into your evaluation?
A. These set the guidelines for local impairment, and -- as well as surface water depletion impairment and the parameters that we can use whether to approve or deny an application.
Q. Okay. So do you find yourself consulting these frequently?
A. I do.
Q. Okay. Well, I want to ask you some questions about how you use them. So let's turn first to Page 2. There's a Paragraph A1. In the first sentence of Paragraph A1 starts, "The Rio Grande stream system is fully allocated and existing rights may not be impaired by proposed appropriations." In your work as -- in your work when you're evaluating a permit application, what does that phrase "fully allocated" mean to you?
A. There's no available water for someone to file a new appropriation for -- that hasn't occurred historically.
Q. Okay. So no -- no -- no new water would be -- no water would be available for a new appropriation?
A. Correct.
Q. Okay. So is that one of the things you look

at is to be sure that a permit to change the location of well isn't sort of a new appropriation masquerading as a change?

A. Absolutely.

Q. Okay.

A. Yes.

Q. What -- what indications would you have that a permit is, in fact, just a change in location -- or, I'm sorry, an application is just a change in location?

A. Change location of well is what you're referring to?

Q. Yes.

A. Okay. Well, we would look at the place of use proposed in the application and determine whether that place of use has been recorded in a declaration, for instance. There's evidence that that place of use has been irrigated in irrigation circumstance prior to the closing of the basin. So it's historically been used, and it's not an area where there's never been a water right attached to the land.

Q. Okay. It's not an area where there's never been a water right attached to the land?

A. Correct.

Q. Okay. So you are looking for a declaration

that the parcel they want to move the well to has been irrigated?

A. Yes. That's correct.

Q. Okay. Even if it was irrigated by something other than the well that they want to move the -- move to that parcel?

A. Well, let me back up. We -- often, a parcel that's in question on the application has been historically irrigated by an off-property well.

Q. Okay.

A. And so, for instance, if that well was drilled in the '50s and has gone defunct or the owner of the property that the well sits on refuses to allow the new -- the other owner access to that well, what'll happen is typically the owner who's filing the application will -- will try -- will ask to change location of well from the POD -- off-property POD to a POD to be drilled on his property. So they have to establish or we have to have record that that piece that is in question has been historically irrigated from an off-property -- off-property well prior to the closing of the basin.

Q. Okay. So in the -- in the circumstance you just described, how do you ensure that the off-property well owner doesn't continue to use the

well for different parcel? I mean, your -- in your setup, you said the off-property -- off-property well owner won't allow the applicant access. Okay. So the applicant comes in and says, "I want to get -- I want to move that well over to my property." But what about the off-property well owner, how do you make sure he doesn't continue to use that well?

A. Okay. So let's say there's a 20-acre parcel that was irrigated by this off-property well. Five acres has been purchased by the new applicant. When we file -- they file that application and we issue a permit, let's say, for that full 5 acres, what happens is we -- in the database, the waters database, that 5 acres is pulled out of the original water right file, and we give a new water right file for that new 5 acres.

Q. I see.

A. It's not new but --

Q. Yes.

A. -- it's broken out.

Q. New owner?

A. Correct. And so essentially, instead of the original off-property water right being a full 20 acres, we'll give that 15 acres, and then the -- the 5 will be attributed to a separate water right file. So

it's kind of being counting, for lack of better words, so just balancing.

Q. And then, I guess, when that -- when that permit, in -- in the example that we're describing, when that permit gets issued then that would be put into the new owner of the five acres adjudication sub file?

A. Possibly. How the adjudication handles that, I'm not sure at this point.

Q. I mean, isn't it possible the new acre -- the new owner of the five acres might not even have an adjudication sub file? Is that possible? Because the well he wants to drill doesn't exist at the time of the hydrographic survey.

A. Right. Probably what occurs will be the full 20 acres that I referred to will have been identified by the original hydrographic survey under one sub file. We, in administration, will take that five acres out and leave the rest as 15. Now, when the adjudication group, when they divide that, I don't know when they'll do that, but --

Q. Okay.

A. Yeah.

Q. Okay. So let's turn now to Page 6. So on Page 6, Paragraph 4 is option to lease off-site --

offset rights for appropriations outside of HIA. Have you had occasion to use the policy that's in Paragraph 4?

A. Would you mind if I read it?

Q. Please.

A. Okay. I've never used that.

Q. Okay. Well, let's turn -- flip back a page to Page 5 and just look at Paragraph 2.

A. Okay.

Q. So Paragraph 2 is, "Applications required for offset." Have you used that paragraph? And please review it.

A. I've never used this language specifically because it's confusing to me.

Q. Have you dealt with offsets?

A. What do you mean by "offsets"?

Q. Well, let's turn back one more page to Page 4. Offset of surface water impacts.

A. Okay.

Q. Then take a look at Paragraph 1 on Page 4.

A. Yes, I have.

MS. KLAHN: Judy do you want a --

MS. COLEMAN: Oh, yes, thank you.

Q. (BY MS. KLAHN) Okay. Tell me a little bit about the -- an application you may have processed

that involved an offset.
A. The first really foray into that was it's LRG 3150. There's a BDEFFA and a whole bunch of them, and how much detail do you want in this, because there's a whole --
Q. Go for it.
A. -- whole lot of -- oh, goodness.
Q. I only get to talk to you once.
A. Okay. Well, an application to change location of well or supplement a well, I don't recall which, but -- but it was a new well, was filed and approved after some hearing and a whole bunch of legal gyrations, but essentially requiring offsets for that amount of water that had not put -- been put to beneficial use up to the declared amount. So --
Q. Okay.
A. -- yeah.
Q. Okay. So there was a -- a declared amount, we'll say a hundred -- make it up, hundred acre feet?
A. Uh-huh.
Q. And there was a determination that they hadn't actually beneficially used the hundred acre feet?
A. Correct.
Q. Okay. And so what was the offset amount

related to that then?
A. Well, it would depend on historically what they actually had put -- put to beneficial use. For instance, in your example, a hundred acre feet is what they had declared, but historically, they'd only put 25 acre feet to beneficial use. So what we did is permitted it such that they could continue -- continue to use that 25 acre feet, and they could continue to -- I hate to use the word develop, but pump up to a hundred, but that 75 -- that difference between the 25 and the hundred, they had to offset with either effluent return flows or discharge credit is really the way I'd like to characterize it or with actual surface water replacement.
Q. Okay. What was the applicant's name?
A. This was Charles Crowder, the original Charles Crowder.
Q. Okay.
A. And that water right has been bounced around a lot of different owners.
Q. And you say there was a hearing about -- to establish all of the boundaries around what this --
A. You know, I -- I may have misspoke -- spoken. I know there were -- there was legal gyrations, but I don't know what hearing, what sort of thing. It was

filed -- I think the final -- what they call supplemental findings that was attached to 3150S-18. So all this stuff occurred, and then finally what we call supplemental findings, and in those findings were kind of a blueprint saying, okay, this is how -- not a blueprint, but this is how we're going to require offsets. And so we've used that essentially for similar applications since that time.

Q. Okay. So that's kind of become your template if you have an application that needs offsets?

A. That's correct.

Q. Okay.

A. That's right.

Q. Okay. And when you -- when you -- when you're dealing with an application that requires offsets, are you -- I think the term you used was discharge credits?

A. That's right.

Q. Is that likely to be effluent?

A. Yes. That's correct.

Q. Okay. So where would a non-municipal water right applicant get a discharge credit? Do they make a deal with a municipality or something?

A. What do you mean by non --

Q. Well, I mean, Charles Crowder is not a city.

A. Oh, I see. Okay. I gotcha.
Q. So how do you -- I mean, how do they establish that they have -- that -- how does the applicant establish we have these offsets, we have these discharge credits, we are -- you know, we can make sure that they're going to go where they're supposed to go, when they're supposed to go there?
A. Okay. Surface water replacement is just not available right now. There's no mechanism for us to -- for them to provide that, but in the case of the Crowder water right, what they use is the discharge credit effluent from, I think it's the Santa Theresa or the City of Sunland Park Wastewater Treatment Plant. So that's where -- and they give us accounting the amount that's being returned to the river, discharge credits to the river. So that's how we work it.
Q. Is the place of use for the Crowder water rights inside the city of Sunland Park?
A. Yes.
Q. Okay. So it's actually water that's being consumed or beneficially used inside the service area and then generating effluent as a result of that beneficial use?
A. That's correct.

Q. Okay.
A. The Crowder water right has many different kind of entities that have all been purchased virtually under the Camino Real regional utility authority.
Q. Okay.
A. So it's, oh, gosh, 24,000, 29,000 acres, just this huge area where --
Q. Is that up northeast?
A. Actually, it's down -- I don't know if you know where Pete Domenici Highway is?
Q. Yeah.
A. That goes to the Mexico border, and all that area, it's the Borderplex. I don't know if you're familiar with that.
Q. Okay.
A. And the Union Pacific, all that area.
Q. Okay. Have you had any other water right applications that would require offsets in the city of Sunland Park service area?
A. Well, it's -- it would be the city of Sunland Park, but that whole --
Q. That --
A. Right. The whole Crowder place of use, as it were. I call it CRRUA now that Camino Real --

THE REPORTER: You call it what?
THE WITNESS: CRRUA, which stands for Camino Real Regional Utility Authority. I always have to think about that.
Q. (BY MS. KLAHN) It's the two R's.
A. That's right.
Q. So inside CRRUA have you had other -- what I'm getting at is you say you get accounting to reflect the offsets on the 3150 application?
A. Yes.
Q. If there are others who also develop or do a change in water right that also requires an offset, I'm just wondering how you're tracking the quantity of effluent to make sure that nothing is getting double counted for offset --
A. Right.
Q. -- purposes.
A. So far the -- the CRRUA water right is the -- is the only entity that's using discharge credits from the city of Sunland Park.
Q. Okay. Okay.
A. But to answer your question further, I think we require them to tell us how much of the effluent that they claim and they're allowed to use.
Q. Okay. Do you sort of have a formula so you

know how much -- whether that effluent is really effluent they can claim?

A. Yes.

Q. Okay. What kind of formula is that?

A. It's not really a formula. It's a -- it's a spreadsheet we use. And then I think the water master enters something into the waters database, but that's outside of my expertise. However, I keep a -- a spreadsheet, and I get those readings from the Camino Real, the CRRUA group now, and so just to verify that they're not double accounting and that they're following what they need to follow. I've been dealing with this CRRUA for years and years, so it's kind of my baby.

Q. Where does the discharge of effluent come into the Rio Grande or does it?

A. It does.

Q. At Sunland Park?

A. Well, exactly where it is, I couldn't give you a lat long, but generally --

Q. South of Mesilla?

A. Oh, yes. Yes. It's near Sunland Park. Exactly where, I don't know. But that effluent, the -- the water is actually dumped into the river.

Q. So we've talked about Paragraph 1, Page 4,

WITNESS CORRECTIONS AND SIGNATURE

Please indicate changes on this sheet of paper, giving the change, page number, line number and reason for the change. Please sign each page of changes.

PAGE/LINE	CORRECTION	REASON FOR CHANGE
12/7:8	"Bayard" not "Bay Area"	
19/9	"As well as" not "as aware as"	
26/1	"being" should be "bean"	
28/3	"BDEFFA" should be LRG-3150-B, LRG-3150-F, LRG-3150-E, LRG-3150-F and LRG-3150-FA."	Changed for clarification
68/18:19	"73513" should be "~~7351-3~~" "7351 dash 3"; "73514" should be "7351 dash 4"	
82/4	"LRN03 dash 0013" and not "LRN-03 without the parenthesis"	
82/10	"LRN03 dash 0013" and not "LRN-03-0013"	
83/12	"LRN03 dash 0013" and not "LRN-03-0013"	
88/13	"depletions" not "solutions."	

CHERYL THACKER

S I G N A T U R E O F W I T N E S S

I, CHERYL THACKER, solemnly swear or affirm under the pains and penalties of perjury that the foregoing pages contain a true and correct transcript of the testimony given by me at the time and place stated with the corrections, if any, and the reasons therefor noted on the foregoing correction page(s).

CHERYL THACKER

Job No. TX 3269302

State of New Mexico
County of Dona Ana
This instrument was acknowledged before me this 4th day of ~~May~~ June 2019 A.D., 2019, ~~by (name of witness)~~:

OFFICIAL SEAL
SYLVANA GARAY
NOTARY PUBLIC - STATE OF NEW MEXICO
My commission expires: 3/8/2023

Notary Public: Sylvana Garay
My commission expires: 3/8/2023

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

THE STATE OF TEXAS :
COUNTY OF HARRIS :

I, HEATHER L. GARZA, a Certified Shorthand Reporter in and for the State of Texas, do hereby certify that the facts as stated by me in the caption hereto are true; that the above and foregoing answers of the witness, CHERYL THACKER, to the interrogatories as indicated were made before me by the said witness after being first duly sworn to testify the truth, and same were reduced to typewriting under my direction; that the above and foregoing deposition as set forth in typewriting is a full, true, and correct transcript of the proceedings had at the time of taking of said deposition.

I further certify that I am not, in any capacity, a regular employee of the party in whose

behalf this deposition is taken, nor in the regular employ of this attorney; and I certify that I am not interested in the cause, nor of kin or counsel to either of the parties.

That the amount of time used by each party at the deposition is as follows:

MS. KLAHN - 02:14:51
MS. THOMPSON - 00:00:00
MS. COLEMAN - 00:17:08
MR. WALLACE - 00:00:00

GIVEN UNDER MY HAND AND SEAL OF OFFICE, on this, the 3rd day of May, 2019.

HEATHER L. GARZA, CSR, RPR, CRR
Certification No.: 8262
Expiration Date: 12-31-19
VERITEXT LEGAL SOLUTIONS
Firm Registration No. 571
300 Throckmorton Street, Suite 1600
Fort Worth, TX 76102
1-800-336-4000

Tab 35

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

****

REMOTE ORAL AND VIDEOTAPED DEPOSITION OF
CHERYL THACKER
SEPTEMBER 18, 2020

****

REMOTE ORAL AND VIDEOTAPED DEPOSITION of CHERYL THACKER, produced as a witness at the instance of the United States, and duly sworn, was taken in the above-styled and numbered cause on September 18, 2020, from 1:33 p.m. to 4:42 p.m., before Heather L. Garza, CSR, RPR, in and for the State of Texas, recorded by machine shorthand, remotely at the offices of HEATHER L. GARZA, CSR, RPR, The Woodlands, Texas, pursuant to the Federal Rules of Civil Procedure and the provisions stated on the record or attached hereto; that the deposition shall be read and signed.

1 R E M O T E A P P E A R A N C E S
2
3 FOR THE PLAINTIFF STATE OF TEXAS:
4 Ms. Sarah A. Klahn
SOMACH SIMMONS & DUNN
5 2701 Lawrence Street, Suite 113
Denver, Colorado 80205
6 (720) 279-7868
sklahn@somachlaw.com
7
-and-
8
Mr. Stuart L. Somach
9 Ms. Theresa C. Barfield
Mr. Francis Goldsberry II
10 SOMACH SIMMONS & DUNN
500 Capitol Mall, Suite 1000
11 Sacramento, California 95814
(916) 446-7979
12 ssomach@somachlaw.com
tbarfield@somachlaw.com
13 mgoldsberry@somachlaw.com
14
FOR THE DEFENDANT STATE OF NEW MEXICO:
15
Mr. Jeffrey Wechsler
16 MONTGOMERY & ANDREWS
325 Paseo De Peralta
17 Santa Fe, New Mexico 87501
(505) 986-2637
18 jwechsler@montand.com
19 -and-
20 Mr. Luis Robles
Ms. Susan Barela
21 ROBLES, RAEL & ANAYA, P.C.
500 Marquette Avenue NW, Suite 700
22 Albuquerque, New Mexico 87102
(505) 242-2228
23 luis@roblesrael.com
susan@roblesrael.com
24
25

FOR THE DEFENDANT STATE OF COLORADO:
Mr. Chad Wallace
Mr. Preston V. Hartman
COLORADO DEPARTMENT OF LAW
1300 Broadway, 7th Floor
Denver, Colorado 80203
(720) 508-6281
chad.wallace@coag.gov
preston.hartman@coag.gov

FOR THE UNITED STATES:
Mr. R. Lee Leininger
Mr. James J. Dubois
U.S. DEPARTMENT OF JUSTICE
999 18th Street, Suite 370
Denver, Colorado 80202
(303) 844-1364
lee.leininger@usdoj.gov
james.dubois@usdoj.gov

-and-

Ms. Judith E. Coleman
U.S. Department of Justice
Post Office Box 7611
Washington, DC 20044
(202) 514-3553
judith.coleman@usdoj.gov
-and-
Ms. Shelly Randel
U.S. DEPARTMENT OF THE INTERIOR
1849 C Street NW
Washington, DC 20240
(202) 208-5432
shelly.randel@sol.doi.gov

-and-

Mr. Christopher B. Rich
U.S. DEPARTMENT OF THE INTERIOR
125 South State Street, Suite 6201
Salt Lake City, Utah 84138
(801) 524-5677

FOR THE EL PASO COUNTY WATER AND IMPROVEMENT DISTRICT NO. 1:

Ms. Maria O'Brien
MODRALL SPERLING ROEHL HARRIS & SISK, P.A.
500 Fourth Street N.W.
Albuquerque, New Mexico 87103
(505) 848-1800
mobrien@modrall.com
-and-
Mr. Renea Hicks
LAW OFFICE OF MAX RENEA HICKS
Post Office Box 303187
Austin, Texas 78703
(512) 480-8231
rhicks@renea-hicks.com

FOR THE ELEPHANT BUTTE IRRIGATION DISTRICT:

Ms. Samantha R. Barncastle
BARNCASTLE LAW FIRM, LLC
1100 South Main, Suite 20
Las Cruces, New Mexico 88005
(575) 636-2377
samantha@h2o-legal.com

FOR THE ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY AND CITY OF LAS CRUCES:

Mr. James C. Brockmann
STEIN & BROCKMANN, P.A.
Post Office Box 2067
Santa Fe, New Mexico 87504
(505) 983-3880
jcbrockmann@newmexicowaterlaw.com

FOR THE CITY OF EL PASO:

Mr. Douglas G. Caroom
BICKERSTAFF HEATH DELGADO ACOSTA, LLP
3711 S. MoPac Expressway Building One, Suite 300
Austin, Texas 78746
(512) 472-8021
dcaroom@bickerstaff.com

FOR THE NEW MEXICO PECAN GROWERS:
Ms. Tessa T. Davidson
DAVIDSON LAW FIRM, LLC
4206 Corrales Road
Post Office Box 2240
Corrales, New Mexico 87048
(505) 792-3636
ttd@tessadavidson.com

FOR THE NEW MEXICO STATE UNIVERSITY:

Mr. John W. Utton
UTTON & KERY, P.A.
Post Office Box 2386
Santa Fe, New Mexico 87504
(505) 699-1445
john@uttonkery.com

VIDEOGRAPHER:

Ms. Kayla Brown

ALSO PRESENT:
Shelly Dalrymple
Kari Olson
Al Blair
Greg Ridgley
John D'Antonio
Robin Cypher
Gary Esslinger
Erek Fuchs
Estevan Lopez
Daniel Ortiz
Arianne Singer

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THE VIDEOGRAPHER: The time is 1:33 p.m. We're on the record.

CHERYL THACKER,

having been first duly sworn, testified as follows:

E X A M I N A T I O N

BY MR. LEININGER:

Q. Will you please state your full name for the record?

A. Yes. It's Cheryl S. Thacker.

Q. Good afternoon. My name is Lee Leininger. I'm an attorney with the U.S. Department of Justice. I'm going to be starting this deposition today. I think I'll be followed by Ms. Klahn and then perhaps Ms. O'Brien, and there may be one or two others. Okay?

A. Okay.

Q. You've had your -- you've had your deposition taken many times before; is that correct?

A. Yes, sir.

Q. And so you understand the ground rules. I will just briefly go over those. Were you in attendance this morning when Mr. Dubois was beginning this deposition with Mr. Lopez?

A. Yes.

Q. All right. So he ran over some ground rules.

I'll just reiterate a few. In at any time you don't understand one of my questions in whole or in part, let me know, please. I'll explain it and rephrase the question. If you answer my question without asking for an explanation, I'll take it you mean you understand what I'm asking. Okay?

A. Okay.

Q. And I'm -- yeah, you'll have to give an audible yes or no to these questions. If there are times today in the middle of one of my questions, you feel like you already know the answer, please let me finish the question. It's important to keep the transcript clean and so please wait until I finish asking the question before you answer. Okay?

A. Okay.

Q. And same way -- same token, if I interrupt you and you had not completed your answer to one of my questions, please let me know so we can have a full answer to your question. Okay?

A. Okay.

Q. From time to time, and I'm sure you know this but Mr. Wechsler who's representing you this afternoon may object to one of my questions, but unless he instructs you not to answer, you're expected to answer the question. Do you understand that?

A. Yes.

Q. Without giving me any specific personal information, is there any mental or physical reason why you're not able to give an accurate and truthful answer to my questions today?

A. No.

Q. Are there any medications that may impair your ability to fully and accurately answer my questions today?

A. No.

Q. And most importantly, we've been taking breaks about every hour so it's about 1:30 right now. If -- you may ask to take a break at any time, but typically we'll go about an hour, so it'll be about 2:30, and we'll break then. Okay?

A. Okay.

Q. Great. So did you receive a copy of the United States notice, 30(b)(6) notice for the State of New Mexico?

MS. KLAHN: Lee, you might want to take appearances at some point.

MR. LEININGER: I apologize. We took appearances this morning, but we have a new witness so let's do that again. So for the United States, we have -- in addition to me, we have Mr. Dubois and Ms.

1 Coleman at the U.S. Department of Justice. With the
2 Department of Interior, we have Chris Rich and Shelly
3 Randel, and if I'm missing anyone else for the U.S.
4 Department -- for the United States, please speak up
5 now. All right. Let's continue with appearances for
6 Texas.
7 **MS. KLAHN:** Sarah Klahn on behalf of the
8 State of Texas, and appearing with me looks like Mac
9 Goldsberry, Stuart Somach, Theresa Barfield, and I
10 think that's all from our office.
11 **MR. LEININGER:** Colorado?
12 **MR. WALLACE:** Good afternoon. This is
13 Chad Wallace for the State of Colorado. Preston
14 Hartman is also participating.
15 **MR. LEININGER:** And let's go to amici.
16 El Paso County Water Improvement District No. 1?
17 **MS. O'BRIEN:** Good afternoon. Maria
18 O'Brien for El Paso County Water Improvement District
19 No. 1. Also on is Renea Hicks and Dr. Al Blair.
20 **MR. LEININGER:** I apologize, Jeff. I
21 didn't get -- I should have gone to you first.
22 **MR. WECHSLER:** No problem. Jeff
23 Wechsler for the State of New Mexico. We've got
24 Estevan Lopez, John D'Antonio, Shelly Dalrymple, Greg
25 Ridgley, Kari Olson, Susan Barela, and Luis Robles.

MR. LEININGER: EBID?

MS. BARNCASTLE: Good afternoon. Samantha Barncastle for EBID, and with me this afternoon will be Gary Esslinger, manager of the district, and Dr. Erek Fuchs.

MR. LEININGER: NMSU?

MR. UTTON: Good afternoon, Lee, this is John Utton representing NMSU.

MR. LEININGER: Hi, John. Pecan growers? I guess Tessa dropped off for the time, pecan growers?

MR. DUBOIS: It looks like she's on but muted.

MR. LEININGER: Tessa, I do see you're on, but you're muted.

Okay. Let's -- let's keep going. We will return. City of El Paso?

MR. CAROOM: Doug Caroom for the City of El Paso, and Daniel Ortiz is on, also.

MR. LEININGER: City of Las Cruces?

MR. BROCKMANN: This is Jim Brockmann on behalf of both Las Cruces and the Albuquerque Bernalillo County Water Utility Authority.

MR. LEININGER: And anyone I've missed, please speak up now.

1 **MR. WECHSLER:** Lee, I missed Arianne
2 Singer earlier so my apologies to her.
3 **MR. LEININGER:** Okay. Anyone else?
4 (No response.)
5 **Q. (BY MR. LEININGER) All right. Let's -- Ms.**
6 **Thacker, let's start then with a question. You were**
7 **identified in New Mexico's response to our 30(b)(6)**
8 **and New Mexico's witness designations of our notice of**
9 **30(b)(6) for specific topics, designated to answer**
10 **specific topics. Are you aware of that?**
11 A. Yes.
12 **Q. Okay. And it's United States Topic C is one**
13 **of them, and I'll just read what the United States**
14 **Topic C is. "New Mexico's administration,**
15 **implementation, and enforcement of its obligations of**
16 **the Compact and under state laws, regulations,**
17 **policies, or actions in, 1, delivery of Rio Grande**
18 **Compact water to the State of New Mexico; 2, delivery**
19 **of Rio Grande Compact water to the State of Texas;**
20 **and, 3, water released from storage meet Compact**
21 **irrigation demands below Elephant Butte reservoir ."**
22 **You were identified as the 30(b)(6) deponent for the**
23 **State of New Mexico to answer questions related to**
24 **that topic. Is that your understanding?**
25 A. Yes.

MR. WECHSLER: Well, and to be clear, Lee, we separated that one topic out between Mr. Lopez and Ms. Thacker. So Ms. Thacker is handling the state laws, regulations, and policies part of that subject.

MR. LEININGER: Okay. Very well.

Q. (BY MR. LEININGER) In the course of this questioning, correct me if I'm asking questions to which you were not -- let's start with -- I'm curious in your role as water resources manager for New Mexico Office of the State Engineer, what your actions and responsibilities are with topics -- with this related topic matter. So let's start with how does -- how does New Mexico ensure it's delivered the amount of water it's entitled to?

A. Oh, I would defer to Rolf Schmidt-Petersen and to Estevan Lopez specific to that question.

Q. All right. So your involvement isn't with regard to tracking or accounting or measuring of water in the Rio Grande that New Mexico as part of its Compact entitlement?

A. As part of the Compact entitlement, I don't have any part in that.

Q. Okay. So let's just test your knowledge here a little bit. Just a reminder that this 30(b)(6) notice is for you to answer questions we have on

behalf of the State of New Mexico, so as I understood with the caveat by Mr. Wechsler, you were identified to answer some of these questions with regard to the Compact and New Mexico's administration enforcement and implementation of its obligations under the Compact. So let's continue here, but if you're at a point where you are going to define the limits of your testimony, I would appreciate it if you'd just let us know sooner rather than later as I go through these questions. Okay?

MR. WECHSLER: Well, and I'm happy to be -- to help with that, Lee, now, if you'd like.

MR. LEININGER: Sure, Jeff. I mean, these questions with regard to administration and enforcement of obligations under the Compact are going to be limited to what the OSE actually does in terms of its accounting policies for purposes of the Compact and delivery of Rio Grande project water under the Compact. Okay?

MR. WECHSLER: Yeah. So -- so any issues that go to the purposes, the function, the accounting under the Compact, in our designation, that's what we listed Mr. Lopez for, and what Ms. Thacker is familiar with are the -- the state laws, the regulations, the policies that have to do with

state law -- state water administration. Separate and apart from the Compact, but obviously as you heard from Mr. Lopez this morning, they're related. So if you have specific questions about what it is the state engineer is doing down there with regard to their laws, regulations, policies, water administration, Ms. Thacker is the person for that.

Q. (BY MR. LEININGER) Okay. Ms. Thacker, how does the -- the state engineer account for the water that it is entitled to -- the Rio Grande water it is entitled to under the Compact?

A. I don't know how a state engineer accounts for the water under the Compact.

Q. Are you aware of how the water from -- that it's delivered from Colorado to New Mexico?

(Audio/technical difficulties.)

MR. LEININGER: I apologize. I cannot hear you. It appears the microphone is not working again. Did anyone else hear that?

MR. WECHSLER: No.

THE VIDEOGRAPHER: Yeah, I didn't hear her. Do you want to go off the record?

MR. LEININGER: Sure.

THE VIDEOGRAPHER: The time is 1:48 p.m. We're off the record.

(Break.)

THE VIDEOGRAPHER: The time is 1:49 p.m. We're on the record.

Q. (BY MR. LEININGER) Okay. Let's test this. Ms. Thacker, can you hear me?

A. Yeah. If you could speak up just a bit.

Q. Sure. I'll try. And we can hear you. That's -- that's the important part. So let's continue with these questions. The Compact is also state law, is it not?

A. You know, again, my knowledge of the Compact is limited.

Q. Do you know if in carrying out your duties as a water resources manager for the New Mexico Office of State Engineer, you must comply with the Compact?

A. Well, I -- I'm not sure about that, but I know I have to comply with the constitution of New Mexico as well as statutes and regulations.

Q. Okay. And one of those statutes is the Rio Grande Compact, correct?

A. Again, I -- my knowledge of the Compact is so limited, I can't speak to that.

Q. If at any time during these questions, you're going to defer to Mr. Lopez or Mr. Schmidt-Petersen, let -- let me know, and specifically let me know which

one you think is appropriate to answer these questions. Okay?

Do you know where -- and I think this is my last question. Do you know where measurement of New Mexico's entitlement to Rio Grande water coming from the State of Colorado takes place?

A. I do not -- again, my knowledge is limited, and I don't use that information for the work I do here.

Q. And who would be knowledgeable of the three -- three other deponents that have been designated?

A. You know, I'm -- I'm not sure. I would say probably Estevan and Rolf Schmidt-Petersen.

MR. WECHSLER: It is Mr. Lopez that we designated for those subjects.

Q. (BY MR. LEININGER) Well, it appears that she was designated for Topic -- Topic C without the specific caveat so let's keep going. Where does New Mexico measure the amount of water for delivery to Texas under the Compact?

A. I don't know. I don't know the answer to that.

MR. WECHSLER: Yeah. And, again, I'll object to the whole line of questioning as outside the scope. In our designation on Topic C, we listed both

Mr. Lopez and Ms. Thacker, and, again, Ms. Thacker is really only here and designated to talk about state law, regulations, and policies with the administration of water in the LRG.

MR. LEININGER: Okay. Well, these questions were designated as both Ms. Thacker and Mr. Lopez, so we may need to bring Mr. Lopez back to answer some of these with specificity. But let's -- let's continue.

Q. (BY MR. LEININGER) This may be more in your wheelhouse, Ms. Thacker. Does New Mexico do any measurement at the border with Texas of the amount of water that actually makes its way -- surface water in the Rio Grande that actually makes its way to Texas?

A. Again, I don't have any knowledge of that. I don't know.

Q. Okay. This is not a Compact question. This is just a question of actual -- your awareness of whether or not there's any measurement of how much water actually gets to Texas?

A. I suspect there is, but I couldn't give you any specifics on it.

Q. All right. Who in the Office of the State Engineer may be aware of whether or not the state actually makes its measurements of physical delivery

of the surface water at the border of Texas?

A. Well, again, I would defer to Estevan Lopez and Rolf Schmidt-Petersen.

Q. You were listening to Mr. Lopez's deposition this morning?

A. I did.

Q. Do you recall he made a statement about how Texas is apportioned 43 percent of surface water after whatever is left of exercise of groundwater pumping in both states? Do you recall his answer along those lines?

A. I don't recall his answer. Again, I don't use any of that information in my day-to-day work.

Q. Do you have any knowledge of New Mexico actually measuring a 43 percent of surface water supply to Texas after the exercise of groundwater pumping in both states? Is there anything done by the Office of State Engineer to actually put a value to that?

MR. WECHSLER: Foundation.

A. I have no idea.

Q. (BY MR. LEININGER) Do you know -- and, again, we're under Topic C, which is related to the Compact to which you were designated. Do you know if New Mexico controls the release of water from project

storage in accordance with irrigation demands?

MR. WECHSLER: Object to foundation.

A. Again, I don't have any knowledge of that.

Q. (BY MR. LEININGER) Okay. Does the Office of State Engineer monitor the release of water from storage?

A. I have no expertise in that -- that matter. I can't answer it.

Q. All right. So you don't know that New Mexico actually monitors release of storage water to ensure that it's used to meet irrigation demands?

A. Well, I'm sure we do, but I don't know any of the specifics at all.

Q. Are you familiar with the Compact?

A. I know very little. Enough to be dangerous.

Q. Okay. Fair enough. So there's -- I think we can get a copy of it if we need to, but there's an Article 1, Section L called, "Usable water in the Compact," and usable water in the Compact is defined as, "All water exclusive of credit water, which is in project storage, and which is available for release in accordance with irrigation demands, including deliveries to Mexico." Are you familiar with that statement?

A. No. I've not read the Compact. I don't use

its rights, it could place a call with the Office of the State Engineer to enforce its priority, correct?

A. That's a loaded question. I'm not following, to be honest with you. Can you be more specific.

Q. Sure. I'll -- I'll break it down. Could a senior water right owner place a call to satisfy his rights, and in placing that call, junior water users may be curtailed? Is that your understanding of how the priority system works?

A. Again, I think a priority call, someone can place a priority call, but with no experience dealing with a priority call, I can't speak with any authority.

Q. Okay. So even under this hypothetical, you're not prepared to answer how the OSE may actually administer a priority call?

A. I'm not prepared. I don't know how we would do that.

Q. And who do you think would be able to answer that question?

A. We would get direction from John D'Antonio, and it's above my pay grade.

Q. Can you define what an over diversion by irrigation water user is in New Mexico?

A. Well, are you referring to surface water or

groundwater or is there a specific thing you're asking.

Q. Well, this term was used by -- you know who Mr. Serrano is?

A. Yes.

Q. And Mr. Dorman?

A. Yes.

Q. And in their depositions, they used the term over diversions. Did you, by chance, review their deposition testimony or did you -- did you participate? Were you present during their deposition?

A. No, I wasn't.

Q. Did you review the transcript?

A. No.

Q. Okay. So I will -- I will just state for these purposes that Mr. Serrano, in particular, referenced over diversions of water rights by irrigation users, and that is my question. It could be over diversion by surface water or could be over diversion of groundwater, but let's take these one at a time. Does the OSE monitor over diversion of a surface water by irrigation user in Elephant Butte Irrigation District?

A. We do not monitor the over diversion of

specific farmers of surface water.

Q. How would you define over diversion?

A. What we do here in the District 4 office is we monitor how much water is pumped from each well, and specific to a specific water right, and an over diversion would be that amount of water diverted that goes beyond their water right.

Q. Okay. Looking at your answer here, you talk about monitoring of how much water is pumped from each well. Do you monitor how much water -- how much surface water is diverted by each water right holder?

A. What we do is in our WATERS database, we include the allotments set by the surface water allotments set by EBID, and we just assume that every water user takes that full allotment of surface water, and then we make sure that the groundwater amount of water is constrained within the Stream System 101 settlement agreement.

Q. Okay. So the OSE does no administration of the amount of surface water that is beneficially used by each of the EBID farmers; is that correct?

A. We just make the assumption that every EBID farmer takes their full allotment.

Q. And the OSE does no monitoring of that or -- well, let's just start there. The OSE does no

monitoring of each farmer diversion of surface water?

A. Not in this office, we don't.

Q. With regard to groundwater, does the OSE monitor how much each farmer is diverting to the groundwater?

A. Absolutely.

Q. Okay. How do you go about doing that?

A. Well, we require metering all wells for irrigation purposes, as well as commercial and non-domestic purposes, and so for irrigation purposes in particular, we require quarterly meter readings and those meter readings are entered into our WATERS database, and that allows us to account for the amount of water each farmer is using.

Q. Okay. In your previous answer, you said with regard to ensuring there's not an over diversion, you make -- I'm looking at your answer here on Line 26:17. "We make sure the groundwater amount of water is constrained within the Stream System 101 settlement agreement." So how does -- how do the OSE then administer to constrain groundwater pumping within the Stream System Issue 101 settlement agreement?

A. Well, I'll go ahead and give you a scenario. In our WATERS database, we input for every farmer the amount of the allotment EBID has designated for that

year. So, for instance, if the amount of water the allotments from EBID surface water is 2 acre-feet per acre per annum, we input that into our WATERS database, and then we look at the Stream System 101 settlement agreement, and we see for most farmers, they have a total FDR farm delivery requirement of 4.5 acre-feet per acre per annum. So what we'll do is straight away, we assume that the farmer will use all the full 2 acre-feet per acre per annum, and what that does, we subtract that from the 4.5 farm delivery requirement, and that gives us a number stating that they have 2.5 acre-feet per acre per annum that can be diverted from their well or wells.

Q. If they exceed -- under your scenario, if they exceed the 2.5 acre-feet per annum, is that an over diversion?

A. It is.

Q. And how do you enforce against an over diversion?

A. Our water master, who is Ryan Serrano and his staff, will notify the farmer that is over diverting, and they will often red tag, literally put a red tag on the well, and there's also written correspondence to those farmers and they investigate and work with the farmer to rectify that over diversion.

Q. Is your well metering, is that realtime?

A. It is not. It's -- we require the farmers to submit their meter readings January, April, July, and October by the 10th of those months.

Q. So let's say in July, you get a meter reading, and it appears that under this scenario which the farmer was entitled to 2.5 acre-feet per annum, pumping, and it's been exceeded, what -- what actions do you take when you get that information?

A. Well, the water master again will contact that farmer and investigate the situation, for instance, talk to the farmer about, well, is -- is your meter working correctly, were the meter readings written down and submitted correctly. Often, that's what happens. The farmer will inadvertently report the meter readings incorrectly or there may be a metering -- there's -- a meter can be tenths or hundredths. They may have a decimal place off. So they'll -- the water master is real diligent about working with the farmers to make sure that those meter readings were entered correctly and submitted correctly. And we'll also go out -- they will, not me, but the water masters will go out and inspect the wells and work with the farmer to make sure that that well is working correctly.

entitled to based on the FDR. Okay?

A. Okay.

Q. And in that scenario where there is already made the determination that they are receiving their permitted amount, is there any analysis as to what that over diversion impacts are on surface flows in the Rio Grande?

A. No. Other than there's no determine other than replacing that water, that over diversion in the following irrigation season on a one-to-one basis.

Q. Okay. Is there any analysis as to what that over diversion impacts are on surface flows and drains?

A. I don't do any analysis like that, no.

Q. The OSE does not do any analysis like that?

A. We do an analysis when application is filed, and that's when we do in my work to make sure that the flows to the river are protected. But as far as the over diversion issue, our view in protecting the water of the surface -- surface water is to have those over diversions be replaced on a one-to-one basis.

Q. But not during the irrigation season?

A. That's correct. Unless the water master comes into an agreement with that farmer in a different manner.

Q. Okay. That threw me for a loop. What do you mean by a different manner? How does that occur during the irrigation season which the over diversion is discovered?

A. You know, I can't -- I threw in a caveat just to make sure that there may be other arrangements that the water masters put together with the farmer, so that's all I was referring to.

Q. Okay. And I'm talking about what arrangements there may be that account for the over diversion and correct for the over diversion during the irrigation season in which the over diversion is occurring. Okay?

A. Uh-huh.

Q. So what -- what, if any, arrangements do the water masters make?

A. You know, I -- the only thing I can think of straight away is if the farmer has a way to repay that water in some other manner, but -- within that same irrigation season, but, you know, I'd have to defer to the water master for specifics. I apologize. I don't know.

Q. Okay. So sitting here today, you're not aware of any of those arrangements?

A. I'm not. It's almost always in the following

irrigation season.

MR. LEININGER: Okay. We've been going well over an hour so I apologize for that, Ms. Thacker, but why don't we -- why don't we take a ten-minute break. Is that okay?

THE WITNESS: Yes, please. Thank you.

THE VIDEOGRAPHER: The time is 2:50 p.m. We're off the record.

(Break.)

THE VIDEOGRAPHER: The time is 3:03 p.m. We're on the record.

Q. (BY MR. LEININGER) So, Ms. Thacker, I only have a few more questions, then I'm going to turn it over to Ms. Klahn. Are you familiar with the AWRM?

A. I am.

Q. Okay. And that's a state statute, correct?

A. Yes, it is.

Q. And it stands for -- I don't actually have a copy of it in front of me, but it stands for alternative water right management; is that correct?

A. I think it's active water resource management.

Q. Oh, okay. That sounds better. Yes, thank you. So are there rules and regulations promulgated for the lower Rio Grande pursuant to the AWRM statute?

A. Did you say for the lower Rio Grande or below the Rio Grande?

Q. I'm sorry. For the LRG, the lower Rio Grande.

A. No, not at this time.

Q. How do you -- what's your understanding of the purpose of the AWRM?

A. Well, the purpose is to -- number one, we can't manage what we don't measure so essentially it's, number one, measuring through metering, and then putting in a water master district, appointing a water master, and just being really clear on the -- the diversions, metering, and being sure, first of all, to make sure that everyone is staying -- all the farmers are not over diverting their waters. So right now, there's what we're actively managing the resource.

Q. Does the AWRM statute allow the OSE to administer within priority?

A. What do you mean by administer within priority? I'm not sure I follow.

Q. Okay. Well, let me be a little more complete in my question. There is no full adjudication of water rights in the lower Rio Grande; is that right? Is that your understanding?

A. That's correct.

Q. So is the AWRM designed to allow the OSE to administer water rights in priority, through priority administration, in lieu of adjudicated rights to water?

A. Well, we don't administer through priority at this time, and my understanding, actually, of AWRM is to manage the water and not have to have a priority call.

Q. Okay.

A. Excuse me -- oh, I'm sorry. Not a priority call. Not have to administer through the priority.

Q. And why, to the best of your knowledge, on behalf of the State of New Mexico, was it necessary to have an AWRM to manage the water and not have a priority call?

A. Well, the AWRM really gave us tools to manage the water, and, you know, for instance, the metering order and designation of the water master. Having the WATERS database and people to input that data and really actively managing and following the groundwater diversions and just all those tools we use.

Q. And it also allows for offsets of water use that may be impacting other water users?

A. What do you mean by "offsets"? I'm not following.

Q. Sure. So if there is, for example, an over diversion of water, the AWRMs would allow for a active management system of offsetting, those impacts of over diversion?

A. Well, the only -- the only way I see is through the same ownership management, and I -- I would say that's one of our tools in our AWRM toolbox, but if it's an over diversion where the farmer is not part of a same ownership management, that is where we require offsets. Replacement water. I prefer to use that word.

Q. Let's say there's a determination that return flows from project releases have declined and have depleted flows in the Rio Grande such that it's affecting deliveries downstream. Do you follow me?

A. I think so.

Q. Okay. Does the AWRM give the OSE authority to curtail groundwater pumping that may be depleting those surface flows?

A. In my knowledge, that's not the intent of the AWRM. That's not one of our tools in our toolbox. It's -- AWRM is used to really, like the acronym says, you know, actively manage the water resource, and we can't manage what we can't measure and so we would -- we -- our goal is to keep the river whole, the whole

system whole, and so, again, that's what's so good about the metering order and the water master, and all these tools we use help us know where we are and so we keep the water right owners, keep those boundaries in place so we know what they're diverting.

Q. Okay. Let me give you another hypothetical. So under this hypothetical, there's no over diversion, no one's exceeding their 4.5 acre-foot per acre farm delivery requirement, but yet there's a determination that there is -- because there is this use of water at the 4.5 acre-foot, there is a depletion of return flows and surface water in the Rio Grande. Okay? That's the -- that's the hypothetical. And the question is: What is the statutory authority that New Mexico has to curtail groundwater pumping that may be depleting those surface water flows?

MR. WECHSLER: Form and foundation.

A. There's a lot of words there. Can you break that down a little bit for me?

Q. (BY MR. LEININGER) Okay. Do you understand the hypothetical?

A. Well, I'm -- I'm puzzled about the -- let's see. Because there is this use of water at the 4.5 acre-foot, there's a depletion of return flows and surface water in the Rio Grande. I don't follow that.

Q. Okay. Let me -- I will try to break it down for you. Let's assume that there is a determination that no irrigator is exceeding his 4.5 farm delivery requirement. Okay? So even though your -- your ability to control over diversions that exceed permitted or declared amounts, this scenario assumes that none of that's taking place. Okay? And yet --

A. None of what's taking place?

Q. Over diversions.

A. Okay. Got you.

Q. Exceeding the 4.5. So irrigators are using 4.5 acre-foot, and yet there is also proof that there are depletions from groundwater pumping affecting surface flows on the Rio Grande, thereby affecting diversions further downstream. Okay? Do you understand?

A. I'd have to look at what do you mean by "proof"?

Q. Well, let's -- let's just for purposes of this hypothetical, it's been proven that the groundwater pumping of 4.5 acre-foot per acre is depleting return flows and there -- therefore depleting surface water in the Rio Grande. Okay?

A. Okay.

Q. So the question is: What's the statutory

project?

A. Well, it's possible; however, again, we have to do an investigation and determine who was causing the depletion.

Q. Sure.

A. Because you can see --

Q. And I -- yeah, I'm sorry to interrupt, but I do want to give Sarah some time here. But the question, again, is just the OSE's statutory authority to administer in priority in the lower Rio Grande given the scenario that the irrigate -- the irrigation of wells is impacting surface water flows. What is that statutory authority? You mentioned the constitution. Is there anything else?

MR. WECHSLER: Object to form; calls for a legal conclusion.

A. Yeah, I'd follow Mr. Wechsler's point. I'm not an attorney, but I do know that we've been given the tools, we've been given the constitution of New Mexico, the statutes, rules and regs, and our ability to permit wells and condition those permits.

Q. (BY MR. LEININGER) And I'm just trying to get -- and really I'm sorry I have to keep coming back to this, but I need some specificity with regard to the tools that the OSE has at its disposal to address this

injury of junior use to a senior water right. So in the lower Rio Grande, you mentioned the constitution, and then you mentioned the statutes, and if you could just define for me what those statutes are that the OSE uses to administer in that scenario?

MR. WECHSLER: Again, object to form.

A. Well, it would depend on the situation to be honest. It would depend on who's causing the injury. We need need more specificity on who's doing -- causing the injury. So, yes, absolutely. We have the authority to -- the state engineer has the authority to protect surface waters of the State of New Mexico and the -- the whole water system, but without knowing specifically who's causing the harm, I can't speak to how we would administer that.

Q. (BY MR. LEININGER) Okay. Without rules and regs promulgated and adopted for the LRG, can the OSE still use the AWRM statute to enforce within priority?

A. Well, my understanding of the AWRM is so we don't have to administer in priority. It's to give us the tools for a priority call -- or administering by a priority is not -- you know, that's the nuclear option, as it were. We want to use AWRMs so that we don't have to do that.

Q. Okay. And that AWRM tool is one that's

available in the lower Rio Grande right now?

A. Well, the state -- statewide regulations, yes. But just because there's no AWRM district-specific regs doesn't mean we don't have the tools to administer water rights.

Q. Sure. And you -- you gave me the explanation of how you would administer water rights. My -- my question had just been what's in your toolbox with regard to what is the United States' ability to deliver project water downstream at head gates where there's a proven causation of depletion of return flows that the United States is entitled to, and it's due to groundwater pumping. Okay? So my understanding is the OSE feels that the AWRM gives them the ability to curtail junior groundwater right if the United States is being impacted in this way; is that right?

MR. WECHSLER: Object to form.

A. No. That's not the intent of the active water resource management to curtail junior groundwater rights. It's to -- I think shortage sharing might be a good way to put it, but we can't administer anything, any water, un -- until we measure it. So that's really the intent of the AWRM, giving us the ability to have the metering order, have a

water master. You know, we have the statewide AWRM regs.

Q. (BY MR. LEININGER) Okay. So -- we're almost done with this line of questioning. So if the United States is showing that it's being injured -- its senior water right is being injured, and the senior water right, as we've discussed, is a surface water right of the Rio Grande, and that's determined to be due to groundwater pumping in New Mexico, you're saying that the active water resource management cannot be used to curtail groundwater -- junior groundwater rights; is that correct?

MR. WECHSLER: Object to form; asked and answered.

A. Well, again, that's not the intent of the AWRM, and your scenario really is very broad and so it doesn't mean that the state engineer doesn't have authority to curtail groundwater, but in your scenario, we don't know who's doing it. We don't know if it's -- where in the aquifer -- where in the basin this is occurring. So to just say, yeah, we'll -- we'll just curtail, what does that mean, we need a lot more specifics and do an investigation, as I mentioned.

Q. (BY MR. LEININGER) So -- so this -- this

assumes that the United States' project water right, and let's give it a 1903 water right is being injured. What I'm hearing -- correct me if I'm wrong, but what I'm hearing is the OSE has tools other than priority administration to fulfill the United States' entire senior water right?

MR. WECHSLER: Object to form.

A. Well, again, that's not the intent of AWRM. And we can't manage what we can't measure, and that's the point of AWRM. And so we don't -- we -- we have ability to do an investigation, to figure out who's causing the harm, if someone is, and so, yes, we -- the state engineer absolutely can curtail, but without specifics, I can't answer beyond that.

Q. (BY MR. LEININGER) And I'll just -- let's just wrap this up with when you say absolutely, the OSE can curtail junior groundwater rights that are effecting or hurting/injuring senior water rights, I'm just trying to understand how the OSE would go about doing that. What -- what laws would they utilize?

MR. WECHSLER: Object to form; calls for a legal conclusion.

A. That's the point of all the statutes is to -- to keep the river system whole, the whole LRG system whole. So the state engineer has the authority to do

groundwater diversions so that the farmers don't exceed their water rights as it is on file.

Q. So what do you mean by shortage sharing?

A. I think that's where our same ownership management comes in to where two farmers can essentially put two farms under one ownership management and where one farmer cannot necessarily irrigate their field, and instead, the other farmer used that water on his lands. So that gives us the tools to do that.

Q. So in that example, one farmer is not irrigating, and the other farmer is using more water than he's entitled to, correct?

A. No, that's not right.

Q. Well, I don't understand where the shortage comes in then?

A. Well, the farmer isn't using more than he's entitled to. It's all within the same water rights as in the two water rights, the mass balance is maintained.

Q. Using more -- the farmer that's using additional water is using more water than he would be able to if his neighbor hadn't agreed to loan him his water, correct?

A. That's true.

Q. And this is the only water district in New Mexico that has an owner management program; isn't that right?

A. I'm not sure about other districts. I can't speak to that.

Q. When -- when you were deposed last spring, you told me you didn't have any involvement with the owner management program. Is that still true?

A. I don't administer it on a day-to-day basis. I do -- I do know how it works, but I don't do the paperwork and I'm not actively involved with it.

Q. Are you involved with the year-end evaluation of whether anybody exceeded the mass balance as you call it under an owner management program?

A. I'm not. Other than I hear Ryan Serrano give a summary and overview, but that's -- he -- he administers that.

Q. So how was the ownership management program shortage sharing again? I don't really feel like I had an answer to that question.

A. Well, I have to back off on that. It may not be shortage sharing.

Q. So can you give me an example of what you mean by shortage sharing?

A. Not right now, no.

Q. So you, as the State of New Mexico, cannot give me an example of shortage sharing? I just want to make sure that's clear on the record. Is that right?

A. Let me think about this a bit. I'm sure I can think of something later, but I can't think of anything right at the moment. I apologize.

Q. Okay. Were you in your current professional position in 2005?

A. Yes.

Q. Were you involved in the state engineer's effort to implement lower Rio Grande specific AWRM regulations?

A. Yes.

MS. KLAHN: Kayla, could you pull up a deposition exhibit for me? It -- it says well metering requirements on the first page.

THE VIDEOGRAPHER: Okay. Give me a moment.

Q. (BY MS. KLAHN) While we're waiting for that to come up, Ms. Thacker, did Mr. D'Antonio or anyone else at the Office of the State Engineer ever give you any instructions or guidance about the role of the Compact in your professional duties?

A. No.

Q. Would that be true in -- because I believe you had two positions with the Office of the State Engineer; is that right?

A. Actually, I've had three.

Q. Have you ever had any instruction or guidance on how the Compact plays into your duties?

A. No.

Q. Thank you.

(Exhibit No. 1 was marked.)

Q. (BY MS. KLAHN) Okay. So the way this works is you should have control of the document that you should be able to see in front of you. Can you see it?

A. I can.

Q. Okay. And this is a document we got from the State of New Mexico somehow or the other in the context of this litigation, and it starts with New Mexico Bates No. 00210791, and it's a collection of documents related to, I believe, the AWRM effort in the lower Rio Grande. The first page is well metering requirements, but I would like you to page down through this to what should be PDF Page 17. And maybe you can flip it so that it's the right way. Perfect. Okay. So the title of this is, "Objectives for Lower Rio Grande District-Specific Regulations for

Implementation of Active Water Resources Management in the Lower Rio Grande Water Master District." I'd ask you to take a look at these objectives, A through M.

A. Okay.

Q. And I'd like to draw your attention to the first bullet point up there, Bullet Point A, "Protect senior water rights from impairment through administration of both surface and groundwater rights within the Lower Rio Grande Water Master District by priority administration or other methods as provided by the AWRM regulations." Do you see that?

A. I do.

Q. So this is -- this was apparently an objective for implementation of Lower Rio Grande specific AWRM rules. Is this an objective of your office in the absence of Lower Rio Grande specific regulations?

MR. WECHSLER: Object to form.

Q. (BY MS. KLAHN) You can answer.

A. Well, I think the state engineer obviously has the authority to administer based on priority administration, but we haven't had to do that since I've been here.

Q. Remind me what it would take for there to be priority administration in your estimation.

A. I would think that someone would have to make a call, and we'd do an investigation and figure out if there were the issues that were -- if there were problems that were indeed causing impairment that's the person calling, and so we would have the -- the state engineer has the authority to stop pumping from junior wells if necessary, but fortunately, we haven't had to do that.

Q. What about between surface water rights, have you ever had to answer a priority call between surface water rights?

A. I don't know. Not that I'm aware of.

Q. I'd like to draw your attention to Paragraph H. This is an objective to establish a system for administration as required to meet downstream interstate delivery entitlements. What do you understand that to mean?

A. I'm really not sure what that means. I need direction on how we would do that. I'm not sure.

Q. I'm going to draw your attention to Paragraph M, "Establish specific identification and enforcement procedures for the water master to follow to curtail illegal use of water, including use of water that exceeds water rights, and to prevent waste of water within the Lower Rio Grande Water Master District."

That was apparently a goal/objective of Lower Rio Grande specific regulations under the AWRM. At this time, are there no specific enforcement procedures for the water master to follow to curtail illegal use of water in the absence of AWRM regulations?

MR. WECHSLER: Object to form; foundation.

A. Well, we have the water master district. We've designated that. We're requiring metering and so absolutely, we have the ability to identify and enforce over diversions.

Q. (BY MS. KLAHN) You -- you've identified metering as a way to identify and enforce over diversions, but I'm interested in illegal use of water, which could be broader than over diversions; would you agree?

A. Well, it's a different designation, but, yes, I agree.

Q. So other than metering, which allows you to identify after the fact and -- and limit somebody the year after an over diversion, not -- not at the actual time of the over diversion, other than that, what other tools or enforcement procedures are in place to curtail illegal use of water?

MR. WECHSLER: Asked and answered.

Q. (BY MS. KLAHN) If -- if that's the only one, tell me.

MR. WECHSLER: Well, I think she answered this earlier with Mr. Leininger.

MS. KLAHN: I'm speaking to the witness.

Q. (BY MS. KLAHN) If that's the only one, tell me.

A. Well, no, for instance, if a farmer puts a pump in the river and doesn't have a water right specifically to pull water from the river, yes, absolutely, the water master can go in there and require that farmer to pull the pump out of the river, and that would be an illegal use of water.

Q. And -- and has that happened in your experience when pumpers have been identified as pulling water illegally out of the river? Has Mr. Serrano gone out there and shut down the pumps?

A. Yes.

Q. When?

A. This was within this last year.

Q. Before that?

A. I believe so, but I -- I don't know of any specific.

Q. So you, as the State of New Mexico today, can identify one instance of the water master going and

S I G N A T U R E O F W I T N E S S

I, CHERYL THACKER, solemnly swear or affirm under the pains and penalties of perjury that the foregoing pages contain a true and correct transcript of the testimony given by me at the time and place stated with the corrections, if any, and the reasons therefor noted on the foregoing correction page(s).

_____

CHERYL THACKER

Job No. 65671

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

THE STATE OF TEXAS :
COUNTY OF HARRIS :

I, HEATHER L. GARZA, a Certified Shorthand Reporter in and for the State of Texas, do hereby certify that the facts as stated by me in the caption hereto are true; that the above and foregoing answers of the witness, CHERYL THACKER, to the interrogatories as indicated were made before me by the said witness after being first remotely duly sworn to testify the truth, and same were reduced to typewriting under my direction; that the above and foregoing deposition as set forth in typewriting is a full, true, and correct transcript of the proceedings had at the time of taking of said deposition.

I further certify that I am not, in any capacity, a regular employee of the party in whose

behalf this deposition is taken, nor in the regular employ of this attorney; and I certify that I am not interested in the cause, nor of kin or counsel to either of the parties.

That the amount of time used by each party at the deposition is as follows:

MS. KLAHN - 00:39:49
MR. WECHSLER - 00:00:00
MR. LEININGER - 01:46:47
MR. WALLACE - 00:00:00
MR. HICKS - 00:17:46
MS. BARNCASTLE - 00:02:45

GIVEN UNDER MY HAND AND SEAL OF OFFICE, on this, the 8th day of October, 2020.

HEATHER L. GARZA, CSR, RPR, CRR
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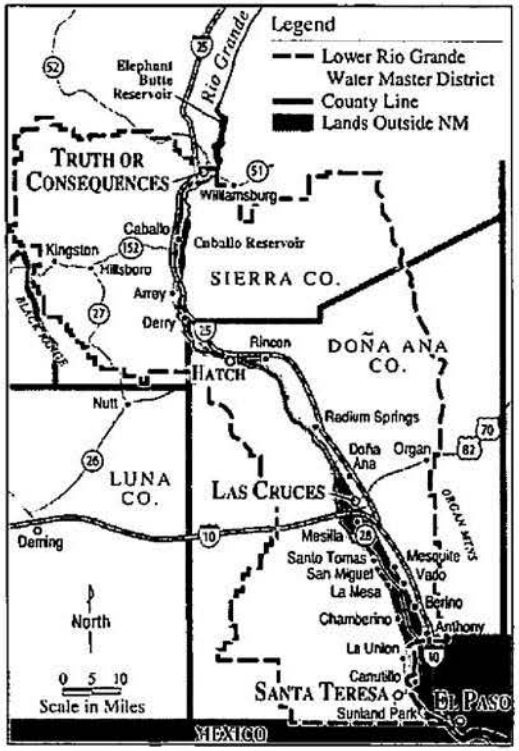
Tab 36

Lower Rio Grande Water Master District



If you own a well that is:

- Located in the Lower Rio Grande Water Master District (see map above)
- AND in use for any purpose other than serving a single household or watering livestock

a Metering Order issued by the New Mexico State Engineer requires you to install a flow meter. This flyer explains key features of new metering rules and where to go for more information.

Active Water Resources Management

The drought of recent years opened our eyes to the urgency of improving water resource management.

Active Water Resources Management (AWRM) comprises a set of tools that the State Engineer is implementing statewide. AWRM programs are designed to ensure senior water rights are respected, to encourage water conservation, and to pave the way for community cooperation to develop alternative means of addressing water shortages.

AWRM programs include:

- Metering
- Water Masters
- District-Specific Rules & Regulations
- Alternatives to Priority Administration

Office of the State Engineer
PO Box 25102
Santa Fe NM 87504-5102
www.ose.state.nm.us/water_info_awrm_basins_lrg_metering_info.html

11/14/05F

Well Metering Requirements

Effective March 2006

Office of the State Engineer
Interstate Stream Commission

Active Water Resources Management
Lower Rio Grande District

Metering: A Vital Water Management Tool

In December 2004, the State Engineer issued an Order setting out mandatory requirements for Lower Rio Grande water right owners with groundwater wells ***other than stock wells and wells serving only a single household.***

The Order requires:

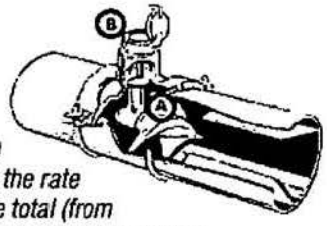
- Buying, installing and maintaining a totalizing flow meter for each well
- Submitting a report of meter model, make, date of installation and other relevant facts to the Office of the State Engineer within 10 days of installation
- Reporting the volume of water pumped quarterly
- Making up any over-diversions during the next accounting year

This Metering Program is key to preventing illegal use and improving conservation. It will also provide the data needed for Lower Rio Grande communities to develop voluntary means of addressing water shortages.

Installation Deadline: March 1, 2006

The Well Metering Order sets forth the basic specifications for meters. In addition, state and local guidelines have been developed that include further information on the kinds of meters that have proven effective, installation, and where to find vendors.

The cost of meters and meter installation will be borne by water right owners. In some cases, meter installation will require pipe reconfiguration or use of straightening vanes to ensure accurate measurement.



A typical flow meter: the main parts consist of a propeller (A) mounted in a short section of pipe and geared to a revolution counter (B) which records the rate of flow and the cumulative total (from "Measuring Irrigation Water With a Flow Meter Guide A-102", New Mexico State University).

The Lower Rio Grande Water Master's duties include inspection of meters and enforcement against illegal uses of water. The first Water Master was hired for the Lower Rio Grande Water Master District early in 2005. Metering Order compliance inspections will begin after March 1, 2006.

At your request and as time allows, the Water Master will inspect your well, advise you of your options for ensuring that your meter works properly and complies with the State Engineer's requirements.

More Information Is Available

Information about the metering program, meter specifications, installation guidelines, and potential vendors, among other topics, is available on the Office of the State Engineer web site or you may request that copies be mailed to you.

Go to:
www.ose.state.nm.us/water_info_awrm_basins_lrg_metering_info.html

E-mail: *lrg.watermaster@state.nm.us*

Or call in Las Cruces: (505) 649-1480

Refer to:
The *Metering Order* issued by the State Engineer

Groundwater Measurement Specifications, which outlines information that applies throughout the state

Groundwater Metering and Measurement Guidelines for the Lower Rio Grande

Vendor List

How to Read Your Meter

To contact the Lower Rio Grande Water Master:

Office of the State Engineer
District Four Office
1680 Hickory Loop, #J
Las Cruces NM 88005
(505) 649-1480

Final

-- Lower Rio Grande Metering Order --

Frequently Asked Questions

1. Q: Why are you requiring us to meter our wells?

A: In order to protect everyone's water rights, the State Engineer needs to know how much water is being used. With an ever-increasing demand on the finite water resources of the state, particularly during times of drought, the water resources of all water districts in the state must be actively managed and administered. The State Engineer can only do so if he has information about all surface water and groundwater diversions in the Lower Rio Grande Water District.

By requiring water right owners to meter their wells the State Engineer is able to collect the information necessary to protect water right owners from illegal diversions and over-diversions. In times of drought, he is able to protect those with senior priority dates from diversions by those with junior priority dates who may not be entitled to divert.

2. Q: How much will it cost to install a meter?

A: The cost of a meter varies. To get an estimate on the cost of a meter, check with vendors. A list of meter vendors is available on the Office of the State Engineer website at www.ose.state.nm.us/water_info_awrm_basins_ lrg_metering_info.html If you do not have Internet access, you can pick up the list at the Office of the State Engineer Las Cruces District Office or request the list by calling (505) 649-1480 or (505) 524-6161.

3. Q: Who is going to pay for the meter?

A: The water right owner is responsible for the costs of purchasing, installing and maintaining the meter.

4. Q: Is financial assistance available?

A: The State Engineer, through the Interstate Stream Commission reloan program, may have some funding available for low interest meter financing. Check with your local soil and water conservation or irrigation district as to availability of such funding.

5. Q: What if I do not comply with the order?

A: Unmetered diversions after March 1, 2006 are illegal. To ensure that water right owners are in compliance with the order, the State Engineer will begin meter inspections shortly after the deadline. Non-compliance will not result in the loss of your water right, but may make you subject to repayment of water and potential financial penalties.

6. Q: Under what authority can the State Engineer order the metering of my water?

A: The legislature, through the state's water laws (Section 72-2-1), has given the State Engineer broad powers to enforce legal limits on water rights and, generally, to administer all water uses in the state. One of his powers is the authority to issue orders, as he finds necessary in his professional judgment, for effective administration of the waters of the state. The metering order issued for the Lower Rio Grande Water Master District is one such order.

Under New Mexico law, all water belongs to the public. As the owner of a water right you have acquired the right to divert water for beneficial use, but you do not own the water itself.

7. Q: What happens if I can't get a meter installed in time?

A: You may be subject to enforcement action until your well is metered. However, if you are having trouble finding a meter or someone to install it, immediately contact the Lower Rio Grande Water Master, Sheldon Dorman. He will be able to provide you with information about obtaining and installing a meter. To contact the water master call (505) 649-1480 or (505) 524-6161, or write the water master at: Office of the State Engineer, 1680 Hickory Loop, Suite J, Las Cruces NM 88005. In addition to describing your situation, also include your Lower Rio Grande well file number.

8. Q: How do I find a meter and someone to install the meter?

A: A list of meter vendors is available on the Office of the State Engineer website at www.ose.state.nm.us/water_info_awrm_basins_ lrg_metering_info.html. If you do not have Internet access, you can pick up the list at the Office of the State Engineer Las Cruces District Office or request the list by calling (505) 649-1480 or (505) 524-6161.

9. Q: Why haven't I heard about this metering requirement before?

A: Since the State Engineer's metering order was issued on December 3, 2004, the Office of the State Engineer has made diligent attempts to inform the public about the metering requirements and the deadline. We have sent numerous news releases to area news media, posted the information on the Office of the State Engineer website, and made all documents available at the Office of the State Engineer's Las Cruces District Office. We also have worked closely with area water user groups concerning the metering requirements.

The State Engineer has prepared a brochure that gives an overview of the metering requirements. In December of 2005, the agency mailed out more than 9,600 copies of this brochure to area water right owners in the Lower Rio Grande. If your water right ownership record with the Office of the State Engineer is current, you were notified.

The brochure can be obtained from the agency website or by calling (505) 524-6161 or (505) 649-1480.

10. Q: If several water right owners divert from one well, do they need more than one meter?

A: In this situation, water right owners have two options:

Option A: Use one meter, sign a well sharing agreement with the other owners, and place it on file with the State Engineer. This document says you agree that you are jointly responsible for not using more than the collective total amount of water allowed.

A well sharing agreement form is available at the Las Cruces District Office or can be downloaded from the State Engineer's website.

Option B: Install an individual meter for each water right.

11. Q: Who will read my meter?

A: Each water right owner is responsible for reading and reporting his own water use.

12. Q: How do I report my meter readings?

A: You can submit your meter readings to the Office of the State Engineer by mail, e-mail, fax, or by dropping them off at the Las Cruces District Office. You may also submit your meter readings through the Internet at www.ose.state.nm.us/doing-business/forms-inst/meter-reading/MeterForms. Meter reading forms are available at the Las Cruces District Office or from the State Engineer website.

13. Q: Where does the data about my water use go? How is it used?

A: It is recorded in the State Engineer's WATERS database and is available on-line. The Office of the State Engineer uses the information to protect all water right owners from illegal diversions, and to make sure that senior water right owners get their water in times of drought.

14. Q: I have a well in my yard. Do I have to put a meter on it?

A: Not if your well is used only for domestic purposes. Domestic purposes include drinking, cooking, sanitary purposes, and cooling. In addition, water right owners can irrigate no more than one acre of non-commercial vegetation (e.g., lawn/landscape or personal garden watering). However, the State Engineer reserves the right to require a meter for any well. Wells used for any other purpose must be metered, regardless of where they are.

15. Q: I have a domestic well that I use only for my domestic/household uses. Do I have to put a meter on it?

A: No. The metering order does not apply to wells used for supplying water to single households.

16. Q: Are stock wells exempted from the metering requirement?

A: Stock wells supplying relatively small amounts of water, such as windmills, are exempt. Feedlots and dairies are not exempt from the metering requirement.

17. Q: I'm not using/not going to use my well, do I have to meter it?

A: If you are not using your meter, the pump must be removed, the well must be capped, and you must notify the water master in writing that you will not be using the well. He will then inspect the well to make sure it is properly decommissioned.

18. Q: Who do I contact to cap my well?

A:

19. Q: How much will you charge for water?

A: The Office of the State Engineer does not charge for water. The State Engineer's job is to administer and protect water rights.

20. Q: Who pays for the Water Master?

A: According to state law, the salary and expenses of the water master are charged to the water right owners in the district, through the county commissions (Section 72-3-4). The amount of the charge is based on the size of the water right each owner has. The State Engineer prepares a budget of the estimated water master expenses and certifies that budget to each county commission located in the water master district. The county commissions treasurers include the amounts owed in the county tax rolls for that year.

21. Q: Can I object to the metering requirements?

A: Submit your comments or concerns by e-mail, or by mail to the addresses shown below. Please be sure to indicate "Lower Rio Grande Metering Requirements" on the envelope or in the e-mail heading.

For further information, please contact the water master at the information listed below:

Water Master
Office of the State Engineer District Four Office
1680 Hickory Loop, Suite J
Las Cruces NM 88005

Email: lrg.watermaster@state.nm.us

Internet: www.ose.state.nm.us/water_ info_awrm_basins_lrg_metering_info.html

Telephone: (505) 649-1480 or (505) 524-6161

include in WM Manual

Metering Requirements Related Documents

Metering Order

Groundwater Metering Brochure

Groundwater Measurement Specifications

Groundwater Metering and Measurement Guidelines for the Lower Rio Grande

Vendor List

New Mexico Office of the State Engineer

PO Box 25102
Santa Fe, New Mexico 87504-5102
PH: (505) 827-6120 FAX: (505) 827-6682

Meter Installation Variance Request Form

I, _____, do hereby request a meter installation variance because:

☐ I can install my meter in a manner that meets the installation requirements of the manufacturer, but not those of the Metering Order.

☐ I cannot install my meter in a manner that meets the installation requirements of either the manufacturer or the Metering Order, but I believe that I can install it in a manner that produces an accuracy within ±10 percent of actual flow.

Please indicate which specification below cannot be met, and explain why:

- ☐ The meter shall be installed according to manufacturer specifications.
- ☐ There shall be no diversions between the wellhead and the meter.
- ☐ The meter shall be installed in such a manner as to ensure full-pipe flow at the location of the meter.
- ☐ The meter shall be installed at a distance of at least 10 pipe diameters downstream from bends in the pipe or changes in pipe diameter.

Explanation: _____

_____

_____

_____

I understand that the Water Master will review my case, and if it is determined that I can meet the Order, I will be required to do so. I also understand that before a variance is granted I must have my meter checked and it must be within ±10% actual flow.

Print Name: _____

Signature: _____ _____ Date: _____

New Mexico Office of the State Engineer

PO Box 25102
Santa Fe, New Mexico 87504-5102
PH: (505) 827-6120 FAX: (505) 827-6682

Meter Installation and Inspection Form

Instructions: Submit this form for all wells, which require measurement of water withdrawals. Fill out one form for each well. Submit changes within 30 days. The individual providing the information herein must sign and date this form in item 8 and complete the address and phone information in item 8 if different from those listed in items 2 or 5. Type or print in BLACK INK. No overstrikes or erasures unless initialed.

1) PERMIT NUMBER: _____

2) PERMITTEE:

Name: _____ Work Phone: _____

Contact: _____ Home Phone: _____

Address: _____

_____

City: _____ State: _____ Zip: _____

WELL LOCATION:

OSE Well Number: _____

a. ____¼ ____¼ ____¼ Section: ____ Township: ____ Range: ____

b. _____ Subdivision

c. Latitude: ____d ____m ____s Longitude: ____d ____m ____s

d. East _____ (m), North _____ (m), UTM Zone 13, NAD _____ (27 or 83)

3) FLOW METER DATA:

Meter Information:	**Primary Meter**	**Secondary Meter**
Manufacturer	_____ /	_____
Model No.	_____ /	_____
Serial No.	_____ /	_____
Meter Size	_____ /	_____
Volumetric Units	_____ /	_____
Multiplier	_____ /	_____

(Form continues on next page)

TX_MSJ_001402

NM_00210799

3) **FLOW METER DATA (Continued):**

Installation Information:	**Primary Meter**		**Secondary Meter**
Installation Date	_____	/	_____
Flow Meter Reading	_____	/	_____
Power Meter Reading	_____	/	_____
Calibration Information:			
Last Calibration Date	_____	/	_____
Internal Diameter (I.D.)	_____	/	_____
Outside Diameter (O.D.)	_____	/	_____

4) **WELL USER (if different from the owner):**

Name: _____ Work Phone: _____

Contact: _____ Home Phone: _____

Address: _____

_____

City: _____ State: _____ Zip: _____

5) **WELL TEST DATA:**

Testing Information:

Well Test Date	_____		Static Water Level	_____	ft
Power Meter Reading	_____	kWh or cfm	Pumping Water Level	_____	ft
Yield	_____	gpm	Pressure Head	_____	psi
Measured Input HP	_____	HP	Total Head	_____	ft

Test Performed By:

Name _____

Mailing Address _____

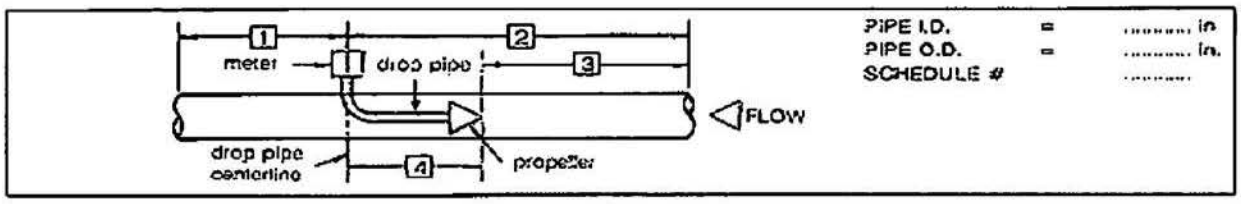
City, State, Zip _____

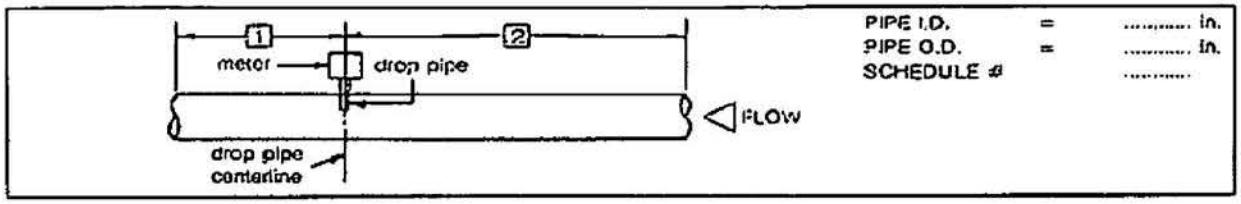
Phone Number _____

(Form continues on next page)

6) FLOW METER INSTALLATION:

Label all fixtures (valves, check valves, elbows, etc.) and changes of pipe diameters within 25 pipe diameters upstream and 5 pipe diameters downstream of the meter installation. Note the type of fixture, the distances to these fixtures, internal and external diameters of straight pipe, and the schedule nos. of straight pipe. Space is provided below for this diagram. You may use a separate sheet if necessary. Use the diagram that most closely matches your type of flow meter.





The numbers 1 through 4 below correspond to the numbers in the diagrams above:

1. Length of straight, unobstructed pipe downstream of meter drop pipe centerline:

   _____ ft _____ in

2. Length of straight, unobstructed pipe upstream of meter drop pipe centerline:

   _____ ft _____ in

3. Length of straight, unobstructed pipe upstream of meter propeller:

   _____ ft _____ in

4. Length of meter drop pipe: _____ ft _____ in

Are valves, changes in pipe diameter or any other flow restrictions located within 25 pipe diameters upstream or 5 pipe diameters downstream of the flow meter? **YES** **NO**

If yes, how far? Upstream: _____ ft _____ in
Downstream: _____ ft _____ in

Are straightening vanes included in this flow meter installation? **YES** **NO**

8) I (WE) HEREBY AFFIRM THAT I (WE) HAVE READ AND UNDERSTAND THE ABOVE FORM AND THAT THE INFORMATION I (WE) HAVE PROVIDED IS TRUE AND CORRECT:

Signature _____
Name (print) _____
Date _____
Mailing Address _____
City, State, Zip _____
Phone Number _____

FLOW METER INSTALLATION GUIDELINES:

1) All valves should be located downstream of the flow meter (excepting check valves).

2) The manufacturers installation instructions must be followed to assure meter measurement accuracy within two (2) percent.

3) The following minimum unobstructed straight pipeline requirements are provided as a general guideline only. Refer to the manufacturers instructions for meter specific installation instructions. Pipe diameters are internal diameters.

   - 10 pipe diameters upstream of propeller without vanes, 5 pipe diameters upstream with vanes
   - 1 pipe diameter downstream of meter
   - 20 pipe diameters upstream to exaggerated flow restrictions or jetting (may be caused by pressure regulator valves, check valves, changes in pipe diameter, etc.) without vanes, 10 pipe diameters with vanes

   Other Meters:
   - 10 pipe diameters upstream of meter
   - 5 pipe diameters downstream of meter
   - 20 pipe diameters upstream to exaggerated flow restrictions or jetting (may be caused by pressure regulator valves, check valves, changes in pipe diameter, etc.)

For Official Use Only:

Well Coordinates: _____

Comments:

_____

_____

_____

_____

_____

_____

Attachment 7

Example Quarterly Meter Read Reporting Form

METER INSTALLATION AND INSPECTION FORM

I Well Information

A) File No. _____

B) Well No. _____

II. Permittee
Name:
Address:

III. Meter Information

A) Serial No. _____

B) No. Of Dials _____

C) Multiplier _____

D) Make _____

E) Units _____

IV. Inspected by _____ **Approved** ☐ **Not in Compliance** ☐

Comments:

multiple

METER REPORT FORM

State Engineer Office
133 Wyatt Drive, Suite 3
Las Cruces, NM 88005

FAX: (505) 524-6160

FILE NO: HU-93

NAME: CBS Maintenance

Please read the meter at the end of each calendar month and submit meter readings on or before the 10th day of the following month.

FILE NO.		MONTH	READING	GALLONS
HU-93	Present:			
	Previous:			

FILE NO.		MONTH	READING	GALLONS
HU-93-S	Present:			
	Previous:			

FILE NO.		MONTH	READING	GALLONS
HU-93-S-2	Present:			
	Previous:			

By: _____

Date: _____

****PLEASE MAKE COPIES OF THIS FORM FOR SUBMITTING YOUR METER READINGS.**

METER INSTALLATION FORM

STATE ENGINEER OFFICE
DISTRICT 4

133 WYATT DRIVE, SUITE 3
LAS CRUCES, NM 88005

PHONE: (505) 524-6161
FAX: (505) 524-6160

FILE NO: _____

NAME: _____

ADDRESS: _____

_____

BY: _____

PHONE: _____ FAX: _____

DATE: _____

THIS *PERMIT* REQUIRES THAT A WELL METER BE INSTALLED PRIOR TO APPROPRIATION OR USE OF WATER. PLEASE COMPLETE METER INFORMATION, SIGN, DATE AND RETURN TO THE STATE ENGINEER OFFICE AS SOON AS THE METER IS INSTALLED. THE METER INSTALLATION WILL THEN BE INSPECTED BY PERSONNEL FROM THE STATE ENGINEER OFFICE.

DATE INSTALLED: _____

METER TYPE: _____

METER SIZE: _____

SERIAL NO. _____

REGISTER: _____

MULTIPLIER: _____

UNITS MEASURED: _____

For State Engineer Office Use Only

_____

_____

_____

_____

_____

_____

_____

FIELD CHECK: _____ DATE: _____

Objectives for

Lower Rio Grande District-Specific Regulations (LRGDSR)

For Implementation of Active Water Resources Management in the Lower Rio Grande Water Master District (LRGWMD)

A. Protect senior water rights from impairment through administration of both surface and ground water rights within the LRGWMD by priority administration or other methods as provided by the AWRM regulations.

B. Maximize the beneficial use of New Mexico's water resources within New Mexico.

C. Specify the parameters within which groundwater may be used to increase water supplies in times of surface water supply shortages.

D. Protect the water supply functions of the aquifers of the Lower Rio Grande Water Master District.

E. Establish the system for administration of water rights under Depletion Limit Administration within the LRGWMD.

F. Establish minimum criteria and the State Engineer's process for consideration of Alternative Administration proposals.

G. Establish the system for conjunctive administration of surface water rights and associated supplemental irrigation wells within the LRGWMD.

H. Establish a system for administration as required to meet downstream interstate delivery entitlements.

I. Establish a system for administration applicable to changes in environmental depletions of water resulting from managed changes in riverine or riparian habitat or changes in reservoir operations.

J. Establish a Generalized Hydrologic Analysis applicable to defined areas within the LRGWMD to support expedited consideration by the State Engineer of Replacement Plans providing for (1) continued water use by junior water users that are subject to administrative curtailment of water use or (2) transactions of Special Water Users Associations.

K. Establish the system for consideration of objections and appeals of Lower Rio Grande Water Master decisions and actions.

L. Promote the expedited marketing and leasing of water rights; facilitate operations of Special Water Users Associations that operate in accordance with state law and OSE regulations.

M. Establish specific identification and enforcement procedures for the Water Master to follow to curtail illegal use of water, including use of water that exceeds water rights, and to prevent waste of water within the LRGWMD.

Approved Project Review Board 1/18/05

STATE OF NEW MEXICO
OFFICE OF THE STATE ENGINEER

IN THE MATTER OF THE CREATION OF	)
THE LOWER RIO GRANDE WATER	)
MASTER DISTRICT FOR THE	)
ADMINISTRATION OF RIGHTS TO	)
THE USE OF GROUND WATER FROM	)
THE LOWER RIO GRANDE GROUNDWATER	)
BASIN OF NEW MEXICO	)

The State Engineer for the State of New Mexico ("State Engineer") is authorized by statute to divide the State into water districts in conformity with the drainage areas for the purpose of performing the essential governmental function of distributing water among water right owners under the laws of the State of New Mexico. The State Engineer may appoint a water master who will have immediate charge of such apportionment of waters.

STATUTORY AUTHORITIES

1. New Mexico law declares that all natural water flowing in streams and watercourses, whether such be perennial, or torrential, within the limits of the State of New Mexico, belong to the public and are subject to appropriation for beneficial use. NMSA 1978, § 72-1-1.
2. The State Engineer has a statutory responsibility to supervise, measure, appropriate, and distribute the waters of the State. NMSA 1978, § 72-2-1, including surface waters , NMSA 1978, §§ 72-5-1 through 37, and groundwaters, NMSA 1978, §§ 72-12-1 through 28, in accordance with the prior appropriation doctrine, as established by New Mexico law, NM Const. art. XVI; NMSA 1978, § 72-1-2.
3. The State Engineer is authorized, if it is in the best interest of the State and the owners of water rights, to establish water districts upon any stream system within the State of New Mexico as necessary for the economical and satisfactory apportionment of said waters. NMSA 1978, § 72-3-1.
4. The State Engineer is authorized, if it is in the interest of public safety and the best interest of water users, to appoint a water master who shall appropriate, regulate and control the waters of such water districts so as to prevent waste. NMSA 1978, § 72-3-2.

FINDINGS OF FACT

1. In order to properly apportion the waters of the Lower Rio Grande stream system in Sierra and Doña Ana Counties, New Mexico, the establishment of the Lower Rio Grande Water Master District ("District") and the appointment of a Water Master in and for the District are necessary.

2. The amount of water in the District is finite and varies from year to year based on annual spring run-off, which is dependent on annual precipitation, and on the amount of groundwater being pumped in the District.
3. The Elephant Butte Irrigation District ("EBID"), and the majority of its constituents, the City of Las Cruces, a number of mutual domestic water users associations, and a number of commercial/industrial users, are all water users in the District.
4. Adjudication of water rights in the Lower Rio Grande stream system and Underground Water Basin has begun, but has not been completed.
5. The recent drought in the State of New Mexico has created a water shortage crisis in the Lower Rio Grande Stream System.
6. The shortage of water in the Lower Rio Grande Stream System is a problem affecting the citizens of Sierra and Doña Ana Counties.
7. Creation of the District is necessary to ensure the economical and satisfactory apportionment of water in the District.
8. Appointment of a Water Master is necessary to ensure the public safety of water users in the District and to ensure protection of existing water rights in the District from impairment.

CONCLUSIONS OF LAW

Creation of Water Master District and Appointment of Water Master

1. The State Engineer concludes that, for the economical and satisfactory apportionment of water in the District, it is in the interest of public safety and in the interest of the water users that the LOWER RIO GRANDE WATER MASTER DISTRICT ("District") should be formed and a Water Master appointed on a permanent basis, so as to administer the groundwaters of the District in accordance with New Mexico law.
2. The District Water Master shall have immediate charge of the apportionment of waters in the District under the general supervision of the State Engineer, and shall appropriate, regulate and control the waters of the District so as to prevent impairment of senior water right owners and to prevent waste.
3. This Order applies to all groundwater rights in the Lower Rio Grande Water Master District, located in Sierra and Doña Ana Counties, State of New Mexico.

Administration of Affected Water Rights

4. The State Engineer concludes that the immediate administration of groundwater rights in the District is necessary for the protection of the public, the protection of prior surface water and groundwater rights, and the prevention of waste.
5. The State Engineer concludes that the Water Master of the District created by this Order shall apportion the waters of the District in accordance with the Active Water Resource Administration regulations for the Lower Rio Grande Water Master District; other existing or future regulations; the Water Master Manual; and any guidelines, directions and supervision provided by the State Engineer.

6. The State Engineer concludes that the Water Master of the District created by this Order shall perform the following specific duties:
   a. Curtail illegal diversions (i.e. any diversion without a water right, or in excess of the elements or conditions of a water right);
   b. Measure and report water usage in the District;
   c. Curtail out-of-priority diversions determined by the State Engineer to be causing injury to senior priority water rights;
   d. Administer water usage according to any agreements entered into by the water right owners of the District; and
   e. Coordinate, where indicated, with the United States Bureau of Reclamation and with the Elephant Butte Irrigation District Ditch Rider(s) so as to ensure appropriate regulation and control of groundwater withdrawals.
7. Additional instructions to the Water Master for the administration of groundwater rights in the District will be based upon available water rights data, hydrologic models, and the State Engineer's best professional judgment.
8. The State Engineer concludes that the District created by this Order shall include the following organizational features:
   a. The appointment of a single Water Master for the District.
   b. The State Engineer may declare sub-districts and appoint sub-district water masters if he deems it necessary.
   c. The Water Master will be a direct employee of the Office of the State Engineer and shall receive compensation in an amount to be determined by the State Engineer. The Water Master shall also be compensated for all actual and necessary expenses incurred in performing the duties of Water Master.
   d. The salary and expenses of the Water Master will be paid monthly by the water right owners through the boards of county commissioners of Sierra and Doña Ana Counties, New Mexico, in accordance with the requirements of NMSA 1978, § 72-3-4. The amount to be paid by each water right owner will be based on the amount of water used by each water right owner, or as otherwise provided for by future legislative acts.
   e. The boundaries of the District may be changed from time to time, as may be necessary in the opinion of the State Engineer, for the economical and satisfactory apportionment of water in the District.

ORDER

IT IS ORDERED that:

1. The LOWER RIO GRANDE WATER MASTER DISTRICT is hereby created to include all groundwater rights within the drainage of the Lower Rio Grande Stream System, within the area depicted on the map attached hereto as Attachment A and incorporated herein by reference.

2. The State Engineer hereby authorizes the appointment of a Water Master for the District for the purpose of administration and apportionment of the groundwaters thereof.

DATED this 3rd day of December, 2004.

JOHN R. D'ANTONIO JR., P.E.
State Engineer

OFFICE OF THE STATE ENGINEER
STATE OF NEW MEXICO

IN THE MATTER OF THE REQUIREMENTS)
FOR METERING GROUNDWATER WITH-)
DRAWALS IN THE LOWER RIO GRANDE)
WATERMASTER DISTRICT, NEW MEXICO)

ORDER

WHEREAS, New Mexico law declares that the water of underground streams, channels, artesian basins, reservoirs or lakes, having reasonably ascertainable boundaries, belong to the public and are subject to appropriation for beneficial use, NMSA 1978, § 72-1-1; and

WHEREAS, the State Engineer has a statutory responsibility to supervise the measurement, appropriation, and distribution the waters of the state, NMSA 1978, § 72-2-1 in accordance with the prior appropriation doctrine, as established by New Mexico law, N.M. Const. art. XVI; NMSA 1978, § 72-1-2; and

WHEREAS, the State Engineer may adopt rules regarding the administration of water and promoting expedited marketing and transfers of water, NMSA 1978, § 72-2-8; NMSA 1978, § 72-2-9.1; and

WHEREAS, the unauthorized use of water to which another is entitled, or the willful waste of surface or underground water to the detriment of another, or the public, is a misdemeanor, NMSA 1978, § 72-8-4; and

WHEREAS, the State Legislature has recognized that the need for water administration is urgent, NMSA 1978, § 72-2-9.1; and

WHEREAS, the groundwaters of the Lower Rio Grande Water Master District are in hydrologic connection with the surface water system of the Lower Rio Grande; and

WHEREAS, a requirement for measuring and reporting ground water uses in the Lower Rio Grande Watermaster District will assist the State Engineer in managing and administering the waters of the Lower Rio Grande stream system; and

WHEREAS, measuring and reporting of ground water diversions in the Lower Rio Grande Watermaster District will promote expedited leasing and marketing of water by ensuring a high degree of accuracy in the determination of actual water use, and assisting in State Engineer analysis of impairment, public welfare and conservation issues; and

WHEREAS, this Order as set out below, providing for measurement and reporting of groundwater uses in the Lower Rio Grande Water Master District, will assist

the State Engineer in performing his statutory duties to protect existing water rights, promote expedited leasing and marketing of water, conserve water, and promote the public welfare by preventing the over-appropriation, illegal use and waste of water,

NOW THEREFORE, I, John R. D'Antonio Jr., State Engineer of the State of New Mexico, do hereby order metering of all groundwater diversions by totalizing flow meters in the Lower Rio Grande Water Master District, unless specifically excluded below. I further order that all metering devices be in place and operational no later than March1, 2006. This date has been decided upon to provide adequate notice to groundwater right owners that meters are now required and to provide sufficient time for their installation so as to avoid hardship.

DEFINITION OF THE LOWER RIO GRANDE WATERMASTER DISTRICT: The Lower Rio Grande Water Master District includes all lands within the Lower Rio Grande Underground Water Basin, Hot Springs Underground Water Basin and Las Animas Creek Underground Water Basin.

METERING OF ALL GROUNDWATER USES IN THE LOWER RIO GRANDE WATERMASTER DISTRICT: A totalizing flow meter, in accordance with the standards set out in this Order, is required for every ground water well within the Lower Rio Grande Water Master District, with the exception of wells that serve the household or domestic uses of a single household, or the irrigation of one acre of noncommercial trees, lawn or garden, or are used for the sole purpose of watering livestock in a grazing operation. Nothing herein shall limit the authority of the State Engineer to require, at a later date, that water uses currently excluded from the requirements of this order be metered. Nothing herein shall limit the authority of the State Engineer to require specific types of meters as a condition of approval for any permit granted by the State Engineer. If the State Engineer procures meters, they shall be purchased from the State Engineer subject to the State Engineer's funding terms. No owners of groundwater rights may divert from wells covered by this Order after March 1, 2006, unless such wells are metered in accordance with the specifications described in this Order.

INSTALLATION, MAINTENANCE AND REPAIR: The water rights owner shall be responsible for installing, maintaining and repairing the meter. The meter shall be installed in accordance with the manufacturer's specifications. The owner shall keep the meter in good working order so as to provide a continuous and accurate record of the amount of water withdrawn or diverted. If the meter is broken or not functioning in accordance with the specifications of this Order, diversion of water from that well shall be discontinued unless estimates of diversion can be made by hour meters or electrical meters associated with the well pump. Estimates using data from hour meters shall be made based upon the listed pump capacity. Broken or non-functioning meters must be repaired within 30 days of the time the meter broke.

REPORTING REQUIREMENTS: Within ten days after meter installation, the owner shall submit to the State Engineer a written record of the meter's make, model, date of installation, initial reading, units of measurement and multiplier (if any); information as

to the presence of an hour meter or electrical meter associated with the well pump; and the Office of the State Engineer file number for the well. The meter readings, and readings from the hour meter or electrical meter associated with the well pump, shall be reported on or before the tenth day of January, April, July and October of each year for the three preceding calendar months, unless otherwise ordered by the State Engineer. However, if a permit or license of the State Engineer requires more frequent meter readings, the terms of the permit or license shall control.

All reporting shall be either electronically through a meter data input system developed by the Office of the State Engineer, or in writing on a form acceptable to the State Engineer. Reports shall include the Office of State Engineer file number for the well, dates of reading, units of measurement and multiplier, if any. If a meter is serviced, repaired or replaced, the owner shall record the meter readings before and after such actions, and shall include the readings in the written report for the quarter in which servicing, repair or replacement occurred.

All overdiversions of water made in one accounting year shall be made up during the accounting year following the year in which the overdiversions occurred.

STANDARDS, SPECIFICATIONS AND GUIDELINES: Each meter shall be of a type acceptable to the State Engineer and shall be installed, maintained and repaired in a manner that is acceptable to the State Engineer. The following minimum standards apply to each meter:

A. The meter shall be a totalizing flow meter with a rated accuracy of plus or minus two (2) percent of actual flow. The installed accuracy of the meter and any secondary equipment such as data recorders shall be within plus or minus ten (10) percent of actual flow. The meter shall be calibrated according to industry standards upon installation, and at least once every three years thereafter.
B. The meter shall be installed, inspected and maintained according to the manufacturer's specifications.
C. The meter shall contain sufficient recording digits to assure that "roll over" to zero does not occur within a one year period.
D. The meter register or display shall record total volume and instantaneous flow rate or be capable of flow rate calculation, be non-resetable, and have a waterproof and tamperproof seal.
E. There shall be no diversions between the wellhead and the meter.
F. The meter shall be installed and maintained in such a manner as to prevent meter error, for example, due to the pipe being incompletely filled with water at the location of the meter.
G. The meter shall be installed and maintained in such a manner as to prevent meter error due to the meter being too close to bends in the pipe or changes in pipe inner diameter. The meter shall be installed at a distance of at least 10 pipe diameters downstream from bends in the pipe or changes in pipe diameter.

H. The meter shall be accessible for reading, inspection and testing by a representative of the State Engineer, including a duly appointed Water Master.
I. The units of measurement and the multiplier, if any, for determining the total amount of water diverted shall be indicated on the meter.

The State Engineer may modify these standards, specifications and guidelines, or adopt additional standards, specifications and guidelines for meters and for their installation, repair and maintenance, or for other alternative measurement methods or devices, which shall be on file in his office.

SUPERSESSION BY A COURT: In the exercise of his statutory authority to measure the public waters, the State Engineer shall consider this Order and any orders entered by a court of competent jurisdiction regulating the use of ground water. Where there is any inconsistency between this Order and the orders of a court of competent jurisdiction, the court's order shall control.

VARIANCES: When the strict application of any provision of this Order would be impracticable or would cause unreasonable hardship, the State Engineer may, at his discretion, grant a variance for a specific instance, provided a written request for the variance is filed with the State Engineer and the State Engineer finds the request justifiable. Alternative methods or devices for measuring water uses are allowable only upon written authorization from the State Engineer.

MODIFICATION OF THIS ORDER: The State Engineer may, at his sole discretion, supplement this Order to accommodate any specific proposals to implement metering of all groundwater diversions in the Lower Rio Grande Water Master District submitted to him by any entity responsible for compliance with, or assuring compliance with, the provisions of this Order. Decisions to supplement this Order will be made upon consideration of any Interstate Stream Commission staff comments after their review of such proposals and as verified by the Lower Rio Grande Water Master.

EFFECTIVE DATE: This Order shall become effective on the date of signature by the State Engineer. No water shall be diverted from any well in the Lower Rio Grande Water Master District after March1, 2006 unless equipped with a functional meter as required in this Order.

WITNESS my hand and seal of my office this 3rd day of December, 2004.

JOHN R. D'ANTONIO JR., P.E.
State Engineer

OFFICE OF THE STATE ENGINEER
STATE OF NEW MEXICO

IN THE MATTER OF THE REQUIREMENTS FOR METERING GROUNDWATER WITHDRAWALS IN THE LOWER RIO GRANDE WATER MASTER DISTRICT, NEW MEXICO	))))	Order No. 172

FIRST AMENDED METERING ORDER

WHEREAS, New Mexico law declares that the water of underground streams, channels, artesian basins, reservoirs or lakes having reasonably ascertainable boundaries, belong to the public and are subject to appropriation for beneficial use, NMSA 1978, § 72-1-1; and

WHEREAS, the State Engineer has a statutory responsibility to supervise the measurement, appropriation, and distribution of the waters of the state, NMSA 1978, § 72-2-1 in accordance with the prior appropriation doctrine, as established by New Mexico law, N.M. Const. art. XVI; NMSA 1978, § 72-1-2; and

WHEREAS, the State Engineer may adopt rules regarding the administration of water and promoting expedited marketing and transfers of water, NMSA 1978, § 72-2-8; NMSA 1978, § 72-2-9.1; and

WHEREAS, the unauthorized use of water to which another is entitled, or the willful waste of surface or groundwater to the detriment of another, or of the public, is a misdemeanor, NMSA 1978, § 72-8-4; and

WHEREAS, the State Legislature has recognized that the need for water administration is urgent, NMSA 1978, § 72-2-9.1; and

WHEREAS, the groundwaters of the Lower Rio Grande Water Master District are in hydrologic connection with the surface water system of the Lower Rio Grande; and

WHEREAS, a requirement for measuring and reporting groundwater uses in the Lower Rio Grande Water Master District will assist the State Engineer in managing and administering the waters of the Lower Rio Grande stream system; and

WHEREAS, measuring and reporting of groundwater diversions in the Lower Rio Grande Water Master District will promote expedited leasing and marketing of water by ensuring a high degree of accuracy in the determination of actual water use, and by assisting in State Engineer analysis of impairment, public welfare and conservation issues; and

WHEREAS, this Order, as set out below, providing for measurement and reporting of groundwater uses in the Lower Rio Grande Water Master District, will assist the State Engineer in performing his statutory duties to protect existing water rights, promote

expedited leasing and marketing of water, conserve water, and promote the public welfare by preventing the over-appropriation, illegal use and waste of water,

NOW THEREFORE, I, John R. D'Antonio Jr., State Engineer of the State of New Mexico, do hereby order metering of all groundwater diversions by totalizing flow meters in the Lower Rio Grande Water Master District, unless specifically excluded below. I further order that all metering devices be in place and operational no later than March 1, 2006. This date has been decided upon to provide adequate notice to groundwater right owners that meters are now required, and to provide sufficient time for their installation so as to avoid hardship. This First Amended Metering Order amends the Metering Order dated December 3, 2004.

DEFINITION OF THE LOWER RIO GRANDE WATER MASTER DISTRICT: The Lower Rio Grande Water Master District includes all lands within the Lower Rio Grande Underground Water Basin, Hot Springs Underground Water Basin and Las Animas Creek Underground Water Basin.

METERING OF ALL GROUNDWATER USES IN THE LOWER RIO GRANDE WATER MASTER DISTRICT: A totalizing flow meter, in accordance with the standards set out in this Order, is required for every groundwater well within the Lower Rio Grande Water Master District, with the exception of wells that serve only the household or domestic uses of a single household, or the irrigation of one acre of noncommercial trees, lawn or garden, or are used for the sole purpose of watering livestock in a grazing operation. Multiple water right owners diverting from a single shared point of diversion may elect to account for their diversions by applying one of the following procedures:

1. Multiple water right owners may install and maintain individual measuring devices for each water right owner's separate diversions from the shared well, so that each metered use may be individually monitored.

2. In the alternative, multiple water right owners may enter into a written well sharing agreement signed by all owners that is acceptable to the State Engineer and filed with the State Engineer, and in which the owners obligate themselves to maintain accurate and timely records of all diversions from the well so that the Water Master can identify easily, and without ambiguity, the owner or owners responsible for any illegal diversion or over diversion from the well. Such well sharing agreement shall provide that, if an illegal diversion or over diversion is identified, and the owner responsible for the illegal diversion or over diversion cannot be easily identified without ambiguity, then all owners subject to the well sharing agreement shall be jointly and severally liable for the illegal diversion or over diversion and its repayment and penalty, if any. Once an illegal diversion or over diversion has been made by owners signatory to a well sharing agreement, the State Engineer will require that all owners subject to that agreement install separate meters for their separate diversions from the well.

Nothing herein shall limit the authority of the State Engineer to require, at a later date, that water uses currently excluded from the requirements of this Order be metered. Nothing herein shall limit the authority of the State Engineer to require specific types of meters as a condition of approval for any permit granted by the State Engineer. After March 1, 2006, no owners of groundwater rights may divert from wells covered by this Order unless such wells are metered in accordance with the specifications described in this Order.

INSTALLATION, MAINTENANCE AND REPAIR: The water right owner shall be responsible for installing, maintaining and repairing the meter. The meter shall be installed in accordance with the manufacturer's specifications. The owner shall keep the meter in good working order so as to provide a continuous and accurate record of the amount of water withdrawn or diverted. If the meter is broken, or not functioning in accordance with the specifications of this Order, diversion of water from that well shall be discontinued unless estimates of diversion can be made by hour meters or electrical meters associated with the well pump. Estimates using data from hour meters shall be made based upon the listed pump capacity. Broken or non-functioning meters must be repaired or replaced within 30 days of the time the meter broke.

REPORTING REQUIREMENTS: Within ten days after meter installation, the water right owner shall submit to the State Engineer a written record of the meter's make, model, date of installation, initial reading, units of measurement and multiplier (if any), information as to the presence of an hour meter or electrical meter associated with the well pump, and the Office of the State Engineer file number for the well. The meter readings, and readings from the hour meter or electrical meter associated with the well pump, shall be reported on or before the tenth day of January, April, July and October of each year, for the three preceding calendar months, unless otherwise ordered by the State Engineer. However, if a permit or license of the State Engineer requires more frequent meter readings, the terms of the permit or license shall control.

All reporting shall be either electronically, through a meter data input system developed by the Office of the State Engineer, or in writing on a form acceptable to the State Engineer. Reports shall include the Office of State Engineer file number for the well, dates of reading, units of measurement and multiplier, if any. If a meter is serviced, repaired or replaced, the owner shall record the meter readings before and after such actions, and shall include those readings in the written report for the quarter in which servicing, repair or replacement occurred.

All over diversions of water made in one accounting year shall be made up during the accounting year following the year in which the over diversions occurred.

STANDARDS, SPECIFICATIONS AND GUIDELINES: Each meter shall be of a type acceptable to the State Engineer and shall be installed, maintained and repaired to be operational in a manner that is acceptable to the State Engineer. The following minimum standards apply to each meter:

A. The meter shall be a totalizing flow meter with a rated accuracy of plus or minus two (2) percent of actual flow. The installed accuracy of the meter and any

secondary equipment such as data recorders shall be within plus or minus ten (10) percent of actual flow. The meter shall be factory calibrated or calibrated according to industry standards upon installation, and shall be tested for accuracy or re-calibrated at least once every three years thereafter.

B. The meter shall be installed, inspected, maintained and repaired according to the manufacturer's specifications.

C. The meter shall contain sufficient recording digits to assure that "roll over" to zero does not occur within a one-year period.

D. The meter register or display shall record total volume and instantaneous flow rate or be capable of flow rate calculation, be non-resetable, and have a waterproof and tamperproof seal.

E. There shall be no diversions between the wellhead and the meter.

F. The meter shall be installed and maintained in such a manner as to prevent meter error, for example, due to the pipe being incompletely filled with water at the location of the meter.

G. The meter shall be installed and maintained in such a manner as to prevent meter error due to the meter being too close to obstructions in the discharge pipe, such as valves, pumps, bends in the pipe or changes in pipe inner diameter. The meter shall be installed at a distance of at least 10 pipe diameters downstream, and at least five pipe diameters upstream from obstructions to flow, unless manufacturer's installation instructions specify a shorter minimum run of straight pipe.

H. The meter shall be accessible for reading, inspection and testing by a representative of the State Engineer, including a duly appointed Water Master.

I. The units of measurement and the multiplier, if any, for determining the total amount of water diverted shall be indicated on the meter.

The Measurement Specifications adopted by the State Engineer and the list of meters that conform to these specifications may be obtained from the District Office and may be found on the State Engineer's website at www.ose.state.nm.us. To install a meter that is not on the State Engineer's list of conforming meters requires that, prior to installation, the State Engineer or the Water Master determine that the meter meets the adopted Measurement Specifications and approve its installation. Any currently installed measuring devices not meeting these specifications must be replaced by March 1, 2006. The State Engineer may modify these standards, specifications and guidelines, or adopt additional standards, specifications and guidelines for meters and for their installation, repair and maintenance, or for other alternative measurement methods or devices, which shall be on file in his office.

SUPERSESSION BY A COURT: In the exercise of his statutory authority to measure the public waters, the State Engineer shall consider this Order and any orders entered by a court of competent jurisdiction regulating the use of groundwater. Where there is any inconsistency between this Order and the orders of a court of competent jurisdiction, the court's order shall control.

VARIANCES: When the strict application of any provision of this Order would be impracticable or would cause unreasonable hardship, the State Engineer may, at his discretion, grant a variance for a specific instance, provided a written request for the variance is filed with the State Engineer and the State Engineer finds the request justifiable. Alternative methods or devices for measuring water uses, and methods of installation, maintenance and repair that do not conform to the minimum Standards, Specifications and Guidelines of this Order, are allowable only upon written authorization from the State Engineer.

MODIFICATION OF THIS ORDER: The State Engineer may, at his sole discretion, supplement or amend this Order to accommodate any specific proposals to implement metering of all groundwater diversions in the Lower Rio Grande Water Master District submitted to him by any entity responsible for compliance with, or assuring compliance with, the provisions of this Order.

EFFECTIVE DATE: This Order shall become effective on the date of signature by the State Engineer. No water shall be diverted from any well in the Lower Rio Grande Water Master District after March 1, 2006 unless the well is equipped with a functional meter as required in this Order.

WITNESS my hand and seal of my office this 20th day of December, 2005.

JOHN R. D'ANTONIO JR., P.E.
State Engineer

Tab 37

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

****

ORAL DEPOSITION OF
ADRIENNE L. WIDMER, P.E.
FEBRUARY 5, 2019

****

ORAL DEPOSITION of ADRIENNE L. WIDMER, P.E., produced as a witness at the instance of the Plaintiff State of Texas, and duly sworn, was taken in the above-styled and numbered cause on February 5, 2019, from 2:48 p.m. to 4:44 p.m., before Heather L. Garza, CSR, RPR, in and for the State of Texas, recorded by machine shorthand, at the offices of LAS CRUCES UTILITIES, 680 North Motel Boulevard, Las Cruces, New Mexico, pursuant to the Federal Rules of Civil Procedure and the provisions stated on the record or attached hereto; that the deposition shall be read and signed.

A P P E A R A N C E S

FOR THE PLAINTIFF STATE OF TEXAS:
Ms. Sarah A. Klahn
Mr. Francis M. Goldsberry II (via telephone)
SOMACH SIMMONS & DUNN
2701 Lawrence Street, Suite 113
Denver, Colorado 80205
(720) 279-7868
sklahn@somachlaw.com

FOR THE DEFENDANT STATE OF COLORADO:
Mr. Chad Wallace (via videoconference)
COLORADO DEPARTMENT OF LAW
1300 Broadway, 7th Floor
Denver, Colorado 80203
(720) 508-6281
chad.wallace@coag.gov

FOR THE DEFENDANT STATE OF NEW MEXICO:

Mr. David A. Roman
ROBLES RAEL ANAYA
500 Marquette NW, Suite 700
Albuquerque, New Mexico 87102
(505) 242-2228
droman@roblesrael.com
-and-
Mr. Michael A. Kopp (via telephone)
TROUT RALEY
1120 Lincoln Street, Suite 1600
Denver, Colorado 80203
(303) 861-1963
mkopp@troutlaw.com

-and-

Ms. Shelly L. Dalrymple
STATE OF NEW MEXICO
SPECIAL ASSISTANT ATTORNEY GENERAL
130 S. Capitol Street
Concha Ortiz Y Pino Building
Santa Fe, New Mexico 87504
(505) 827-6150
shelly.dalrymple@state.nm.us

FOR THE UNITED STATES::
Mr. James J. Dubois
U.S. DEPARTMENT OF JUSTICE
999 18th Street, Suite 370
Denver, Colorado 80202
(303) 844-1375
james.dubois@usdoj.gov

-and-

Ms. Shelly Randel
U.S. DEPARTMENT OF THE INTERIOR
1849 C Street NW
Washington, DC 20240
(202) 208-5432
shelly.randel@sol.doi.gov

FOR CITY OF LAS CRUCES:

Mr. Jay F. Stein
STEIN & BROCKMANN, P.A.
505 Don Gaspar
Santa Fe, New Mexico 87505
(505) 983-3880
jfstein@newmexicowaterlaw.com
-and-
Ms. Marcia B. Driggers
LAS CRUCES CITY ATTORNEY'S OFFICE
700 North Main, Suite 3200
Las Cruces, New Mexico 88004
(575) 541-2128
marcyd@las-cruces.org

FOR ELEPHANT BUTTE IRRIGATION DISTRICT:
Ms. Samantha R. Barncastle
BARNCASTLE LAW FIRM, LLC
1100 South Main, Suite 20
Las Cruces, New Mexico 88005
(575) 636-2377
samantha@h2o-legal.com

FOR ALBUQUERQUE - BERNILLO COUNTY WATER UTILITY AUTHORITY:

Mr. James C. Brockmann
STEIN & BROCKMANN, P.A.
505 Don Gaspar
Santa Fe, New Mexico 87505
(505) 983-3880
jcbrockmann@newmexicowaterlaw.com

ALSO PRESENT:
Mr. Phil King
Mr. Ryan Serrano
Ms. Cheryl Thacker
Mr. Jorge Garza
Ms. Rhonda Diaz

EXAMINATION INDEX

WITNESS: ADRIENNE L. WIDMER, P.E.

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ADRIENNE L. WIDMER, P.E.,
having been first duly sworn, testified as follows:
E X A M I N A T I O N
BY MS. KLAHN:
Q. Good afternoon, Ms. Widmer. May I call you Adrienne?
A. Yes.
Q. My name is Sarah Klahn. I'm here today representing the State of Texas, and you're here for your deposition. Would you state your name and spell it for the record, please?
A. Sure. Adrienne Widmer. Adrienne is A-D-R-I-E-N-N-E, last name Widmer, W-I-D-M-E-R.
Q. And your work address, please?
A. 680 North Motel Boulevard, Las Cruces, New Mexico.
Q. And you're employed by the City of Las Cruces Utility Department; is that correct?
A. Yes.
Q. Okay.
MS. KLAHN: Would you mark that?
(Exhibit No. 57 was marked.)
Q. (BY MS. KLAHN) You've been handed Exhibit 57, which is the State of Texas's notice of deposition of Adrienne Widmer. Have you -- have you seen that

before?
A. I believe so.
Q. And you understand that you're here to give testimony under oath in the original lawsuit, Texas versus New Mexico?
A. Yes.
Q. Okay. What is your title at the utility department?
A. Water administrator.
Q. And how long have you been in that position?
A. Since about November of 2013.
Q. What did you do before that?
A. I was the regulatory environmental services and technical support administrator.
Q. Also for the City of Las Cruces Utilities?
A. Yes, ma'am.
Q. And prior to that, what was your --
A. I was the utility projects and the water rights manager.
Q. How many years have you worked for the utility department here?
A. Since August of 2006.
Q. Okay. Prior to 2006, August, 2006, where did you work?
A. Molzen-Corbin & Associates.

Q. What's that?
A. That's an engineering and consulting firm.
Q. And how long were you there?
A. 11-and-a-half years.
Q. Okay. Did that job with the engineering firm involve water rights issues?
A. Yes.
Q. Did you work with clients on water rights matters?
A. In general, yes.
Q. In general. Is that the main focus of that firm or do you do other kinds of -- did they do other kinds of engineering?
A. Other types of engineering.
Q. Okay.
A. The water rights was just happened to be that -- it was more engineering.
Q. How long were you with that private firm?
A. 11-and-a-half years.
Q. Oh, I'm sorry. You said that.
A. That's okay.
Q. 1995 then about?
A. I believe that.
Q. Okay.
A. Somewhere about then.

Q. Okay. When did you graduate from college?
A. December of 1991.
Q. Okay. What was your job between '91 and '95?
A. I spent two years with the U.S. Army Corps of Engineers in Sacramento and then when came back here, I was pretty much an office manager for a produce company.
Q. What did you do for the Army Corps in Sacramento?
A. I was one of their rotational engineers.
Q. What's that mean?
A. They send you through different parts of the district and then after your rotational internship, then they put you where they think you are most apt to be successful.
Q. Did you get to the point where they put you in a permanent spot?
A. I got to the point where they offered me a permanent spot.
Q. Where was that?
A. With the environmental section.
Q. And you preferred to come back here apparently?
A. Yes.
Q. Are you from Las Cruces?

A. Born in Albuquerque, raised in Cruces since I was five.
Q. Okay. Did you go to NMSU?
A. Yes.
Q. What was your major?
A. Civil engineering.
Q. Any graduate experience?
A. No.
Q. So just so I don't ask you five times, you've been in your current position since 2013, and prior to that, you've been with the utilities since 2006?
A. Yes. But it was the end of 2013 for my present position.
Q. Okay. All right. Now, in -- when you joined the utilities department in 2006, what was it about the job that you applied for that was interesting to you?
A. The project management.
Q. What kinds of projects were you managing?
A. Water and wastewater.
Q. Did you manage any water projects related to the city's groundwater rights in -- during that time period?
A. I'm sorry. I'm not sure I completely understand your question.

Q. It wasn't a very precise question. Just trying to get at the -- when you say water and wastewater, would that have -- let me ask it this way: If there were, for example, wells -- municipal wells drilled between 2006 and the end of 2013, is that something that you would have been involved in?

A. Yes.

Q. How about applications filed with the Office of the State Engineer, is that something that would have gone across your desk?

A. Yes.

Q. How about applications with the Department of the -- I'm not sure what the New Mexico agency is, but the Department of Environmental Quality, whoever permits wastewater, would you have dealt with those kinds of issues in that position?

A. Yes.

Q. Okay. So in making the switch from the position you held in 2006 -- and I'm sorry -- tell me what the title was again in 2006?

A. The utility projects and water rights manager.

Q. Okay. And in making that switch to your current position, the title of which is?

A. Water administrator.

Q. What -- how did your job responsibilities change?

A. I went from engineering to operations.

Q. Okay. So on a day-to-day basis, what kinds of things are you doing that you didn't do in the project and water rights manager position?

A. Dealt with hands on. So operations is water production, waterline maintenance, meter valve hydrants. Those are the three subsections within water, and water production is in charge of making sure that the wells, pumps, motors, boosters, tanks, PRVs are all in working order in order to provide water to the system. Waterline maintenance is in charge of maintaining waterlines, service lines. If there is a break in the system anywhere, to get that fixed, meter valve hydrants. They install the meters. They exercise and replace valves. They exercise and maintain fire hydrants, so engineering is calculating. Operations is doing the work.

Q. Do you make a -- are you the one that would make a decision about which well field to pump from for raw water supplies on a given day?

A. No.

Q. Who would make that decision?

A. Our SCADA system, which is the supervisory

control and data acquisition system.

Q. So the system is programmed to make those determinations, which well field to pump from on a given day?

A. Yes.

Q. And who does the programming?

A. That is a mixture of the operators and the SCADA manager. It's all dependent on which wells are assigned to which tanks.

Q. Who supervises those individuals?

A. That would be the water production supervisor.

Q. Do you deal with the legal requirements for the city's well permits? In other words, do you ensure that if the Office of the State Engineer has imposed a limitation on pumping a particular water supply in the City of Las Cruces, that those limitations are abided by?

A. Yes.

Q. Can you give me an example of -- of something recently that you've done in that respect where you've had to look at the permit and direct somebody at utilities, okay, we need to do it this way? Does that make sense?

A. It'd be nice if you were a little more

specific.

Q. If -- can you -- let -- help me out with this. Is there a -- under the utilities water rights, are you allowed to pump without regard to the quantity associated with each well?

MR. STEIN: I'm going to have to object. Could you specify the water rights that you're talking about?

Q. (BY MS. KLAHN) Well, I'm just trying -- I'm really not trying to trap anybody. I'm just trying to get a sense of the type of decision making she does with regards to the water sources that the city has?

MR. STEIN: But they all have different parameters.

MS. KLAHN: I'm sure that's true.

MR. STEIN: It's not one size fits all.

MS. KLAHN: I'm sure that's true. I'm trying to get a sense of an example that she might be able to think of that she's -- that Adrienne has dealt with recently.

MR. STEIN: So you're looking for a well that might have a specific limit on it and how compliance was undertaken by Adrienne?

MS. KLAHN: Exactly.

MR. STEIN: Okay.

MS. KLAHN: Just the pure kind of nuts and bolts of that.

Q. (BY MS. KLAHN) Does that make sense?

A. Yes.

Q. Okay.

A. So we can talk about Well 68 on the East Mesa. Staff was instructed to run it 24/7, because the water rights specifically associated with that particular well running that particular pump doesn't produce enough water to ever exceed the permitted amount so turn that -- turn it on.

Q. Okay. All right. That's -- that is a good example. So in -- given that kind of day-to-day experience, what has been your involvement with the City's 40-year plan process?

A. To review the 40-year plan.

Q. For accuracy and completeness?

A. In general.

Q. Okay. Anything else related to the 40-year plan that would be within your scope, your job description?

A. Review and make comment.

Q. Okay. Now, in the 40-year plan, there's a statement that the Shoemaker company, whatever they're called -- sorry, Shoemaker & Associates put the plan

together, I think it's something like under the direction of Jorge Garcia, the director -- executive director of the utilities department. How would his involvement in this 40-year plan differ from yours?

A. I'm sorry. You'll have to ask him.

Q. So you --

A. I know what my scope is.

Q. So you don't know what Mr. Garcia's involvement is with the master plan?

A. He reviews everything.

MS. KLAHN: Let's mark this 58.

(Exhibit No. 58 was marked.)

Q. (BY MS. KLAHN) Before I -- before I get into that, what is the utility -- what is the city, the utility's relationship with the Elephant Butte Irrigation District?

A. They're another agency. When you say "relationship" --

Q. Does the utility department consider itself -- I think I've seen this some place, I could probably find it -- a member of EBID?

A. I would say yes.

Q. Why is that?

A. Because the City of Las Cruces has surface water rights.

Q. Surface water rights in the Elephant Butte Irrigation District Project?
A. Yes.
Q. Do -- does the City use those surface water rights for municipal purposes?
A. For municipal purposes?
Q. Correct.
A. No.
Q. Why not?
A. From my understanding, it's because there hasn't been an M&I agreement of some sort.
Q. An agreement with who?
A. I think between the city, EBID, and the state, most likely. I can't -- I can't say 100 percent sure.
MR. STEIN: You're not required to speculate --
THE WITNESS: Okay.
MR. STEIN: -- if you don't know.
Q. (BY MS. KLAHN) So let's take a look at the Exhibit 58, which I just handed you. I would ask you to turn in here to Section 1.2. We may come back to the first part of this, but let's start with Section 1.2. So the title of Section 1.2 is, "Develop alternate supply." And if you look at the second

sentence there on Page 3, the sentence reads, "Development of an alternate supply is generally based on physical limitations and physical legal/administrative constraints as opposed to deficiency in the amount of existing water rights and permits." Do you see that?

A. Yes.

Q. Did I read it correctly?

A. I believe so.

Q. What does that mean?

A. I think I would have to read the full Section 1.2 and contemplate it prior to answering that question.

Q. Is this one of the sections of the 40-year water development plan that you would have been involved in, review -- I forget what the words were that you used that you -- accuracy and completeness?

A. I'm not sure I understand the question.

Q. Is this one of the sections of the 40-year water development plan that you would have reviewed for accuracy and completeness? That was your testimony earlier, that you reviewed the 40-year master plan or at least some part of it, for accuracy and completeness. Is this section one of those?

A. I don't believe I used the word accuracy or

completeness. I think I said that I reviewed it and gave comment.

Q. Is this a section that you would have reviewed and given comments on?

A. I don't recall.

Q. This was completed in April of 2017, so that's about two years ago. And you don't -- at this time as you sit here today, you do not recall what -- whether you give comments on this section or reviewed it; is that correct?

A. I don't believe that I gave comment on this section.

Q. Okay. The second -- the sentence after that says, "Potential legal/administrative constraints may arise from the general stream adjudication or Texas v. New Mexico and Colorado Original No. 141." Do you see that there?

A. Yes.

Q. What does potential legal/administrative constraints mean in that sentence?

MR. STEIN: Testify only if you recall giving comments on that.

MS. KLAHN: Well, that wasn't the scope of the question. I asked her whether or not she could tell me what that means, whether she commented on it

of it, you know what I mean, just in general.

Q. Sure. So you're saying in general, you understand the Rio Grande to be a future potential water supply, but you don't know what conditions would have to be in place before the city would move forward with the project like that?

A. Okay. Repeat that again, please.

Q. Well, your answer was confusing, so I was just trying to state what I think you meant, but maybe it's better for you to say it yourself. Do you know what the considerations are that the city would require to be in place before they would move forward with the Rio Grande as an alternate water supply?

A. I think I would need to research this one to find out if they've delineated the factors associated with it where it says, "Contingent on a number of factors."

Q. That's exactly my question. You don't know what the factors are, as you sit here today; is that right?

A. I believe that is correct.

Q. Okay.

MS. KLAHN: Let's mark this.

(Exhibit No. 60 was marked.)

Q. (BY MS. KLAHN) So you've just been handed

Exhibit 60, but before we get into that, let me just ask you to talk generally as the operations person. What is your understanding of the most reliable water supply that -- well, let me back up.

It's my understanding the city has three well fields, at least three planned well fields; is that correct?

A. Yes.

Q. The West Mesa, which hasn't been drilled, the valley floor or LRG-430 wells, and the east side?

A. Correct.

Q. Jornada del Muerto?

A. Jornada del Muerto.

Q. Sorry.

A. That's okay. Tongue twister.

Q. So those are the three supplies the city relies on for -- sorry -- LRG-430 and the Jornada supply are the two supplies the city currently relies on; is that right, in terms of supplies?

A. Can I ask him a question?

Q. No. That's the whole point of this. If you don't know, you don't know. And if I -- if I used a word that you don't agree with, clarify.

A. Yeah. I need you to kind of clarify. Are we only talking about these three aquifers that then are

associated with LRG-430 --

MR. STEIN: Let me --

Q. (BY MS. KLAHN) Yes?

MR. STEIN: -- interject. Are you trying to get each source of groundwater supply for the City of Las Cruces?

MS. KLAHN: Yes.

MR. STEIN: Tell her what each source of groundwater supply for the City of Las Cruces is.

A. So we have the valley wells. Okay. And then on top of the valley wells, then we do have some East Mesa wells, and then we do have some West Mesa wells, which then also has a different West Mesa permit. There are LRG-430 wells on the East Mesa. There are LRG-430 wells on the West Mesa. We also purchased the Jornada water system, and we purchased the Mesa development water system, which also have wells associated with those, so I want to make sure that I'm not confusing what question you're trying to ask me.

Q. (BY MS. KLAHN) That's perfect. That's very helpful. Thank you.

A. Okay.

Q. So of the -- when you're think -- and I'm just trying to speak about this in the terms that you think about them as the operations person, and that's

why it's helpful to have you clarify it that way. Thinking about things in terms of the operations person for Las Cruces Water, what -- which of those sources you just enumerated would you consider to be the most reliable? Reliable in the sense that you know you can always go to that source, and you're going to -- you're going to be able to get water.

A. I would say all of those sources.

Q. So they're all equally reliable in your -- in your mind right now at least?

A. In my mind, yes, they are.

Q. Yeah. And by "right now," like, in the future, things could change, but as of today?

A. I would say yes.

Q. Okay. And so the 40-year plan spends a fair amount of its -- the -- fair amount of the 40-year plan involves a discussion about alternate water sources. Why is there so much emphasis on alternate water sources in the 40-year plan?

A. In case they're ever needed.

Q. Do you think you have enough current supply based on your understanding of the aquifer levels and so on, do you have enough current supply for the next 50 years in -- in the existing -- with the existing portfolio of sources that you have?

A. We rely on the 40-year water development plan, which has recommendations from professionals, the geo-hydrologists, and we would be following what the 40-year water development plan based on those recommendations.

Q. So if they say go look at water rights in the Mimbres Basin to acquire for alternate supply, you would go to the Mimbres Basin and look at water rights?

A. We would probably consider it.

Q. When? What would be the compelling event that would cause you to take steps to go look at alternate water supplies?

MR. STEIN: Objection as to lack of foundation that Ms. Widmer is the sole person to make these decisions. I mean, she has not testified that she is. Implementation of the 40-year plan is not the problems of one person.

Q. (BY MS. KLAHN) You can answer.

A. I would refer you to the utility director --

Q. Okay.

A. -- for that type of a -- of a question.

Q. Okay. So you've been handed Exhibit 60, and this is Exhibit D from the 40-year plan, and the title of it is background on surface water resources. Is

this a section of the 40-year plan that you would have had an opportunity to review and comment on or at least -- and if not the whole thing, are there any parts of it that you would have reviewed and commented on?

A. I don't believe I made comment on this.

Q. So the first section of this is what I'm interested in, and that's D.1, and it's entitled the, "Rio Grande Project." Do you see that?

A. Uh-huh.

Q. What involvement as the operations person do you have with the city's interest in the Rio Grande Project?

A. Could you please repeat the question again?

Q. In your current professional position, what involvement do you have with the city's interests -- let me back up.

Does the city own land and water rights in the Rio Grande project under EBID?

A. Yes.

Q. What involvement do you have with those interests in your current position?

A. In my current position, I would approve to pay the EBID assessment.

Q. Okay. If an EBID member came to you and said

WITNESS CORRECTIONS AND SIGNATURE

Please indicate changes on this sheet of paper, giving the change, page number, line number and reason for the change. Please sign each page of changes.

PAGE/LINE	CORRECTION	REASON FOR CHANGE
13/7	deal not dealt	word
13/15	they instead of to	word
13/16	period after fixed new sentence Capital M on meter & remove period after hydrant	

ADRIENNE L. WIDMER, P.E.

1 S I G N A T U R E O F W I T N E S S
2
3 I, ADRIENNE L. WIDMER, P.E., solemnly swear or
4 affirm under the pains and penalties of perjury that
5 the foregoing pages contain a true and correct
6 transcript of the testimony given by me at the time
7 and place stated with the corrections, if any, and the
8 reasons therefor noted on the foregoing correction
9 page(s).
10
11
12 ADRIENNE L. WIDMER, P.E.
13
14
15
16
17 Job No. 3169876
18
19
20 OFFICIAL SEAL
21 LINDA DAWSON
NOTARY PUBLIC - STATE OF NEW MEXICO
22 My commission expires: Oct. 2020
23
24
25

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

THE STATE OF TEXAS :
COUNTY OF HARRIS :

I, HEATHER L. GARZA, a Certified Shorthand Reporter in and for the State of Texas, do hereby certify that the facts as stated by me in the caption hereto are true; that the above and foregoing answers of the witness, ADRIENNE L. WIDMER, P.E., to the interrogatories as indicated were made before me by the said witness after being first duly sworn to testify the truth, and same were reduced to typewriting under my direction; that the above and foregoing deposition as set forth in typewriting is a full, true, and correct transcript of the proceedings had at the time of taking of said deposition.

I further certify that I am not, in any capacity, a regular employee of the party in whose

behalf this deposition is taken, nor in the regular employ of this attorney; and I certify that I am not interested in the cause, nor of kin or counsel to either of the parties.

That the amount of time used by each party at the deposition is as follows:

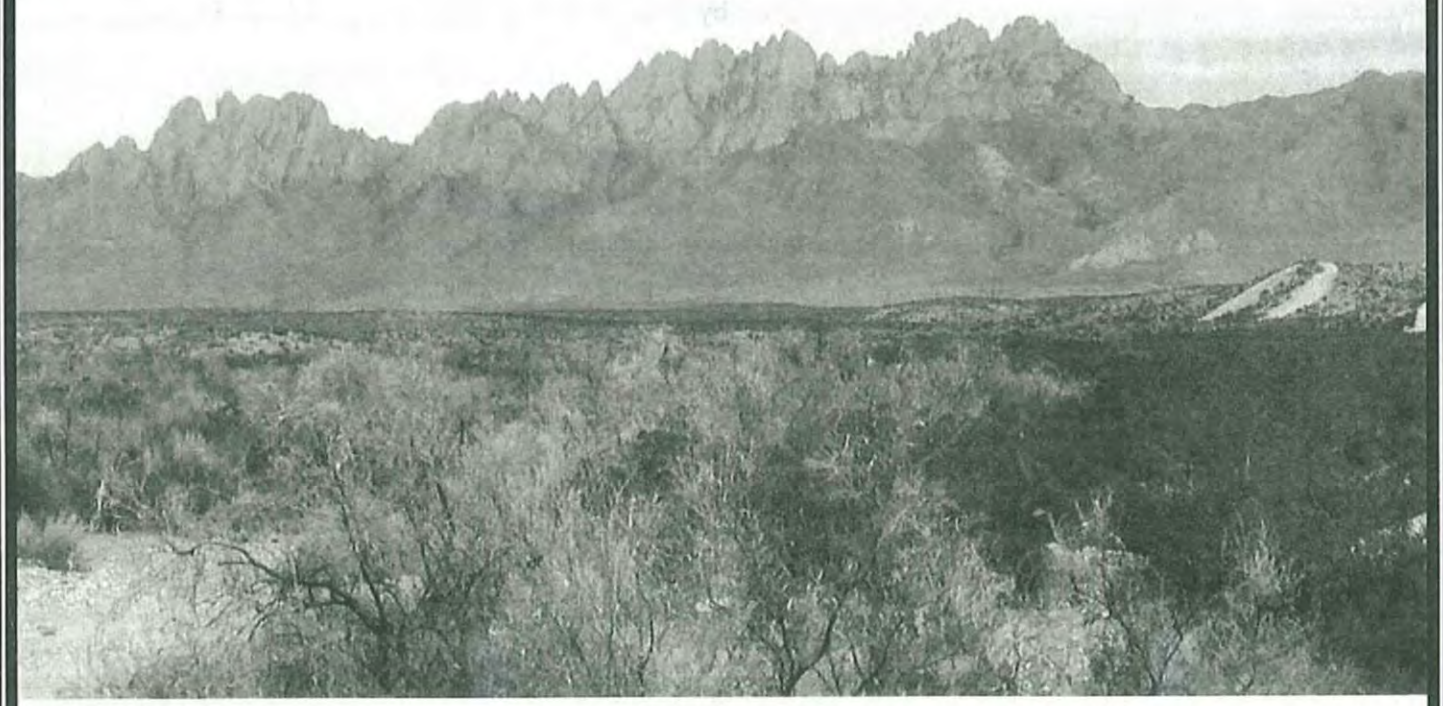
MS. KLAHN - 02:20:43
MR. STEIN - 00:00:00
MR. ROMAN - 00:00:00
MR. DUBOIS - 00:00:00
MS. BARNCASTLE - 00:00:00
MR. BROCKMANN - 00:00:00
MR. WALLACE - 00:00:00

GIVEN UNDER MY HAND AND SEAL OF OFFICE, on this, the 25th day of February, 2019.

HEATHER L. GARZA, CSR, RPR, CRR
Certification No.: 8262
Expiration Date: 12-31-19
VERITEXT LEGAL SOLUTIONS
Firm Registration No. 571
300 Throckmorton Street, Suite 1600
Fort Worth, TX 76102
1-800-336-4000

Tab 38

CITY OF LAS CRUCES 40-YEAR WATER DEVELOPMENT PLAN



by

Annie M. McCoy, CPG

John W. Shomaker, PhD, CPG

JOHN SHOMAKER & ASSOCIATES, INC.
Water-Resource and Environmental Consultants
2611 Broadbent Parkway NE
Albuquerque, New Mexico 87107
www.shomaker.com
505-345-3407

prepared for

Las Cruces Utilities
City of Las Cruces

April 2017

WIDMER
58
5-Feb-2019

CITY OF LAS CRUCES 40-YEAR WATER DEVELOPMENT PLAN

by

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CITY OF LAS CRUCES
40-YEAR WATER DEVELOPMENT PLAN

EXECUTIVE SUMMARY

The City of Las Cruces is in the Mesilla Basin along the Rio Grande, and extends into the West Mesa area on the edge of the Mesilla Basin, and into the East Mesa area in the southern part of the Jornada del Muerto Basin (Fig. 1). The Mesilla Basin and Jornada del Muerto Basin represent two sub-basins within the Lower Rio Grande Basin. The City relies on groundwater from its Valley and West Mesa Well Fields in the Mesilla Basin, and East Mesa Well Field in the Jornada del Muerto Basin, for its potable water supply (Fig. 2). The groundwater supply is produced from the Quaternary-age river valley alluvium, and the thick, unconsolidated Quaternary- to Tertiary-age Upper and Middle Santa Fe Group basin-fill sediments (Fig. 3).

Wastewater is treated at the City's Jacob A. Hands wastewater treatment facility, East Mesa water reclamation facility, and West Mesa wastewater treatment plant (Fig. 2). The Jacob A. Hands wastewater treatment facility also receives wastewater from other water systems in the Mesilla and Jornada del Muerto Basins, and the East Mesa water reclamation facility also receives wastewater from other water systems in the Jornada del Muerto Basin. Treated effluent from the Jacob A. Hands wastewater treatment facility is discharged as return flow to the Rio Grande. The East Mesa water reclamation facility produces very high quality reclaimed (Class A) water for landscape irrigation, and the West Mesa wastewater treatment plant produces reclaimed water used for sprinkler-irrigation of native vegetation in the West Mesa Industrial Park.

Groundwater diversions for Las Cruces Utilities water supply represent only 6.5 percent of total metered groundwater diversions in the Lower Rio Grande Basin (Fig. 4; NMOSE, 2016a; NMOSE, 2016b; 2011 to 2015 average). The majority of groundwater diversions are for irrigated agriculture, at about 84 percent of total metered groundwater diversions. In terms of both groundwater and surface water demand, groundwater diversions for Las Cruces water supply represent only 4.5 percent of the total water demand in the Lower Rio Grande water planning region (NMISC, 2016; 2010 data). If Las Cruces' return flow to the Rio Grande is considered, then Las Cruces water supply represents only 2.6 percent of the total regional water demand.

Moreover, the City's priority date of 1905 for its LRG-430 *et al.* water rights is both pre-Project and pre-Rio Grande Compact, thus providing it with the right to affect surface flows of the Rio Grande.

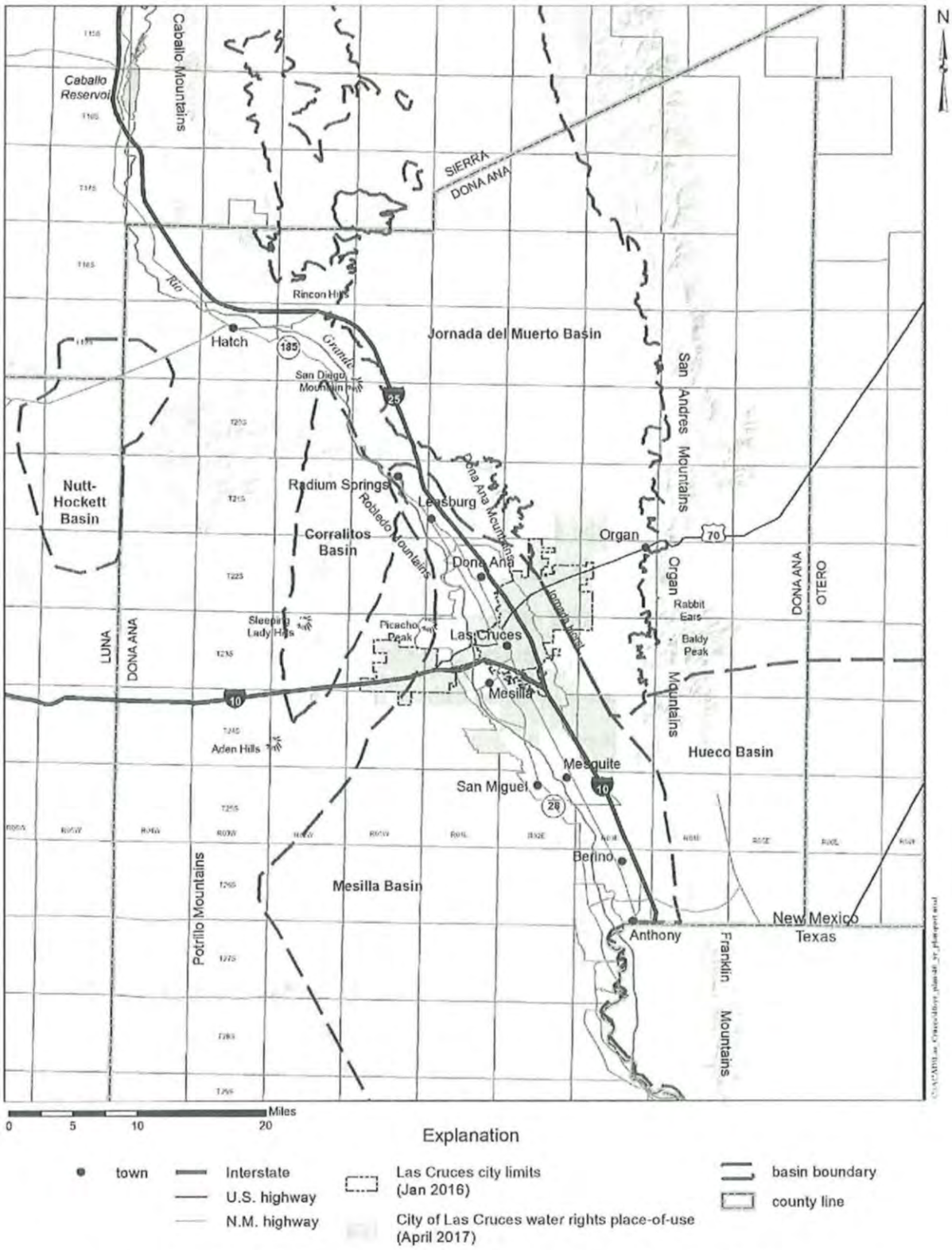

Figure 1. Map of the Mesilla Basin and southern part of the Jornada del Muerto Basin showing City of Las Cruces.

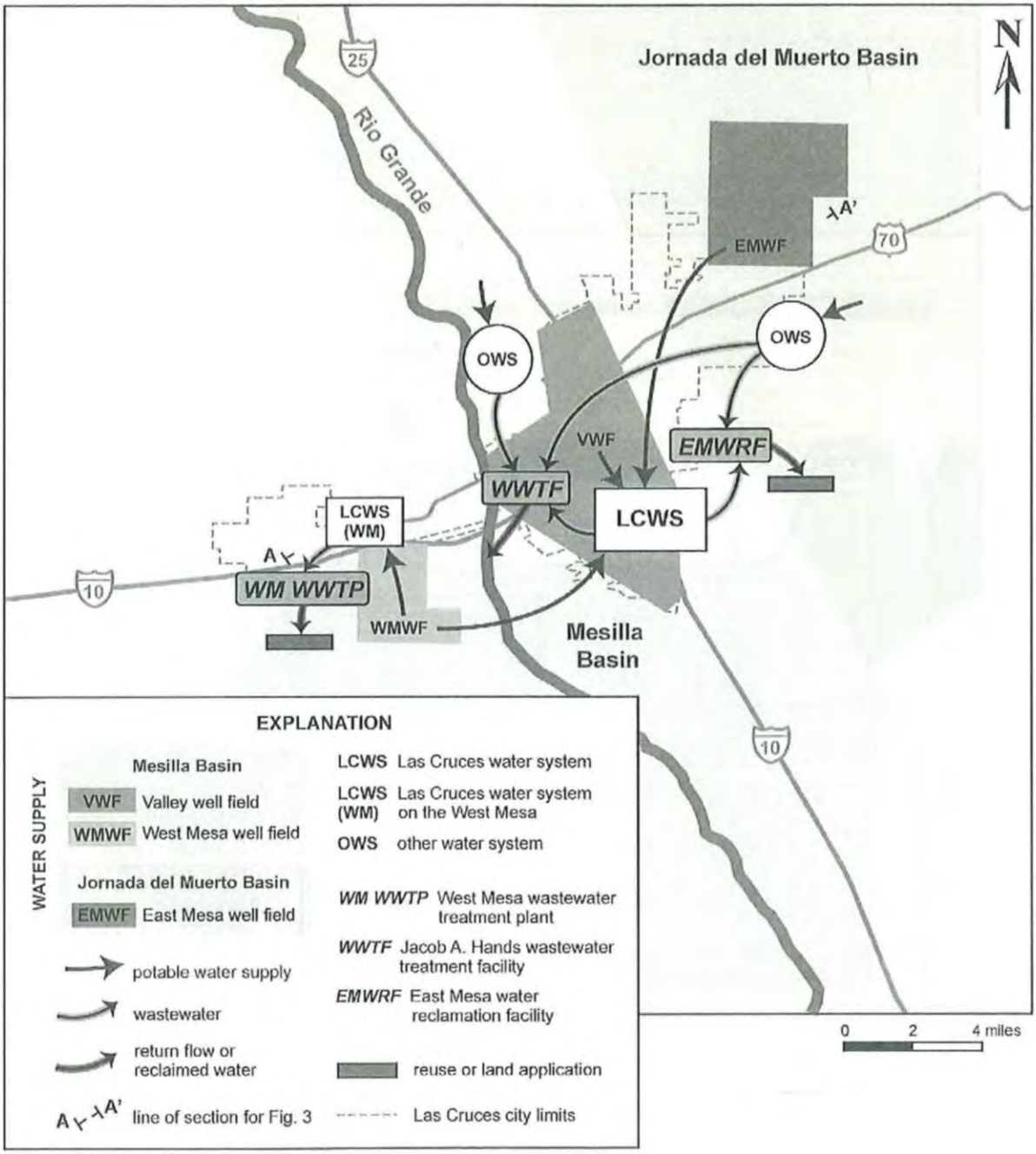

Figure 2. Schematic illustration of City of Las Cruces water supply, and water and wastewater system.

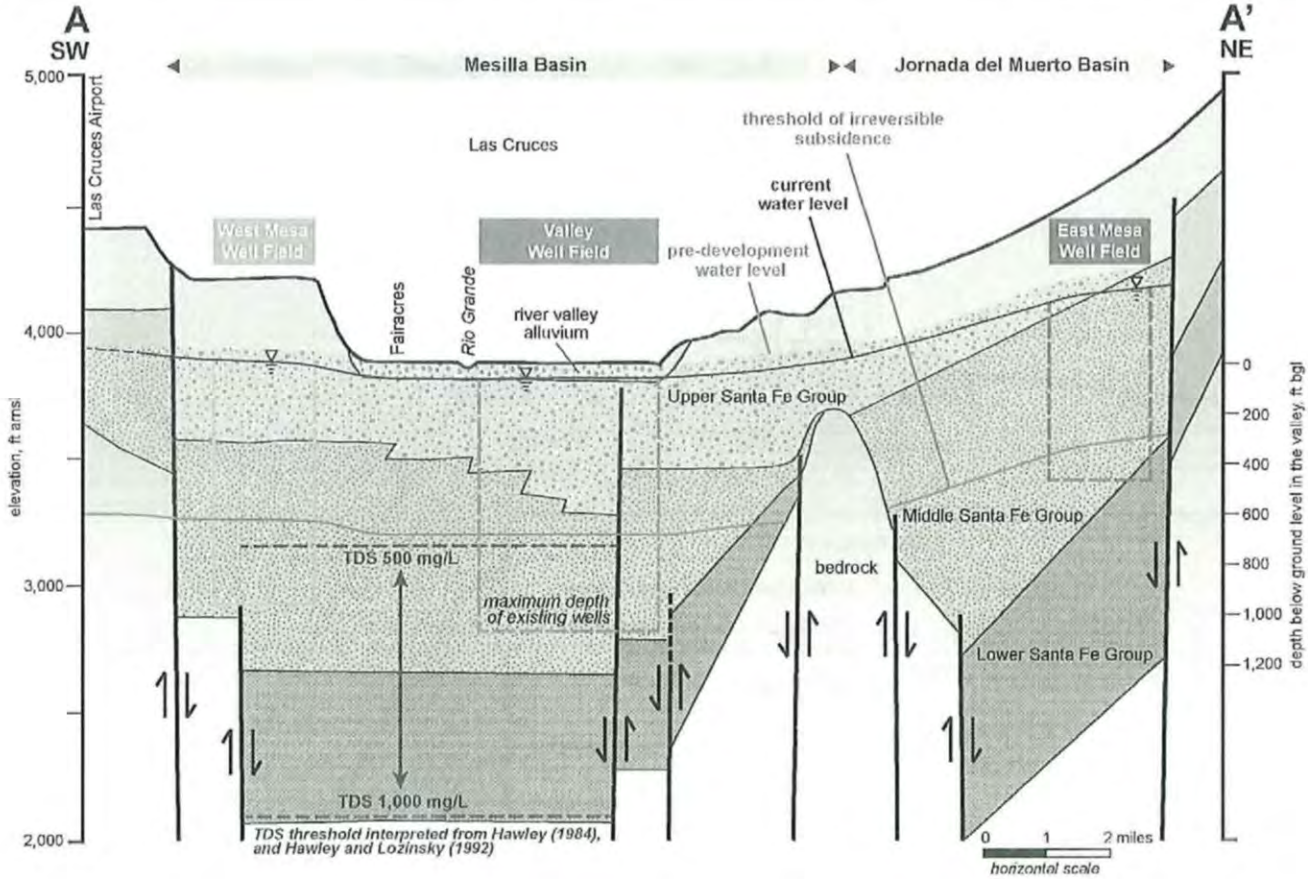

Figure 3. Schematic southwest-to-northeast hydrogeologic cross-section of City of Las Cruces area, after Hawley and Kennedy (2004).

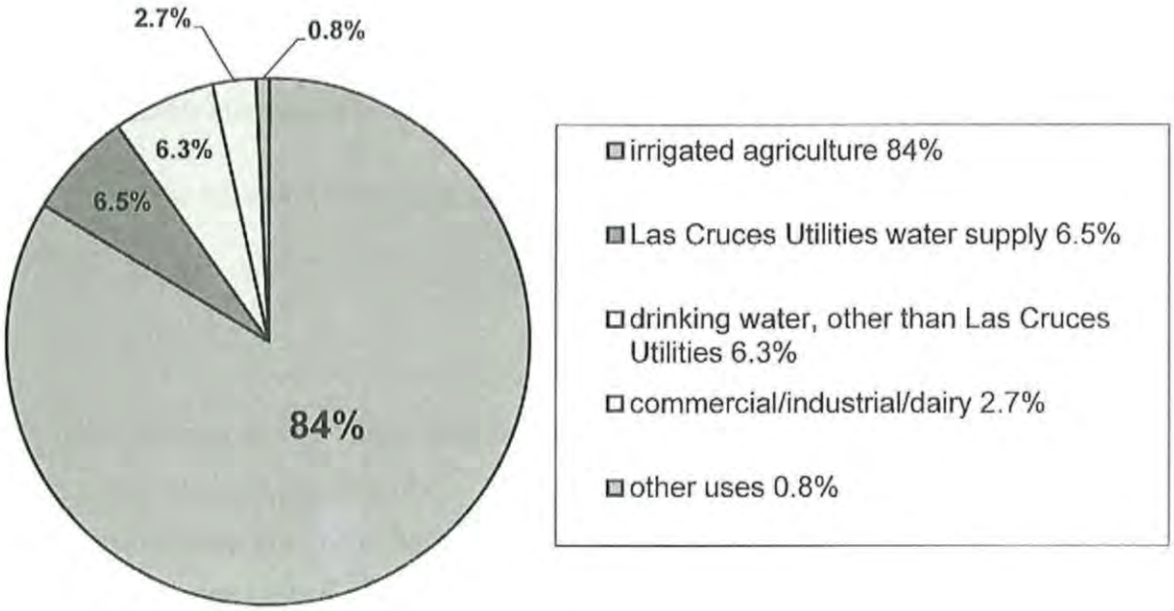

Figure 4. Chart summarizing groundwater diversions in the Lower Rio Grande Basin, 2011 to 2015.

Implementation of the City's water development plan will benefit the people of Las Cruces by providing a safe and reliable water supply while limiting water waste, optimizing efficiency of water use, preventing pollution of water supply, and remediating contaminated groundwater. The City's water development plan is consistent with the following principles defined by consensus by the National Groundwater Association (NGWA):

- "Groundwater sustainability: The development and use of groundwater resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences."
- "Resilience: The capacity of a groundwater (or water-resources) system to withstand either short-term "shocks" (e.g., drought) or long-term change (e.g., climate change). When discussing resilience, the timeframe under consideration should be defined. Resilience applies to both water quantity and quality and may be an important concept as part of groundwater sustainability."
- "Adaptive management: A staged decision-making approach to long-term groundwater (water-resources) management with an aim to reducing uncertainty over time via system monitoring."

Las Cruces Utilities (LCU) will develop and maintain a sustainable water supply for City of Las Cruces over the next 40 years by:

- Using existing groundwater rights and permits in the Mesilla Basin and Jornada del Muerto Basin
- Developing thresholds for water quality and quantity, beyond which alternate water supply must be developed
- Developing an alternate water supply
- Practicing proactive conservation
- Monitoring water resources

Las Cruces' principal goal is to continue to beneficially use its existing water rights from its LRG-430 et al. well field and to perfect and beneficially use the water rights from its East Mesa and West Mesa well fields and to protect its right to do so in court proceedings and in its interaction with other water users in the Lower Rio Grande Water Users' Organization.

Development of an alternate supply is necessary due to water-level declines, and the transition to groundwater pumping from storage. Groundwater pumping from storage, also referred to as groundwater mining, is occurring in the shallow part of the aquifer in the Mesilla Basin due to a shortage of surface water and increased pumping for irrigated agriculture. A shortage of surface water also has implications for the City's ability to use return flow to meet streamflow offset requirements associated with groundwater permits, due to conditions on the use of return flow associated with the City's LRG-430 et al. water right. Thus, development of an alternate water supply is generally based on physical limitations, as opposed to deficiency in the amount of existing water rights and permits.

Water-level trends in the Mesilla Basin and the southern Jornada del Muerto Basin are being monitored under the City's water-level monitoring program. Water-level declines must be managed in order to avoid eventual irreversible subsidence and compaction of the aquifer, which would result in diminished capacity for aquifer recharge. Water-level declines may also be accompanied by a decrease in groundwater quality. Thus, the timing of development and implementation of alternate supply will be based on the threshold of irreversible subsidence, water quality thresholds, and appropriate warning indicators, within and beyond the 40-year planning timeframe. Figure 3 illustrates the threshold of irreversible subsidence as defined for the Mesilla Basin and Jornada del Muerto Basin. The need to consider alternate supplies may also be triggered by legal constraints arising from *Texas v. New Mexico & Colorado,* Original No. 141.

Importation of groundwater, aquifer storage and recovery with reclaimed water, and development of deep brackish-water wells and desalination, have been identified as potential sources for alternate supply. Sources for importation evaluated for potential implementation within the 40-year planning period include groundwater from the Corralitos Basin, Nutt-Hockett Basin, Mimbres Basin, or Salt Basin. These potential sources of alternate supply are considered in this Plan, and would need to be reviewed by the New Mexico Office of the State Engineer prior to determination of a policy direction from the LCU Board.

PROJECTED GROWTH

Las Cruces' low- and medium-growth population projections are referenced from City planning documents; the high-growth projection of 2.4-percent annual growth reflects historical average growth. Planning according to the historical average rate will allow LCU to perfect the water rights in the place-of-use area. However, LCU recognizes that there is some overlap with areas served by other utilities and place-of-use of water rights from other utilities, such as Moongate Water Company. Considering high growth and water conservation, the demand served by LCU would increase to 44,207 acre-feet per year (ac-ft/yr) by 2055.

WATER CONSERVATION GOALS

Las Cruces has and continues to refine the implementation and practice of its Water Conservation Program. Las Cruces is implementing its Water Conservation Program proactively and systematically, and in a manner appropriate to the conditions and needs of the community. The City is utilizing the highest and best technology available and economically feasible for the intended use to ensure conservation of water to the maximum extent practical. It may not be possible to meet the City's water demands by conservation alone, in the case that current and future activities in the Lower Rio Grande Basin pose challenges to using existing rights and permits to meet demand.

Las Cruces' goals for gallons per capita day (GPCD) water use will be met by the continued practice of the Water Conservation Program. Las Cruces has the goal of reducing total GPCD water use to 140 GPCD by 2055, by reducing single-family residential GPCD, working with industrial, commercial, and institutional customers, conservation at City facilities, and by reducing non-revenue water to 9 percent of diversions. It should be noted that this GPCD goal does not yet apply to customers of the former Jornada Water Company, recently acquired by LCU; water use data for the former Jornada Water Company are currently inadequate to determine a realistic GPCD goal for these customers.

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CITY OF LAS CRUCES
40-YEAR WATER DEVELOPMENT PLAN

1.0 WATER-SUPPLY DEVELOPMENT PLAN

1.1 Introduction

The City of Las Cruces is in the Mesilla Basin along the Rio Grande, and extends into the West Mesa area on the edge of the Mesilla Basin, and into the East Mesa area in the southern part of the Jornada del Muerto Basin. The City relies on groundwater from its Valley and West Mesa Well Fields in the Mesilla Basin, and well fields on the East Mesa in the Jornada del Muerto Basin, for its potable water supply. Figure 5 shows the City's existing wells. Wastewater is treated at the City's Jacob A. Hands wastewater treatment facility, East Mesa water reclamation facility, and West Mesa wastewater treatment plant. Treated effluent from the Jacob A. Hands wastewater treatment facility is discharged as return flow to the Rio Grande.

Groundwater diversions for Las Cruces water supply represent only 6.5 percent of total metered groundwater diversions in the Lower Rio Grande Basin (see Fig. 4; NMOSE, 2016a; NMOSE, 2016b; 2011 to 2015 average). In terms of both groundwater and surface water demand, groundwater diversions for Las Cruces water supply represents only 4.5 percent of the total water demand in the Lower Rio Grande water planning region (NMISC, 2016; 2010 data). If Las Cruces' return flow to the Rio Grande is considered, then Las Cruces water supply represents only 2.6 percent of the total regional water demand. Moreover, the City's priority date of 1905 for its LRG-430 *et al.* water rights is both pre-Project and pre-Rio Grande Compact, thus providing it with the right to affect surface flows of the Rio Grande.

Las Cruces 40-year water development plan has been prepared by John Shomaker & Associates, Inc. (JSAI) under the supervision of Las Cruces Utilities (LCU), and Utilities Director, Dr. Jorge Garcia. Implementation of the water development plan will benefit the people of Las Cruces by providing a safe and reliable water supply for residential, institutional, commercial, industrial, and recreational uses, and firefighting. The plan also aims to limit water waste, optimize efficiency of water use, prevent pollution of water supplies, and remediate contaminated groundwater.

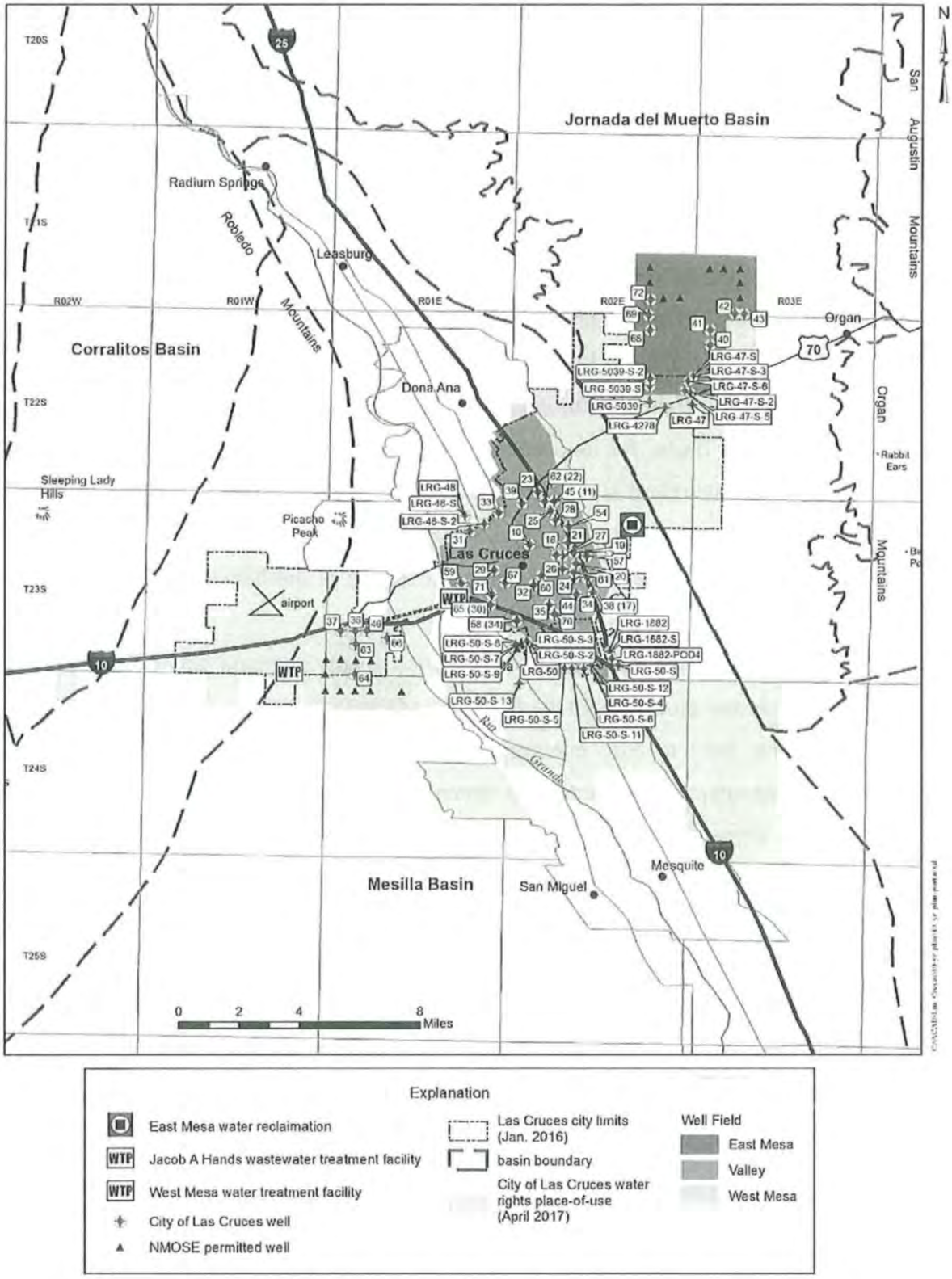

Figure 5. Map of City of Las Cruces area showing the East Mesa, West Mesa, and Valley Well Fields, and existing wells and permitted well locations.

1.2 Develop Alternate Supply

Las Cruces Utilities (LCU) will develop and maintain a sustainable water supply for the City of Las Cruces over the next 40 years by developing an alternate water supply in addition to using existing groundwater rights and permits. Development of an alternate water supply is generally based on physical limitations and potential legal/administrative constraints, as opposed to deficiency in the amount of existing water rights and permits. Potential legal/administrative constraints may arise from the general stream system adjudication or *Texas v. New Mexico and Colorado*, Original No. 141. Development of an alternate supply is necessary due to water-level declines in the Mesilla and Jornada del Muerto Basins, and the transition to groundwater pumping from storage. Groundwater pumping from storage, also referred to as groundwater mining, is occurring in the shallow part of the aquifer in the Mesilla Basin due to a shortage of surface water and increased pumping for irrigated agriculture.

A shortage of surface water also has implications for the City's ability to use return flow to meet streamflow offset requirements associated with groundwater permits, due to conditions on the use of return flow associated with the City's LRG-430 et al. water right. Return flow associated with LRG-430 et al. cannot be consumptively used, or used to fulfill offset requirements associated with other permits, when Elephant Butte Irrigation District's (EBID's) surface-water irrigation allotment is less than 2 acre-feet per acre. The City's existing portfolio of groundwater rights and permits is intended to be used in combination, with depletions from pumping under the West Mesa permit offset by return flows associated with the LRG-430 et al. right and the East Mesa permits (Appendices A, B, and C). If return flows from LRG-430 et al. cannot be used for offsets, or if LRG-430 et al. and East Mesa pumping must be curtailed due to water-level declines, this poses challenges to using existing rights and permits to meet demand.

Water-level trends in the Mesilla Basin and the southern Jornada del Muerto Basin are being monitored under the City's water-level monitoring program, and declines must be managed in order to avoid eventual irreversible subsidence and aquifer compaction, which would result in diminished capacity for aquifer recharge. Water-level declines may also be accompanied by a decrease in groundwater quality. There is evidence for accelerating water-level declines in the Jornada del Muerto Basin, as can be expected as a result of pumping and low-permeability boundaries within the aquifer. In the Mesilla Basin, inactive City supply wells monitored by the City, and observation wells monitored by the USGS, also show declines. Some of these declines

in the Mesilla Basin appear to be accelerating in response to increased pumping for irrigated agriculture and diminished short-term recharge. Farmers will likely deepen wells in the Mesilla Basin in years to come, thereby accelerating declines in the deeper part of the aquifer in which City wells are completed. The New Mexico Universities Working Group on Water Supply Vulnerabilities (2015) indicates that "the Mesilla Valley aquifer may no longer have the capacity to provide a reliable, supplemental supply during extended drought conditions and with the current levels of intensive use of groundwater." This statement refers to extended drought conditions such as those experienced in Las Cruces area in the 1960s, and 2009 through 2014; periods with consecutive years of below-average annual precipitation. The "current levels of intensive use of groundwater" refers to the increased pumping for irrigated agriculture in the shallow part of the aquifer in the Mesilla Basin.

1.3 Rio Grande Surface Water Will Not Be Pursued for Alternate Supply

Due to current and projected availability of surface water in the Rio Grande, LCU will not pursue efforts to develop this source as an alternate water supply at this time; any future consideration of developing this source would be contingent on a number of factors. The Upper Rio Grande Impact Assessment (BOR, 2013) indicates that supplies from all native water sources to the Rio Grande are projected to decrease by an average of about one third overall. Projections show increased variability in flows on a monthly and annual basis in the future. Climate change modeling for the region indicates earlier snowmelt runoffs and warmer average temperatures, leading to increased variability in the magnitude, timing, and spatial distribution of streamflow.

The New Mexico Universities Working Group on Water Supply Vulnerabilities (2015) indicates that the Rio Grande has in recent years exhibited earlier peak flows and diminished streamflow efficiency, defined as the volume of downstream snowmelt runoff per unit of winter precipitation. They recommend that water managers consider the full range of NRCS (Natural Resources Conservation Service) predicted flows, "in this regard we note the dismal 10% of average at the low end of the range of projected flows at San Marcial." Appendix D provides a description of surface-water resources.

The volume of water stored in Elephant Butte Reservoir upstream of Las Cruces decreased precipitously between 2000 and 2004, is now about one-quarter of what it was between 1985 and 1999, and is projected to continue to decrease (BOR, 2013).

1.4 Potential Sources for Alternate Supply

Importation of groundwater from nearby basins, aquifer storage and recovery with reclaimed water, and development of deep brackish wells and desalination, have been identified as potential sources for alternate supply. Sources for importation evaluated for potential implementation within the 40-year planning period include groundwater from the Corralitos Basin, Nutt-Hockett Basin, Mimbres Basin, or Salt Basin (Fig. 6). The NMOSE has declared the Lower Rio Grande, Nutt-Hockett, Mimbres, and Salt Underground Water Basins; the Corralitos Basin is part of the Lower Rio Grande Underground Water Basin. Sources for alternate supply in the Corralitos Basin, Nutt-Hockett Basin, and Mimbres Basin would likely take the form of a transfer of leased or purchased water rights, whereas the source for alternate supply in the Salt Basin may take the form of a new appropriation. The New Mexico Office of the State Engineer (NMOSE) has not forbidden transfers across basin boundaries, and there are many instances in which this practice of groundwater importation is occurring. Currently, there are several pending applications before the NMOSE for major interbasin transfers.

In the sections below, potential sources for alternate supply are discussed in broad, qualitative terms of institutional constraints, technical feasibility, capital and operating costs, environmental impacts, and potential amounts of water available. This discussion is not intended to be a rigorous analysis of feasibility, but is intended to provide useful information for initial prioritization of potential sources.

1.4.1 Importation of Groundwater from the Corralitos, Nutt-Hockett, or Mimbres Basins

The Corralitos, Nutt-Hockett, and Mimbres Basins lie to the west of Las Cruces (Fig. 6). Importation of groundwater from these basins holds potential in the case that groundwater becomes available for lease or purchase within the 40-year planning period.

The Corralitos Basin is within 4 miles of Las Cruces Airport, and would therefore not require a major extension of LCU infrastructure. The Corralitos Basin contains unconsolidated sediments of the Quaternary-to-Tertiary-age Santa Fe Group, up to about 300 ft thick (JSAI, 2004). Water columns in wells typically range from 50 to 150 ft. Well yields up to 1,000 gallons per minute (gpm) have been reported. Little water quality data are available for groundwater in the Corralitos Basin; based on available data, total dissolved solids (TDS) concentrations may exceed the secondary (aesthetic-related) drinking water standard of 500 milligrams per liter (mg/L) in some wells. The Corralitos Basin is a sub-basin of the Lower Rio Grande, and groundwater flows across low-permeability boundaries of the sub-basin.

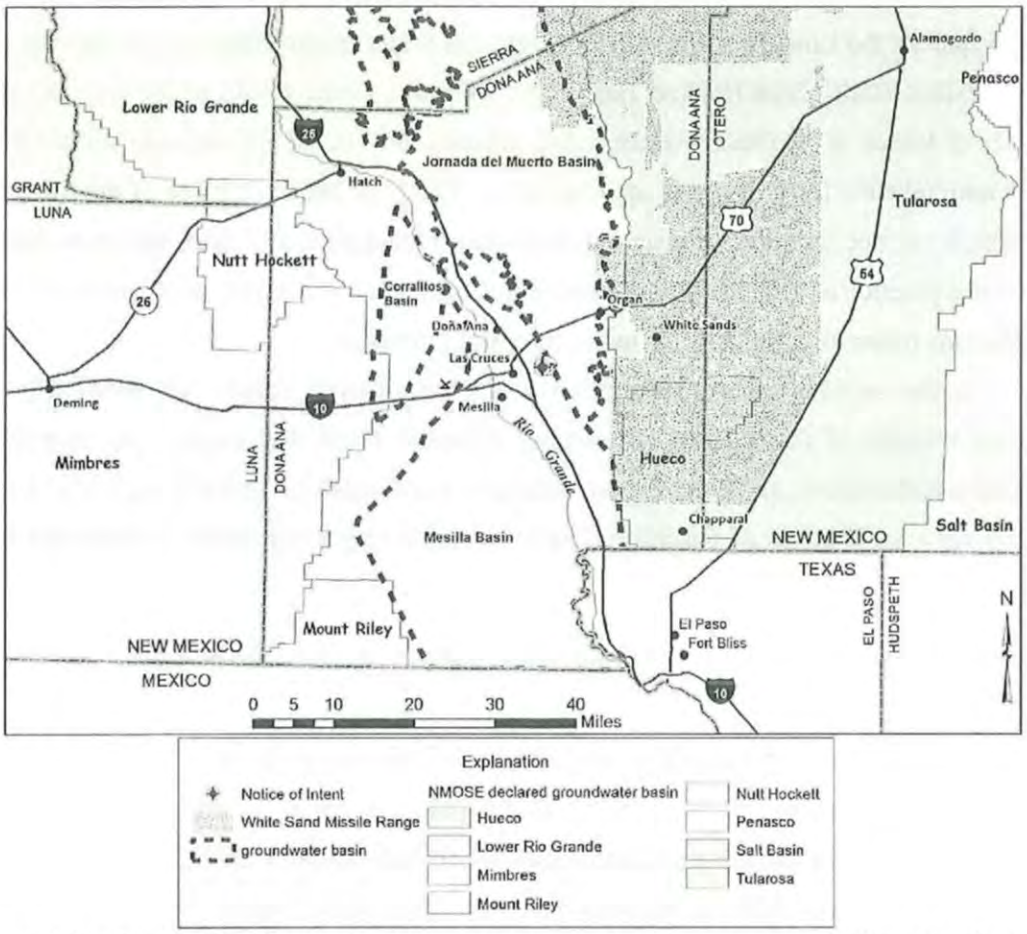

Figure 6. Map of southern New Mexico showing potential sources for alternate supply for the City of Las Cruces.

The Nutt-Hockett Basin is located about 14 miles northwest of the Corralitos Basin, and contains up to 500 ft of unconsolidated sediments of the Quaternary-to-Tertiary-age Santa Fe Group and Tertiary-age volcanic rocks (JSAI, 2004). Well yields up to 3,000 gpm have been reported. Groundwater quality is relatively good, although arsenic concentrations may be elevated above the primary drinking water standard of 0.010 mg/L in some wells. Groundwater in the Nutt-Hockett Basin generally flows to the northeast towards the Rio Grande.

The Mimbres Basin lies west of the Corralitos Basin. The basin area covers more than 4,000 square miles. Deming, New Mexico, in the central part of the Mimbres Basin, is about 50 miles west of Las Cruces. The Mimbres Basin is filled with up to 2,400 ft of poorly-consolidated sediments of the Quaternary-to-Tertiary-age Gila Conglomerate; the thickest deposits are near Deming (JSAI, 2006b). Wells for municipal use and irrigated agriculture in the Deming area yield hundreds of gpm to 1,000 gpm. Groundwater in the Gila Conglomerate aquifer in the Mimbres Basin is generally of good quality, although brackish groundwater does occur in the southeastern part of the basin, southeast of the Deming area (Hanson et al., 1994).

1.4.1.1 Institutional Constraints

As mentioned above, the NMOSE has not forbidden transfers across basin boundaries, and groundwater importation remains feasible from a water-rights permitting standpoint. Water rights permit applications for the Corralitos, Nutt-Hockett, or Mimbres Basin would likely take the form of transfer of existing groundwater rights. In the case of the Corralitos and Nutt-Hockett Basins, existing groundwater rights associated with irrigated agriculture may become available for lease or purchase, and in the case of the Mimbres Basin, existing groundwater rights associated with irrigated agriculture or mining-related industrial use may become available for lease or purchase. If groundwater rights associated with irrigated agriculture are transferred, the amount available for transfer is limited to the consumptive use (irrigated acreage multiplied by the consumptive irrigation requirement (CIR)).

From the infrastructure and right-of-way (ROW) standpoint, pipeline infrastructure would primarily cross BLM lands and State lands in the parts of the basins in Doña Ana County. There are significant areas of private lands in the parts of the Nutt-Hockett and Mimbres Basins in Luna County, to the west of Doña Ana County. The SunZia Southwest Transmission Project appears to have successfully negotiated ROW for above-ground transmission lines on BLM and

State lands, and minor areas of private lands, in Luna County in 2015. Interstate highway ROW along Interstate-10 between Las Cruces and Deming, or railroad ROW between Las Cruces and Deming and between Deming and Hatch, could potentially be utilized for pipelines from the Mimbres and Nutt-Hockett Basins.

1.4.1.2 Technical Feasibility

Insight on technical feasibility of groundwater importation via pipeline may be gained by reviewing the Eastern New Mexico Rural Water System (also referred to as the Ute Pipeline Project), a 151-mile-long proposed pipeline project designed to provide municipal and industrial water supply to several communities and Cannon Air Force Base in eastern New Mexico, a combined population of 73,000 (Widdison, 2015). Construction of this project began recently due to depletion of potable groundwater resources in the region, and it represents an example of an existing project for comparison.

Particularly applicable may be a phase of the Ute Pipeline Project referred to as the Interim Groundwater Pipeline (IGWP), designed to provide interim water supply by leasing or purchasing agricultural water rights until the project extends to Ute Reservoir, the ultimate water source for the Ute Pipeline Project. Construction of the IGWP began in 2015 with an estimated 10-year construction timeframe to supply 4,849 ac-ft/yr via a 97.5-mile pipeline, whereas the total project is to be constructed within a 25-year timeframe and supply 16,450 ac-ft/yr (ENMWUA, 2015).

Building pipeline infrastructure to the Corralitos Basin is likely the most technically feasible because the Corralitos Basin is within 4 miles of Las Cruces Airport. Building pipeline infrastructure to the Nutt-Hockett Basin would be similarly technically feasible; the Nutt-Hockett Basin is located about 14 miles northwest of the Corralitos Basin. In the case of the Corralitos Basin and Nutt-Hockett Basin, insight on technical feasibility may be gained by reviewing the development of infrastructure to convey groundwater from Las Cruces' East Mesa Well Field for municipal water supply.

1.4.1.3 Capital and Operating Costs

Insight on capital costs may be gained by reviewing the Ute Pipeline Project's IGWP. The IGWP includes about 97.5 miles of pipeline to be constructed within a 10-year timeframe to supply 4,849 ac-ft/yr. Capital costs to build the IGWP are estimated at $105.1 million (2015 dollars; ENMWUA, 2015), or about $1.1 million per mile when divided by 97.5 miles.

Capital costs could be significantly higher for a pipeline project that involves booster pump stations and other infrastructure considerations required by large elevation differences. The IGWP includes at least three booster pump stations across an area with relatively moderate elevation change of 600 ft. Capital costs could vary significantly depending on whether pipeline may be installed by trenching, ripping, or blasting.

Capital costs for a well field and pipeline project in the Corralitos, Nutt-Hockett, and Mimbres Basins would also include services related to well field development (in the case that well rehabilitation or replacement is needed), permitting, and system engineering and design.

Operating expenses would include energy, chemicals, labor, routine maintenance and repairs, and debt payment for capital costs of construction; other expenses such as replacements, expansions, and new technology would be minimal in the early years of project operation. Operating expenses associated with energy may be reduced in the case that renewable energy resources are developed in combination with the project, as is becoming increasingly common with new water projects.

1.4.1.4 Environmental Impacts

An Environmental Assessment would be required for a project involving federal lands, influence, funding, or agency actions, and would need to consider the impacts of the proposed action and alternatives. The Environmental Assessment would evaluate impacts on the affected environment and resources, which could include water resources, soils and geologic resources, land cover and vegetation, grazing, wildlife, cultural resources, socioeconomic resources, environmental justice, land use, energy requirements, transportation, air quality, climate change, and visual resources.

Environmental Assessment, Biological Assessment, and issuance of "Finding of No Significant Impacts" was a 3-year process in the case of the Ute Pipeline Project (Widdison, 2015). Environmental Assessment was an approximately 5-year process in the case of the SunZia Southwest Transmission Project (Scoping Report dated April 2010, U.S. Bureau of Land Management (BLM) Record of Decision (ROD) dated January 2015), and an 8-year process in the case of the Alamogordo Regional Water Supply Project (Scoping Report dated April 2005, BLM ROD dated August 2012).

1.4.1.5 Potential Amounts of Water Available

In the case of the Corralitos Basin, irrigation of 635 acres with 1,905 ac-ft/yr has been declared under NMOSE File No. LRG-468 et al. in the southeastern part of the Corralitos Basin. Relatively high transmissivities have been interpreted for the LRG-468 et al. wells, but the aquifer to the north and south of this zone appears to have lower transmissivity, indicating that high transmissivity may be localized in the basin (JSAI, 2004). Although a CIR of 1.92 ac-ft/ac was established for the water right in the 1993 temporary transfer LRG-468-A, the Rio Grande Adjudication has established a CIR of 2.6 ac-ft/ac for future transfers to non-irrigation purposes of use that shall apply to all irrigated acreage in the Lower Rio Grande. Thus, the maximum transfer associated with the water right would likely be 1,651 ac-ft/yr. It should be noted that a 2002 application to transfer 1,000 ac-ft/yr was withdrawn, possibly due to a letter from the State Land Office claiming that the water rights were appurtenant to State Trust Lands, and the applicant did not have the State Land Commissioner's consent to sever the water rights from Trust Lands.

In the case of the Nutt-Hockett Basin, the potential amounts of water available would likely be limited based on the quantity of agricultural groundwater rights that may become available for lease or purchase. Pumping for irrigated agriculture in the Nutt-Hockett Basin was estimated by the NMOSE to be 17,185 ac-ft/yr in 2010 (NMOSE, 2013), of which 13,493 ac-ft/yr was consumptively used (net pumping). The actual quantity of agricultural groundwater rights that may become available for lease or purchase would likely be significantly less than the net pumping associated with agricultural rights, as the area has a strong tradition of growing high-value crops such as chile, which will likely be preserved and continue.

In the case of the Mimbres Basin, the potential amounts of water available would likely be limited based on the quantity of agricultural groundwater rights that may become available for lease or purchase primarily in the area near Deming. Net pumping for irrigated agriculture in the Mimbres Basin in Luna County was estimated by the NMOSE to be 24,879 ac-ft/yr in 2010 (NMOSE, 2013), although a portion of that likely occurred near the New Mexico-Mexico border. The NMOSE estimated an additional 29,553 ac-ft/yr of surface water from the Mimbres River consumptively used for irrigation in Luna County in 2010.

JSAI has estimated net pumping for irrigated agriculture in the Deming area of the Mimbres Basin to range from 12,000 to 18,000 ac-ft/yr between 2006 and 2015 based on irrigated acreage evident in historical aerial photographs and a CIR of 1.80 ac-ft per acre.

In the Mimbres Basin, groundwater rights associated with mining-related industrial use may also become available for lease or purchase primarily in the area northwest of Deming, in Grant County. Pumping for mining use in Grant County was estimated by the NMOSE to be 7,882 ac-ft/yr in 2010 (NMOSE, 2013).

1.4.2 Importation of Groundwater from the Salt Basin

The Salt Basin lies to the east of Las Cruces (Fig. 6). Importation of groundwater from the Salt Basin holds potential as a joint project based on geography and major facilities in the area; the Salt Basin boundary is 35 to 40 miles from White Sands Missile Range (WSMR) Post Headquarters, which is in turn about 20 miles from Las Cruces.

The Salt Basin is one of the few remaining groundwater basins in New Mexico that contains large undeveloped areas, and groundwater recharge to the basin has been estimated at about 60,000 ac-ft/yr (JSAI, 2010). The Salt Basin spans about 5,095 square miles and straddles the New Mexico-Texas border, with about 43 percent of the basin area in New Mexico and 57 percent of the basin area in Texas. The Salt Basin aquifer is composed of carbonate rocks and alluvium-filled structural basins. The alluvium and fractured and karstified carbonate rocks have high permeability, and are surrounded by lower permeability bedrock. The majority of pumping in the basin has occurred close to the New Mexico-Texas border near Dell City, Texas. The New Mexico State Engineer declared the Salt Underground Water Basin in 2002 in an effort to regulate development by investors planning to import water from the Salt Basin to the El Paso metropolitan area.

1.4.2.1 Institutional Constraints

As mentioned above, the NMOSE has not forbidden transfers across basin boundaries, and groundwater importation remains feasible from a water rights permitting standpoint. Water rights permit applications for the Salt Basin may take the form of a new appropriation of groundwater. The New Mexico Interstate Stream Commission (NMISC) has filed applications to appropriate 90,000 ac-ft/yr based on the NMISC's interest in reserving the groundwater resource for potential future development for meeting interstate compact obligations on the Rio Grande and the Pecos River, or for use by New Mexico communities (Widdison, 2013). Importation of groundwater from the Salt Basin by Las Cruces would potentially be aligned with the NMISC's

interests and the intent of their existing application, as Las Cruces' treated effluent is discharged as return flow to the Rio Grande, and Las Cruces' water sources in the Lower Rio Grande would be replaced with the Salt Basin source.

From the infrastructure and ROW standpoint, pipeline infrastructure would primarily cross federal lands, and would involve cooperation from agencies including WSMR (U.S. Army). An example of a similar ROW project is the SunZia Southwest Transmission Project, the 2015 approval of which was contingent on burial of segments of transmission lines in order to mitigate impacts to military operations at WSMR.

1.4.2.2 Technical Feasibility

Insight on technical feasibility of groundwater importation via pipeline may be gained by reviewing the Ute Pipeline Project's Interim Groundwater Pipeline (IGWP), as discussed above in Section 1.4.1.2. Construction of the IGWP began in 2015 due to depletion of potable groundwater resources in the region, and it represents an example of an existing project for comparison.

1.4.2.3 Capital and Operating Costs

Insight on capital costs may be gained by reviewing the Ute Pipeline Project's IGWP, as discussed above in Section 1.4.1.3. Capital costs for a Salt Basin well field and pipeline project would also include services related to well field development, permitting, and system engineering and design.

Operating expenses would include energy, chemicals, labor, routine maintenance and repairs, and debt payment for capital costs of construction; other expenses such as replacements, expansions, and new technology would be minimal in the early years of project operation. Operating expenses associated with energy may be reduced in the case that renewable energy resources are developed in combination with the project, as is becoming increasingly common with new water projects.

1.4.2.4 Environmental Impacts

As discussed above in Section 1.4.1.4, an Environmental Assessment would be required for a project involving federal lands, influence, funding, or agency actions, and would need to consider the impacts of the proposed action and alternatives. Environmental Assessment, Biological Assessment, and issuance of "Finding of No Significant Impacts" for this type of project would likely be a three- to 8-year process.

1.4.2.5 Potential Amounts of Water Available

Groundwater recharge to the Salt Basin has been estimated at 60,000 ac-ft/yr, with about 87 percent of recharge in the New Mexico part of the basin and about 13 percent of recharge in Texas (JSAI, 2010). Recharge to the Salt Basin occurs by direct infiltration of precipitation in areas at higher elevations and areas of fractured rock, and infiltration of storm-water runoff into drainage channels, including the Sacramento River drainage, and alluvial fans. This estimate of 60,000 ac-ft/yr is in general agreement with a number of studies that present estimates ranging from about 55,000 to 100,000 ac-ft/yr (Bjorklund, 1957; Ashworth, 1995; Mayer, 1995; JSAI, 2002; Hutchison, 2008; DBSA, 2010). A recent study presents a much lower estimate of 6,000 to 12,000 ac-ft/yr based on environmental tracers (Sigstedt et al., 2016), but the discrepancy between this estimate and earlier estimates is unclear and the study does not include a discussion of their estimate in the context of the hydrogeologic conceptual model and basin water balance established by previous studies, or water-level trends. The range of water-availability estimates are bracketed on the high end by the estimated maximum sustainable yield of 150,000 ac-ft/yr (Livingston Associates, 2002).

The majority of pumping in the basin has occurred in the Texas part of the basin near Dell City, Texas. Net pumping was estimated at 89,000 ac-ft/yr, on average, between 1948 and 2009 (JSAI, 2010; this estimate is considered to be somewhat high). Net pumping in the New Mexico part of the basin has been estimated by the NMOSE to range from 1,580 and 10,130 ac-ft/yr between 1980 and 2010 (NMOSE *New Mexico water use by categories* series technical reports, e.g., NMOSE, 2013). The NMISC has applied to the NMOSE to appropriate a total of 90,000 ac-ft/yr from three applications (Widdison, 2013). The applications remain pending, and have received protests.

1.4.3 Aquifer Storage and Recovery with Reclaimed Water

The East Mesa water reclamation facility is used to collect wastewater from interceptors serving the East Mesa, High Range, and Sonoma Ranch areas, and produces very high quality reclaimed water for landscape irrigation, dust suppression, and supply to purple hydrants for fire suppression (Fig. 5). Important customers include the Sonoma Ranch Golf Course, Veteran's Park, Sagecrest Park, the closed Foothills Landfill, the City compost operation, Las Cruces Dam Environmental Restoration Project, and Centennial High School. Peak summer demand from the facility is about 700,000 gallons per day; however, the facility must ramp down in winter when there is very little demand for the water. The City has permits to discharge to a nearby arroyo, but that has been found to be unpopular with the public and is therefore not considered a practicable

option. Ramping down the facility each year poses operational issues, as the treatment system functions best with relatively consistent flow, as opposed to large seasonal fluctuations. Thus, reclaimed water produced from the East Mesa water reclamation facility during the winter represents a source that is not fully utilized and is a potential source for alternate supply.

LCU would like to utilize this source for alternate supply through an aquifer storage and recovery (ASR) project with well injection. Several City wells are located in close proximity to the reclaimed water pipeline, and could potentially be converted to injection wells. However, the current regulatory environment poses major challenges that may prohibit such a project. Treating the water to be injected to drinking-water quality, as would probably be required, is cost-prohibitive for LCU at this time. LCU is open to exploring other levels of treatment, with cooperation and support from regulatory agencies; for example, treatment that would decrease nitrate concentrations might be sufficient. LCU may also explore options for permitting disposal wells that would allow for injection, and applying to the NMOSE for potential return flow credit.

1.4.3.1 Institutional Constraints

New Mexico State agencies have regulatory processes for ASR and injection wells, and several ASR projects are in progress in New Mexico. Although the current regulatory environment poses permitting challenges, as ASR projects gain momentum in New Mexico and elsewhere in the U.S., regulations may be reviewed and modified for a more streamlined process and variances based on hydrogeologic conditions.

1.4.3.2 Technical Feasibility

The technical feasibility of ASR depends on aquifer characteristics, and the capacity of the aquifer to store water at the proposed ASR project site. In general, the technical feasibility of ASR using injection wells in appropriate areas has been demonstrated by projects in the U.S. and abroad. The Mesilla Basin and Jornada del Muerto Basins have been recognized as having excellent potential for ASR (Hawley, 2016).

1.4.3.3 Capital and Operating Costs

Capital costs may include modification of existing wells or completion of new wells as injection wells. Capital costs would also include services related to permitting, and system engineering, design, and testing. The capital costs of an ASR project with reclaimed water may be the lowest overall capital costs among the potential sources for alternate supply discussed in Section 1.4 of this Plan. Factors increasing capital costs of an ASR project would include the need to complete new wells, and the need to treat water to be injected, to drinking-water quality.

1.4.3.4 Environmental Impacts

In the case of ASR and injection wells, the primary focus of environmental impacts assessment would likely be assessment of impacts on groundwater in the project area. Disturbance of the landscape would be minimal compared to the groundwater importation and pipeline projects discussed in the sections above, and the project may be executed wholly on City-owned lands.

1.4.3.5 Potential Amounts of Water Available

The East Mesa water reclamation facility has a capacity of 1,000,000 gallons per day (about 1,121 ac-ft/yr). Average water reuse diversions for the winter months November through March represent about 58 percent of average water reuse diversions for the summer months April through October (2011 to 2015 data), and reflect the lack of demand for reclaimed water during the winter months. Under-utilization of the facility in the winter months equates to about 340 ac-ft/yr, based on data from 2011 to 2015. Thus, the potential amounts of water from an ASR project based on current capacity of the East Mesa water reclamation facility are relatively small compared to potential amounts of water available from groundwater importation projects discussed in the sections above.

1.4.4 Deep Brackish Wells and Desalination

Deep brackish groundwater resources where the top of the aquifer is more than 2,500 ft deep and the water has total dissolved solids (TDS) concentrations in excess of 1,000 milligrams per liter, represent a potential source for alternate supply (JSAI, 2008). Las Cruces filed Notice of Intent (NOI) for an estimated 5,000 ac-ft/yr of production from selected locations on City-owned lands on the East Mesa prior to passage of legislation in 2009 in which NMSA 72-12-25 was amended to give the State Engineer jurisdiction over these resources for municipal supply (Fig. 6). A technical memorandum prepared by Daniel B. Stephens & Associates, Inc. (DBSA, 2015) evaluates desalination, the process of physically removing dissolved solids from water for potable consumption, in Las Cruces.

Major limitations to developing deep brackish wells and a desalination project include the costs to drill and complete deep wells, to pump water from great depth, and to build, operate, and maintain a desalination treatment plant, and dispose of brine concentrate. The cost of constructing a deep well may be more than $500 per foot. Operation and maintenance for a desalination plant would potentially increase the cost to produce drinking water by three to five times (DBSA, 2015).

Concerns unique to inland desalination projects include uncertainty regarding the magnitude of the resource, issues relating to water treatment for constituents in groundwater such as silica, and disposal of brine concentrate (Thomson, 2016). If brine concentrate is to be disposed of via deep well injection instead of evaporation ponds, there are major costs associated with permitting, construction, testing, and operation of injection well(s), and construction of infrastructure to convey concentrate to the injection well(s). Pipeline construction materials costs alone would be significant, as materials must be able to withstand highly-corrosive brine concentrate. It is possible that the water treatment cost component could decrease in the future, if membrane technology becomes cheaper, but significant costs related to permitting, construction, materials, and operation and maintenance would remain.

Due to the significant costs associated with developing deep brackish-water wells and a desalination project, this alternative is ranked as the last potential source for alternate supply within the 40-year planning period, after groundwater importation.

1.4.4.1 Institutional Constraints

In order to minimize the potential for institutional constraints, the City filed NOIs for locations on City-owned lands prior to passage of legislation in 2009 in which NMSA 72-12-25 was amended to give the State Engineer jurisdiction over these resources for municipal supply.

1.4.4.2 Technical Feasibility

The technical feasibility of deep brackish wells and desalination in appropriate areas has generally been demonstrated by projects in the U.S. and abroad. Within relatively close proximity to Las Cruces, the joint desalination facility operated by El Paso Water Utilities and Fort Bliss represents the world's largest inland desalination plant.

Technical feasibility is particularly complex for inland desalination projects in which the magnitude of the resource is uncertain, water treatment must address constituents in groundwater such as silica, and disposal of concentrate is a major issue.

1.4.4.3 Water Quality

TDS concentrations for the target deep aquifer may range from 1,500 to 7,500 mg/L due to water-rock interactions (JSAI, 2008). Sulfate concentrations may be high due to dissolution of gypsum, and concentrations of dissolved metals may be high due to high heat flow, volcanic rocks, and mineralization in the area. As mentioned above, water treatment for silica in groundwater is another concern unique to inland desalination projects.

1.4.4.4 Capital and Operating Costs

Capital costs would include completion of new deep brackish wells and possibly injection wells depending on the method chosen for disposal of brine concentrate, and construction of a desalination treatment plant. Las Cruces' NOI on the East Mesa considers five wells, each completed to a depth of 5,000 to 6,000 ft. As mentioned above, the cost of constructing a deep well may be more than $500 per foot, and possibly as high as $1,000 per foot. Capital costs would also include services related to permitting, and system engineering, design, and testing.

Operating costs associated with deep brackish wells and desalination would likely represent the highest operating costs among the potential sources for alternate supply discussed in Section 1.4 of this Plan. Operating costs would include costs to pump water from great depth, operate and maintain a desalination treatment plant, and dispose of brine concentrate, in addition to operating costs common to other groundwater projects, such as energy, chemicals, labor, routine maintenance and repairs, and debt payment for capital costs of construction.

1.4.4.5 Environmental Impacts

In the case of deep brackish wells and desalination, the primary focus of environmental impacts assessment would likely be assessment of impacts on groundwater and surface water in the region. The lateral extent of disturbance of the landscape would be less than the disturbance created by the groundwater importation and pipeline projects discussed in the sections above, and the project may be executed wholly on City-owned lands. If evaporation ponds are the method chosen for disposal of brine concentrate, environmental impacts assessment associated with air quality, wildlife, and the potential for contamination of the vadose zone, groundwater, and the land surface, would be significant.

1.4.4.6 Potential Amounts of Water Available

Las Cruces' NOI on the East Mesa includes an estimate of total production of 5,000 ac-ft/yr. The joint desalination facility operated by El Paso Water Utilities and Fort Bliss has the capacity to produce up to 27.5 million gallons of fresh water per day (about 30,825 ac-ft/yr), which likely represents the current upper limit on capacity of a state-of-the-art inland desalination facility.

1.5 Timeline for Implementation of Alternate Supply

The timeline for implementation of an alternate supply will likely be based on a threshold related to physical supply, such as a drawdown threshold not to be exceeded due to potential for irreversible subsidence and aquifer compaction. A water quality threshold would also need to be considered; as water-level declines may be accompanied by a decrease in groundwater quality, to the point that water treatment may be necessary for the existing supply. There is also a possibility that the threshold may take the form of a water-resources management threshold, as discussed in Section 2.11.

1.5.1 Drawdown Threshold

The maximum drawdown threshold, or threshold of irreversible subsidence, has been established for Las Cruces based on the method presented by Heywood (1992), which is based on the difference between present elevations in the Rio Grande Valley and bordering mesa areas. This difference is representative of the net overburden removed by the cycle of erosion and re-aggradation between the mid-Pleistocene and Holocene. The change in effective stress is estimated to occur at a calculated freshwater hydraulic head decline of [1.2 times the thickness of eroded overburden]. At Las Cruces, this thickness is based on the elevation change between the airport on the West Mesa at an elevation of about 4,450 ft above mean sea level (amsl), and Fairacres (North Fairacres Road) at an elevation of about 3,900 ft amsl, or about 550 ft. Multiplied by 1.2, the change in effective stress would occur at a decline of 660 ft from pre-development heads for Las Cruces water supply wells in the Valley of the Mesilla Basin (Fig. 3).

The change in effective stress could occur at a significantly lower decline on the East and West Mesas, as Heywood (1992) notes, "the preconsolidation stress threshold for overlying late Pleistocene or Holocene fluvial sediments and Bolson sediments outside the Rio Grande Valley may be significantly lower as it is for analogous sediments elsewhere (Holzer, 1981)."

1.5.2 Drawdown Warning Indicator

A drawdown warning indicator should be developed in order to ensure protection of the aquifer in the case that the drawdown threshold is approached, and to trigger actions towards alternate supply. Las Cruces' water-level monitoring program, described in Section 2.9, will

provide the data to indicate whether the drawdown threshold is being approached. A drawdown warning indicator could be defined based on trends or changes observed in the water-level monitoring dataset, such as:

- Increase in 5- or 10-year running average water-level decline rate, such that the decline rate, if sustained, would lead to water-level declines approaching the drawdown threshold near the end of the 40-year planning period.
- Acceleration of the rate of water-level decline, such that the acceleration rate, if sustained, would lead to water-level declines approaching the drawdown threshold near the end of the 40-year planning period.

The drawdown warning indicator may require a certain level of statistical significance or confidence to avoid a false indication due to variance or noise in the dataset. The drawdown warning indicator may require that trends or changes be observed in a certain number of wells, or a specific set of wells designated as sentinel wells or representative of a substantial part of the total water supply.

The period of record for Las Cruces' water-level monitoring program is now long enough that long-term water-level trends are emerging for the majority of wells included in the program (JSAI, 2016); however, another 5 or 10 years of continued monitoring may be required to achieve the statistical significance required for a drawdown warning indicator.

1.5.3 Water Quality Threshold

Groundwater-level declines approaching the drawdown threshold may be accompanied by a decrease in groundwater quality. At the point that the quality of the existing supply has deteriorated to the point that treatment is needed, it may become more practical to implement an alternate supply. In terms of total dissolved solids (TDS), although the secondary (aesthetic-related) drinking water standard is 500 mg/L, the threshold would likely be closer to 1,000 mg/L. Existing Las Cruces water-supply wells typically produce water with TDS concentrations ranging from 300 to 500 mg/L, with occasional TDS results as high as 900 mg/L. TDS concentration of 1,000 mg/L typically represents the lower limit of waters defined as "brackish." The drawdown threshold will likely be reached prior to the TDS threshold in Las Cruces area of the Mesilla Basin (see Fig. 3); therefore it may be more reasonable to tie the water-quality threshold to a constituent other than TDS.

The TDS threshold is a major issue of discussion in the Mesilla Basin south of Las Cruces, near the border with Texas and Mexico. By some estimates, a TDS threshold may be reached within 10 to 15 years in that area. Other estimates indicate that there is enough fresh water to meet demand for the next two decades in that area (Albuquerque Journal Editorial Board, 2016). Due to the TDS threshold issue in the region, it is important to consider development of alternate supply with deep brackish wells and desalination for long-range planning, even though such a project may currently have a low ranking in terms of potential alternate supply due to associated costs (see Section 1.4.4, above). In a recent article discussing groundwater development in the Mesilla Basin, the manager of EBID made reference to the "West Mesa aquifer" containing "50 million acre-feet of economically extractable water, less brackish than the water being extracted in east El Paso" (LeCompte, 2016). It is unclear what potential undeveloped groundwater resource is being referred to as the "West Mesa aquifer" in the article, in terms of location and depth, but it does not appear to coincide with the City's West Mesa Well Field as described in this Plan.

The water-quality threshold may also be tied to concentrations of naturally-occurring uranium in groundwater in Las Cruces area of the Mesilla Basin. Seven City wells in the Mesilla Valley (Wells 10, 19, 20, 21, 24, 38, and 44) are not currently in service due to elevated naturally-occurring uranium concentrations in groundwater. The primary drinking water standard for total uranium is 30 micrograms per liter, which would represent the threshold beyond which water treatment is needed.

1.5.4 Groundwater Level Declines

Decline from pre-development heads is on the order of 40 to 50 ft, and current rates of decline are on the order of 1 to 2 ft/yr, for Las Cruces wells in the Valley of the Mesilla Basin, based on pre-development heads as presented in JSAI (2006a) and recent water levels (JSAI, 2016). Appendix E presents hydrographs for selected wells in the Mesilla Basin. Rates of decline appear to be accelerating in a number of wells in the Mesilla Basin (e.g., Figs. E12, E14, E16, E17, E21, and E22); 2 ft/yr would be expected to represent the minimum rate of decline for future projections. However, we do not have a good way to estimate future decline rates if the water table becomes disconnected from the river in areas of heavy pumping, especially where there is little irrigation, as is the case for some Las Cruces wells in the Valley. Thus, rates of decline for future projections could be significantly greater than 2 ft/yr.

Decline from pre-development heads is currently on the order of 60 to 70 ft, and current rates of decline are on the order of 3 to 4 ft/yr, for Las Cruces wells in the Jornada del Muerto Basin, based on pre-development heads as presented in JSAI (1996) and recent water levels (JSAI, 2016). Appendix F presents hydrographs for selected wells in the Jornada del Muerto Basin. Rates of decline appear to be accelerating in wells in the Jornada del Muerto Basin (e.g., Figs. F5 through F7); thus 4 ft/yr would be expected to represent the minimum rate of decline for future projections.

1.6 Planning for Several Possible Future Scenarios

The water-supply development plan must allow LCU the flexibility to meet current and future demand under several potential future scenarios, including:

- Groundwater use will be subject to the implications of the 2008 Operating Agreement among U.S. Bureau of Reclamation (BOR), Elephant Butte Irrigation District (EBID), and El Paso County Water Improvement District No. 1 (EPCWID). This scenario will likely lead to increased pumping of supplemental irrigation wells, and accelerated drawdowns, which may affect pumping of Las Cruces wells close to the Rio Grande and result in more pumping in the Jornada del Muerto Basin.
- Groundwater use will not be affected by the Operating Agreement, but will be subjected to conventional administration by NMOSE. Under this scenario, the City's preference is to pump from the Mesilla Basin.
- Management of the river and groundwater that is hydrologically connected to the river will be "federalized," and the City will be required to enter into a contract with BOR to continue to divert groundwater in the Lower Rio Grande Basin.

These potential future scenarios are discussed in detail in Section 2.11.

2.0 WATER RIGHTS AND WELLS

Las Cruces has well fields in the Mesilla Basin (Fig. 5; Valley and West Mesa Well Fields) and the southern Jornada del Muerto Basin (Fig. 5; East Mesa Well Field), from which groundwater is produced under the terms of NMOSE Permit No. LRG-430 et al., which represents a groundwater right of 21,869 ac-ft/yr with a priority date of 1905.

In the Mesilla Basin, Las Cruces also has permits to develop groundwater rights of 5,042 ac-ft/yr (LRG-389, LRG-399, and LRG-5818 et al.) in the Valley, and 8,000 ac-ft/yr on the West Mesa (West Mesa permit LRG-3275 et al.). In the Jornada del Muerto Basin, Las Cruces has permits to develop a groundwater right of 10,200 ac-ft/yr (East Mesa permits LRG-3283 through LRG-3285 and LRG-3288 through LRG-3296) and permits to develop groundwater rights of 107 ac-ft/yr (LRG-5039 et al.). Las Cruces recently acquired Jornada Water Company with permits to develop a groundwater right of 5,961 ac-ft/yr in the Mesilla and Jornada del Muerto Basins (LRG-47 et al., LRG-48 et al., LRG-50 et al., LRG-1882 et al., and LRG-4278).

In addition to groundwater rights, the City currently owns or leases about 1,412 acres of surface-water rights in EBID. A full annual surface-water allotment from EBID is 3 ac-ft/ac, but the allotment depends on flows in the Rio Grande.

A summary of the City's current rights and permits is presented in Table 1, and a summary description of existing wells is presented in Table 2. Table 3 indicates the NMOSE well number associated with each existing and planned City well. A summary of data for existing wells is provided in Appendix G. Two of LCU's wells (Wells 18 and 27) currently in service in the Valley are operating as plume capture wells for the tetrachloroethylene (PCE) plume at the Griggs and Walnut Superfund site. Water pumped from Wells 18 and 27 is treated and stored in a tank, and the City uses the treated water for municipal water supply; treatment system operation and reporting to the U.S. Environmental Protection Agency (EPA) is being performed voluntarily until LCU has a consent decree with EPA, and represents a positive example of proactive water management. Seven wells in the Valley are not currently in service due to naturally-occurring elevated uranium concentrations in groundwater. LCU has been developing flexible infrastructure to allow for delivery of water to different parts of the water system, and east-west redundancy within the system. Implementation of enhanced meter calibration and automatic meter reading (AMR) ensures compliance with water rights and permits.

Table 1. Summary of City of Las Cruces water rights and permits

NMOSE File No.	basin	water-right status	diversion amount, ac-ft/yr
LRG-430 et al.	Mesilla/ Jornada del Muerto	pre-basin, conditional use of return flow [a]	21,869
LRG-3283 through LRG-3285, LRG-3288 through LRG-3296 East Mesa permit	Jornada del Muerto	permitted, new appropriations, minimal offsets required [b]	10,200
LRG-3275 et al. West Mesa permit	Mesilla	permitted, new appropriations, offsets required [c]	8,000
LRG-389	Mesilla	permitted, new appropriations, offsets required [d]	2,550
LRG-399	Mesilla	permitted, new appropriations, offsets required [e]	1,700
LRG-5818 et al.	Mesilla	permitted, new appropriations, offsets required [f]	792
LRG-5039 et al.	Jornada del Muerto	permitted, new appropriations, offsets required	107
LRG-47 et al., LRG-48 et al., LRG-50 et al., LRG-1882 et al., LRG-4278	Mesilla/ Jornada del Muerto	permitted, new appropriations, offsets required	5,961
groundwater rights and permits			51,179
surface water rights owned		adjudicated [g]	1,412 acres

[a] In periods of drought in which EBID allotment to irrigators is less than 2 ac-ft/ac, Las Cruces is not to consumptively use treated effluent derived from LRG-430 wells, but instead must return effluent to stream system.
[b] Total of 100 ac-ft/yr in offsets required after 40 years, total of 644 ac-ft/yr in offsets required after 100 years.
[c] Amount of water that may be diverted re-evaluated and determined by NMOSE annually subject to any offset debt from previous calendar year(s) and anticipated availability of offsets in the current calendar year, pursuant to Return Flow Plan (JSAI, 2009).
[d] The City has permit to drill well LRG-389, but the well has not been drilled due to groundwater quality issues at the permitted location.
[e] 435.5 ac-ft/yr of rights already transferred into LRG-399.
[f] Total diversion amount is 792 ac-ft/yr. Offsets required for diversions exceeding 42.46 ac-ft/yr (maximum beneficial use). 15 ac-ft/yr serving Southwest Environmental Center.
[g] A full surface-water allotment from EBID is 3 ac-ft/ac, but the allotment depends on flows in the Rio Grande.
NMOSE - New Mexico Office of the State Engineer
EBID - Elephant Butte Irrigation District
ac-ft/yr - acre-feet per year

Table 2. Summary of existing City of Las Cruces wells

wells	well field	basin	NMOSE File No.	water-right status	diversion amount, ac-ft/yr
Wells 10, 18-21, 23-33, 35, 38, 39, 44, 45, 54, 57-62, 65, 67, 70, 71, Driving Range, Paz Park	Valley	Mesilla Basin	LRG-430 et al.	pre-basin	21,869
Wells 36, 37, 46, 63, 64	West Mesa				
Wells 42, 43	East Mesa	Jornada del Muerto Basin	LRG-430 et al. [a]		
Well 40	East Mesa		LRG-3289	permitted, new appropriations, minimal offsets required [b]	10,200
Well 41	East Mesa		LRG-3288		
Well 68	East Mesa		LRG-3290		
Well 69	East Mesa		LRG-3291		
Well 72	East Mesa		LRG-3292		
Well 71 [d]	Valley	Mesilla Basin	LRG-399	permitted, new appropriations, offsets required	1,700
Wells 66, S-4, S-6	Valley		LRG-5818 et al.	permitted, new appropriations, offsets required [c]	792
Wells LRG-5039, LRG-5039-S, LRG-5039-S-2	East Mesa	Jornada del Muerto Basin	LRG-5039 et al.	permitted, new appropriations, offsets required	106.866
Wells LRG-47 thru -47-S-6, LRG-48 thru -48-S-2, LRG-50 thru -50-S-13, LRG-1882 thru -1882-POD4, LRG-4278	East Mesa	Mesilla Basin and Jornada del Muerto Basin	LRG-47 et al., LRG-48 et al., LRG-50 et al., LRG-1882 et al., LRG-4278	permitted, new appropriations, offsets required	5,961

[a] These wells to be transferred to East Mesa permit (LRG-3283 through LRG-3285, LRG-3288 through LRG-3296)
[b] Total of 100 ac-ft/yr in offsets required after 40 years, total of 644 ac-ft/yr in offsets required after 100 years.
[c] Total diversion amount is 792 ac-ft/yr. Offsets required for diversions exceeding 42.46 ac-ft/yr (maximum beneficial use). 15 ac-ft/yr serving Southwest Environmental Center.
[d] Well 71 (LRG-430-S-44) permitted as supplemental point of diversion under LRG-399.
NMOSE - New Mexico Office of the State Engineer
ac-ft/yr - acre-feet per year

Table 3. Existing and planned City of Las Cruces wells and associated NMOSE file numbers

NMOSE Well No.	City Well No.	well field	status
LRG-430	10	Valley	not currently in service [b]
LRG-430-S	44	Valley	not currently in service [b]
LRG-430-S-2	45 (11)	Valley	not currently in service
LRG-430-S-3	58 (12, 34)	Valley	in service
LRG-430-S-4	38 (17)	Valley	not currently in service [b]
LRG-430-S-5	18	Valley	in service [a]
LRG-430-S-6	19	Valley	not currently in service [b]
LRG-430-S-7	20	Valley	not currently in service [b]
LRG-430-S-8	21	Valley	not currently in service [b]
LRG-430-S-9	62 (22)	Valley	in service
LRG-430-S-11	24	Valley	not currently in service [b]
LRG-430-S-12	26	Valley	in service
LRG-430-S-13	25	Valley	in service
LRG-430-S-14	27	Valley	in service [a]
LRG-430-S-15	28	Valley	in service
LRG-430-POD57	29B	Valley	in service
LRG-430-S-17	65	Valley	in service
LRG-430-POD58	31B	Valley	in service
LRG-430-POD59	32B	Valley	in service
LRG-430-S-20	33	Valley	in service
LRG-430-S-21	35	Valley	in service
LRG-430-S-22	36	West Mesa	not currently in service
LRG-430-S-23	37	West Mesa	not currently in service
LRG-430-S-25	54	Valley	not currently in service
LRG-430-S-27	39	Valley	in service
LRG-430-S-29	42	East Mesa	in service
LRG-430-S-30	43	East Mesa	in service
LRG-430-S-31	57	Valley	not currently in service
LRG-430-POD56	59B	Valley	in service
LRG-430-S-33	Driving Range	Valley	not currently in service
LRG-430-S-34	Paz Park	Valley	in service
LRG-430-S-35	60	Valley	not currently in service

[a] operating as plume capture well for Griggs and Walnut tetrachloroethylene (PCE) plume
[b] elevated uranium concentrations
[c] casing collapsed
NMOSE - New Mexico Office of the State Engineer

Table 3. Existing and planned City of Las Cruces wells and associated NMOSE file numbers (continued)

NMOSE Well No.	City Well No.	well field	status
LRG-430-S-36	46	West Mesa	in service
LRG-430-S-37	61	Valley	in service
LRG-430-S-38	63	West Mesa	in service
LRG-430-S-39	64	West Mesa	not currently in service
LRG-430-S-40	48	West Mesa	not yet drilled
LRG-430-S-41	49	West Mesa	not yet drilled
LRG-430-S-42	67	Valley	in service
LRG-430-S-43	70	Valley	in service
LRG-430-S-44	71	Valley	in service
LRG-3283	No. not assigned	East Mesa	not yet drilled
LRG-3284	No. not assigned	East Mesa	not yet drilled
LRG-3285	No. not assigned	East Mesa	not yet drilled
LRG-3288	40	East Mesa	in service
LRG-3289	41	East Mesa	in service
LRG-3290	68	East Mesa	in service
LRG-3291	69	East Mesa	in service
LRG-3292	72	East Mesa	not currently in service
LRG-3293	No. not assigned	East Mesa	not yet drilled
LRG-3294	No. not assigned	East Mesa	not yet drilled
LRG-3295	No. not assigned	East Mesa	not yet drilled
LRG-3296	No. not assigned	East Mesa	not yet drilled
LRG-399	No. not assigned	Valley	not yet drilled
LRG-5818-S-7	66	Valley	not currently in service
LRG-5818-S-8	S-8	Valley	not yet drilled
LRG-5818-S-9	S-9	Valley	not yet drilled
LRG-5818-S-10	S-10	Valley	not yet drilled
LRG-5039	-	East Mesa	in service
LRG-5039-S	-	East Mesa	in service
LRG-5039-S-2	-	East Mesa	in service
LRG-47	-	East Mesa	in service
LRG-47-S	-	East Mesa	not currently in service
LRG-47-S-2	-	East Mesa	in service

[a] operating as plume capture well for Griggs and Walnut tetrachloroethylene (PCE) plume
[b] elevated uranium concentrations
[c] casing collapsed
NMOSE - New Mexico Office of the State Engineer

Table 3. Existing and planned City of Las Cruces wells and associated NMOSE file numbers (concluded)

NMOSE Well No.	City Well No.	well field	status
LRG-47-S-3	-	East Mesa	in service
LRG-47-S-5	-	East Mesa	in service
LRG-47-S-6	-	East Mesa	in service
LRG-48	-	Valley	in service
LRG-48-S	-	Valley	not currently in service
LRG-48-S-2	-	Valley	in service
LRG-50	-	Valley	in service
LRG-50-S	-	Valley	not currently in service
LRG-50-S-2	-	Valley	not currently in service
LRG-50-S-3	-	Valley	not currently in service
LRG-50-S-4	-	Valley	in service
LRG-50-S-5	-	Valley	not currently in service
LRG-50-S-6	-	Valley	not currently in service
LRG-50-S-7	-	Valley	not currently in service
LRG-50-S-8		Valley	not yet drilled
LRG-50-S-9		Valley	not yet drilled
LRG-50-S-11	-	Valley	in service
LRG-50-S-12	-	Valley	in service
LRG-50-S-13	-	Valley	in service
LRG-1882	-	Valley	not currently in service
LRG-1882-S	-	Valley	in service
LRG-1882-POD4	-	Valley	in service
LRG-4278	-	East Mesa	not currently in service

[a] operating as plume capture well for Griggs and Walnut tetrachloroethylene (PCE) plume
[b] elevated uranium concentrations
[c] casing collapsed
NMOSE - New Mexico Office of the State Engineer

2.1 LRG-430 et al. Wells in the Valley

The LRG-430 wells located in the Rio Grande Valley of the Mesilla Basin include 25 wells that are currently in service and pumped under Las Cruces' LRG-430 et al. groundwater right, which has a diversion right of 21,869 ac-ft/yr (Tables 1 through 3). The LRG-430 et al. right has a pre-Rio Grande project, 1905 priority date. As indicated in the LRG-430 Subfile Order (Appendix A), Las Cruces is not to consumptively use the treated effluent derived from the LRG-430 wells in periods of drought in which the EBID allotment to irrigators is less than 2 ac-ft/ac, but instead must return the effluent derived from the wells to the stream system.

The 25 wells currently in service in the Valley were completed between 1953 and 2012, to depths ranging from 460 to 1,070 ft. The wells have pumping capacities generally ranging from 300 to 2,900 gpm. Non-pumping water levels range from 30 to 240 ft, and pumping water levels range from 80 to 350 ft.

2.2 LRG-430 et al. Wells on the West Mesa

The LRG-430 wells located on the West Mesa of the Mesilla Basin include two wells that are currently in service and pumped under Las Cruces' LRG-430 et al. right, Wells 46 and 63 (Tables 1 through 3).

Wells 46 and 63 were completed in 1982 and 1996 to depths of 1,288 ft and 1,290 ft, respectively, with pumping capacities of 2,300 gpm and 3,100 gpm, respectively. Non-pumping water levels are 330 ft and 355 ft, and pumping water level is about 395 ft in these wells.

2.3 LRG-430 et al. Wells on the East Mesa

The LRG-430 wells located on the East Mesa in the Jornada del Muerto Basin include two wells that are currently in service and pumped under the City's LRG-430 et al. right, Wells 42 and 43 (Tables 1 through 3). These wells may eventually be transferred to the East Mesa permits LRG-3283 through LRG-3285 and LRG-3288 through LRG-3296.

Wells 42 and 43 were completed in 1998 to depths of 1,170 ft and 1,150 ft, respectively. The wells have pumping capacities of 1,670 and 1,500 gpm. Non-pumping water levels are 520 ft and 550 ft, and pumping water levels are 640 ft and 670 ft.

2.4 LRG-3283 through LRG-3285 and LRG-3288 through LRG-3296, Wells on East Mesa

The East Mesa permits LRG-3283 through LRG-3285 and LRG-3288 through LRG-3296 in the Jornada del Muerto Basin, for a total diversion of 10,200 ac-ft/yr, were approved by the NMOSE on February 4, 2002 (Table 1, Appendix B). These permits require 100 ac-ft/yr in offsets

after 40 years, and 644 ac-ft/yr in offsets after 100 years of pumping; however, diversions under these permits will generate much more return flow than that. The remainder of the return flow is used to offset depletions associated with other permits including the West Mesa permit (Section 2.5 below), or water reclamation projects. The term "offsets" refers to the amount of water that is lost from the river as a result of pumping. Pumping a well can lead to some reduction of flow in the river either by intercepting water that would otherwise discharge to the river or by inducing some recharge from the river; the amount of the reduction is required to be offset. The offset requirements associated with pumping under the East Mesa permits are relatively small because the wells are far from the river, and there is a low-permeability boundary in the form of a bedrock high between the East Mesa Well Field in the Jornada del Muerto Basin, and the Rio Grande in the Mesilla Basin.

The East Mesa Well Field now includes four wells in service and pumped under the East Mesa permits (Table 3). These wells were completed between 1988 and 2012 to depths of 815 to 1,170 ft. The wells have pumping capacities of 520 to 1,440 gpm. Non-pumping water levels are 320 to 480 ft, and pumping water levels are 430 to 575 ft.

2.5 LRG-3275-POD1 through LRG-3275-POD7, Wells on the West Mesa

The West Mesa permit LRG-3275 et al. on the West Mesa of the Mesilla Basin, for a total diversion up to 8,000 ac-ft/yr, was approved by the NMOSE on March 9, 2010 (Table 1, Appendix C). Permit conditions indicate that the amount of water that may be diverted under LRG-3275 et al. will be re-evaluated and determined by NMOSE annually subject to any offset debt from previous calendar year(s) and anticipated availability of offsets in the current calendar year, pursuant to the Return Flow Plan (JSAI, 2009; Appendix H). Permit conditions also require a system gallons per capita day (GPCD) goal of 180 GPCD within 20 years, updates to the Water Conservation Plan every 10 years, progress reports on implementation of the 40-Year Plan every 10 years (at a minimum), and annual reports to NMOSE on water conservation efforts, overall GPCD and residential GPCD, and American Water Works Association (AWWA) system water audit. Wells have not yet been completed under LRG-3275 et al.

2.6 LRG-389, LRG-399 and LRG-5818 et al. Permits in the Valley

Permits LRG-389, for a diversion of 2,550 ac-ft/yr with offsets required, and LRG-399, for a diversion of 1,700 ac-ft/yr with offsets required, in the Valley of the Mesilla Basin, were approved by the NMOSE in 1989 (Table 1, Appendix I). The City has transferred a total of about 435.5 ac-ft/yr of groundwater rights into LRG-399.

LRG-389 has not yet been drilled, and extensions of time have been filed with the NMOSE. The permitted well location has been identified as having poor groundwater quality with respect to concentrations of naturally-occurring uranium. The permitted location may need to be further evaluated in terms of water quality variations with depth.

Alternative points of diversion for LRG-399, and for LRG-430-S-44 as supplemental well, were approved by the NMOSE on August 21, 2008. LRG-399 has not yet been drilled. LRG-430-S-44 (Well 71) was drilled in 2006 to a depth of 725 ft. The pumping capacity is 2,900 gpm, the non-pumping water level is about 40 ft, and the pumping water level is about 120 ft.

The LRG-5818 et al. permits are for a total diversion of 792 ac-ft/yr with offsets required (Tables 1 through 3, Appendix J). LRG-5818-S-7 (Well 66) has been drilled. Of the permitted 792 ac-ft/yr, 15 ac-ft/yr serves the Southwest Environmental Center for wetland restoration. Offsets are required for diversions exceeding 42.46 ac-ft/yr.

2.7 LRG-5039 et al., Mesa Development Acquisition, Wells on the East Mesa

City of Las Cruces has acquired the Mesa Development permit LRG-5039 et al., and associated wells, on the East Mesa in the Jornada del Muerto Basin (Tables 1 and 2, Appendix K). The acquisition was based on the amount that has been put to beneficial use, 106.866 ac-ft/yr. The City will not be able to acquire unperfected groundwater rights, if any, remaining under LRG-5039 et al.

LRG-5039 et al. includes three wells that are currently in service (Table 3). These wells were completed between 1964 and 1990 to depths of 550 to 600 ft. The wells have pumping capacities of 500 gpm each. The non-pumping water level is about 350 ft for these wells.

2.8 LRG-47 et al., LRG-48 et al., LRG-50 et al., LRG-1882 et al., and LRG-4278, Jornada Water Company Acquisition, Wells in the Valley and on the East Mesa

City of Las Cruces has acquired the Jornada Water Company permits LRG-47 et al., LRG-48 et al., LRG-50 et al., LRG-1882 et al., and LRG-4278, and associated wells in the Valley in the Mesilla Basin and on the East Mesa in the Jornada del Muerto Basin (Tables 1 and 2, Appendix Q). The acquisition totals 5,961 ac-ft/yr. The acquisition includes 14 wells that are currently in service based on meter records on file with the NMOSE (Table 3).

2.9 Water-Level Monitoring Program

LCU has maintained a water-level monitoring program, under which groundwater-level data have been collected at the City's supply wells based on a defined methodology and QA/QC process from mid-2011 to present (JSAI, 2016). The monitoring program includes monthly hand-

measurements collected at over 40 wells, plus transducer measurements recorded on an hourly basis in 12 wells plus the nested Jornada shallow, middle, and deep piezometers. Monitoring program wells are located in the Valley of the Mesilla Basin, on the West Mesa of the Mesilla Basin, and on the East Mesa of the Jornada del Muerto Basin. Water-level trends in these wells and the Jornada nested piezometer, plus USGS-monitored piezometers located close to the Rio Grande in Las Cruces, are analyzed in annual reports prepared for LCU (JSAI, 2016).

2.10 NMSU-Las Cruces Water Agreement

Las Cruces water system has been interconnected with the New Mexico State University (NMSU) water system since approximately 1967. The mutual water delivery responsibilities have been set forth in various agreements dated January 1, 1967 and March 23, 1983, which replaced the 1967 Agreement; and related agreements known as the Afton Agreement dated March 8, 2004, the Supplemental Agreement dated March 12, 2007, and the Letter of Understanding dated October 12, 2012. These agreements collectively were for short term emergency and peaking purposes capped at 3,500 ac-ft/yr. There was a Third Amendment to Ground Lease Agreement dated March 1, 2015 in which the City conditionally agreed to buy additional water from NMSU. The City has fully performed the water related provisions in the Letter of Understanding and the Third Amendment, and has terminated the Supplemental Agreement. Therefore, the 1983 Agreement remains in effect, and future water deliveries needed by the City from NMSU are reasonably expected to be minimal.

2.11 Legal Issues and Constraints

Many legal and administrative constraints affect the distribution of water in the Lower Rio Grande Basin, many of them unresolved, and at issue in pending litigation. A comprehensive summary of legal and administrative constraints may be found in the current draft of the 2016 Lower Rio Grande Regional Water Plan,[1] but that summary does not deal in any detail with the fundamental questions of state versus federal jurisdiction over surface water released from Elephant Butte Reservoir and groundwater in the underlying aquifer, the United States' claims for the Rio Grande Project, and associated issues that are important to Las Cruces. Those issues are now being addressed in *Texas v. New Mexico and Colorado* in the United States Supreme Court, and in *State of New Mexico v. Elephant Butte Irrigation Dist.,* the adjudication of Lower Rio Grande water rights in New Mexico State District Court. The following paragraphs describe the current status of the litigations in lay-reader language.

[1] See New Mexico State Engineer website: http://www.ose.state.nm.us/Planning/RWP/region_11.php.

TX_MSJ_001498

2.11.1 Rio Grande Project Operating Agreement and *Texas v. New Mexico and Colorado*

The management of Rio Grande Project surface water directly affects rights to divert groundwater in the Lower Rio Grande, and therefore has an important impact on the water available under Las Cruces' groundwater rights. Las Cruces presently relies entirely on groundwater for its municipal supply and will do so in the future. The constraints under which it uses groundwater will depend on three factors - implementation of the Operating Agreement, the Original Action brought by Texas in the United States Supreme Court, and the water rights adjudication in State District Court. Litigation currently pending in the U.S. Supreme Court, *Texas v. New Mexico and Colorado,* Original, No. 141, is likely to establish principles of water management and administration in the Lower Rio Grande for the future. Much of the following summary is derived from an *amicus curiae* brief filed in 2013 by the City's legal counsel,[2] from the City's *amicus curiae* brief in support of the State of New Mexico's Motion to Dismiss the case,[3] and from a 2009 report to Las Cruces by John Shomaker & Associates.[4]

The Operating Agreement

In 2008, an Operating Agreement was negotiated among EBID, EP No. 1, and the U.S. Bureau of Reclamation (BOR) to govern the releases of surface water from Elephant Butte Reservoir. In effect, rather than sharing shortages as would have occurred under the earlier management of the system, in which each acre in both EBID and EP No. 1 would receive the same annual allocation, EP No. 1 instead receives the annual amount of water that would be consistent with the "D2 curve" developed by the BOR as if the Project Supply conditions for the period 1951-1978 remained unchanged. The D2 curve relates the historical amount of water available to divert from the river at canal headings ("Project Supply") with the amount released from reservoir storage ("Project Release"), recognizing that part of the water applied to lands becomes return flow, available to be diverted again. The relationship between the two annual quantities, Project Release and Project Supply, defined for the period 1951-1978, and expressed as the D2 curve, determined the total amount of water that could be diverted from the Rio Grande by EBID, EP No. 1, and the Republic of Mexico. Mexico will receive the amount determined from the "D1 curve," which is based on the amount of water available to be released, regardless of the amount of water that remains for EBID. Shortages of Project surface water would be borne by EBID.

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2 City of Las Cruces' *Amicus Curiae* Brief Opposing Texas' Motion for Leave to File a Bill of Complaint and Supporting Defendants, *State of Texas v. State of New Mexico and State of Colorado*, March 11, 2013.

3 City of Las Cruces' *Amicus Curiae* Brief in Support of New Mexico's Motion to Dismiss Texas' Complaint and the United States' Complaint in Intervention

4 Shomaker, J.W., 2009, Long-term effects on Lower Rio Grande water supply of Rio Grande Project Operating Agreement ("D3") and Pecan-Growers Settlement with State Engineer: John Shomaker & Associates, Inc., consultant's report to City of Las Cruces.

However, the conditions in the basin no longer reflect the 1951-1978 relationship defined by the D2 curve, and "[a]fter the Operating Agreement became public, hydrologic analysis by New Mexico revealed that the effect of the Operating Agreement was to alter the historical releases of the Rio Grande Project surface water from Elephant Butte Reservoir which had been made 57% to EBID and 43% to EP No. 1 [based on the areas of irrigated lands in the respective projects] to a new ratio, possibly as low as 38% to EBID and 62% to EP No. 1. The consequence is to significantly increase groundwater pumping in New Mexico, thus decreasing groundwater in storage where the City's groundwater rights are located."[5]

One implication of the Operating Agreement is that supplemental irrigation pumping to supply EBID lands would increase, so that groundwater levels in the Lower Rio Grande Basin in general, and the Mesilla Valley in particular, would decline, rather than being roughly in equilibrium as had been the case historically. Groundwater mining may eventually lead to an unsustainable condition. On August 8, 2011, New Mexico filed suit in federal district court in New Mexico[6] to invalidate the Operating Agreement. The City of Las Cruces intervened in the case on February 17, 2012, on Count V of New Mexico's Complaint, *i.e.*, to compel the United States to complete an Environmental Impact Statement (EIS) identifying the effects of increased groundwater pumping on water in storage in the aquifer, where the City's rights are located, over the projected 50-year life of the Operating Agreement. The City has actively participated in the NEPA process related to the BOR's proposed EIS.

Texas v. New Mexico & Colorado

Evidently concerned that the favorable treatment of EP No. 1 under the Operating Agreement might be in jeopardy, Texas filed a Motion for Leave to File a Bill of Complaint in the United States Supreme Court on January 8, 2013, alleging that New Mexico had violated the terms of the Rio Grande Compact by allowing diversions of surface water and groundwater in excess of the 1938 conditions, more specifically that "[t]he Rio Grande Compact is predicated on the understanding that delivery of water at the New Mexico–Texas state line would not be subject to additional depletions beyond those that were occurring at the time the Rio Grande Compact was executed. New Mexico, through the actions of its officers, agents and political

[5] City of Las Cruces' *Amicus Curiae* Brief Opposing Texas' Motion for Leave to File a Bill of Complaint and Supporting Defendants, *State of Texas v. State of New Mexico and State of Colorado*, March 11, 2013, p. 7.

[6] *State of New Mexico v. U.S. Bureau of Reclamation et al.*, No. 1:2011-cv-00691-JB-ACT.

subdivisions, has increasingly allowed the diversion of surface water, and has allowed and authorized the extraction of water from beneath the ground, downstream of Elephant Butte Dam, by individuals or entities within New Mexico for use within New Mexico. The excess diversion of Rio Grande surface water and the hydrologically connected underground water downstream of Elephant Butte Reservoir adversely affects the delivery of water that is intended for use within the Rio Grande Project in Texas."[7] New Mexico contends that the Compact does not govern the delivery of water at the state line, and that it has met the terms of the Compact.

On March 31, 2014, the United States was granted leave to intervene in *Texas v. New Mexico & Colorado.* The United States contends that groundwater in storage is "Project supply" for which contracts are required with BOR by users of groundwater in New Mexico. Texas and the United States argue that it was "understood" that the Rio Grande Compact requires the delivery of a specific amount of water at the New Mexico-Texas state line. They argue that the Rio Grande Compact resulted in a tacit apportionment of the groundwater of the Lower Rio Grande, resulting in New Mexico being locked into 1938 conditions not applicable to Texas and the United States, then posit that all surface water and hydrologically-connected groundwater below Elephant Butte Reservoir in New Mexico are Rio Grande Project water, which the United States contends cannot be diverted without obtaining a water supply contract from it. *See* United States' Complaint in Intervention at 4, ¶¶ 12 and 13. This position results in New Mexico being divested of state jurisdiction over all surface water and groundwater in the Lower Rio Grande, assuming that all groundwater is hydrologically connected, threatening the viability of Las Cruces' water supply and requiring the City to enter into a water supply contract with the United States to divert groundwater in the Lower Rio Grande for municipal use, despite the fact that the City's groundwater use was initiated more than 100 years ago, prior to the Rio Grande Project. New Mexico filed a Motion to Dismiss which addressed claims by both Texas and the United States. Las Cruces filed an *amicus curiae* brief in support of New Mexico's motion. Oral argument was held before the Court's Special Master, Gregory Grimsal, in New Orleans on August 19, 2015. A draft Report was issued for comments on July 1, 2016, and comments were received from the parties and amici on August 1, 2016. A conference call hearing was held on August 11, 2016.

[7] Texas' Motion for Leave to File Complaint, Complaint, and Brief in Support of Leave to File Complaint, *State of Texas v. State of New Mexico and State of Colorado,* January 2013, p. 9.

In his draft Report, the Special Master denied New Mexico's motion to dismiss Texas' claims, but granted the motion to dismiss the United States' claims with the following proviso - he recommended that "the Court extend its original, but not exclusive, jurisdiction...to allow for the resolution by the Court of the United States' project claims to occur simultaneously with the resolution of Texas's compact claims against New Mexico. (First Report of Special Master, 2011, p. 205)." If the Court concurs, and the United States prevails on this point, Las Cruces' groundwater may be deemed to be Rio Grande Project water and the City may be required to enter into a contract with the BOR to continue to divert it. In that case, it is possible that the water would be subject to re-assignment to, for example, Endangered Species Act purposes, as has occurred in the Middle Rio Grande.

Las Cruces has established, in the context of the adjudication of Lower Rio Grande water rights (see below), a priority date of 1905 for its pre-basin (and pre-Rio Grande Project) water rights under File No. LRG-430. The Special Master's report (see First Report of the Special Master, June 28, 2016, p. 184) seems to imply that such pre-basin and pre-Rio Grande Project rights are recognized, but that the water to supply them must come from the New Mexico allocation under the Rio Grande Project. The question remains, then, whether Las Cruces' rights would be fully supplied in priority, in their status as senior to the January, 1906 filing of the notice of appropriation for the Rio Grande Project by the U.S. Reclamation Service (see, e.g., First Report of the Special Master, June 28, 2016, p. 83), as they would be under New Mexico law, or would be subject to the shortage-sharing implicit in the distribution of water within the Project (see, e.g., Frank Clayton letter, reproduced in part in First Report of the Special Master, June 28, 2016, p. 179). If the Rio Grande Project is the "sole method" by which the Rio Grande valley in New Mexico receives its equitable apportionment from the stream (First Report of the Special Master, June 28, 2016, p. 175), it seems probable that Las Cruces would share shortages.

The Special Master's report does not deal explicitly with the relation between groundwater and surface water, and seems to treat surface water and its allocation as the only hydrologic issue. This could be the situation only if the groundwater system has always been and will continue to be full. In that context, the streamflow depletion associated with declared pre-Lower Rio Grande Basin groundwater rights, such as LRG-430, would represent an appropriation to be supplied by Rio Grande Project surface water in amounts equivalent to the amounts pumped from wells, less the return flow to the river. Arguably the withdrawal from groundwater in storage in the aquifer represented by a permanent lowering of the water table should not be considered an appropriation of Project water, although any natural replenishment of the water withdrawn from storage, if and as it occurs, would be by Project water.

The Utton Transboundary Resources Center at the University of New Mexico has described the consequences of a New Mexico loss in part as follows (references omitted).[8]

> [It]...would be very expensive for the communities in south-central New Mexico in terms of losses in agricultural and supporting businesses and to the state in general. The area is already strained by reduced surface water availability from the drought and under the Operating Agreement. If the U.S. Supreme Court ordered curtailment of groundwater pumping, the pecan orchards and other crops may be severely damaged or lost. The Supreme Court could also order restitution in the form of water or money or both. Texas is asking the Court for compensation for New Mexico pumping since the date of the Rio Grande Compact, that is, 1938. If, as in the Pecos litigation, New Mexico must retire farmland water rights to accommodate a judgment, the cost has been estimated to be upwards of $1 billion dollars. If solutions such as augmentation well fields or pipelines are required, millions more will follow.
>
> However, the cost of doing nothing could be just as devastating. In June of 2012, the Interstate Stream Commission reported that estimated value of water reallocated in the Project between EBID and EP No. 1 was between several million to 2.5 billion dollars.
>
> Between the reallocation and the [then continuing] drought, farmers, municipalities and others have turned increasingly to groundwater. Not only does extensive groundwater use threaten the aquifer sustainability but it also threatens to change the aquifers from sustainably managed resources to mined resources. If groundwater pumping must continue over the long run, river losses to the aquifers are likely to remain high, and deliveries to EP No. 1 will continue to be a problem.

Another consequence of a New Mexico loss in the Supreme Court may be "federalization" of the management of the river. The United States has alleged that "New Mexico has allowed the diversion of surface water and the pumping of groundwater that is hydrologically connected to the Rio Grande downstream of Elephant Butte Reservoir by water users who either do not have contracts with the Secretary [of the Interior] or are using water in excess of contractual amounts...," and has asked the Supreme Court to "declare that New Mexico...may not permit parties not in privity with the Bureau of Reclamation...to intercept or interfere with delivery of water from the Rio Grande Project (see First Report of the Special Master, June 28, 2016, p. 188)."

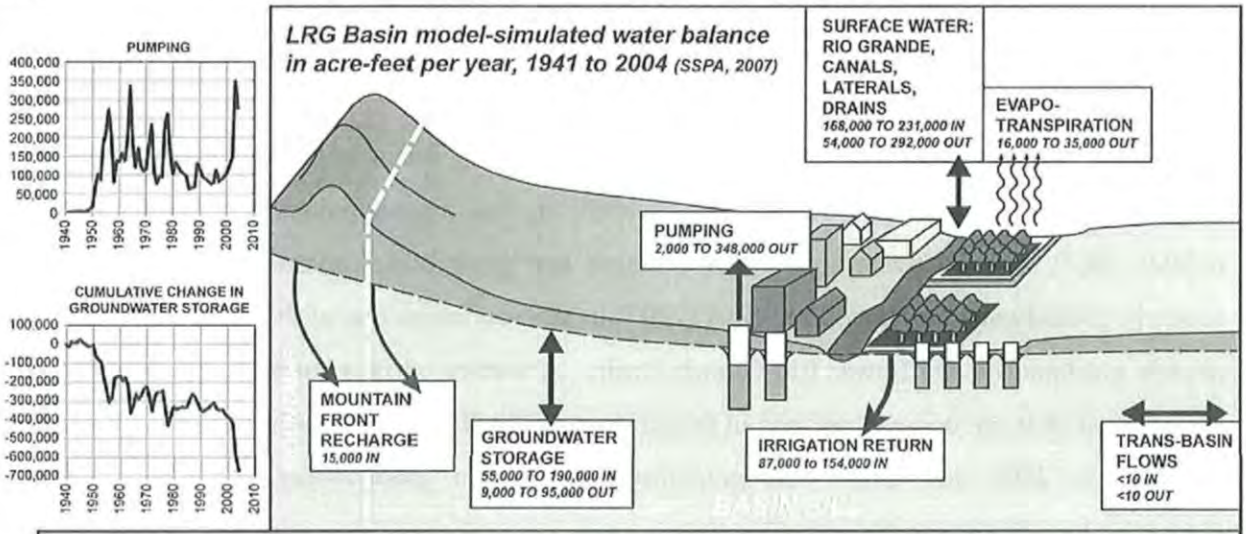
[8] Utton Transboundary Resources Center, University of New Mexico, 2013, *uttoncenter.unm.edu/pdfs/2013-05-16_BushnellTx-NM-Final.pdf*

If New Mexico ultimately prevails in *Texas v. New Mexico and Colorado*, and operation of the Rio Grande Project returns to something like the pre-Operating Agreement procedures, it seems likely that some of the economic stress in the Lower Rio Grande would still occur if water shortages continue. The probability of priority administration seems likely to increase, and either in that context or in a process of promulgating new administrative guidelines, the State Engineer may seek to curtail or limit groundwater pumping. Las Cruces' 1905, pre-Rio Grande Project, priority date would presumably protect the City's full supply from the LRG-430 rights in the case of a priority call, but permits for supplemental and replacement wells may become more difficult to obtain under new administrative guidelines.

Figure 7 presents a summary of the Lower Rio Grande Basin water balance based on the groundwater flow model prepared for the NMOSE by S.S. Papadopulous & Associates, Inc. (SSPA, 2007), and illustrates how water shortages and groundwater pumping have resulted in losses in groundwater storage. The SSPA (2007) model represents one of the most sophisticated models available for the Lower Rio Grande Basin. A version of it is currently being updated, and other models are being developed in preparation for the litigation described above. The high pumping in 2003 and 2004, and precipitous decline in groundwater storage, is likely representative of more recent years.

2.11.2 Rio Grande Adjudication

New Mexico v. EBID, et al., 96-CV-888 (1996) is a state court adjudication being undertaken to identify and to formalize the scope and the description of valid water rights in the area between the Elephant Butte Dam and the state line with Texas. The adjudication is one of the largest in New Mexico and will determine water right claims in about 14,000 subfiles - each of which deals with one or more water rights - and for about 18,000 claimants. The adjudication court and the parties are also working out the stream system issues: so-called because their resolution will affect many if not all of the claimants in the case. The court has or will determine the following stream system issues: 1) the farm delivery requirement (FDR) and the consumptive irrigation requirement (hereinafter CIR) for all crops; 2) the groundwater rights of the Elephant Butte Irrigation District (hereinafter EBID); 3) the status and description of domestic wells; 4) the rights and the nature of the rights of the United States in the Rio Grande Project; 5) the claims of those whose water rights predate those of the Project; and 6) the claims of the Nathan Boyd Estate.



		Year with maximum pumping - 2003	Year with high pumping - 2004	Year with average pumping - 1997	Year with low pumping - 1986	Year with minimum pumping - 1941
INFLOW	Groundwater storage	189,531	95,767	76,456	55,293	72,080
	Mountain-front recharge	15,318	15,318	15,318	15,318	15,318
	Irrigation return	109,415	87,084	123,095	154,273	96,665
	Surface water	167,716	176,440	231,046	223,330	201,183
	Trans-basin flows	7	7	7	8	7
	Total inflow	481,988	374,616	445,923	448,223	385,254
OUTFLOW	Groundwater storage	9,288	26,960	72,731	95,127	58,816
	Pumping wells	348,416	276,832	82,854	62,900	2,262
	Evapotranspiration	19,155	16,420	32,934	35,434	32,370
	Surface water	105,441	54,464	257,386	254,790	292,034
	Trans-basin flows	5	5	6	7	7
	Total outflow	482,305	374,681	445,910	448,258	385,488
Net loss/gain in groundwater storage		*-180,244*	*-68,807*	*-3,725*	*+39,834*	*-13,264*

Figure 7. Illustration of Lower Rio Grande Basin water balance based on the groundwater flow model prepared by SSPA (2007).

As of the writing of this report, the adjudication court has established the farm delivery requirements and consumptive irrigation requirements for irrigation, and, as may be of interest to Las Cruces, has ordered that "[f]or future transfers to non-irrigation purposes of use, a CIR of 2.6 afay (ac-ft/yr per acre) shall apply to all irrigated acreage in the Lower Rio Grande," and that "[o]nly the full amount of combined surface water rights and groundwater rights can be transferred."[9] The court has also established the groundwater rights of the EBID.[10] The court granted a motion to dismiss the claims of the Boyd Estate, and the New Mexico Court of Appeals has affirmed the adjudication court's dismissal. A newly raised issue to be resolved is "the question of whether surface water rights developed before the Rio Grande Project and now served by the Project were extinguished by any means."[11] This may become important for Las Cruces in that depletion of the Rio Grande due to pumping under the pre-Project groundwater rights represents an implied pre-Project surface-water right. The City may make pre-Project claims for uses by the Acequia Madre de Las Cruces in connection with this stream system issue.

As of the State's annual report for Fiscal Year 2016,[12] the majority of the City of Las Cruces rights, consisting of the LRG-430 wells with the right to divert 21,839 ac-ft/yr, and excepting the Jornada and West Mesa wells and some other rights, had been adjudicated. Almost all of the rights in the Nutt-Hockett and Rincon sections of the Lower Rio Grande had been adjudicated, and offers of judgment had been served for about one-half of the subfiles in the combined Northern Mesilla and Southern Mesilla sections. Of the total number of subfiles in the Mesilla sections, about 35 percent had been adjudicated.

The United States' interest, designated as Stream System Issue No. 104, has been partially completed. On August 16, 2012, the Court ruled that the United States' interest consisted of surface water stored in Elephant Butte Reservoir and released for use by the Rio Grande Project - and not a commensurate amount of groundwater. An outstanding issue concerns the United States' priority date. The United States claims a date of no later than March 1, 1903. The City and the State assert that the United States' priority date is January 23, 1906, for 730,000 ac-ft/yr, and April 14, 1908, for 60,000 additional ac-ft/yr in accordance with filings by the U.S. Reclamation service with the Territorial Engineer. The adjudication court has not yet decided the priority date issue.

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[9] See Final Judgment, SS-97-101, *New Mexico v. EBID, et al.*, 96-CV-888 (1996), August 22, 2011.

[10] See Stipulated Subfile Order, Subfile No. LRS-28-003-0018, *New Mexico v. EBID, et al.*, 96-CV-888 (1996), October 4, 2010.

[11] See Order designating Stream System Issue No. 107 regarding surface water rights developed before the Rio Grande Project, SS-97-107, *New Mexico v. EBID, et al.*, 96-CV-888 (1996), July 6, 2016.

[12] Lower Rio Grande Adjudication Bureau, State of New Mexico's Rule 71.3 Report, FY 2016.

From the layman's point of view, the outcome of the adjudication would seem largely irrelevant if Texas prevails in Texas v. New Mexico and Colorado, and the distribution of all waters downstream from Elephant Butte dam by the Bureau of Reclamation is based on acreages and shortage-sharing rather than priority administration. It would remain only to determine the fraction of New Mexico's allocation that is represented by Las Cruces' pre-Project water rights, and for Las Cruces to enter into a contract with the Bureau of Reclamation.

2.11.3 Return Flow Discussion

Las Cruces' water rights and permits carry with them a variety of conditions, including requirements for discharge of certain amounts of water to the natural system after use. Las Cruces' Return-Flow Plan (JSAI, 2009), which compiles the various requirements for return flows, and presents the City's plan for meeting them, was accepted by the NMOSE in 2009. Figure 8 presents a schematic illustration of the City's return-flow requirements and accounting.

2.11.4 Water Banking Discussion

Discussions of water banking and how it might be implemented in the Lower Rio Grande Basin to repay groundwater over-diversion and out-of-priority diversion are ongoing among the NMISC, NMOSE, and stakeholders in the region (Colby, 2015). Water banking in the Lower Rio Grande Basin will depend on the outcome of *Texas v. New Mexico and Colorado* (see Section 2.11.1, above).

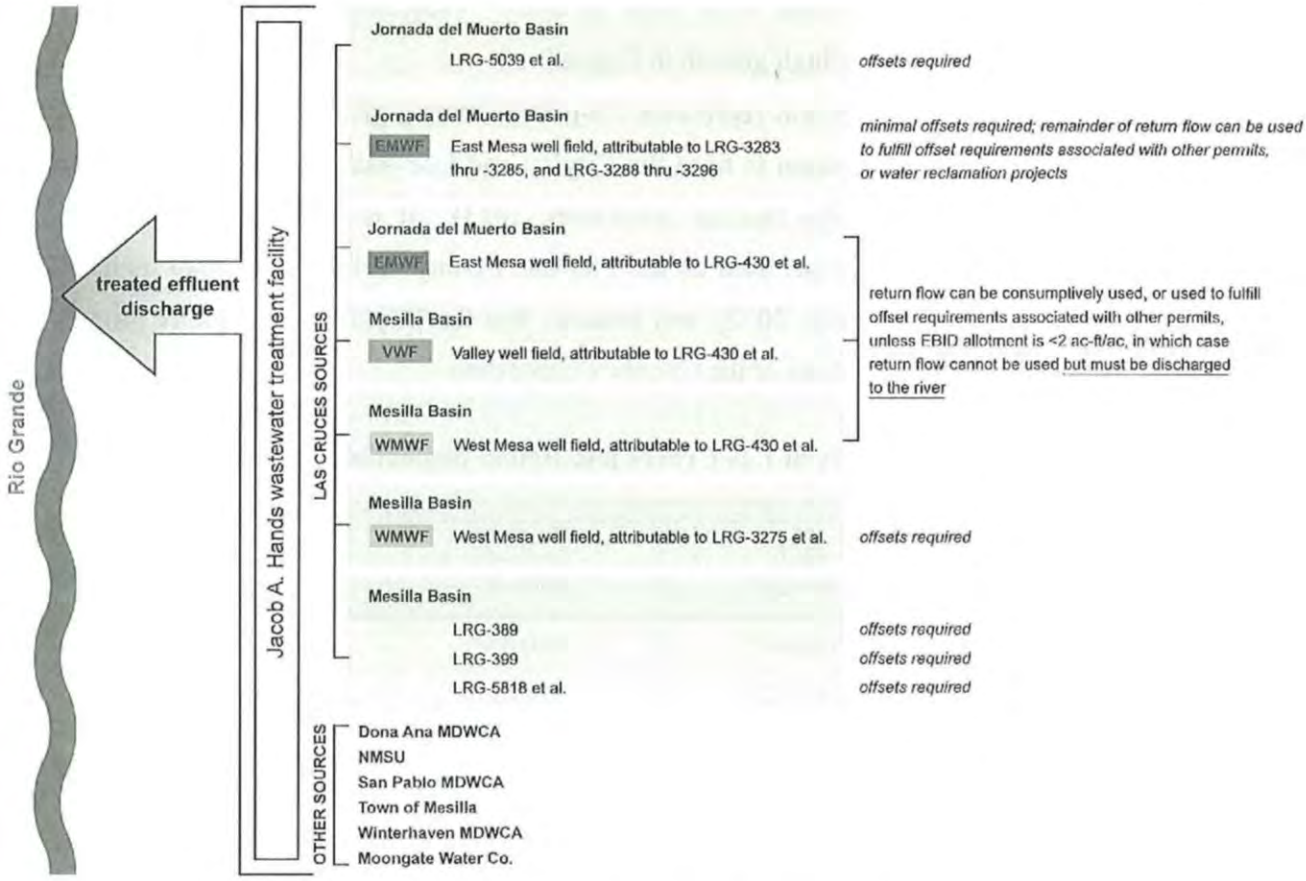

Figure 8. Schematic illustration of City of Las Cruces return flow accounting.

3.0 WATER DEMAND PROJECTIONS

Water demand projections are based on projected population growth and goals for total gallons per capita per day (GPCD) water use.

3.1 Population Projections

Figure 9 and Table 4 present projected population growth for 2015 to 2055. Figure 9 also presents historical population growth from 1960 to 2014. Projected population growth is presented as lines spanning low to high growth in Figure 9.

The medium-growth projection represents 1.9-percent annual growth between 2015 and 2055. The medium-growth projection is from the City's Land Use Assumptions Study (Water and Wastewater Impact Fee Study; Duncan Associates, 2013). It is based on the range of estimated population growth forecasts used by the City and County in the Vision 2040 regional planning project (Doña Ana County, 2012), and assumes that the City's share of future growth will be a consistent 46.9-percent share of the County's population.

Table 4. City of Las Cruces population projections

year	high growth [a]	medium growth [b]	low growth [c]
2015	109,094 [d]	109,094 [d]	109,094 [d]
2020	122,829	119,859	117,544
2025	138,293	131,687	126,462
2030	155,704	144,682	135,481
2035	175,307	158,959	144,500
2040	197,378	174,645	153,519
2045	222,228	191,878	162,753
2050	250,207	210,813	172,542
2055	281,708	231,616	182,920

[a] 2.4-percent annual growth (historical average, 1960-2014)

[b] Based on 1.9-percent annual growth indicated in City of Las Cruces Water and Wastewater Impact Fee Study, Land Use Assumptions (Duncan Associates, 2013)

[c] 1.5-percent annual growth (2015 to 2023) decreasing to 1.2-percent annual growth (2035 to 2055), City of Las Cruces Comprehensive Plan 2040 (City of Las Cruces, 2013)

[d] 2015 estimate presented in City of Las Cruces fiscal year 2015-2016 budget adopted by the City Council in May 2015, plus 2,016 Jornada Water Company customers outside City limits multiplied by average household size of 2.43 (U.S. Census 2010)

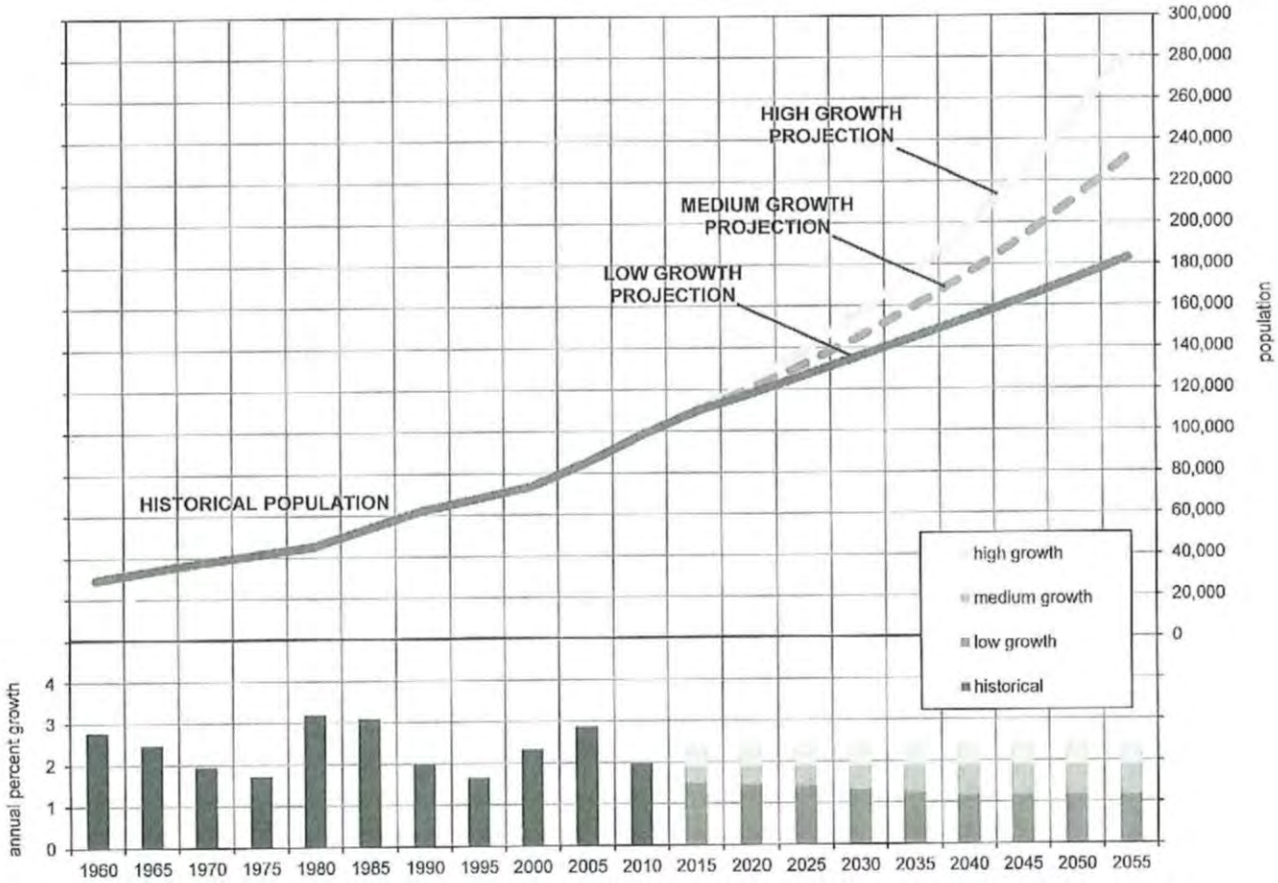

Figure 9. Graph showing City of Las Cruces historical and projected population growth, and percent annual growth, 1960 to 2055.

The high-growth projection is based on U.S. Census historical population data for City of Las Cruces from 1960 to present, with an average annual growth rate of 2.4 percent. Although population growth has been significantly less than the historical average over the last few years, the historical average growth rate should be considered for long-range planning purposes. Planning according to the historical average rate will allow LCU to perfect the water rights in the place-of-use area; LCU recognizes that there is some overlap with areas served by other utilities and place-of-use of water rights from other utilities, such as Moongate Water Company.

The low-growth projection represents 1.5-percent annual growth in 2015 decreasing to 1.2-percent annual growth in 2035. The low-growth projection is from the City's Comprehensive Plan 2040 (City of Las Cruces, 2013), which was adopted by City Council in November 2013. It agrees closely with population projections for Doña Ana County prepared by the University of New Mexico Geospatial and Population Studies (GPS) Group, which represents 1.5-percent annual growth in 2015 decreasing to 1.0-percent annual growth in 2035 (GPS Group; https://bber.unm.edu/demo/ PopProjTable2.htm).

The New Mexico Universities Working Group on Water Supply Vulnerabilities (2015) indicates that "recent investments and developments in the Santa Teresa, NM area will likely lead to additional businesses (re)locating to the area, and thus to additional population growth." In early 2014, the Union Pacific Santa Teresa Intermodal Terminal was opened. Located about 40 miles from Las Cruces near the Santa Teresa Port of Entry, the terminal can handle 250,000 shipping containers annually. Santa Teresa also includes two industrial parks.

A Las Cruces Sun-News article from October 19, 2015, indicates that plans for construction of the Center for Innovation, Testing and Evaluation (CITE) are moving forward on a 500-acre site about 25 miles west of Las Cruces (Gibbs, 2015a). CITE will be used for scientific research and testing of innovative technologies, building materials, and renewable energy, and will be open to private companies to test products. The facility could be operational by 2018, and the construction investment could run as high as $600 million. CITE will offer the opportunity for interconnection and research with NMSU, Spaceport, and other regional assets.

Las Cruces also includes the 1,800-acre West Mesa Industrial Park, located about 8 miles west of the City and directly south of Las Cruces Airport. The Industrial Park currently has 14 tenants, and it is the City's intent to develop light industry, general manufacturing, and aviation related and technology based industries, within the Industrial Park over the 40-year planning period. The City is dedicated to bringing in industries and manufacturing businesses that will expand and diversify the local economic base and provide new jobs for the community. A Las Cruces Sun-News article from September 10, 2015, indicates that manufacturing businesses in the Industrial

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Park are showing growth. F&A Dairy Products has two processing plants, and is currently hiring as it ramps up from 80-percent production capacity to 100-percent capacity. ARCA Space Corporation and Engineered Wire Products are also hiring (Gibbs, 2015b).

The NMOSE GPCD Calculator calculates utility-served population based on actual single-family and multi-family residential connections, and U.S. Census data on household size and population in group quarters. In the case of City of Las Cruces, utility-served population has ranged from about 98 to 105 percent of U.S. Census population, and 100 percent of U.S. Census population on average. Therefore, it was not necessary to adjust City population numbers to reflect utility-served population even though some areas on the East Mesa are served by Moongate Water Company. The current utility-served population has been adjusted to account for 2,016 new utility customers (formerly Jornada Water Company customers) outside the City limits, multiplied by an average household size of 2.43 (U.S. Census 2010).

3.2 Goals for Total Gallons Per Capita Per Day Water Use

Using historical data on total diversions, and utility-served population calculated using the NMOSE GPCD spreadsheet (version 2-05) and U.S. Census 2010 data, total GPCD water use was calculated for years 2009 to 2015 and presented in Table 5. Figure 10 presents current and projected total GPCD water use, and Figure 11 presents average total GPCD use by month (also see Appendix L). Total GPCD represents total water supply (total water diverted plus imports minus exports) divided by the population served by the utility.

Current total GPCD of 181 GPCD does not factor in GPCD for former Jornada Water Company customers; water use data for the former Jornada Water Company are currently inadequate to calculate GPCD for these customers. Current total GPCD of 181 GPCD does not factor in the City's effluent discharge to the Rio Grande. If effluent discharge to the Rio Grande (attributable to City water sources; 39 percent of total water supply on average, 2009-2014) were factored into Las Cruces GPCD, the City's current total GPCD would be only 110 GPCD. Current total GPCD of 181 GPCD is in-line with the average for Doña Ana County of 182 GPCD based on GPCD calculations for 63 public water systems (NMISC, 2016). It should be noted that this GPCD dataset for Doña Ana County includes high variability, and may include data of varying quality.

Las Cruces has the goal of reducing total GPCD water use to 165 GPCD by 2030, and 140 GPCD by 2055 (Fig. 8). This number does not factor in former Jornada Water Company customers; water use data for the former Jornada Water Company are currently inadequate to determine a realistic GPCD goal for these customers. This number does not factor in effluent discharge to the Rio Grande. Table 5 presents projected total GPCD use, and corresponding reductions in total GPCD use with respect to the current value of 181 GPCD (2009 to 2015 average).

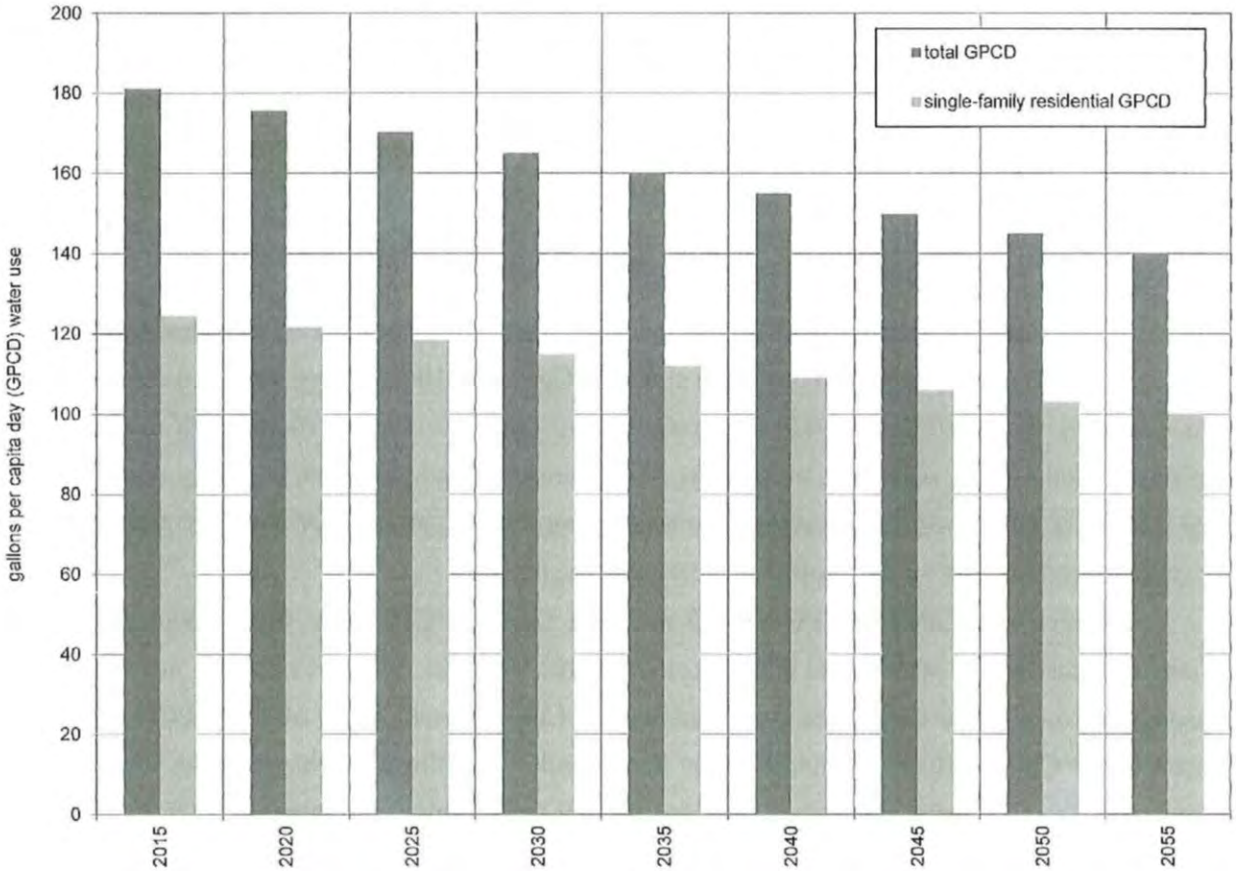

Figure 10. Chart showing City of Las Cruces current and projected total and single-family residential gallons per capita per day (GPCD) water use, 2015 to 2055.

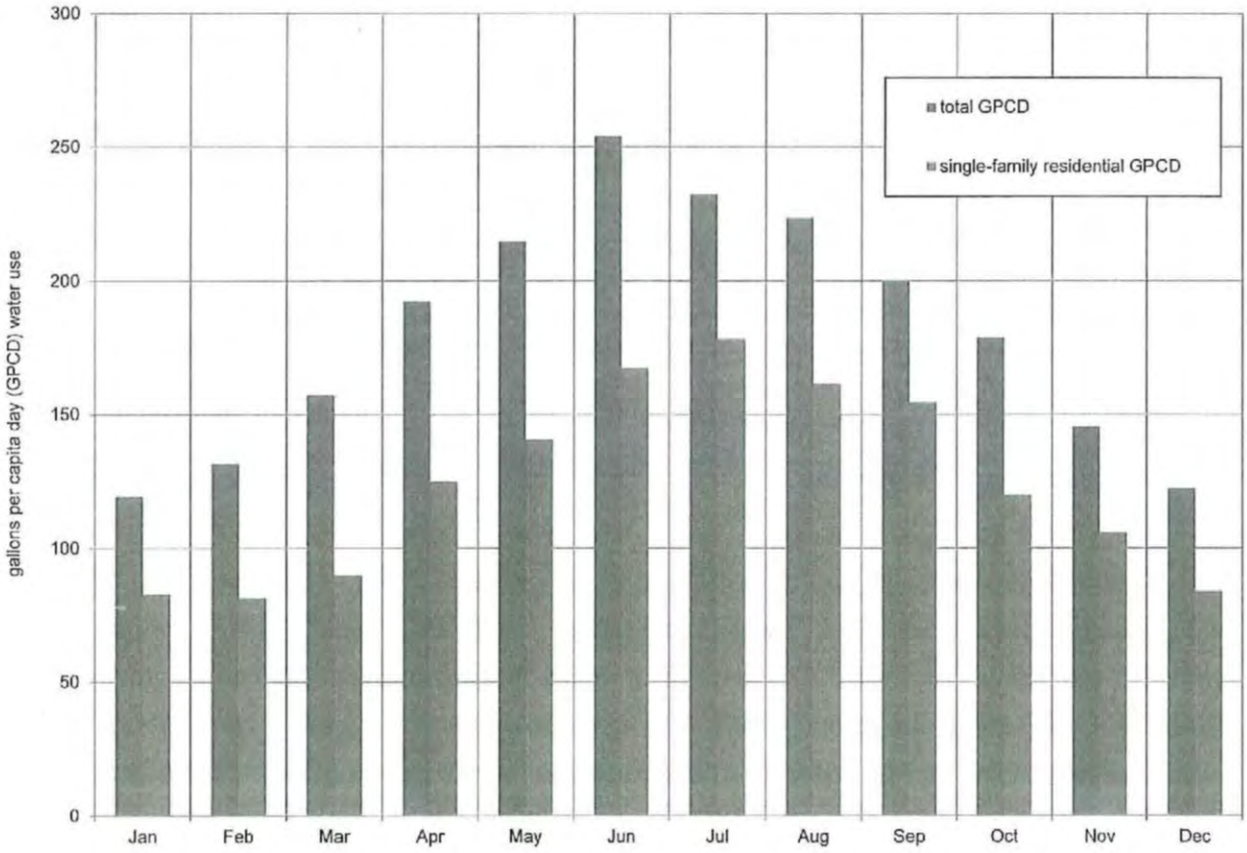

Figure 11. Chart showing City of Las Cruces average (2009 to 2015) total and single-family residential gallons per capita per day (GPCD) water use by month.

Table 5. City of Las Cruces total GPCD projections

year	total GPCD	reduction in total GPCD with respect to 2009-2015 average value [a]	tactics for reducing total GPCD
2009	188	-	-
2010	181	-	-
2011	192	-	-
2012	184	-	-
2013	176	-	-
2014	176	-	-
2015	171	-	-
2009-2015 avg	181	0	-
2015	181	0	reduce non-revenue water to 9 percent; reduce single-family residential GPCD use; implement Water Conservation Program
2020	176	5	
2025	170	11	
2030	165	16	
2035	160	21	
2040	155	26	
2045	150	31	
2050	145	36	
2055	140	41	

[a] based on high-growth population projections

GPCD - gallons per capita per day

Details on how the City will meet the goal of reducing total GPCD water use to 140 GPCD by 2055 are presented in Section 4: Water Conservation. Total GPCD water use goals will be met by implementation of the Water Conservation Program, which aims at reducing single-family residential GPCD and also works with City government and industrial, commercial, and institutional customers, and by reducing total non-revenue water from the 2010-2015 average of 15 percent of diversions, to 9 percent by 2055.

Las Cruces' total GPCD goal of 140 GPCD will allow the City to maintain the ability to serve future commercial and industrial accounts that will develop in the West Mesa Industrial Park over the next 40 years, thereby regulating industrial development to insure environmental sustainability and protect water quality. Las Cruces is part of the rapidly-developing commercial and industrial complex along the U.S./Mexico border. As the City grows over the next 40 years, Las Cruces' water system will serve existing and new water users in the commercial and industrial sectors, while private water companies and mutual domestic water consumers associations in the area will serve primarily residential users. Thus, the proportion of City water used for commercial and industrial purposes may grow, and the proportion of City water used for residential purposes may decrease.

Las Cruces' total GPCD goal of 140 GPCD is progressive in comparison to other water systems in the southern part of New Mexico (Table 6). City of Alamogordo has a goal of 165 GPCD (Livingston Associates, 2006; JSAI, 2005). The preliminary 40-year plan for City of Hobbs does not indicate a specific goal, and uses 264 GPCD when calculating projected demand (DBSA, 2009a). The 40-year plan for City of Deming does not indicate a specific goal, and uses 206 GPCD when calculating projected demand (DBSA, 2009b). City of Lovington has a goal of 242 GPCD (JSAI, 2014). Truth or Consequences/Williamsburg has a goal of 176 GPCD (WHPacific, 2012). City of Jal indicates a goal of 165 GPCD; however, this is in terms of residential GPCD (JSAI, 2005). The City of Jal 40-year plan uses 290 GPCD when calculating projected demand.

Table 6. Comparison of City of Las Cruces total GPCD goal with other water systems in southern New Mexico

community	projected year	projected population [b]	projected total demand, ac-ft/yr	total GPCD goal
Las Cruces	2055	269,058	42,222	140
Alamogordo	2045	58,663	10,842	165
Alamogordo without wastewater reuse	2045	58,663	10,842 + 3,363 [a]	216
Hobbs	2050	54,660	16,190	264
Deming	2050	39,526	9,119	206
Lovington	2053	22,670	6,157	242
Truth or Consequences and Williamsburg	2050	14,134	2,795	176
Jal	2045	6,127	1,990	290

[a] 3,000,000 gallons per day wastewater reuse
[b] high growth projection

ac-ft/yr - acre-feet per year
GPCD - gallons per capital per day

It is important to note a key difference between these water systems and Las Cruces: Las Cruces has return flow, and these other systems do not (with the exception of Truth or Consequences/Williamsburg). In the case of Alamogordo, wastewater reuse is considered into its total GPCD goal of 165 GPCD; its total GPCD goal without wastewater reuse would be about 216 GPCD.

3.3 Goals for Single-Family Residential Gallons Per Capita Per Day Water Use

Single-family residential GPCD water use, calculated for years 2009 to 2015, is presented in Table 7. Historical single-family residential GPCD water use was calculated using the NMOSE GPCD spreadsheet (version 2-05). Figure 10 presents current and projected single-family residential GPCD water use. Figure 11 presents average single-family residential GPCD use by month (also see Appendix L). Single-family residential use represents about half of total use in Las Cruces (Fig. 12).

Table 7. City of Las Cruces single-family residential GPCD water use

year	single-family residential GPCD	reduction in single-family residential GPCD with respect to 2010-2014 average value
2009	132	-
2010	125	-
2011	133	-
2012	126	-
2013	123	-
2014	119	-
2015	114	
2009-2015 average	125	-
2015	125	0
2020	122	3
2025	118	7
2030	115	10
2035	112	13
2040	109	16
2045	106	19
2050	103	22
2055	100	25

GPCD - gallons per capita per day

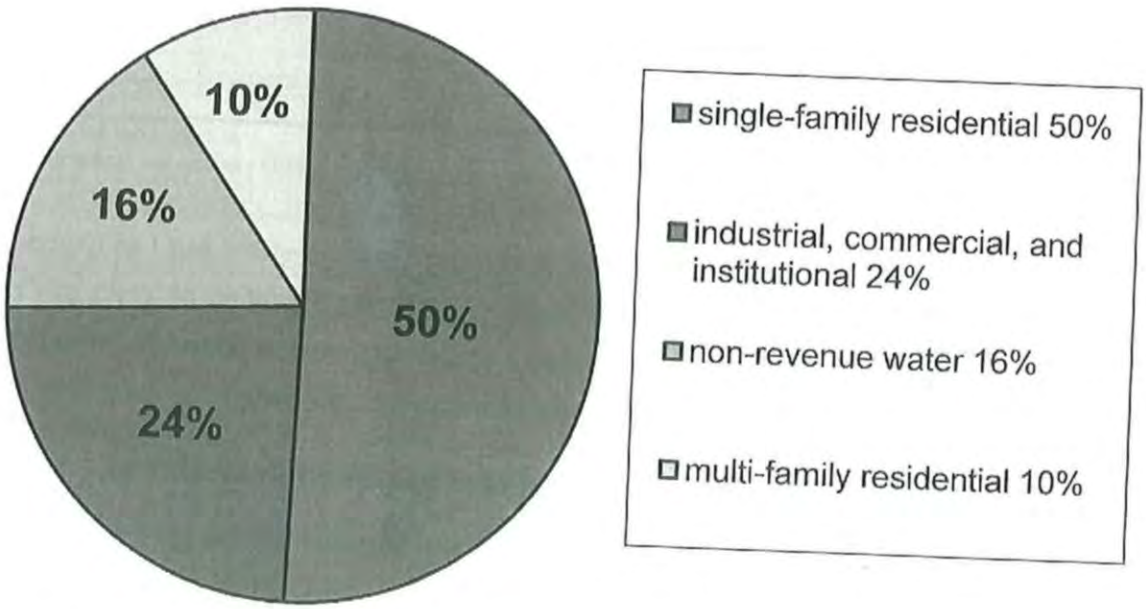

Figure 12. Chart summarizing City of Las Cruces average (2010 to 2014) water use.

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Las Cruces has the goal of reducing single-family residential GPCD use to 100 GPCD by 2055 (Table 7). This savings of 25 GPCD in terms of single-family residential GPCD translates to a 17 GPCD savings in terms of total GPCD. Thus, the City's goal for reducing total GPCD use over the next 40 years will be accomplished in part through the reduction of single-family residential GPCD water use.

The City's single-family residential water use in summer (June, July, and August) is, on average, more than double the single-family residential water use in winter (November, December, January, February, and March) (Fig. 11; Appendix L), due to the City's semi-arid to arid climate (Appendix M) and the resultant landscape irrigation and use of evaporative coolers in summertime.

3.4 Water Demand Projections

Water demand projections for years 2015 through 2055 presented in Table 8, in terms of total diversions, are based on projected population growth and projected total GPCD use.

Figure 13 presents a graph of projected demand from 2015 to 2055, under low- to high-growth scenarios, and the City's groundwater rights and permits. Figure 13 shows that, under the high-growth scenario, diversions will exceed the LRG-430 et al. pre-basin right plus East and West Mesa permits at the end of the 40-year planning period, and approach the City's total groundwater rights and permits.

During the 40-year planning period, LCU aims to develop an alternate supply up to the amount 44,207 ac-ft/yr to meet current and future demand in the case that activities in the Lower Rio Grande Basin pose challenges to using existing rights and permits to meet demand.

Table 8. City of Las Cruces water demand projections [projected population * projected total GPCD water use]

year	high growth, ac-ft/yr	medium growth, ac-ft/yr	low growth, ac-ft/yr
2015	22,133	22,133	22,133
2020	24,186	23,601	23,145
2025	26,404	25,143	24,145
2030	28,797	26,759	25,057
2035	31,440	28,508	25,915
2040	34,293	30,343	26,672
2045	37,364	32,262	27,365
2050	40,666	34,264	28,044
2055	44,207	36,347	28,705

ac-ft/yr - acre-feet per year

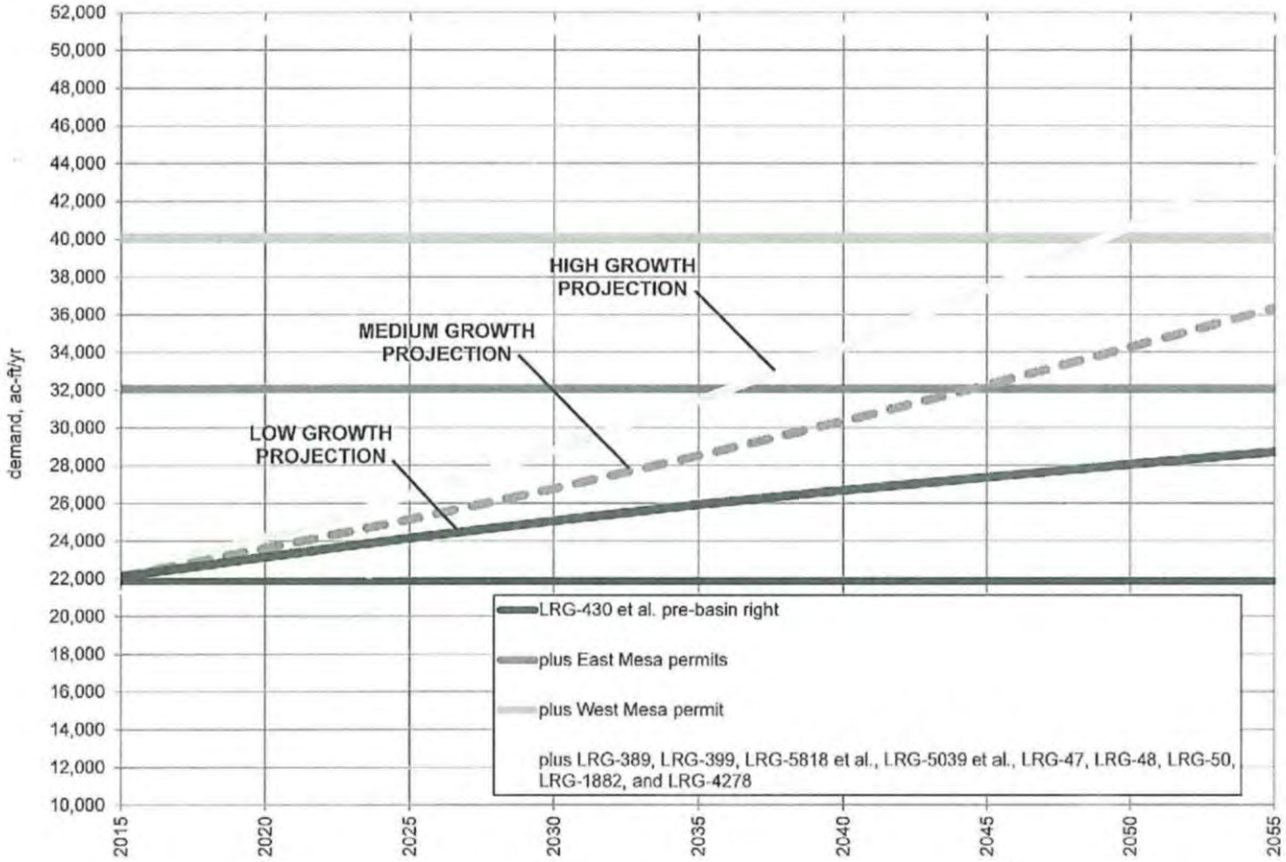

Figure 13. Graph showing City of Las Cruces projected water demands for 2015 to 2055 under low to high growth rate scenarios, City's total existing adjudicated water rights, and existing permits.

3.5 Non-Revenue Water

Non-revenue water is defined by the AWWA water balance (Table 9). Between 2010 and 2015, Las Cruces' non-revenue water represented about 15 percent of total diverted water (Table 10; also see AWWA water audit worksheets completed annually for LCU and included in Appendix P: Water Conservation Plan). The City's Infrastructure Leakage Index (ILI) is about 3.40, which is typical for a community the size of Las Cruces in the United States, with existing water supply infrastructure capable of meeting long-term demand as long as reasonable leakage management controls are in place.

Non-revenue water numbers may be somewhat elevated due to water system flushing, hydrant flushing, and fire protection field testing (unbilled authorized deliveries, see Table 9). These flushing processes represent important preventive maintenance, remove sediment from lines, and are critical to fire protection. These processes are described in the City's Standard Operating Procedure on Hydrants Flushing, included as Appendix N. Some hydrant flushing is performed for the City's iron and manganese program. Although not required by law, LCU chlorinates the water supply to eliminate any potential issues with coliform bacteria; however, even a tiny amount of chlorine can cause iron and manganese to drop out of solution in the water, turning it red. Although there are no health risks associated with the red water, LCU has a program to address it, which involves a fire hydrant flushing procedure in affected areas. Details are included in the LCU Red Water Fact Sheet, included in Appendix N.

The City is utilizing the highest and best technology available and economically feasible for the intended use to ensure conservation of water to the maximum extent practical. In order to reduce non-revenue water, the City operates an advanced supervisory control and data acquisition system (SCADA) with redundant flow meters at a number of locations, and conducts numerous water and wastewater system rehabilitation projects. The City has performed global positioning system (GPS) addressing of utility meters to help locate leaks more quickly, and has implemented enhanced meter calibration and automatic meter reading (AMR). A water metering program has been implemented recently on most water production and waterline maintenance trucks, to track non-revenue water. Another effort to account for non-revenue water is a pilot program to log water consumption from the Fire Department Training Facility and hose-testing hydrants, as well as water meters on hydrants used for field construction. Annual water and wastewater rehabilitation expenditures planned through 2021 range from $7.7 to $15.9 million. Table 11 presents the details of the City's 5-Year Capital Improvement Program for water and wastewater rehabilitation.

AWWA has set an industry standard goal of less than 10 percent for water losses (AWWA, 1996). The City has the goal of reducing non-revenue water from 15 percent of total diversions to 9 percent of total diversions by 2055 through water and wastewater system rehabilitation. This reduction of non-revenue water would translate to a reduction of 8 GPCD in terms of total GPCD.

Table 9. American Water Works Association (AWWA) water balance

total water diverted	authorized deliveries	billed authorized [a]	billed metered	revenue
			billed unmetered	
		unbilled authorized [b]	unbilled metered	non-revenue
			unbilled unmetered	
	water losses	apparent losses [c]	unauthorized	
			customer metering inaccuracies	
			systematic data handling errors	
		real losses [d]	leakage on transmission and/or distribution lines	
			leakage and overflows at Utility storage tanks	
			leakage on service connections	

[a] examples include metered deliveries for residential, industrial, commercial, and institutional use, and park and golf course irrigation
[b] examples include metered main flushing, sewer cleaning, potable well flushing, non-potable production
[c] examples include theft and vandalism, customer metering inaccuracies, and data handling errors
[d] examples include line leakage, and storage tank leakage and overflow

Table 10. City of Las Cruces non-revenue water and total water losses

year	total diversions, ac-ft/yr	authorized deliveries, [a] ac-ft/yr	non-revenue water, ac-ft/yr	percentage of diversion that represents non-revenue water	water losses, ac-ft/yr	percentage of diversion that represents water losses	ILI [b]
2010	20,235	17,194	3,208	16	3,041	15	4.24
2011	21,796	18,487	3,444	16	3,309	15	3.73
2012	20,626	17,260	3,464	17	3,366	16	3.69
2013	19,540	17,268	2,302	12	2,272	12	2.12
2014	19,760	16,543	3,241	16	3,217	16	3.36
2015	19,430	16,674	2,892	15	2,756	14	3.28
average	20,231	17,238	3,092	15	2,994	15	3.40

[a] includes billed (account and bulk sales) and unbilled (main flushing, sewer cleaning, potable well flushing, non-potable production) metered deliveries
[b] ILI = Infrastructure Leakage Index (real losses / unavoidable annual real losses)
ac-ft/yr - acre-feet per year

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Table 11. Summary of City of Las Cruces 5-Year Capital Improvement Program for water and wastewater rehabilitation

rehabilitation project	fiscal year expenditures, millions of U.S. dollars					
	2016 (funded)	2017	2018	2019	2020	2021
drill replacement wells	2.896	1.846	-	-	-	-
line extension	0.655	-	-	-	-	-
pump station for well	-	-	0.464	-	0.492	-
pump station rehabilitation	-	0.070	-	0.072	-	0.074
rehabilitate pump/PRV	-	-	-	-	-	-
reservoir rehabilitation	-	0.410	-	-	-	-
SCADA rehabilitation	0.015	0.015	-	-	-	-
street improvement projects	1.594	1.194	-	-	-	-
street utility rehabilitation	1.784	0.840	0.788	0.827	0.868	0.912
water production	-	-	-	-	-	-
water projects 2015A	8.763	8.763				
total water rehabilitation	**15.707**	**13.138**	**1.252**	**0.899**	**1.360**	**0.986**
force main rehabilitation	0.168	0.200	0.173	-	0.179	-
lift station renovations	0.330	0.330		0.340	-	0.350
line rehabilitation	0.137	0.172	0.176	0.181	0.185	0.190
line and manhole rehabilitation	0.538	0.100	0.103	0.106	0.109	0.113
East Mesa water reclamation	0.025	0.225	0.225	0.225	0.225	0.225
SCADA rehabilitation	0.150	0.100	-	-	-	-
street improvement project	1.571	1.171	-	-	-	-
street utility rehabilitation	1.591	1.591	1.639	1.688	1.739	1.791
WWTF operations	0.100	0.100	0.100	0.100	0.100	0.100
WWTF primary clarifier	1.400	1.200	-	-	-	-
WWTF rehabilitation	3.036	3.227	3.323	3.423	3.526	3.632
WWTF odor control	0.150	-	-	-	-	-
wastewater projects 2015A	5.011	5.011	-	-	-	-
total wastewater rehabilitation	**14.207**	**13.427**	**5.739**	**6.063**	**6.063**	**6.401**
total water and wastewater rehabilitation	**29.914**	**26.565**	**6.991**	**6.962**	**7.423**	**7.387**

SCADA - supervisory control and data acquisition system
WWTF - wastewater treatment facility

4.0 WATER CONSERVATION

4.1 Introduction

LCU is utilizing the highest and best technology available and economically feasible for the intended use to ensure conservation of water to the maximum extent practical. It may not be possible to meet the City's water demands by conservation alone, in the case that current and future activities in the Lower Rio Grande Basin pose challenges to using existing rights and permits to meet demand.

Las Cruces has adopted a comprehensive Water Conservation Program to ensure the long-range sustainability of the City's water supply. While other cities have successfully implemented demand-side reductions in the face of drought or emergency shortages, Las Cruces is implementing its Water Conservation Program proactively and systematically, and in a manner appropriate to the conditions and needs of the community. In 2003, Las Cruces City Council approved the Water Utility Drought and Water Emergency Response Plan (Appendix O). The City's Water Conservation Ordinance was enacted in 1999, and the Phase I 2005-2010 Water Conservation Program was approved by City Council in April 2005. In 2014, a revised and simplified version of the Water Conservation Ordinance was enacted (Appendix P), with administrative fees for violations of outdoor vegetation watering restrictions and water wasting restrictions. The LCU Water Conservation Plan was submitted to NMOSE in 2012, and an updated version is appended to this 40-year plan as Appendix P.

Future conservation measures will be chosen based on the City's needs and evaluation of the Water Conservation Program performance: specifically, shifts in metered demand in response to implementation of various conservation measures. Evaluation of long-range success of a conservation program, as acknowledged in New Mexico Administrative Code Title 17, Chapter 14, comes with the understanding that every community is unique and dynamic in its population, and commercial and industrial base, and conservation measures should be implemented in a manner that is efficient and cost-effective.

Pursuant to the NMOSE's (1999) definition of conservation, "any action that reduces the amount of water withdrawn from water supply sources, reduces consumptive use, reduces the loss or waste of water, improves the efficiency of water use, increases recycling and reuse of water, or prevents the pollution of water," the City of Las Cruces' Water Conservation Program

is being implemented in a comprehensive manner incorporating the highest levels of quantification of program performance. Methods of quantification and demand trending are being utilized to direct and maintain optimum benefits of actual water conserved with the costs of implementation to the community. Whenever possible, conservation shall be reported in terms of GPCD, yet it must also be understood that the City is engaged in best management practices that may not be quantifiable in terms of GPCD saved. Examples of best management practices that conserve water through pollution prevention include the following:

- Wellhead Protection Program
- Industrial Pollution Prevention compliance and enforcement
- Storm Water Management Plan and Ordinance
- Remediation of contaminated sites
- Solid Waste Department Recycling Program
- Las Cruces Dam Environmental Restoration Project
- Rio Grande Riparian Ecological Corridor Project

Las Cruces is committing substantial economic resources to these best management practices, which represent the City's responsibility to the protection of water resources. For example, Las Cruces is collaborating with Doña Ana County and the U.S. EPA to remediate the Griggs and Walnut groundwater tetrachloroethylene (PCE) plume. LCU Wells 18 and 27 are operating as plume capture wells. Water pumped from Wells 18 and 27 is treated and stored in a tank, and the City uses the treated water for municipal water supply; treatment system operation and reporting to the EPA is being performed voluntarily until LCU has a consent decree with EPA, and represents a positive example of proactive water management.

Las Cruces Dam Environmental Restoration Project represents a fully coordinated effort between U.S. Army Corps of Engineers, Las Cruces, and other federal, tribal, and local entities to restore over 78 acres of riparian habitat, about 4 acres of playa habitat, and construct several acres of emergent wetlands on the east side of Interstate-25 within the City limits. A limited amount of reclaimed water from the East Mesa water reclamation facility will facilitate the wetlands, and storm runoff will facilitate riparian habitat restoration, with socioeconomic and recreational benefits for the community (USACE, 2011).

Las Cruces is providing up to 15 ac-ft/yr of water under LRG-5818 et al. to Southwest Environmental Center for the Rio Grande Riparian Ecological Corridor Project, a wetland restoration project.

4.2 Baseline Water Conservation

4.2.1 Water Conservation Program

The City's Water Conservation Program works to reduce water use among city residents and customers, and within the city government, and utilizes the following components:

- Reporting
- Education and on-line resources
- Working with City departments
- Indoor efficiency
- Outdoor efficiency
- Compliance
- Planning
- Ordinances and regulations

These components to the Water Conservation Program are briefly summarized below, and described in detail in the updated version of the Water Conservation Plan appended to this 40-year plan as Appendix P.

4.2.1.1 Reporting

LCU provides GPCD water use reports and AWWA water audits to NMOSE on an annual basis.

4.2.1.2 Education and On-line Resources

The Water Conservation Program provides education programs for adults and children including Lush and Lean Workshops, Water Festival, and Demonstration Garden. The Water Conservation Program provides numerous on-line resources on the City's website (http://www.las-cruces.org/WaterConservation) including:

- Lush and Lean Workshops
- Water Festival
- Demonstration Garden
- Report Water Waste
- Tips for Residential Conservation
- How to Detect Leaks, and How to Read a Water Meter
- Water Efficiency Checklist
- Other Water Conservation Resources, including Calculating Water Needs of Plants, and Rainwater Harvesting Resources

4.2.1.3 Working with City Departments

The Water Conservation Program assists the Parks and Recreation Department with water conservation by providing water audits, and consulting on irrigation issues, water accounts, and level of use. The Water Conservation Program also assists with the Sustainability Program (see Section 4.2.6) and Planet Footprint, an energy and environmental scorekeeping program to which the City subscribes that monitors the City's electric, gas, and water accounts.

4.2.1.4 Indoor Water Efficiency

The Water Conservation Program performs informal water audits for LCU customers with high water bills, and promotes indoor water efficiency through educational programs (see Section 4.2.1.2). The Water Conservation Program has created a water efficiency evaluation form for use by homebuyers, homeowners, and inspectors.

4.2.1.5 Outdoor Water Efficiency

The Water Conservation Program performs informal water audits for LCU customers with high water bills, and promotes outdoor water efficiency practices such as use of Smart irrigation controllers and calculation of water needs of plants (on-line resources provided, see Section 4.2.1.2). The City's Demonstration Garden is an educational tool for promoting outdoor water efficiency.

4.2.1.6 Compliance

The Water Conservation Program assists with compliance to the City's water-conserving ordinances and regulations by publicizing the watering rules, receiving calls from community members reporting water wasting, and providing field staff to observe and record violations, and actively monitor problematic sites. Water Conservation Program staff encourage responsible parties to fix problems, and administer notices of violation and fees where called for, variances for special situations, and appeals to fees.

4.2.1.7 Planning

The Water Conservation Program provides input and helps develop planning documents related to water conservation including:

- Water Conservation Plan
- Drought and Water Emergency Response Plan
- Regional Water Plan
- City Comprehensive Plan
- 40-Year Water Development Plan

4.2.1.8 Ordinances and Regulations

The Water Conservation Program has provided input and helped to develop the City's Water Conservation Ordinance, and helps with evaluation of proposed legislation.

4.2.2 Water Conservation Ordinance

The City's current Water Conservation Ordinance was adopted in August 2014. To review the entire Water Conservation Ordinance, refer to Appendix P. It includes an odd/even address watering schedule, and restrictions on daytime landscape watering between April 1 and September 30. Violators of the Water Conservation Ordinance are subject to progressively higher administrative fees until the violation ceases or until a variance is granted. Administrative fees are assessed on active City utility accounts. In lieu of paying the first administrative fee, the responsible person may have a landscape water audit performed by an authorized irrigation auditor.

4.2.3 Design Standards and Storm Water Ordinances

The City's Design Standards (Land Development Code, Chapter 32) include requirements for urban drainage, soils, plant materials, and erosion control. The City's Storm Water Management code (Land Development Code, Chapter 34, Article III) promotes the elimination or reduction of pollutants from entering the city's municipal separate storm sewer system, control over discharges to and from the system, and quality of surface water and groundwater within the City limits. The Storm Water Management code includes numerous prohibitions and requirements related to discharges, release reporting and cleanup. The Storm Water Management code also prohibits the installation of impervious underlayment for landscaping related uses.

4.2.4 Water Reclamation

The City currently practices wastewater reclamation on the East Mesa and on the West Mesa. The East Mesa water reclamation facility is used to collect wastewater from interceptors serving the East Mesa, High Range, and Sonoma Ranch area, and produces very high quality reclaimed water for landscape irrigation, dust suppression, supply to purple fire hydrants, and potential supply to a future aquifer storage and recovery project. Customers include the Sonoma Ranch Golf Course, Veteran's Park, Sagecrest Park, the closed Foothills Landfill, the City compost operation, Las Cruces Dam Environmental Restoration Project, and Centennial High School. The facility has the capacity to treat 1,000,000 gallons per day. Peak summer demand from the facility is currently about 710,000 gallons per day; however, the facility must ramp down in winter when there is very little demand for the water.

On the West Mesa, reclaimed water is treated at the West Mesa wastewater treatment plant and used for sprinkler-irrigation of native vegetation in the West Mesa Industrial Park. The facility has the capacity to treat 400,000 gallons per day, and is currently operating below design capacity.

4.2.5 Water Rates

The City's current water rate structure represents a cost-of-service pricing program and is not considered a primary conservation tool, although the single-family residential rate increases above the 3,000-gallon volume threshold, and summer rates are higher (City of Las Cruces, 2015). Under the cost-of-service pricing program, single-family residential rates are $0.70 per 1,000 gallons per month (gal/mo) of water up to 3,000 gallons, and $2.08 per 1,000 gallons above 3,000 gal/mo during the summer period (June through September; $1.89 per 1,000 gallons above 3,000 gal/mo during the non-summer period). To review rates for commercial, industrial, multi-unit, parks, and bulk water categories, refer to Appendix P.

4.2.6 Sustainability Program

The City's Sustainability Program draws from a well-established sustainability framework, the Triple Bottom Line, designed to help organizations balance economic vitality, environmental health, and social responsibility. It is a departure from making decisions based solely on the financial bottom-line and reflects a greater awareness of the impacts of decisions on the

environment, society and the economy. The City's Sustainability Action Plan, adopted by the City Council in June 2014, includes the following water-related 3-year objectives for the Sustainability Program:

- Monitor water consumption in City facilities and other operations to identify variances monthly for departmental review
- Reduce water consumption in City buildings, parks, and operations by 3 percent of the end of 2013 baseline rate
- Continue reduction of non-revenue water from end of 2013 baseline level
- Increase green infrastructure capabilities in four City-owned properties
- Put into place mechanisms to fulfill new National Pollutant Discharge Elimination System permit requirements

These objectives involve collaboration of numerous City departments including LCU, Public Works, Parks and Recreation, Information Technology, Fire, Police, and Community Development.

4.3 Water Conservation Plan

The LCU Water Conservation Plan was submitted to NMOSE in 2012, and an updated version is appended to this 40-year plan as Appendix P. The Water Conservation Plan aims to meet the City's conservation goals, and meet conditions of approval associated with the City's water rights permits.

The Water Conservation Plan indicates evaluation, continuation, modification, or update of the baseline water conservation measures described above in Section 4.2. Some baseline measures are relatively new; for example, the process of assessing administrative fees for violations of the water conservation ordinance was adopted in 2014, and the full impact of this measure has not yet been realized. The new process of assessing administrative fees also offers the opportunity to establish a database of repeat offenders. Water efficiency and leak detection audit was implemented as a voluntary conservation measure beginning in October 2011. Thus, baseline measures have contributed to increased water conservation as customers have become aware of these measures; this allows LCU the opportunity for outreach and education to individual customers based on data.

The Water Conservation Plan evaluates baseline and past water conservation measures, and is used to determine whether they are working, need adjustment or modifications, and provides for recommendations and improvements. For example, the odd/even address watering schedule and the daytime landscape watering restrictions from April 1st through September 30th, are working as effective conservation measures to control peak water demand. The educational and outreach programs are working, and are continually being extended to homeowners, commercial and industrial customers, youth and seniors to encourage water conservation.

The Water Conservation Plan identifies numerous voluntary, mandatory, and supply-side conservation measures to be maintained, enhanced, and evaluated to meet conservation goals over the 40-year planning period.

4.4 Meeting Total GPCD Goals

Total GPCD water use goals will be met by implementation of the Water Conservation Program, which aims at reducing single-family residential GPCD, working with industrial, commercial, and institutional customers, conservation at City facilities, and reducing total non-revenue water. A savings of 25 GPCD in terms of single-family residential GPCD, translates to a 17 GPCD savings in terms of total GPCD; thus, the City's goals for reducing total GPCD use over the next 40 years will be accomplished in part through the reduction of single-family residential water use. In addition, the City's goal of reducing total non-revenue water to 9 percent of total diversions, translates to a reduction of 8 GPCD in terms of total GPCD; thus, the City's goal for reducing total GPCD use over the next 40 years can also be accomplished in part through the reduction of non-revenue water. Additional GPCD savings will be achieved through the Water Conservation Program by working with industrial, commercial, and institutional customers, and through conservation at City facilities.

Tab 39

IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

****

REMOTE ORAL AND VIDEOTAPED DEPOSITION OF
LEE WILSON, Ph.D.
JULY 23, 2020

****

REMOTE ORAL AND VIDEOTAPED DEPOSITION of LEE WILSON, Ph.D., produced as a witness at the instance of the Plaintiff State of Texas, and duly sworn, was taken in the above-styled and numbered cause on July 23, 2020, from 9:03 a.m. to 3:07 p.m., before Heather L. Garza, CSR, RPR, in and for the State of Texas, recorded by machine shorthand, at the offices of HEATHER L. GARZA, CSR, RPR, The Woodlands, Texas, pursuant to the Federal Rules of Civil Procedure and the provisions stated on the record or attached hereto; that the deposition shall be read and signed.

1 R E M O T E A P P E A R A N C E S
2

FOR THE PLAINTIFF STATE OF TEXAS:
3

Ms. Sarah A. Klahn
4 SOMACH SIMMONS & DUNN
2701 Lawrence Street, Suite 113
5 Denver, Colorado 80205
(720) 279-7868
6 sklahn@somachlaw.com
7 -and-
8 Mr. Stuart L. Somach
SOMACH SIMMONS & DUNN
9 500 Capitol Mall, Suite 1000
Sacramento, California 95814
10 (916) 446-7979
ssomach@somachlaw.com
11
12 FOR THE DEFENDANT STATE OF NEW MEXICO:
13 Ms. Lisa M. Thompson
TROUT RALEY
14 1120 Lincoln Street, Suite 1600
Denver, Colorado 80203
15 (303) 861-1963
lthompson@troutlaw.com
16
-and-
17
Mr. Luis Robles
18 ROBLES, RAEL & ANAYA, P.C.
500 Marquette Avenue NW, Suite 700
19 Albuquerque, New Mexico 87102
(505) 242-2228
20 luis@roblesrael.com
21
FOR THE DEFENDANT STATE OF COLORADO:
22
Mr. Preston V. Hartman
23 COLORADO DEPARTMENT OF LAW
1300 Broadway, 7th Floor
24 Denver, Colorado 80203
(720) 508-6281
25 preston.hartman@coag.gov

FOR THE UNITED STATES:
Mr. James J. Dubois
U.S. DEPARTMENT OF JUSTICE
999 18th Street, Suite 370
Denver, Colorado 80202
(303) 844-1375
james.dubois@usdoj.gov

-and-

Ms. Shelly Randel
U.S. DEPARTMENT OF THE INTERIOR
1849 C Street NW
Washington, DC 20240
(202) 208-5432
shelly.randel@sol.doi.gov
-and-
Mr. Christopher B. Rich
U.S. DEPARTMENT OF THE INTERIOR
125 South State Street, Suite 6201
Salt Lake City, Utah 84138
(801) 524-5677

FOR THE CITY OF LAS CRUCES:

Mr. Jay F. Stein
STEIN & BROCKMAN, P.A.
Post Office Box 2067
Santa Fe, New Mexico 87504
(505) 983-3880
jfstein@newmexicowaterlaw.com

FOR THE NEW MEXICO STATE UNIVERSITY:
Mr. John W. Utton
UTTON & KERY, P.A.
Post Office Box 2386
Santa Fe, New Mexico 87504
(505) 699-1445
john@uttonkery.com

VIDEOGRAPHER:
Ms. Kayla Brown

ALSO PRESENT:
Gary Esslinger
Erek Fuchs
Phil King
Ian Ferguson
Bert Cortez
Ken Knox

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THE VIDEOGRAPHER: The time is 9:03 a.m. We're on the record.

(The witness was sworn.)

MS. KLAHN: Before we get started, let's take appearances. For the State of Texas, I'm Sarah Klahn. I don't see anyone else on for the State of Texas, but if there's someone else who I've missed, speak up and let me know.

New Mexico?

MS. THOMPSON: Yes. Lisa Thompson on behalf of the State of New Mexico, and I believe it's just me today.

MS. KLAHN: Okay. United States of America?

MR. DUBOIS: This is Jim Dubois on behalf of the United States, and I believe Chris Rich is from the Solicitor's Department of Interior is also on.

MS. KLAHN: All right. EBID?

MS. ONTIVEROS: Naomi Ontiveros for Gary Esslinger. He'll be in and out.

MS. KLAHN: Thank you.

MR. DUBOIS: Sarah, I'm sorry. I'll also note that -- that Shelly Randel from the solicitor's office is on at least for a while.

MS. KLAHN: Looks like Ian Ferguson is, too, maybe.

MR. DUBOIS: No -- you're right. And Ian is, as well. My apologies.

MS. KLAHN: Okay. I skipped right over my favorite state, Colorado.

MR. HARTMAN: Thanks, Sarah. Preston Hartman for the State of Colorado.

MS. KLAHN: How about City of Las Cruces?

MR. STEIN: This is Jay Stein for the City of Las Cruces.

MS. KLAHN: New Mexico State? Looks like John Utton is on but doesn't want to make a record of his presence. Anyone else I've missed?

MR. UTTON: I'm sorry, Sarah. I was muted. This is John Utton representing NMSU.

MS. KLAHN: Okay. Thanks. Anyone else on that wants to make a record of their appearance?

(No response.)

LEE WILSON, Ph.D.,

having been first duly sworn, testified as follows:

E X A M I N A T I O N

BY MS. KLAHN:

Q. Good morning, Dr. Wilson. How are you?

A. Fine. Thank you. How are you?

Q. Good. Have you ever been deposed before?

A. Yes, ma'am.

Q. Could you get a little closer to your microphone?

A. How's that?

Q. Better. Thank you.

A. I can't get too much closer than this.

Q. No, you can't. So when was the last time you were deposed?

A. Oh, several years ago.

Q. Okay. But presumably, you're familiar with the rules of a deposition? We should endeavor not to speak over each other, so the court reporter can create a clear record. If you don't understand a question, please ask me to repeat it. I'll be happy to do so. If you answer a question, I'm going to assume that you believe you have knowledge to support your answer, and even though this is sort of an extraordinary situation where you're in, what, are you in Albuquerque or Santa Fe right now?

A. Santa Fe.

Q. Santa Fe. I'm in Denver. The court reporter is in Houston. Lisa is in Denver. We're in all sorts of different places. The oath you took is good in a

A. Stuff that was specific -- very specific to Las Cruces. She said she just didn't have the time to get familiar enough to defend them, and she didn't see any reason why I couldn't write my own report.

Q. Let's go down --

A. Pretty much the stuff that's in my report is what she didn't feel she had time to get on top of.

Q. Okay. So let's go down to the next bill, which would be for April -- the April bill for -- no, the May bill for April services. Yeah. In the month of April, what were you working on?

A. Same stuff.

Q. Okay. Down to the next bill, which would be the June bill for the month of May. So what -- this was more hours and more -- a higher total. What were you -- what were y'all working on in that month?

A. That's when I started drafting my -- my report. So it was research related to that, then writing and interaction. There was still going on at that time -- I think in May, we had a hydrology committee meeting, if I recall, on the model -- the state's model. We were still doing conservation stuff. Roger was still looking particularly at the USGS model. We were also looking at -- at -- at the -- the published USGS model. A lot of that was --

that's when I really started working on -- on the document that ended up being disclosed on the 15th.

Q. Okay. So let's go to the next bill. So this would be work done during the month that the New Mexico disclosure came out that had your non-retained expert summary of opinions in it, so some of the time here was presumably spent helping to prepare that; is that right?

A. Correct.

Q. And then after June 15th, what did you work on?

A. Well, I was -- at that point, I was able to look at Dr. Barroll's report and -- and the other reports, I didn't -- as I say, I've only really looked at Peggy's closely. I began to start pulling together the supporting materials, organizing them.

Q. Okay.

A. I -- I also at that time, there were -- I think that's when I really started looking at depositions.

Q. Which ones?

A. Oh, I want to say -- I don't have a memory in front of me, but I looked at -- at Phil King and Erek Fuchs, Al Blair, Rolf Schmidt-Petersen, John D'Antonio. I started looking at Estevan Lopez's depo,

1 but I didn't -- I haven't finished that.
2 **Q. Okay.**
3 **MS. KLAHN:** Kayla, would you put up the
4 document I e-mailed to Heather this morning? It's the
5 State of New Mexico's disclosure of rebuttal expert
6 witnesses dated June 15th, 2020.
7 (Exhibit No. 2 was marked.)
8 **Q. (BY MS. KLAHN) So this has been marked LW002,**
9 **and it's the document that contains your summary of**
10 **opinions. If you could get into that document,**
11 **Dr. Wilson, and scroll down to Page 4.**
12 A. Okay. I'm trying to figure out how to
13 accomplish that.
14 **Q. Yeah, it is cumbersome, I know.**
15 A. Page 4?
16 **Q. Yeah.**
17 A. Yeah.
18 **Q. Okay. So what I see in that first paragraph**
19 **is a sentence that starts with some preliminaries and**
20 **says, "Dr. Wilson will provide testimony in rebuttal**
21 **to the opinions of Dr. J. Phillip King, including**
22 **Dr. King's statements that, quote, there is currently**
23 **no effective administrative scheme for non-project**
24 **groundwater users to offset their impact on the RGP**
25 **and, therefore, on EBID." Do you see that?**

A. Yes. Yes.

Q. And then -- and then the second part of that sentence goes on, "As well as Dr. King's statement that, quote, to further exacerbate the situation, groundwater withdrawals by non-project water users in New Mexico have increased dramatically over the past 40 years, end quote." Do you see that?

A. Yes.

Q. Those -- that is the scope of the opinions that you're responding to; is that correct?

A. I -- I believe so. There may be some stray thing in there, but that's certainly my focus.

Q. Okay. The last sentence of that paragraph says, "For his work in this matter, Dr. Wilson has received no compensation other than the compensation he receives from the City of Las Cruces in his capacity as a consultant." So you are being paid for your work in this case, correct?

A. Yes. We just saw the bills.

Q. Yes. Okay. So let's go through this and then we'll take a look at the documents that your lawyers provided in response to the subpoena. If you go down to the next page to Page 5, "A summary of the facts and opinions to which Dr. Wilson is expected to testify are as follows." Number one there

says, "Extensive information on the City of Las Cruces' water supplies and water rights as provided in the City of Las Cruces' 40-year water development plan. This plan includes projections of the City's growing need to expand its groundwater supplies." Can you tell me how the information in that Paragraph No. 1 relates to the two statements we looked at over on Page 4 that are the scope of your rebuttal opinions in this case?

A. It doesn't -- it isn't directly related to Dr. King. It's the -- it's a sort -- a foundation document that I rely on for some of the -- the opinions that I express later on.

Q. Okay. I'm not going to read every single word in this summary of facts and opinions, but if you could just look at Paragraph 2 and --

A. Yes.

Q. -- that relates to the origins of the City of Las Cruces; would you agree?

A. The origins of the City of Las Cruces and the growth -- and its growth over the years.

Q. Okay. Is that similarly foundational information that you have summarized here in order to respond to Dr. King's testimony?

A. I believe so. I'm looking at it. I -- I

think that's correct, yes.

Q. How does the Paragraph 3, which relates to the water supplies for the City of Las Cruces, how does that relate to the opinions expressed by Dr. King that you're responding to?

A. Well, he -- he's talking about -- I would have to go back and see it. Let me --

Q. Yeah. You're welcome to move around.

A. No, I -- I'm going to -- basically, he's talking about -- I think I do need to go back. So he's talking about no effective administrative scheme for non-project groundwater users to offset their impact and groundwater withdrawals by non-project water users have increased. So the subject is groundwater withdrawals of -- his primary focus is on groundwater withdrawals and so Paragraph 3 and -- and -- primarily is where the -- is pointing to where Las Cruces does its groundwater withdrawals. So, again, that's -- that's a foundation for the actual discussion. But this is -- this is responding to him by saying this is where our groundwater comes from.

Q. Okay. And then number -- Paragraph No. 4, "The City's groundwater diversions are subject to regulation and oversight by the New Mexico State Engineer. The City works closely with OSE to ensure

that it remains in compliance with its State of New Mexico permits."

A. Without a period.

Q. Without a period. Which statements is that responsive to?

A. Again, this's responsive to Dr. King's basic assertion that there is no regulation. On EBID water users, they're pretty much left untouched. So this is a initial statement, which I will -- which I elaborate on considerably later on that we are, in fact, regulated and overseen by the state engineer and that we -- that we work very closely with a lot of activity done by the City to make sure we comply with our permits.

Q. So Dr. King's statement, if you want to go back up to Page 4, you're welcome to do so, but Dr. King's statement says, "There's currently no effective administrative scheme."

A. That's what he says. That's right. And this is a rebuttal to that.

Q. And for administration, what do you understand Dr. King's scope of the word administration to mean?

A. Something that would effectively manage and control diversions and lead to offsets so that those

1 **not allowed to fully consume all of the water?**
2 A. No. There would be no -- there would be no
3 practical ability of the City to find some other way
4 to use the water such as the reuse project when --
5 knowing that the supply was not only interruptible,
6 but almost constantly interruptible. The City simply
7 would not do that. So as a practical matter, the
8 exemption is meaningless. It -- the -- the
9 requirement is permanent.
10 **Q. As -- as a legal matter?**
11 A. No. I'm not a lawyer. But as -- as a
12 decision maker, as an engineer, as a water manager, no
13 water manager would take a water supply that's so
14 unreliable and invest lots of money on the off chance
15 that they might get something from it.
16 **Q. I think you said earlier that you were**
17 **assuming about 90 percent of the pumping at 11,000**
18 **acre-feet would affect the river flow; is that**
19 **correct?**
20 A. Yes.
21 **Q. Okay. So if LRG-430, under LRG-430, 21,869**
22 **acre-feet are pumped, that would effect the river in a**
23 **roughly 90 percent of that; is that correct?**
24 A. If that ever happened, yes.
25 **Q. Okay. And then there is some return flow**

1 **from that, that comes through the wastewater treatment**
2 **plant?**
3 A. There's a return flow from that, yes, and
4 from whatever -- from sources like the Jornada should
5 they also be being used.
6 **Q. Correct. Okay. And the -- the increase in**
7 **use in the Jornada started when?**
8 A. Around 20 -- after 2000, before 2010.
9 **Q. Okay. All right.**
10 MR. DUBOIS: Okay. I don't have any
11 more questions. Thank you.
12 THE WITNESS: Thank you.
13 MR. STEIN: If there are no more direct
14 questions, I'm going to ask for about ten minutes and
15 decide if I'll do any cross.
16 MS. KLAHN: All right. Colorado?
17 Preston, do you have any questions?
18 (No response.)
19 MS. KLAHN: I guess not. So ten-minute
20 break, Mr. Stein?
21 MR. STEIN: Yes.
22 THE VIDEOGRAPHER: The time is 2:57 p.m.
23 We're off the record.
24 (Break.)
25 THE VIDEOGRAPHER: The time is 3:07 p.m.

1 We are on the record.
2 MR. STEIN: I have no questions.
3 MS. KLAHN: Okay. So I think unless
4 anybody -- Preston, going once, going twice? This
5 deposition is concluded, and, Kayla, if you could let
6 your people know that we do not need a deposition
7 setting for tomorrow or do you want us to handle it
8 from our end?
9 THE VIDEOGRAPHER: No, I can let them
10 know.
11 MS. KLAHN: Okay.
12 THE VIDEOGRAPHER: Okay. The time is
13 3:07 p.m. We're off the record.
14 (The deposition concluded at 3:07 p.m.)
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1 WITNESS CORRECTIONS AND SIGNATURE
2 Please indicate changes on this sheet of paper,
giving the change, page number, line number and reason
3 for the change. Please sign each page of changes.
4 PAGE/LINE CORRECTION REASON FOR CHANGE
5 P. 8, Line 8 "GBCD" should be "GPCD" Transcript correction
6 P. 38, line 20 "deep-couple" should be "decouple" Transcript correction
7 P. 53, line 2 "G2" should be "D2" Transcript correction
8 P. 60, line 24 Insert "is" before or after "certainly" Transcript correction
9 P. 83, line 14 "back" should be "buck" Transcript correction
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23 Lee Wilson
LEE WILSON, Ph.D.
24
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IN THE SUPREME COURT OF THE UNITED STATES
BEFORE THE OFFICE OF THE SPECIAL MASTER
HON. MICHAEL J. MELLOY

STATE OF TEXAS	)	
	)	
Plaintiff,	)	
	)	Original Action Case
VS.	)	No. 220141
	)	(Original 141)
STATE OF NEW MEXICO,	)	
and STATE OF COLORADO,	)	
	)	
Defendants.	)	

THE STATE OF TEXAS :
COUNTY OF HARRIS :

I, HEATHER L. GARZA, a Certified Shorthand Reporter in and for the State of Texas, do hereby certify that the facts as stated by me in the caption hereto are true; that the above and foregoing answers of the witness, LEE WILSON, Ph.D., to the interrogatories as indicated were made before me by the said witness after being first remotely duly sworn to testify the truth, and same were reduced to typewriting under my direction; that the above and foregoing deposition as set forth in typewriting is a full, true, and correct transcript of the proceedings had at the time of taking of said deposition.

I further certify that I am not, in any capacity, a regular employee of the party in whose

behalf this deposition is taken, nor in the regular employ of this attorney; and I certify that I am not interested in the cause, nor of kin or counsel to either of the parties.

That the amount of time used by each party at the deposition is as follows:

MS. KLAHN - 03:19:40
MS. THOMPSON - 00:00:00
MR. DUBOIS - 00:28:22
MR. HARTMAN - 00:00:00

GIVEN UNDER MY HAND AND SEAL OF OFFICE, on this, the 6th day of August, 2020.

HEATHER L. GARZA, CSR, RPR, CRR
Certification No.: 8262
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EXHIBIT
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No. 141, Original

IN THE
SUPREME COURT OF THE UNITED STATES

STATE OF TEXAS,
Plaintiff,
v.
STATE OF NEW MEXICO and
STATE OF COLORADO,
Defendants.

OFFICE OF THE SPECIAL MASTER

STATE OF NEW MEXICO'S DISCLOSURE OF REBUTTAL EXPERT WITNESSES

HECTOR H. BALDERAS
Attorney General of New Mexico
TANIA MAESTAS
Chief Deputy Attorney General
CHOLLA KHOURY
Assistant Attorney General
MARCUS J. RAEL, JR.*
Special Assistant Attorney General
STATE OF NEW MEXICO
P.O. Drawer 1508
Santa Fe, New Mexico 87501
505-239-4672

*Counsel of Record

June 15, 2020

TO ALL PARTIES AND THEIR ATTORNEYS OF RECORD:

Pursuant to Federal Rule of Civil Procedure 26(a)(2) and the Case Management Plan adopted by the Honorable Michael J. Melloy, Special Master, on September 6, 2018, as amended ("CMP"), including the Special Master's May 26, 2020 Order extending the State of New Mexico's ("New Mexico") deadline to file expert rebuttal reports for its *modeling experts* to July 15, 2020, New Mexico hereby discloses the identities of the following retained *non-modeling rebuttal experts*:

1. Richard Allen, Ph.D., P.E.
   Evapotranspiration Plus LLC
   631 Saratoga Drive
   Twin Falls, ID 83301
   (208) 320-2837

2. Margaret Barroll, Ph.D.
   691 East Zia Road
   Santa Fe, NM 87505
   (505) 660-8079

3. Dana L. K. Hoag, Ph.D.
   415 E. Laurel St
   Fort Collins, CO 80524
   (970) 217-3149

4. David Jordan, M.S., P.E.
   INTERA
   6000 Uptown Boulevard NE
   Suite 220
   Albuquerque, NM 87110
   (505) 246-1600

5. Estevan R. Lopez, P.E.
   Estevan Lopez Consulting LLC
   P.O. Box 302
   Peñasco, NM 87553
   (575) 770-0866

6. Lewis Munk, Ph.D.
   Munk Consulting, LLC
   1074 Sugar Road

Rio Rancho, NM 87124
(505) 508-9040

7. Jennifer Stevens, Ph.D.
Stevens Historical Research Associates
445 West Main Street
Boise, ID 83702
(208) 426-0206

8. Bryan Thoreson, Ph.D., P.E.
Davids Engineering, Inc.
1772 Picasso Avenue, Suite A
Davis, CA 95618

In accordance with Federal Rule of Civil Procedure 26(a)(2)(B) and the CMP, and agreement between the parties, written reports prepared and signed by the above-referenced retained experts are served concurrently herewith. Please note that the expert rebuttal report of David Jordan, with Intera, generally discusses certain Land IQ proprietary information that counsel for Texas asserts cannot be disclosed to individuals who have not executed the Acknowledgement of Agreement to Be Bound attached as Exhibit A to the Stipulated Protective Order entered October 9, 2019. Consequently, a copy of Mr. Jordan's report will be provided separately only to individuals who have executed the Acknowledgement of Agreement to Be Bound.

With the exception of Mr. Jordan's rebuttal report, all written reports and supporting data, files, and references are available to download using the following link:

https://troutlaw.sharefile.com/d-sfc05695a8414f9b9

New Mexico is also transmitting all reports and other disclosures to the Veritext Vault, and will notify all parties and amici when they are available from Veritext.

New Mexico continues to reserve its right to rely upon and use the testimony of any and all expert witnesses identified by all parties to this action and to present rebuttal testimony to any

such witnesses. New Mexico also reserves the right to amend or supplement this disclosure pursuant to Federal Rules of Civil Procedure 26(a)(2) and 26(e).

Additionally, pursuant to Federal Rule of Civil Procedure 26(a)(2)(C), New Mexico hereby discloses the following non-retained rebuttal expert witness:

1. Lee Wilson, Ph.D.
   Lee Wilson and Associates
   105 Cienega Street
   Santa Fe, New Mexico 87501

Under Rule 26(a)(2)(C), Dr. Wilson will provide testimony in rebuttal to the opinions of Dr. J. Phillip King, including Dr. King's statements that "[t]here is currently no effective administrative scheme for non-Project groundwater users to offset their impact on the RGP and therefore on EBID," *United States of America's Disclosure of Expert Rebuttal Witness Dr. J Phillip King* at 11, as well as Dr. King's statement that, "[t]o further exacerbate the situation, groundwater withdrawals by non-Project water users in New Mexico have increased dramatically over the past 40 years." *Id*. Dr. Wilson's qualifications are summarized in his curriculum vitae, attached as **Exhibit A**. Dr. Wilson's opinions are based on his work as a consultant to the City of Las Cruces for 40 years. For his work in this matter, Dr. Wilson has received no compensation other than the compensation he receives from City of Las Cruces in his capacity as a consultant.

The subject matter of Dr. Wilson's expected expert testimony, including a summary of the specific facts and opinions, are as follows:

Subject matter: Dr. Wilson will provide opinions on the City of Las Cruces' water use, past, present and future, including locations of Las Cruces wells, the hydrologic isolation of the wells located in the Jornado Bolson, and the City's offsets.

Summary of facts and opinions: A summary of the facts and opinions to which Dr. Wilson is expected to testify are as follows:

1. Extensive information on the City of Las Cruces' (City) water supplies and water rights is provided in the "City of Las Cruces 40-year Water Development Plan" (2017). This plan includes projections of the City's growing need to expand its groundwater supplies.
2. Las Cruces was founded in 1849, had a population of a few thousand persons when the Rio Grande Project was authorized, had a population of about 8,000 when the Rio Grande Compact was adopted, had a population of about 43,000 when the Lower Rio Grande Underground Water Basin was declared in 1980, and has a current population of more than 100,000 in the City limits with considerably more in the service area.
3. The initial water supplies for Las Cruces were diverted from Acequia Madre de Las Cruces. Today the City obtains its groundwater supplies from two geologic areas, the Mesilla Bolson and the Jornada Bolson.
4. The City's groundwater diversions are subject to regulation and oversight by the New Mexico State Engineer (OSE). The City works closely with OSE to ensure that it remains in compliance with its State of New Mexico permits
5. The City's LRG-430 et al. combined and comingled water rights are adjudicated at 21,869 acre-feet per year (AFY) with a priority date of 1905.
6. The City has steadily developed the LRG-430 et al. water rights over time through diversions from dozens of wells, most of which are located in the Mesilla Bolson and are of large capacity (several hundred to a few thousand gpm each).
7. Offsets are not required for the exercise of LRG-430 et al. but in periods of drought (EBID allotment less than 2 AFY per acre) the City is required to discharge all of its effluent to the river. As a practical matter the City commits all of its effluent to the river all of the time.
8. State Engineer Permits LRG-3283-3285 and 3288-3296 are the City's permitted groundwater rights for 10,200 AFY in the Jornada del Muerto. The City has been diverting Jornada water for 30 years.

9. Minimal offsets are required for the City's Jornada wells due to their hydrological isolation from the Mesilla Basin and the Rio Grande.

10. If the City continues to grow as it has in the past, then within a few decades the City expects to develop a new source of groundwater, up to 8,000 AFY from wells on the West Mesa under permit LRG-3275 et al. The State Engineer requires that river effects from diversions from these new West Mesa wells must be fully offset.

11. At the time the Lower Rio Grande Underground Water Basin was declared in 1980, the City's LRG-430 et al. diversions were almost 11,000 AFY. Currently the City's total diversions are about 21,000 AFY. Of the 10,000 AFY increase in the last 40 years, as much as half has come from the City's Jornada wells.

12. Overall, the effects of the City's pumping on the Rio Grande are largely offset by several factors, such as the importation of water from the Jornada as discussed above, and the fact that some river effects occur at times when the Rio Grande Project is not operating. Also important is that the City has a large and continuous discharge of highly treated wastewater directly into the Rio Grande above Mesilla Dam.

13. The City owns EBID water rights on more than 1,350 Project acres that have been acquired over many years from City extensions of water lines to serve new development on small parcels with EBID rights, and the purchase of rights from various farms for possible use should EBID provide surface water to the City. The annual EBID assessment for these acres is on the order of $120,000 per year.

14. Fallowing of these rights, as now occurs on most of the tracts, effectively increases the supply to other EBID farms. Formal retirement of the acreage and transfer of the rights into City permits would provide offsets to stream effects from City pumping that remain after the considerations discussed in paragraph 12 are accounted for.

15. The 1938 "Rio Grande Joint Investigation in the Upper Rio Grande Basin," documents water uses that were part of the Project at that time. This report indicates that the acreage for the Elephant Butte Irrigation District includes lands for "Cities, Towns and Villages." Based on Census data for 1940, in 1938 the only "City" using water within the District was Las Cruces.

16. The effects of the City's pumping as of 1978 when the D2 curve was adopted by the Bureau of Reclamation are appropriately discussed in the report of Dr. Peggy Barroll.

17. In summary, since it was first established in 1849, the City has diligently developed its water supply with important benchmarks that include the initiation of the LRG-430 et al. diversions with a 1905 priority, and diversions of nearly 11,000 AFY existing when the Lower Rio Grande Underground Water Basin was declared in 1980.

18. Pumping effects are limited because a large component of the current supply is imported from the Jornada, and effects that may occur are compensated for by a large wastewater discharge directly to the river, and may be offset by fallowing of the City's EBID water rights.

Respectfully submitted: June 15, 2020

HECTOR H. BALDERAS
Attorney General of New Mexico
TANIA MAESTAS
Chief Deputy Attorney General
CHOLLA KHOURY
Assistant Attorney General
STATE OF NEW MEXICO
P.O. Drawer 1508
Santa Fe, New Mexico 87501
505-239-4672

JEFFREY WECHSLER
Special Assistant Attorney General
MONTGOMERY & ANDREWS
325 Paseo de Peralta
Santa Fe, NM 87501
505-986-2637

JOHN DRAPER
Special Assistant Attorney General
DRAPER & DRAPER LLC
325 Paseo de Peralta
Santa Fe, NM 87501
505-570-4591

MARCUS J. RAEL, JR.*
LUIS ROBLES
Special Assistant Attorneys General
ROBLES, RAEL & ANAYA, P.C.
500 Marquette Avenue NW,
Suite 700
Albuquerque, New Mexico 87102
505-242-2228
marcus@roblesrael.com
**Counsel of Record*

BENNETT W. RALEY
LISA M. THOMPSON
MICHAEL A. KOPP
Special Assistant Attorneys General
TROUT RALEY
1120 Lincoln Street, Suite 1600
Denver, Colorado 80203
303-861-1963

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STATE OF TEXAS,

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♦

OFFICE OF THE SPECIAL MASTER

♦

STATE OF NEW MEXICO'S CERTIFICATE OF SERVICE

♦

This is to certify that on the June 15, 2020, I caused a true and correct copy of the **State of New Mexico's Disclosure of Rebuttal Expert Witnesses** to be served by e-mail on all counsel of record and interested parties on the Service List, attached hereto.

Respectfully submitted this June 15, 2020.

/s/ Michael Kopp

Michael A. Kopp
Special Assistant Attorney General
TROUT RALEY
1120 Lincoln Street, Suite 1600
Denver, Colorado 80203
(303) 861-1963

SPECIAL MASTER

HONORABLE MICHAEL J. MELLOY
Special Master
United States Circuit Judge
111 Seventh Avenue, S.E., Box 22
South Terrace – Suite 370
Cedar Rapids, IA 52401-2101

TXvNM141@ca8.uscourts.gov
(319) 432-6080
(service via email and U.S. mail)

MICHAEL E. GANS
Clerk of the Court
United States Court of Appeals – Eighth Circuit
Thomas F. Eagleton United States Courthouse
111 South 10th Street, Suite 24.329
St. Louis, MO 63102

TXvNM141@ca8.uscourts.gov
(314) 244-2400

UNITED STATES

JAMES J. DUBOIS*
R. LEE LEININGER
THOMAS K. SNODGRASS
DAVID W. GEHLERT
U.S. DEPARTMENT OF JUSTICE
Environment & Natural Resources Division
999 18th Street
South Terrace – Suite 370
Denver, Colorado 80202
SETH C. ALLISON, Paralegal

james.dubois@usdoj.gov
(303) 844-1375
Lee.leininger@usdoj.gov
(303)844-1364
Thomas.snodgrass@usdoj.gov
(303)844-7233
david.gehlert@usdoj.gov
(303)844-1386
Seth.allison@usdoj.gov
(303)844-7917

NOEL J. FRANCISCO*
Solicitor General
JEAN E. WILLIAMS
Deputy Assistant Attorney General
FREDERICK LIU
Assistant to the Solicitor General
U.S. DEPARTMENT OF JUSTICE
950 Pennsylvania Avenue, NW
Washington, DC 20530-0001

supremectbriefs@usdoj.gov
(202)514-2217

STEPHEN M. MACFARLANE
U.S. DEPARTMENT OF JUSTICE
Environment & Natural Resources Division
501 I Street, Suite 9-700
Sacramento, CA 95814

stephen.macfarlane@usdoj.gov
(916) 930-2204

JUDITH E. COLEMAN Judith.coleman@usdoj.gov
JOHN P. TUSTIN (202) 514-3553
U.S. DEPARTMENT OF JUSTICE john.tustin@usdoj.gov
Environment & Natural Resources Division (202) 305-3022
P.O. Box 7611
Washington, D.C. 20044-7611

STATE OF NEW MEXICO

HECTOR H. BALDERAS hbalderas@nmag.gov
New Mexico Attorney General tmnaestas@nmag.gov
TANIA MAESTAS ckhoury@nmag.gov
CHOLLA KHOURY psalazar@nmag.gov
Chief Deputy Attorney General (505) 239-4672
Assistant Attorney General
STATE OF NEW MEXICO
P.O. Drawer 1508
Santa Fe, New Mexico 87501
PATRICIA SALAZAR - Assistant

MARCUS J. RAEL, JR.* marcus@roblesrael.com
LUIS ROBLES luis@roblesrael.com
Special Assistant Attorneys General chelsea@roblesrael.com
ROBLES, RAEL & ANAYA, P.C. pauline@roblesrael.com
500 Marquette Avenue NW, Suite 700 (505) 242-2228
Albuquerque, New Mexico 87102
CHELSEA SANDOVAL – Firm Administrator
PAULINE WAYLAND - Paralegal

BENNETT W. RALEY braley@troutlaw.com
LISA M. THOMPSON lthompson@troutlaw.com
MICHAEL A. KOPP mkopp@troutlaw.com
Special Assistant Attorneys General (303) 861-1963
TROUT RALEY
1120 Lincoln Street, Suite 1600
Denver, Colorado 80203

JEFFREY WECHSLER jwechsler@montand.com
Special Assistant Attorney General (505) 986-2637
MONTGOMERY & ANDREWS
325 PASEO DE PERALTA
SANTA FE, NM 87501

JOHN DRAPER john.draper@draperllc.com
Special Assistant Attorney General (505) 570-4591
DRAPER & DRAPER LLC
325 PASEO DE PERALTA SANTA FE, NM 87501

STATE OF COLORADO

PHILIP J. WEISER eric.olson@coag.gov
Attorney General of Colorado karen.kwon@coag.gov
ERIC R. OLSON chad.wallace@coag.gov
Solicitor General nan.edwards@coag.gov
KAREN M. KWON (720) 508-6281
First Assistant Attorney General
CHAD M. WALLACE*
Senior Assistant Attorney General
COLORADO DEPARTMENT OF LAW
1300 Broadway
Denver, CO 80203
NAN EDWARDS, Paralegal

STATE OF TEXAS

STUART SOMACH* ssomach@somachlaw.com
ANDREW M. HITCHINGS ahitchings@somachlaw.com
ROBERT B. HOFFMAN rhoffman@somachlaw.com
FRANCIS M. "MAC" GOLDSBERRY II mgoldsberry@somachlaw.com
THERESA C. BARFIELD tbarfield@somachlaw.com
SARAH A. KLAHN sklahn@somachlaw.com
BRITTANY K. JOHNSON bjohnson@somachlaw.com
RICHARD S. DEITCHMAN rdeitchman@comachlaw.com
SOMACH SIMMONS & DUNN, PC (916) 446-7979
500 Capital Mall, Suite 1000 (916) 803- 4561 (cell)
Sacramento, CA 95814 cgarro@somachlaw.com
CORENE RODDER - Secretary crodder@somachlaw.com
CHRISTINA GARRO – Paralegal ydelacruz@somachlaw.com
YOLANDA DE LA CRUZ - Paralegal crivera@somachlaw.com
CRYSTAL RIVERA - Secretary (512) 463-2012

KEN PAXTON
Attorney General

JEFFREY C. MATEER
First Assistant Attorney General
DARREN L. McCARTHY
Deputy Attorney General for Civil Litigation
PRISCILLA M. HUBENAK Priscilla.Hubenak@oag.texas.gov
Chief, Environmental Protection Division
P.O. Box 12548
Austin, TX 78711-2548

AMICI / FOR INFORMATIONAL PURPOSES ONLY

ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY

JAMES C. BROCKMANN* (505) 983-3880
JAY F. STEIN jcbrockmann@newmexicowaterlaw.com
STEIN & BROCKMANN, P.A. jfstein@newmexicowaterlaw.com
P.O. Box 2067 administrator@newmexicowaterlaw.com
Santé Fe, New Mexico 87504

PETER AUH (505) 289-3092
ALBUQUERQUE BERNALILLO COUNTY pauh@abcwua.org
WATER UTILITY AUTHORITY
P.O. Box 568
Albuquerque, NM 87103-0568

CITY OF EL PASO

DOUGLAS G. CAROOM* (512) 472-8021
SUSAN M. MAXWELL dcaroom@bickerstaff.com
BICKERSTAFF HEATH DELGADO smaxwell@bickerstaff.com
ACOSTA, LLP
2711 S. MoPac Expressway
Building One, Suite 300
Austin, TX 78746

CITY OF LAS CRUCES

JAY F. STEIN * (505) 983-3880
JAMES C. BROCKMANN jcbrockmann@newmexicowaterlaw.com
STEIN & BROCKMANN, P.A. jfstein@newmexicowaterlaw.com
P.O. Box 2067 administrator@newmexicowaterlaw.com
Santé Fe, New Mexico 87504

JENNIFER VEGA-BROWN (575) 541-2128
MARCIA B. DRIGGERS jvega-brown@las-cruces.org
LAW CRUCES CITY ATTORNEY'S OFFICE marcyd@las-cruces.org

P.O. Box 20000
Las Cruces, New Mexico 88004

ELEPHANT BUTTE IRRIGATION DISTRICT

SAMANTHA R. BARNCASTLE* (575) 636-2377
BARNCASTLE LAW FIRM, LLC (575) 636-2688 (fax)
1100 South Main, Ste. 20 samantha@h2o-legal.com
P.O. Box 1556
Las Cruces, NM 88004
JANET CORRELL – Paralegal janet@h2o-legal.com

EL PASO COUNTY WATER IMPROVEMENT DISTRICT NO. 1

MARIA O'BRIEN* (505) 848-1803 (direct)
SARAH M. STEVENSON mobrien@modrall.com
MODRALL, SPERLING, ROEHL, HARRIS sarah.stevenson@modrall.com
& SISK, PA
Suite 1000
500 Fourth Street N.W.
P.O. Box 2168
Albuquerque, New Mexico 87103-2168
SHANNON GIFFORD – Legal Assistant shannong@modrall.com
LAMAI HOWARD – Legal Assistant lamaih@modrall.com

RENEA HICKS rhicks@renea-hicks.com
LAW OFFICE OF MAX RENEA HICKS
P.O. Box 303187
Austin, TX 78703

HUDSPETH COUNTY CONSERVATION AND RECLAMATION DISTRICT NO. 1

ANDREW S. "DREW" MILLER* (512) 320-5466
KEMP SMITH LLP dmiller@kempsmith.com
919 Congress Avenue, Suite 1305
Austin, TX 78701

STATE OF KANSAS

DEREK SCHMIDT (785) 296-2215
Attorney General of Kansas toby.crouse@ag.ks.gov
JEFFREY A. CHANAY bryan.clark@ag.ks.gov
Chief Deputy Attorney General
TOBY CROUSE*
Solicitor General of Kansas

BRYAN C. CLARK
Assistant Solicitor General
DWIGHT R. CARSWELL
Assistant Attorney General
120 S. W. 10th Ave., 2nd Floor
Topeka, KS 66612

NEW MEXICO PECAN GROWERS

TESSA T. DAVIDSON* ttd@tessadavidson.com
DAVIDSON LAW FIRM, LLC (505) 792-3636
4206 Corrales Road
P.O. Box 2240
Corrales, NM 87048
JO HARDEN – Paralegal jo@tessadavidson.com

NEW MEXICO STATE UNIVERSITY

JOHN W. UTTON* (505) 699-1445
UTTON & KERY, P.A. john@uttonkery.com
P.O. Box 2386
Santa Fe, New Mexico 87504

General Counsel gencounsel@nmsu.edu
New Mexico State University
Hadley Hall Room 132
2850 Weddell Road
Las Cruces, NM 88003

Exhibit A
Resume of Lee Wilson
105 Cienega Street
Santa Fe, New Mexico 87501

EDUCATION AND CERTIFICATION

Ph.D., Geology, Columbia University (1971). Specializations in geomorphology, hydrology, ecology (collectively what is today referred to as "environmental science").

B.A., Geology, Yale University (1964); minor in ecology.

Certified Professional Hydrogeologist #220 (American Institute of Hydrology).

EXPERIENCE AT LEE WILSON AND ASSOCIATES

Since 1973, Dr. Wilson has been President of Lee Wilson and Associates (LWA), a water resource and environmental consulting firm based in Santa Fe, New Mexico. His work generally falls into three categories, each of which is discussed more fully below:

- Technical analysis of water resources for more than 500 projects;
- Author and project director for several dozen environmental management and impact evaluations, including 17 years as an EPA mission contractor;
- Expert testimony on a broad array of water resource and environmental issues in dozens of court and regulatory cases.

Also provided below is information on Dr. Wilsons experience in other areas of resource management while at LWA; and his work as administrator of a successful small business.

WATER RESOURCES

The water resources projects that Lee Wilson has worked on have dealt with issues as follows.

- Water-supply master planning for municipalities and water authorities. Responsible for projecting water demands, design of conservation programs, assessing streamflow supplies on a probabilistic basis, evaluating well field performance, modeling oversight of well field impacts and reservoir operations, developing strategies for water rights acquisition, investigating water quality problems, designing wellhead protection programs, assessing water-resource regulations, and performing tradeoff analyses of water-supply alternatives based on engineering, economic, environmental and legal considerations.
- Evaluation of water quality impacts and/or clean-up programs for hazardous waste disposal, hydrocarbon leaks and spills, brine pits, coal mining and transport, power plant operations, pipeline construction, salt mining, geothermal development, septic tanks, sewage lagoons, sludge disposal, land application of wastewater, feedlots, dairies, swine breeding facilities, aquaculture, natural saline seeps, watershed development, petrochemical manufacturing, other manufacturing,

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offshore oil and gas activities, disposal of dredged materials. Note that impacts to soils have been considered in many of these evaluations.

- Assessment of wastewater management alternatives, ranging from conventional treatment and discharge, to recycling alternatives including potable reuse; and evaluation of service area alternatives, especially extension of sewer lines to environmentally sensitive areas.
- Geotechnical/hydrologic components of four dozen dam safety inspections and seismic evaluations (for the Corps of Engineers and state agencies), and numerous other projects involving evaluation of flood hazards, Section 404 permits and/or stormwater management.

There are many specific LWA projects that display Dr. Wilson's ability to tackle complex and or unique water resource issues. These include the following.

- Development of 70,000 acre-feet per year well field and acquisition of more than $200 million in water rights in Canadian River Basin of Texas, through program of test drilling, data interpretation, and well design. Other work for this client -- the Canadian River Municipal Water Authority -- has involved hydrogeology investigations and conceptual design of a successful brine control system; reservoir firm yield and salinity evaluations; and assessment of hydrologic impacts of watershed brush control.
- Project manager and senior hydrologist for the Central Platte River groundwater and surface water modeling program (COHYST).
- Design of New Mexico's statewide program for groundwater quality monitoring, the first such program in the United States.
- Evaluation of numerous groundwater contamination events involving hydrocarbons, solvents, heavy metals, nitrates and other contaminants, for energy companies, major industrial companies, landowners and governments.
- Development of the nation's first set of criteria for use in evaluating full-scale potable recycling of wastewater (for the Hueco Bolson Recharge Project, El Paso Texas, now operational for 30 years).
- Design of EPA's prototype Wellhead Protection Program for Indian Lands.
- Development of the nation's first aquifer identification procedures and maps for EPA's Underground Injection Control Program.
- Writing of stream standards for seven Indian tribes in New Mexico.
- Assessment of runoff and contamination risks from Los Alamos National Laboratory, New Mexico, resulting from Cerro Grande wildfire. Currently we are the groundwater consultant on a team responsible for Natural Resource Damage Assessment at LANL (and for other locations in New Mexico including White Sands Missile Ranch and the Rio Algom mine). The current LANL assignments address contamination by the explosive RDX in Canon del Valley and by chromium in Sandia and Mortendad Canyons.
- Support to State of Florida with respect to determining minimum stream flow requirements for the endangered Manatee population at Volusia Blue Spring; subsequent work for the past several years involved peer review of dozens of minimum flow designations for rivers, lakes and springs throughout the St. Johns River Basin.

- Preparation of 33 county-level maps of aquifer vulnerability for the New Mexico Underground Storage Tank program (republished on New Mexico Environmental Department web site at http://www.nmenv.state.nm.us/fod/LiquidWaste/aoc.html).
- Performance of hydrologic and regulatory assessments of aquifer management rules for the Edwards Aquifer Authority, Texas; and quantified water-rights values for the Authority.
- Support to design and implementation of extensive studies to assess impacts of water appropriations on Guadalupe River, Texas, including effects on the endangered whooping crane and sensitive mussel species.
- Consultant to Alcoa mining regarding permitting of industrial wells and securing of bond release at Sandow Mine, Texas.
- Active as water rights consultant for more than a dozen communities throughout New Mexico, responsible for oversight of water-rights transfers and compliance with state permit conditions; one example is our oversight of acquisition and transfer of more than $30 million worth of water rights to the Village of Los Lunas; another is preparation of numerous community water conservation plans, currently including the City of Las Cruces.

ENVIRONMENTAL MANAGEMENT AND IMPACT ASSESSMENT

Dr. Wilson's projects in environmental management and impact assessment include the following, which typically involve evaluations related to all aspects of the environment, including air, water, soils, biota, and human resources.

- LWA was selected in 1984 as level-of-effort NEPA contractor for EPA Region 6; this contract was re-awarded or extended annually for 17 years until our retirement in 2001. Under this contract, Dr. Wilson was the lead participant in over 60 work assignments that included:
  - preparation of state-of-the-art reports on cumulative impacts, EIS post-audits, and NEPA risk assessments;
  - author of a unique Record of Decision that effectively served as a biological opinion under the Endangered Species Act;
  - team leader for EISs on a major lignite mine and power plant, a very large petrochemical plant, oil and gas activities in the Territorial Seas, and dredged materials disposal in the Atchafalaya Delta;
  - team leader for EAs on surface coal mining and confined animal feedlot operations; and responsible for analysis of a Clean Lakes Program project, a generic programmatic agreement for Section 106 of the National Historic Preservation Act, and an investigation of alternatives for beneficial use of dredge spoil in the Laguna Madre, Texas, and statewide in Louisiana and Texas. Our work on coastal restoration for EPA is discussed elsewhere.
- Prior to the EPA contract LWA prepared numerous impact statements, many of which were of special interest:
  - the first third-party EIS performed in the U.S. (for EPA, on the City of Albuquerque wastewater treatment facilities);
  - the first BLM grazing EIS that was completed without a court challenge (McGregor Range);

- a 1980 EIS that developed EPA's criteria for potable reuse of wastewater (City of El Paso); and
- a 1982 wastewater EIS (for EPA on Taos Ski Valley) which has been described as "exactly what CEQ wanted to accomplish when they reformed the EIS process".

- Lee Wilson served Alcoa Corp. as advisor for a controversial EIS prepared by a Third-Party consultant regarding a major coal mine project in Texas. Key issues included groundwater development, effects on endangered species, and the secondary effects of mine-supported energy generation and smelting. The EIS was not challenged. LWA continues to advise Alcoa on a variety of environmental permitting matters.
- Current or recent LWA work on impact issues includes:
  - support to Louisville Gas and Electric regarding Section 404 permitting issues in Kentucky;
  - preparation of assessments of arsenic treatment projects for the City of Albuquerque;
  - evaluation of water resource impacts for a Forest Service EIS being prepared on a major uranium mine in New Mexico, where large quantities of groundwater will be withdrawn for mine depressurization; and
  - a BLM EIS on a copper mine where water issues were paramount.
- Our impact assessments of diverse project types have included: municipal flood control; in-situ copper mining; in-situ potash mining; the eutrophication effects of urban runoff; construction of a natural gas pipeline; the agricultural impacts of wastewater service extensions; the groundwater impacts (quantity/quality) at a large cooling reservoir constructed in karst terrain; construction/use of a limited access freeway; chemical manufacturing; a pulp and rayon mill; tribal wastewater disposal; trans-national air pollution; and arsenic treatment systems.
- Dr. Wilson also has taught courses on impact analysis. Course sponsors/venues include the Autonomous University of Mexico (Mexico City, 2 courses), FLACAM in Lima, Peru (students from 5 countries), VUB in Brussels, Belgium (students from 20 countries), and the Inter-American Development Bank in Jamaica (students from 10 Caribbean countries).

EXPERT TESTIMONY

Dr. Wilson's experience as an expert witness includes the following.

- Current or recent expert designations and assignments in federal or state courts include:
  - for Datacard and General Electric in a contamination case in California;
  - for El Paso Corporation as a hydrogeology expert in several cases involving ground-water contamination in New York, Florida, New Jersey and New Hampshire;
  - for Taos Pueblo as a water-rights expert in an adjudication case; for several New Mexico municipalities in cases involving protested water rights transfers;
  - for a rock quarry and separately a sand mine, both in Texas with respect to well permitting;
  - for acequia associations in the Rio San José Adjudication (New Mexico);
  - for the City of Las Cruces in the Lower Rio Grande adjudication.

- for Heritage Corp. before a Federal Court in Dallas regarding groundwater contamination in Winkler County TX;
- for McAllen Ranch before an arbitration panel in Houston regarding soil and groundwater contamination in McAllen County, TX;
- for the Town of Florence Arizona Southwest Value Partners, before an Arizona Hearing Officer regarding an in-situ mining water quality permit;
- he is currently providing expert advice to a major aquaculture project in south Texas.

- An example of testimony regarding groundwater contamination was for Fina and Dominion in a 7-year case involving hydrocarbon releases in McAllen, Texas. We researched local soil characteristics, groundwater hydrology and contamination, examined potential sources including pipelines and old gas stations, and evaluated diverse issues including mobility of phase-separated gasoline and fingerprinting of natural gas condensate.
- For the State of Florida, Dr. Wilson provided expert testimony in federal court cases regarding interstate water issues, especially relating to competition for streamflows between urban Atlanta, major recreational reservoirs, large-scale irrigation, and the environmental resources of the Apalachicola River floodplain and estuary in Florida.
- Dr. Wilson's past expert work for the State of Nebraska involved two U.S. Supreme Court cases. The more recent dealt with the Republican River Compact, where issues related to streamflow hydrology, groundwater modeling, Compact accounting, reservoir operations and water-rights administration. Dr. Wilson previously was a lead expert for Nebraska in its interstate litigation on the North Platte Decree; the issues there included protection of environmental flows for the critical habitat of the Whooping Crane; and municipal needs in Wyoming.
- Of past cases, the largest by far was Dr. Wilson's role as chief expert regarding water resource and environmental issues raised in federal litigation brought by a coal slurry pipeline against six railroads ("ETSI case"). This involved extensive research and focused testimony regarding the environmental impacts of coal slurry pipelines, including comparison of impacts to coal transport by unit trains; and regarding the genuineness of railroad protests to permits under the Clean Water Act, Clean Air Act, Resource Conservation and Recovery Act, Endangered Species Act and other statutes and regulations in South Dakota, Wyoming, Oklahoma, Arkansas, Texas and Louisiana.
- Another well publicized expert appearance was as chief technical witness for the City of El Paso in its landmark challenge of a statute barring the interstate transport of groundwater. There, testimony dealt with long-term municipal water supply needs; alternatives ranging from desalting to recycling; surface and groundwater impacts of a 296,000 acre-feet per year diversion; and diverse socio-economic issues related to water use and interstate commerce.
- Other past testimony and/or litigation advice has been provided in hazardous waste disposal, water rights, water rates and water quality cases for clients ranging from major corporations (Johnson and Johnson, Waste Management Inc., Phillips Petroleum, Marathon Oil, OXY Petroleum, Budget Rent-a-Car, ELF-Atochem) to environmental and citizen groups (Sierra Club, La Raza Unida). Dr. Wilson is currently involved in two remediation projects under jurisdiction of the Railroad Commission of Texas, one on behalf of a landowner, one on behalf of an oil and gas producer.

RESOURCE MANAGEMENT

These projects involve specialized aspects of environmental and water resource management.

- LWA's EPA contract included extensive work in restoration of Louisiana's coastal wetlands. Dr. Wilson oversaw preparation of a handbook for managing wetlands impacts of oil and gas development; prepared ecosystem restoration plans and studies (such as a project to divert Mississippi River water to restore Lake Maurapas swamps -- the largest such project so far conceived); evaluated specific projects involving land management, mariculture and barrier islands; and helped write "Coast 2050", the master plan for achieving no net loss of wetlands.
- LWA has undertaken a number of specialized studies aimed at the innovative management of environmental resources. Lee Wilson:
  - Developed a method by which water supply is quantified and used as the basis of land use density zoning (for Santa Fe County, NM)
  - created a standardized list of subdivision covenants for water conservation;
  - performed the nation's first size-partitioned inventory of fugitive dust, which involved all natural as well as man-related particulate sources in a desert area with numerous tailings piles, copper mines, mills and unpaved roads;
  - prepared the conceptual scope for City of Albuquerque's hazardous waste management master plan;
  - drafted an environmental code for City of Santa Fe, dealing with issues which range from toxic air pollutants to electromagnetic radiation from power lines; and
  - input to design of a project to restore the hydrology of a sacred wetland on Taos Pueblo.

PRIOR EXPERIENCE, ACCOMPLISHMENTS, HONORS AND PUBLICATIONS

- 1972-1973. Senior Staff Scientist with an environmental consulting firm based in New York City and Dallas, responsible for preparing more than a dozen major EISs and assessments in California, Indiana, New York, North Carolina, Pennsylvania and Texas; projects included large water supply and flood control reservoirs, landfills, coal-fired power plants and land development.
- 1965-1971. miscellaneous short-term assignments, including observer-member of an Australian government team performing an inventory of soil, water and biological resources in the Northern Territory; and lecturer in geology, geomorphology, Pleistocene geology and geophysics at Columbia University, Briarcliff College and Brock University.
- LWA was selected by EPA in its 1994 National Award for Outstanding Achievements as a Small Business Contractor.
- Columbia University Fellowship for advanced study in remote sensing at International Training Center, Delft, Netherlands (1969-70)
- NSF Summer Institute Fellowship in hydrology/hydraulics, Colorado State University (1968).
- Food Fair National Scholar, Yale University, 1960-64

- Member of more than one dozen professional and environmental organizations, including Geological Society of America (Elected Fellow) and National Wildlife Society (Life Member).
- Member of the International Association for Impact Assessment; Chairman of Training and Professional Development Committee (2003-2007); in 2004 received IAIA's award for Outstanding Service.
- For LWA, author of more than 400 technical reports, many distributed widely by government agencies.
- Ten contributions to the Encyclopedia of Earth Sciences series. Scientific articles published in: Groundwater; Water Resources Research; Water Resources Bulletin; American Journal of Science; Bulletin of the International Association of Hydrology; Bulletin of the Geological Society of America; Rev. Geographique Physique et de Geologie Dynamique; EIS Annual Review; Environmental Impact Assessment Review; Journal of Soil and Water Conservation; American Water Works Association Proceedings; Physical Geography.
- Keynote speaker at UNESCO symposium on erosion and sedimentation, Paris, 1977; member of AWRA scientific exchange program with the Peoples Republic of China (1985); member of City of San Antonio delegation to Kumamoto, Japan, water conference (1990); member of EPA/DOE international workshop on EIS methodology (1991); keynote speaker New Mexico Legislature water retreat (2000); member of Advisory Council for the Caroline and William N. Lehrer Distinguished Chair in Water Engineering at Texas A&M University's Biological and Agricultural Engineering Department (2005).

WRITTEN REPORTS

With one exception, all of Lee Wilson's written reports in the last 10 years (i.e. 2020-2020) are in the form of professional reports submitted to or on behalf of clients. The exception is that with my co-author Maria Partidario, in 2011 I authored the chapter "Professional and institutional capacity building for SEA" in Handbook of Strategic Environmental Assessment, published by Earthscan.

EXPERT TESTIMONY IN THE LAST FOUR YEARS

Expert report submitted to New Mexico State Engineer on behalf of Lea County with reference to water right applications in the Lea County Underground Water Basin by Intrepid Potash (Files L-4247 and L-2724).

Expert report and rebuttal report submitted to New Mexico State Engineer on behalf of the City of Santa Fe regarding permit applications: availability of water; nature and extent of claimed water right; whether the granting of the application would result in impairment of existing water rights; whether granting the application would be detrimental to the public welfare of the state; whether granting the application would be contrary to the conservation of water within the state.

Expert reports, deposition, affidavits before the New Mexico State Engineer on behalf of the City of Gallup regarding application for permits to appropriate ground water within the Gallup underground water basin of New Mexico. Key issues were developing a conjunctive use strategy to determine need for new wells, given the existing stressed aquifer and potentially unreliable surface water from a proposed federal project.

Affidavit before the U.S. Environmental Protection Agency Environmental Appeals Board on behalf of the Town of Florence AZ, regarding EPA's decision to retain the aquifer exemption granted to a very large mining project, even though the current project is almost two orders of magnitude smaller; and to exempt the aquifer that overlies the ore body on the basis that it is mineral producing, even though the only producible resource it contains is drinking water. The affidavit stated that in other respects, EPA's UIC permit was responsive to prior submittals and is protective.

On behalf of the Association of Community Ditches of Rio San José in a water rights adjudication of Rio San Jose watershed before the Thirteenth Judicial District Court, Cibola County, NM, Cause No. CB-83-190-CV & CB-83-220-CV. Report and testimony evaluates Pueblo claims through quantification of actual Pueblo water supply, duty of water, and acreage.

Expert report and deposition in Superior Court of the State of California, Case No. 30-2008-00078246-CU-TT-CXC, on behalf of SABIC Innovative Plastics US, LLC and General Electric Company. Report provides extensive evaluation of perchlorate contamination of shallow groundwater from the former LNP site in the South Basin Ground water Protection Program area of the Orange County Water District. Data Card was also a client, and settled out prior to submittal of the expert report

Expert report and hearing testimony before the Texas Council of Environmental Quality (TCEQ) on behalf of the Guadalupe-Blanco River Authority regarding its permit application. The issues are the hydrological and ecological impacts of a proposal to appropriate surplus Guadalupe River flows for direct use and/or for storage in an underground or surface reservoir. Subjects addressed included issues in TCEQ and Corps of Engineers permitting and potential impacts to sensitive species including the whooping crane and several rare mussels.

On behalf of the Town of Florence AZ and Southwest Value Partners in support of appeal to the Arizona Water Quality Appeals Board and Arizona courts. This was a follow up to extended testimony and multiple affidavits regarding a discharge permit issued by ADEQ for an in-situ copper mine pilot project. The original hearing (2014) focused on issues of compliance, monitoring, and sufficiency of information and included extensive review of geologic, hydrologic and geochemical data and assessment of ground water flow and fate and transport models. The initial decision was to reject the ADEQ permit and remand for major changes. An amended permit was issued which was largely compliant with remand requirements; one portion remains under appeal. Current efforts focus on evaluation of pilot project performance, an application for a commercial mine, and EPA's possible commercial permit.

On behalf of Black Mountain Sand, hearing testimony before State of Texas hearing officers regarding a mining company application for well permits from the Wintergarden Groundwater Conservation District. Testimony related to evaluation of water resources in the Carrizo aquifer, the impacts of groundwater withdrawals for mining purposes, and evaluation of expert reports prepared for Protestants.

On behalf of James McAllen, expert report and hearing testimony in an arbitration proceeding contesting the Plaintiff's expert estimates of the costs of remediation of soils contaminated with iron sponge containing mercury. Wilson's prior testimony regarding contamination on McAllen Ranch was in 2010.

Tab 41

FIGURE 1: The Rio Grande basin

Tab 42

FIGURE 2: The Upper Rio Grande basin

Tab 43

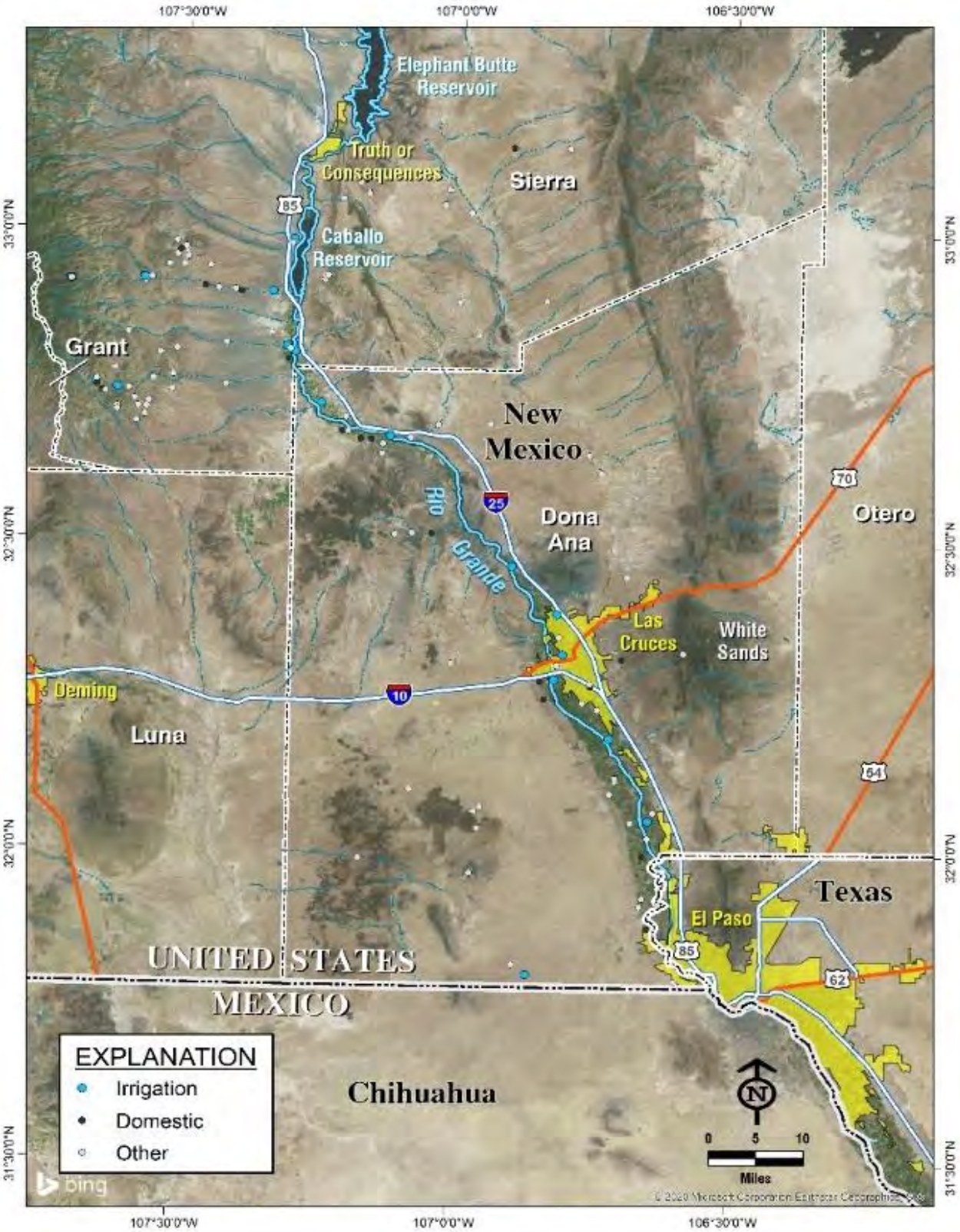

FIGURE 3: Groundwater wells in New Mexico in 1938

Tab 44

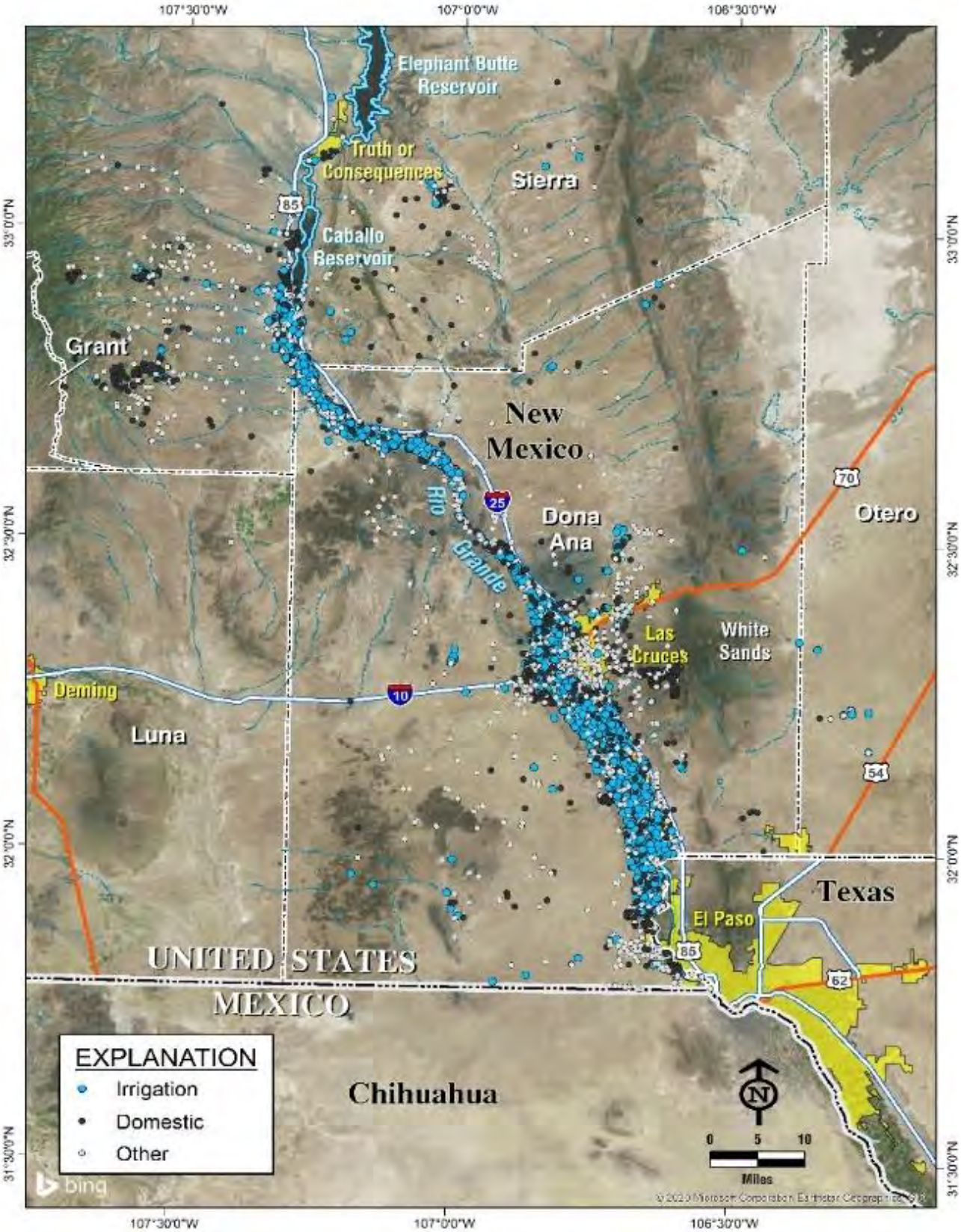

FIGURE 4: Groundwater wells in New Mexico in 2020

Tab 45

FIGURE 5: Map of Rio Grande Project Area

Tab 46

TABLE 90.—*Estimated percentages of reservoir water, arroyo inflow, and drainage in net diversions and disposal of reservoir releases, Elephant Butte-Fort Quitman section, 1930–36*

Division or item	Mean disposal of reservoir water 1930–36 (percentage distribution)	Mean percentage content, 1930–36, in net diversions, of—			
		Unused reservoir releases [1]	Arroyo inflow	Drain flow and seepage	Total
Rincon	8.5	97.5	2.2	[2] 0.3	100.0
Mesilla	46.4	89.8	2.8	7.4	100.0
El Paso	18.4	58.4			
Upper El Paso (Franklin canal)		61.5	3.4	35.1	100.0
Lower El Paso (Tornillo canal)		38.2	4.1	57.7	100.0
Rio Grande Project	73.3	79.8	3.0	17.2	100.0
Hudspeth	2.2	33.9	6.1	60.0	100.0
Juarez (Mexico)	11.4	49.5	5.4	45.1	100.0
Upper Juarez		58.3	3.1	38.6	100.0
Lower Juarez		24.4	11.8	63.8	100.0
Riverbed losses	9.2				
Passing Fort Quitman	3.9	17.2	14.8	68.0	100.0
Total	100.0				

[1] Distinguished from returned drainage originally from the reservoir.
[2] Invisible accretion to river.

Estimates based on detail study of all available data, 1930–36, on river flow, reservoir releases, diversions, wastes, drain flow, and arroyo inflow.

FIGURE 6: Table 90 of the JIR

Tab 47

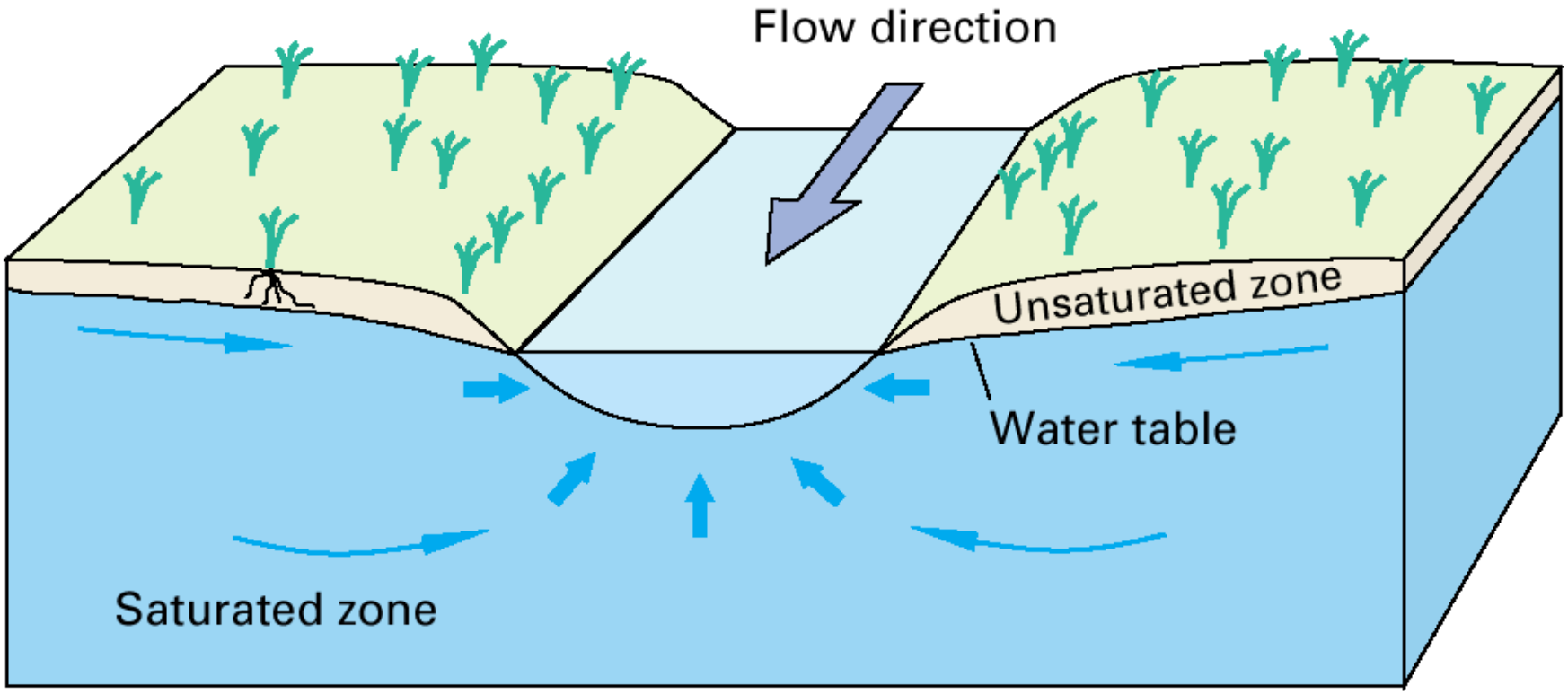

FIGURE 7: Illustration of a Gaining Stream (from Winter and others, 1988)

Tab 48

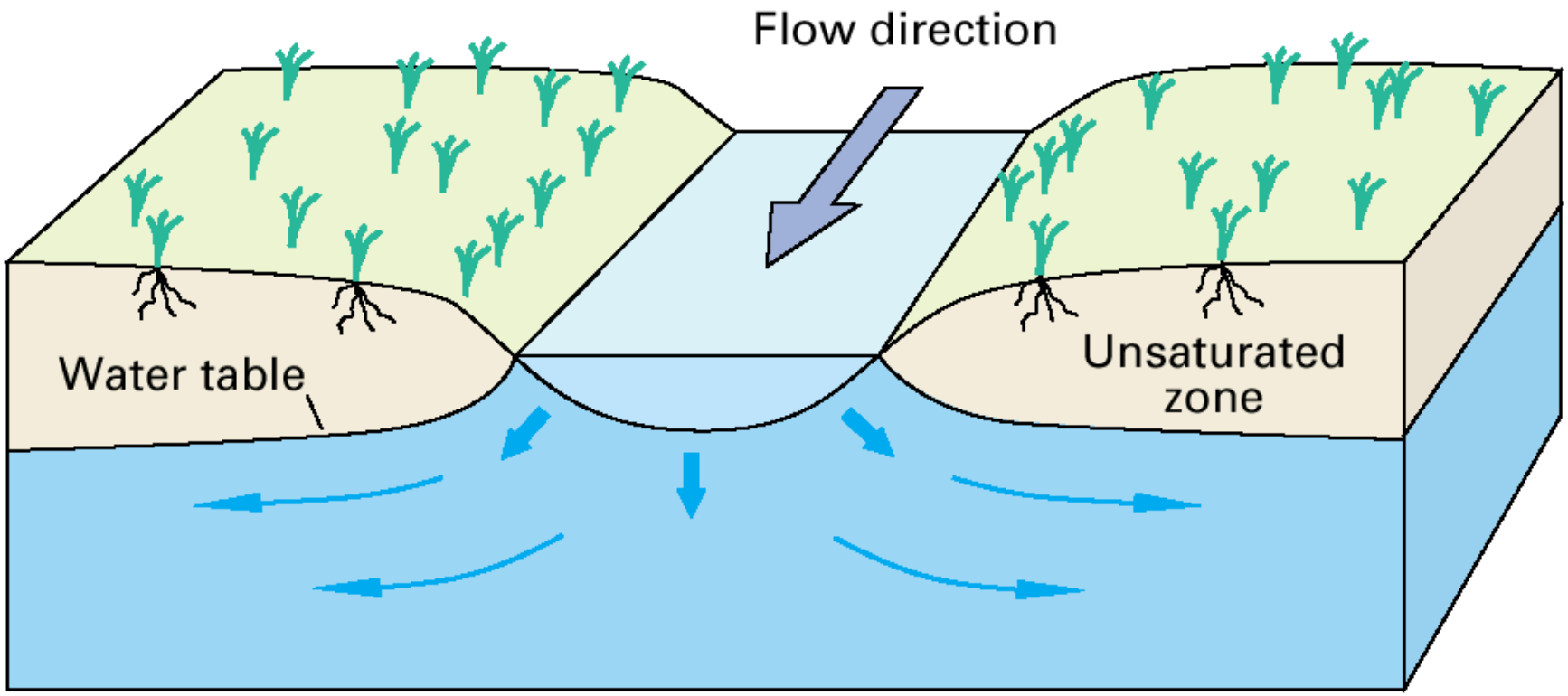

FIGURE 8: Illustration of a Losing Stream (from Winter and others, 1988)

Tab 49

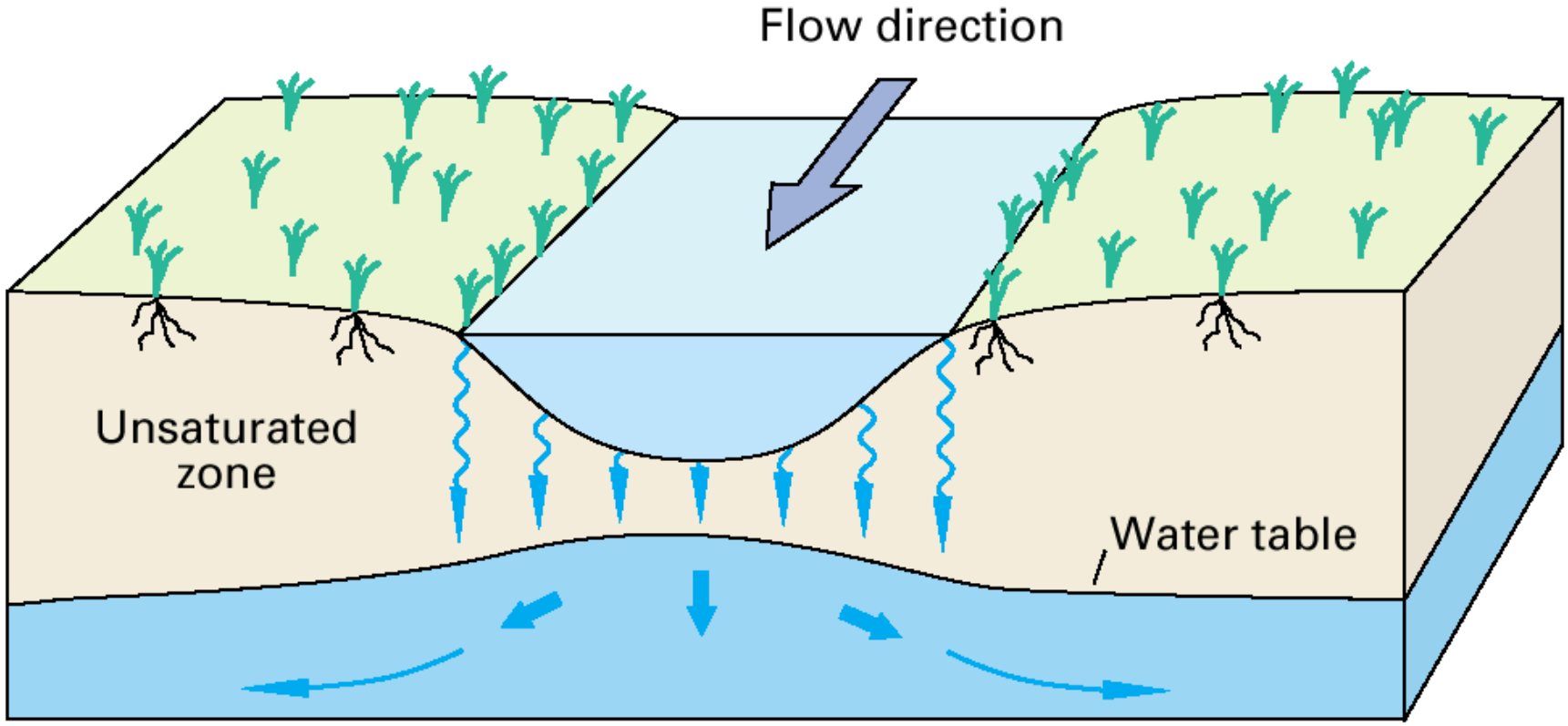

FIGURE 9: Illustration of a Disconnected Stream (from Winter and others, 1988)

Tab 50

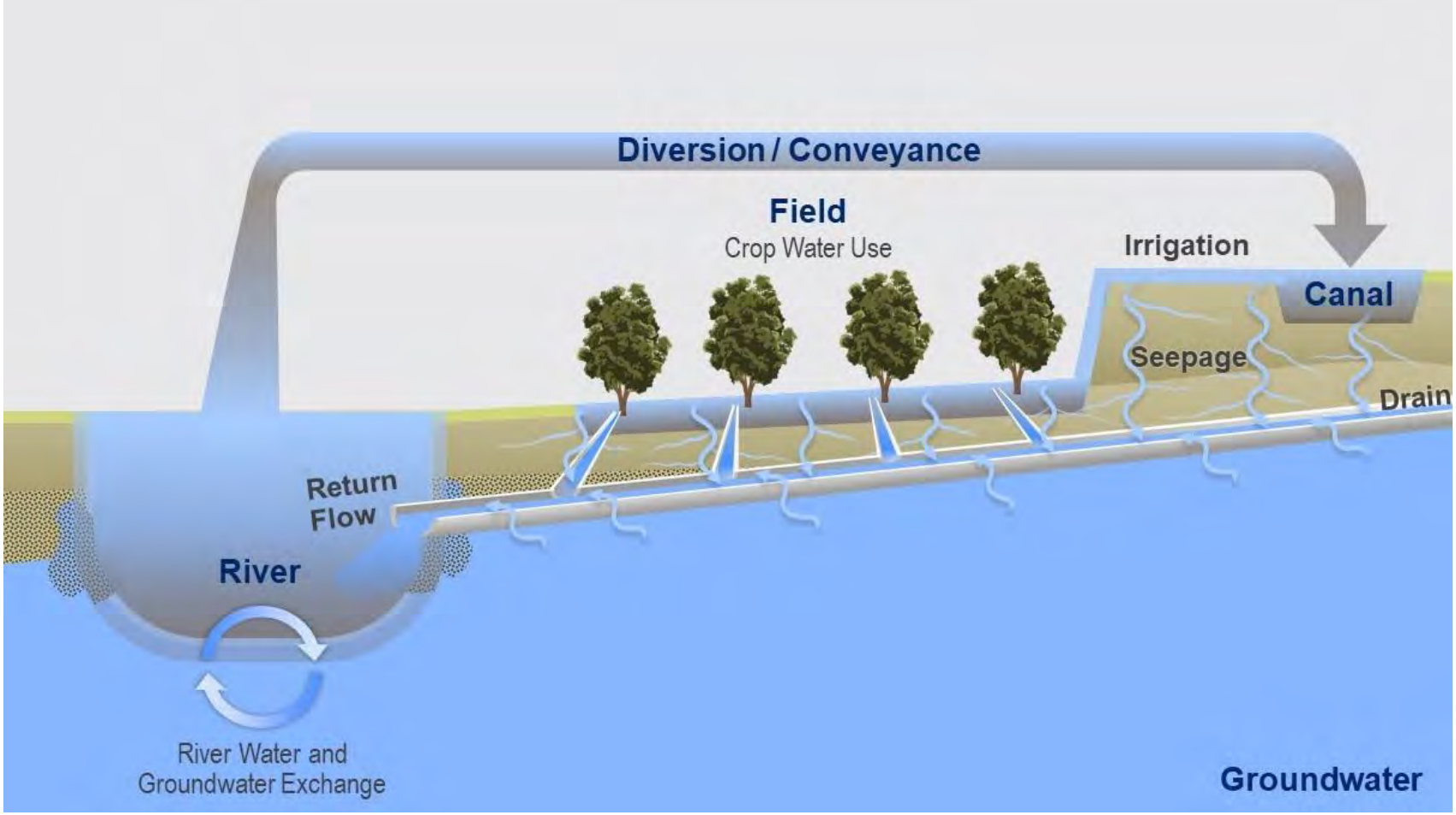

FIGURE 10: Schematic of Rio Grande and Groundwater System Interaction Prior to Development of Groundwater Pumping in Rincon and Mesilla basins

Tab 51

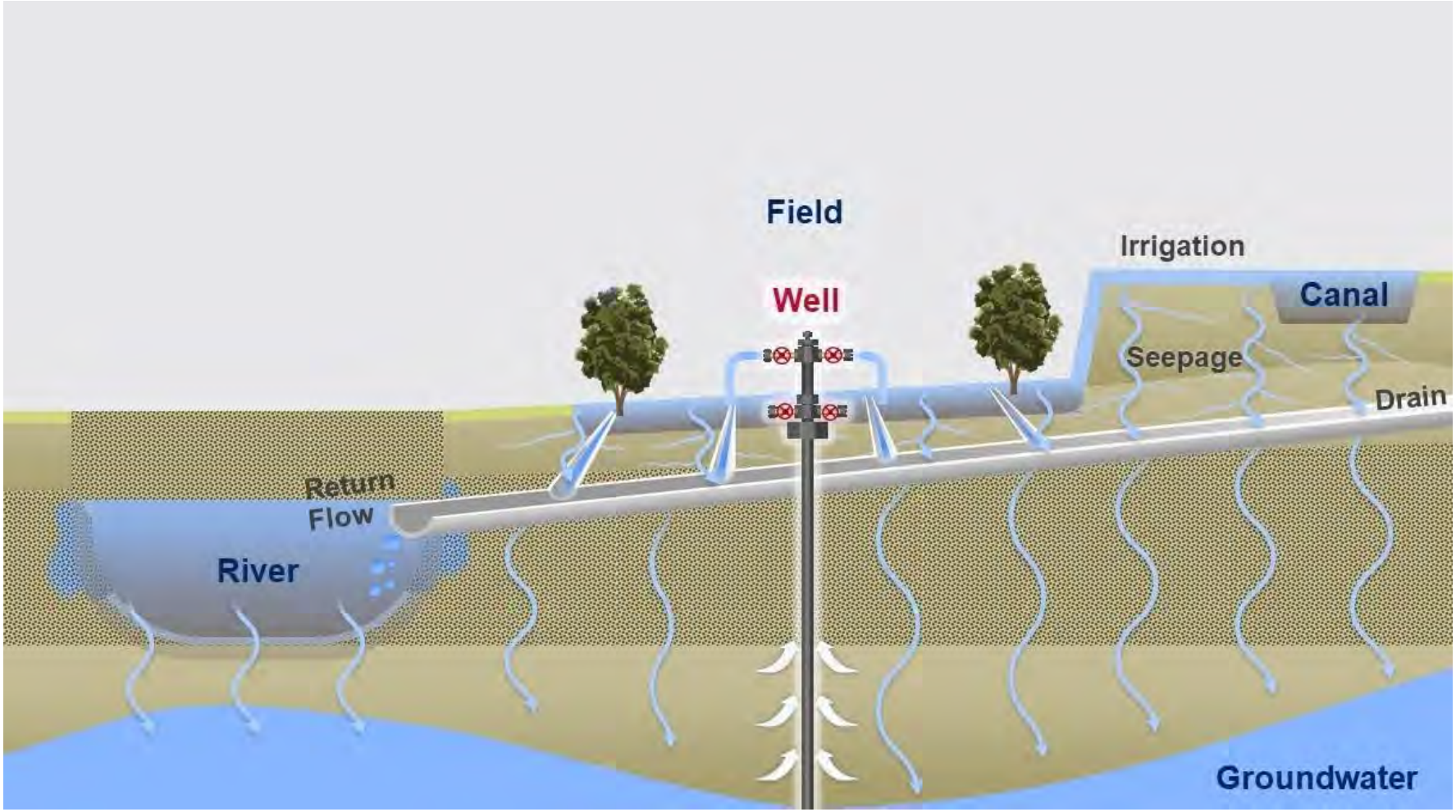

FIGURE 11: Schematic of Rio Grande and Groundwater System Interaction After Development of Groundwater Pumping in Rincon and Mesilla basins

Tab 52

No. 141, Original

In the

SUPREME COURT OF THE UNITED STATES

STATE OF TEXAS,

Plaintiff,

v.

STATE OF NEW MEXICO and
STATE OF COLORADO,

Defendants.

OFFICE OF THE SPECIAL MASTER

DECLARATION OF SCOTT A. MILTENBERGER, Ph.D. IN SUPPORT OF THE STATE OF TEXAS'S MOTION FOR PARTIAL SUMMARY JUDGMENT; MEMORANDUM OF POINTS AND AUTHORITIES IN SUPPORT THEREOF FEDERAL RULE OF CIVIL PROCEDURE 56

Stuart L. Somach, Esq.*
Andrew M. Hitchings, Esq.
Robert B. Hoffman, Esq.
Francis M. Goldsberry II, Esq.
Theresa C. Barfield, Esq.
Sarah A. Klahn, Esq.
Brittany K. Johnson, Esq.
Richard S. Deitchman, Esq.
SOMACH SIMMONS & DUNN, PC
500 Capitol Mall, Suite 1000
Sacramento, CA 95814
Telephone: 916-446-7979
ssomach@somachlaw.com
**Counsel of Record*

November 2, 2020

I, Scott A. Miltenberger, declare as follows:

1. I am a professional consulting historian, specializing in water and natural resources issues. I am a partner at JRP Historical Consulting, LLC (JRP), located at 2850 Spafford Street, Davis, CA 95618. My qualifications to render the opinions contained in this Declaration are set forth in my professional resume, attached hereto as Attachment 1 and incorporated herein by this reference.

2. I have been retained as an expert by Somach Simmons & Dunn to provide expert opinions and testimony on behalf of the State of Texas as to the history and historical issues concerning the Rio Grande Compact of 1938 ("Compact" or "Compact of 1938").

3. To develop my expert opinions, I researched, collected, and analyzed thousands of archival documents, published primary and secondary sources, and academic monographs over the course of eight years. This material was obtained by myself, my former business partner (now retired) Mr. Stephen Wee, and JRP staff under my direction (all of whom possess graduate degrees in history) from several federal, state, and local records repositories. These include:

- The National Archives in Washington, DC;
- The National Archives at College Park, Maryland;
- The National Archives at Denver, Colorado;
- The National Archives at Fort Worth, Texas;
- The Dolph Briscoe Center for American History at The University of Texas at Austin;
- The Texas State Archives in Austin;
- The C.L. Sonnichsen Special Collections Department of the University of Texas at El Paso;
- The El Paso Historical Society;
- The New Mexico State Records Center and Archives in Santa Fe;
- The University of New Mexico Center for Southwest Research and Special Collections in Albuquerque;
- The New Mexico State University Archives and Special Collections in Las Cruces;

- History Colorado (formerly the Colorado Historical Society) in Denver;
- The Water Resource Archives at Colorado State University, Fort Collins;
- The American Heritage Center at the University of Wyoming in Laramie;
- The Water Resources Collections and Archives at the University of California, Riverside; and
- The Harvard Law School Library, Historical and Special Collections, in Cambridge, Massachusetts.

4. I have also examined documents produced in this litigation by the states of Texas, Colorado, and New Mexico, and the United States. I have reviewed expert reports submitted in this action by New Mexico and the United States. I further reviewed the *First Interim Report of the Special Master* and the historical documents appended to that Report.

5. Based on my review of the historical record of the Rio Grande Compact of 1938, the following sub-paragraphs are a summary of my opinions regarding the states' agreed-to apportionment of the Rio Grande. I have, in brackets, indicated the specific locations within this declaration that provide support in the historical record for these opinions. True and correct copies of all the references contained in the footnotes of this declaration are attached as Attachment 2. The references may also be viewed in the electronic version of this declaration by selecting the links embedded in the footnote citations.

a. The Rio Grande Compact of 1938 was rooted in the conflicts over upstream depletions in the Upper Rio Grande Basin that began in the late-nineteenth century and persisted into the twentieth century. The issue of depletions and responses to that issue – the 1896 federal embargo, the federal Rio Grande Reclamation Project ("Rio Grande Project," or "Project"); the 1906 Mexican treaty, the Compact negotiations of the 1920s and 1930s, Texas's suit against New Mexico, and the Rio Grande Joint Investigation – shaped the Compact's "equitable apportionment" [paragraphs 6-19];

b. That "equitable apportionment" did not assign a specific quantity of water to each state. Rather, because the water resources of the basin were considered to be fully appropriated, the Compact was designed effectively to freeze depletions at

the Colorado-New Mexico state line and at San Marcial to "present conditions" to ensure "present uses" of water downstream of these points as of 1938. All three states nonetheless had "freedom of development" of their waters, provided depletions did not exceed those permitted by the Compact [paragraphs 20-28];

c. For Texas specifically in 1938, "present uses" required flows to be delivered by New Mexico at San Marcial to produce a 790,000 acre-feet (af) average annual release from Elephant Butte Dam. Only by diversion and re-diversion through the Rio Grande Project could this water serve lands in Texas down to Ft. Quitman pursuant to the Compact. Development of the Project rendered a state line delivery to Texas by New Mexico impossible, and thus San Marcial, at the head of the reservoir created by the federal dam, became the *de facto* state-line delivery to Texas [paragraphs 29-46]; and

d. The historical record indicates that groundwater was not considered a source of water augmentation to the existing surface water supply at the time of the Compact. Hydrological investigations prior to and following the Compact highlighted an interdependence between basin groundwater and surface flows in the Rio Grande. Later studies suggested groundwater could be used as a supply in times of drought or even a sustainable source of water within certain limits but recognized that groundwater extraction would ultimately deplete surface flows below Elephant Butte. By at least the 1950s, the New Mexico State Engineer was aware of this as well, and by the 1980s acknowledged that groundwater pumping since the 1950s imperiled the Compact [47-62].

CONFLICTS OVER UPSTREAM DEPLETIONS IN THE UPPER RIO GRANDE BASIN FORM THE ESSENTIAL HISTORICAL CONTEXT OF THE RIO GRANDE COMPACT OF 1938

6. Conflicts over upstream depletions in the Upper Rio Grande Basin form the essential historical context for the Rio Grande Compact of 1938. Water users in Mexico near Juarez, in New Mexico's Mesilla Valley, and in Texas's El Paso Valley began complaining in the 1890s that diversions within Colorado's San Luis Valley, near the Rio Grande headwaters, diminished river flows reaching their lands. In response to Mexican protests, the federal government imposed an "embargo," or moratorium, on the use of federal land for reservoirs and other water facilities in 1896.[1] This action largely forestalled further private irrigation efforts in San Luis Valley, and facilitated both development of the federal Rio Grande Reclamation Project in New Mexico and Texas (authorized by Congress in 1905, extending the provisions of 1902 Reclamation Act) and an international treaty with Mexico in 1906.[2] Water from the Project's Elephant Butte Dam was to serve Mexico under the treaty and lands in southern New Mexico and western Texas by contract. Despite agitation by Colorado, federal authorities retained the embargo with little modification into the 1920s to protect the waters intended for Elephant Butte from upstream depletions.[3]

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[1] D.B. Francis, Secretary, to The Commissioner of the General Land Office, December 5, 1896. ff. RG48 E-631 Rio Grande Project, Contract, Suspension of Applications for use of water of the Rio Grande, Box No. 41 Rio Grande, Rouge Canyon, Sacramento Valley, Saint Mary's River, Salt River, Entry 631 Records Relating to Specific Reclamation Projects 1889-1907, Records of the Department of the Interior, Office of the Secretary, Record Group 48 [hereafter RG 48], National Archives at College Park, Maryland [hereafter NARA II]; and National Resources Committee, *Regional Planning Part VI – The Rio Grande Joint Investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and Texas 1936-1937*, vol. 1 (GPO, 1938) [hereafter *JIR*], 8.

[2] *An Act Relating to the construction of a dam and reservoir on the Rio Grande, in New Mexico, for the impounding of the flood waters of said river for purposes of irrigation*, February 26, 1905, chap. 798, Public No. 104, 33 Stat. 814; *Proclamation of the Convention Between the United States and Mexico, signed at Washington on May 21, 1906, Providing for the equitable distribution of the waters of the Rio Grande for Irrigation Purposes*, January 16, 1907. Folder 690, Rio Grande Project. Corres. With Secy of State and Others as to Claims of Mexico. June 1, 1905 to Dec. 31, 1909, Box 823 Rio Grande, 874A- -690, Entry 3 General Administrative and Project Records, 1902-1919 [hereafter Entry 3], Record Group 115, Records of the Bureau of Reclamation [hereafter RG 115], National Archives at Denver [hereafter NARA-Denver]; and *JIR*, 8.

[3] Ottamar Hamele, "The Embargo on the Upper Rio Grande," November 11, 1924, 13-15, and 20-30. 8-3 Rio Grande Distribution of Waters (Loose File), Box 1638 8-3, Rio Grande C-D, Central Classified File 1907-1936 [hereafter CCF 1907-36], RG 48, NARA II; and *JIR*, 8.

7. In the early 1920s, Colorado sought to conclude an interstate compact solely with New Mexico to obtain relief from the embargo. Concern about renewed upstream depletions in the wake of a Colorado-New Mexico compact led Texas to push for its inclusion in the negotiations, and the upstream states acquiesced.[4] Revocation of the embargo in 1925 and federal approval of new right-of-way applications in Colorado prompted New Mexico to withdraw from the negotiations.[5]

8. The three states did not meet again until December 1928. At that conference, Colorado argued that construction of a Colorado state line reservoir would not impair flows to New Mexico and Texas, that it would only make use of waters otherwise wasted in the basin or lost to Mexico, and in fact, the downstream states stood to benefit from augmented flows into Elephant Butte created by upstream storage. New Mexico and Texas, however, feared that Colorado's plans would imperil water projects in their respective states. New Mexico expressed concern for the fledgling Middle Rio Grande Conservancy District ("MRGCD") project above San Marcial and insisted that a quantity of water for delivery at the Colorado-New Mexico state line be fixed. Texas was protective of the Project's water supply which it maintained served lands down to Ft. Quitman.[6]

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[4] First Meeting, Rio Grande River Compact Commission, Breadmoor Hotel, Colorado Springs, Colo., Sunday, October 26, 1924, 1-37. Folder 1. First Meeting Rio Grande Compact Commission. Oct. 26, 1924, Box 02-D.002, MS 0235 Elephant Butte Irrigation District Records, 1883-1981, Rio Grande Historical Collections, New Mexico State University Archives and Special Collections, Las Cruces

[5] Hubert Work to The Commissioner of the General Land Office, Rio Grande Embargo, May 20, 1925. ff. 032.02 Rio Grande Basin Water Rights; Rio Grande River Basin Embargo. THRU 1925 Transfer Case, Box No. 924 Rio Grande Basin 023.- -032.02, Entry 7, Project Files, 1919-1929, General Administrative and Project Records, 1919-1945 [hereafter Entry 7], RG 115, NARA Denver; J.O. Seth, Rio Grande Commissioner for New Mexico, to Hon. A.T. Hannett, Governor of New Mexico, June 1, 1925. ff. Gov. Arthur T. Hannett Rio Grande Compact Commission, 1925, 209, Box 5, Serial No. 14153, Governor Arthur T. Hannett report, penal papers, New Mexico State Records Center and Archives, Santa Fe [hereafter NMSA].

[6] Proceedings of the Rio Grande Compact Conference, Held December 19-20-21, 1928, At Santa Fe, New Mexico, 3, 10-11, and 13-19. ff. Rio Grande Compact Commission Records, 1924-1941, 1970, Richard F. Burges Papers, Proceedings of the Rio Grande Compact Conference Held Dec. 19-20-21 at Santa Fe, N.M. (Title page, 78 pp.), Box 2F471, Rio Grande Compact Commission Records, 1924-1941, 1970 [hereafter RGCCR, 1924-1941, 1970], Dolph Briscoe Center for American History, The University of Texas at Austin [hereafter UTA].

9. The resulting temporary compact of February 1929 reflected the impasse among the states over the question of whether proposed upstream developments would deplete flows to the detriment of existing uses downstream. The compact provided for construction of a Closed Basin drain and a "State line reservoir" by the federal government (Article II) and the establishment of several stream-gaging stations to gather flow data (Article III). The compact also restricted any further upstream depletions until consummation of a permanent compact. Neither Colorado at the state line (Article V) nor New Mexico at Elephant Butte (Article XII) was to "cause or suffer the water supply" of the river "to be impaired by new or increased diversions or storage" during the duration of this compact, which was set to expire in June 1935. New Mexico further recognized that "prior vested rights above and below Elephant Butte Reservoir shall never be impaired hereby" (Article XII). Whether a "closed basin drain and the State line reservoir be built" in Colorado prior to the compact's expiration, the commissioners for each state were to meet in June 1935 for "the purpose of concluding a Compact . . . providing for the equitable apportionment of the use of the waters of the Rio Grande among said States" (Article VII).[7]

10. When negotiations for a permanent compact resumed in December 1934, little progress was made.[8] The following month, Colorado made a detailed presentation, arguing once more that reservoir construction in the San Luis Valley would not deplete downstream

[7] Francis C. Wilson, Rio Grande Compact Commissioner, *Rio Grande Compact: Report of Commissioner for New Mexico and Memorandum of Law on Interstate Compacts on Interstate Streams* 2/19/29, 4 (Article II), 5-6 (Article III), 6 (Article V), 7 (Article VII), and 9 (Article XII), and 11-21. ff. 032.1, Rio Grande Basin. Water Rights: Rio Grande Compact. THRU 1929., Box 924 Rio Grande Basin 023.- -032.02, Entry 7, RG 115, NARA Denver.

[8] Proceedings of the Rio Grande Compact Conference held at Santa Fe, New Mexico, December 10-11, 1934, 1-38. ff. Proceedings of the Rio Grande Compact Commission, Santa Fe, New Mexico. 1934-1935, Box 62, Series 7: Publications and reports, 1856-1992 and undated [hereafter Series 7], Subseries 7.1: Compacts and rivers, 1893-1986 and undated [hereafter Series 7.1], Papers of Delph E. Carpenter and Family [hereafter PDECF], Water Resources Archives [hereafter WRA], Colorado State University, Fort Collins [hereafter CSU-FC]; and S. O. Harper to Secretary of the Interior, December 14, 1934. File No. 8-3 (Part 2), Rio Grande-Distribution of Waters-Compact, C-D, August 18, 1930-February 25, 1936, Box 1638, CCF 1907-1936, RG 48, NARA II.

flows. New Mexico and Texas, although not convinced, agreed to a two-year extension of the temporary compact, until June 1937, to consider Colorado's proposal in detail.[9]

11. During this period, concern in Texas that MRGCD's operations within the Middle Rio Grande Valley were impairing the Elephant Butte water supply in violation of the 1929 compact led the state to file a complaint against New Mexico and the district in the United States Supreme Court in October 1935.[10] After extensive hearings, citing the current investigation by the National Resources Committee ("NRC") and at the request by counsel representing Texas, New Mexico, and MRGCD, Special Master Charles Warren recommended postponement of the case until January 1938, to give the states an opportunity to conclude a compact. The Supreme Court subsequently approved his recommendation, and adoption of the 1938 Compact brought an end to the suit.[11]

12. The investigation referenced by Warren was a direct outgrowth of the stalemate in the Upper Rio Grande Basin over the question of permissible upstream depletions. The NRC – a special working group within the Roosevelt administration that

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[9] Proceedings of the Rio Grande Compact Commission, Santa Fe, January 28-30, 1935, 1-45. ff. Proceedings of the Rio Grande Compact Commission, Santa Fe, New Mexico. 1934-1935, Box 62, Subseries 7.1, Series 7, PDECF, WRA, CSU-FC.

[10] The State of Texas, By Wm. McCraw, Its Attorney General, H. Grady Chandler, Assistant Attorney General, Richard F. Burges, Walter S. Howe, Edwin Mechem, Of Counsel, Supreme Court of the United States, October Term, 1935, No. – Original, *State of Texas, Complainant, vs. State of New Mexico, et al.*, Motion for Leave to File Bill of Complaint and Bill of Complaint [October 29, 1935]. w. Texas' Briefs, A.G. 51-238, *State of Texas v. State of New Mexico, et al.*, Box 1993/127-1, Litigation Files, Texas Attorney General [hereafter LF-TAG], Texas State Archives, Austin [hereafter TSA].

[11] Special Master to Richard F. Burges, Esquire, March 26, 1937. ff. 4-1 Warren Charles, Correspondence re Texas v. New Mexico June 1936; *State of Texas v. State of New Mexico, No. 12 Original, 1936 Term, Statement by Special Master*, March 5, 1937, 4-7. ff. Warren Charles, Correspondence re Texas vs. New Mexico / March, 1937, Box 4 Correspondence, Notes, Reports re: Texas vs. New Mexico, Series 1: Materials re: cases, Charles Warren Papers 1885-1954, Manuscripts Unit, Harvard Law School Library, Historical and Special Collections, Cambridge, Massachusetts; *Supreme Court of the United States, October Term 1936, No. 12 Original, State of Texas vs. State of New Mexico, et al., Ad Interim Report of the Special Master*, received Mar. 26, 1937, 9-10 and 12-13; and *Supreme Court of the United States, October Term 1936, No. 10 Original, State of Texas vs. State of New Mexico, et al., Final Report of the Special Master*, filed Sep. 25, 1939, 4-6. ff. RG 267, Entry 26, TX v NM #10, Box 401 1939 to 1939 PI 139, Entry 26, Original Jurisdiction Case Files, 1792-2005 [hereafter Entry 26], Record Group 267, Records of the Supreme Court of the United States [hereafter RG 267], National Archives Building, Washington, DC [hereafter NAB].

aimed to foster planned development of the nation's natural resources – appointed a "Board of Review" ("Board") in September 1935, a month prior to Texas's filing in the Supreme Court, "to consider various projects and problems related to the use and control of waters" in the Upper Rio Grande Basin.[12]

13. Surveying the problems posed by increased water consumption above existing projects, the Board concluded in September 1935 that "the water resources of the Rio Grande were fully appropriated." The most established uses of the Rio Grande flow, reflecting the basin's history, emanated from the waters stored in Elephant Butte for the Rio Grande Project. The Board expressed concern that proposed and existing upstream projects in New Mexico above San Marcial (notably, MRGCD's) and in Colorado's San Luis Valley imperiled this supply.[13]

14. By the 1930s, the Project had been fully developed. Waters entering the federal dam not only fulfilled the 1906 Mexican treaty obligation of 60,000 af annually, but also served lands downstream to Ft. Quitman.[14] Under notices of appropriation filed with the New Mexico territorial engineer, the United States Reclamation Service (predecessor to the Bureau of Reclamation, or BOR) claimed 730,000 af annually in 1906, and "[a]ll of the unappropriated water of the Rio Grande and its tributaries" at Elephant Butte in 1908.[15]

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[12] *JIR*, 10.

[13] "Report of the Rio Grande Board of Review," September 13, 1935, 1, and 3-8. Folder 390-Rio Grande Joint Investigation Purpose and Organization, 1935-1937 [hereafter Folder 390], Box 26, Frank Adams Collection [hereafter FAC], Water Resources Collections and Archives, University of California, Riverside [hereafter WRCA].

[14] *JIR*, 83-84.

[15] B.M. Hall, Supervising Engineer to Mr. David L. White, Territorial Irrigation Engineer, Jan. 23, 1906. ff. 41 New Mexico, Water Appropriations- -General, Thru 1910, Box 6 38C- -41; and Supervising Engineer [Louis C. Hill] to Mr. Vernon L. Sullivan, Territorial Engineer, Subject: Supplemental notice of the intention of the United States to use the waters of the Rio Grande for irrigation purposes on the Rio Grande Project, April 14, 1908. ff. 41-D New Mexico. Water Appropriations. RIO GRANDE PROJECT THRU 1910, Box 9 41B- -41D, Entry 3, RG 115, NARA Denver.

15. Absent importation of water from outside the basin, the Board believed "adjustments in use rather than new uses" was required.[16] It therefore recommended certain projects already approved by certain agencies be disapproved and that no future projects for the Upper Rio Grande Basin's waters proceed without the NRC's prior approval. A September 1935 executive order adopted this recommendation, and effectively reinstated the embargo.[17]

16. The Board also proposed a joint federal-state investigation to develop the information that would assist the states in formulating a permanent compact.[18] The Rio Grande Compact Commission embraced this idea when it was presented by NRC representatives in December 1935, provided that the investigation would be limited to the "collection, correlation and presentation of factual data."[19]

17. Available in the late summer of 1937 and published in February 1938, the *Rio Grande Joint Investigation* report, or *JIR*, compiled a considerable amount of information. It described the Upper Rio Grande Basin's geography and known hydrology and surveyed all the important events leading to the investigation, beginning with the nineteenth-century protests over upstream depletion. Laying out the water resources problem of the basins, the monumental report offered data and detailed analyses of hydrology, hydrogeology, irrigation development and irrigated acreage, and water uses and requirements for the basin's three major sections defined by geography and history – Colorado's San Luis Valley, New

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[16] "Report of the Rio Grande Board of Review," September 13, 1935, 1. Folder 390, Box 26, FAC, WRCA.

[17] "Report of the Rio Grande Board of Review," September 13, 1935, 8. Folder 390, Box 26, FAC, WRCA; and Franklin D. Roosevelt, To Federal agencies concerned with projects or allotments for water use in the Upper Rio Grande Valley above El Paso, September 23, 1935. File No. 8-3 (Pt. 7). Reclamation Bureau - Rio Grande Project - Rio Grande River - Distribution of Waters – General, February 6, 1933 to December 12, 1956, Box 1642, 8-3, Rio Grande, R, Riverton, CCF 1907-1936, RG 48, NARA II.

[18] "Report of the Rio Grande Board of Review," September 13, 1935, 10. Folder 390, Box 26, FAC, WRCA.

[19] "Resolution Passed by Rio Grande Compact Commission at Santa Fe, New Mexico," December 3, 1935, 1-2. Folder 401-Rio Grande Compact Commission Resolutions, 1935-1937, Box 26, FAC, WRCA.

Mexico's Middle Rio Grande Valley above San Marcial, and the lands between Elephant Butte and Ft. Quitman – all to assist in apportioning the Rio Grande waters to meet present and future needs in these sections.[20]

18. With information from the *JIR*, the Rio Grande Compact engineering advisors, Royce Tipton for Colorado, John Bliss for New Mexico, Raymond Hill for Texas, and E.B. Debler for the United States, developed the "technical basis" for a Compact that was adopted in March 1938 and apportioned the waters of the Rio Grande.[21] Central to that apportionment were two delivery schedules for the basin's three sections: one for Colorado to New Mexico near the state line (Article III), and another for New Mexico to Texas at the head of Elephant Butte Reservoir (Article IV).[22] These delivery points were effectively the same points that the 1929 compact had used to restrict depletions. These schedules, in Tipton's words, "would insure each section of the basin against injury by acts of water uses in another section and yet would permit of the construction and operation of additional reservoirs above Elephant Butte Reservoir."[23]

19. Upstream depletions have continued to be a source of conflict despite the Compact. On two prior occasions, Texas has defended its downstream supply against the upstream states. In 1951, the state revived its suit against New Mexico and MRGCD, alleging once again that district operations were diminishing flows that should reach Elephant Butte

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[20] Proceedings of the Meeting of the Rio Grande Compact Commission Held in Santa Fe, New Mexico, September 27, to October 1, 1937, 1 and 6-8. Unnamed folder 5, Box 2F463, Rio Grande Compact Comm'n. Frank B. Clayton Papers [hereafter RGCC-FBCP], UTA; and *JIR*, 7-18 and passim.

[21] R.J. Tipton, *Analysis of Report of Committee of Engineers to Rio Grande Compact Commissioner, Dated December 27, 1937* (February, 1938), 1. ff. 70, Box 44-70, MSS 312 Michael Creed Hinderlider Collection, 1897-1987 [hereafter MCHC 1897-1987], History Colorado, Denver [hereafter HC]; and "Rio Grande Compact," in Proceedings of the Meeting of the Rio Grande Compact Commission Held at Santa Fe, March 3rd to March 18th, inc., 1938, Appendix No. 11, 72-82. ff. 032.1 Rio Grande Basin, Corres. re Compact between States of Colorado; New Mexico & Texas re Rio Grande Basin Water Rights Jan. 1938 thru May 1939, Box No. 936 Rio Grande Basin 023._246., Entry 7, RG 115, NARA Denver.

[22] "Rio Grande Compact," Article III and Article IV, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 74-78. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[23] Tipton, *Analysis*, 6. ff. 70, Box 44-70, MCHC 1897-1987, HC.

pursuant to the Compact.[24] In 1966, Texas and New Mexico together filed suit in the Supreme Court against Colorado, alleging that the upstream state was failing to adhere to its Compact delivery obligations and was depleting the waters available downstream.[25]

"PRESENT CONDITIONS" AND "PRESENT USES" IN 1938 STRUCTURED THE "EQUITABLE APPORTIONMENT" OF THE WATERS OF THE RIO GRANDE IN THE UPPER RIO GRANDE BASIN AMONG THE STATES OF COLORADO, NEW MEXICO, AND TEXAS

20. "Present conditions" and "present uses" in 1938 structured the "equitable apportionment" of the waters of the Rio Grande in the Upper Rio Grande Basin among the states of Colorado, New Mexico, and Texas. In developing the basis for an apportionment in the fall of 1937, the Rio Grande Compact engineering advisors "avoided discussion of the relative rights of waters users in the three States," and did not assign each state a fixed quantity of water.[26] They concurred with the Board and the *JIR* that only water from outside the basin could address all on-going and then-planned water uses in the basin fully, and did not consider the development of groundwater as an additional source of supply.[27]

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[24] In the Supreme Court of the United States, October Term, 1951, No. . . . , Original, *State of Texas, Plaintiff, v. State of New Mexico, et al. Defendants, Motion for Leave to File Complaint and Complaint*, 2-3, and 10-14. The complaint was eventually "dismissed because of the absence of the United States as indispensable party. No. 9. *Orig – State of Texas v. State of New Mexico, et al.*, Filed April 28, 1952, 6-24-58. ff. RG 267 Entry 26 TX v. NM #9, Box 459 1957 (Begin TX v. MN #9) to 1957, Entry 26, RG 267, NAB.

[25] In the Supreme Court of the United States, October Term, 1966, No. . . . , Original, *State of Texas and State of New Mexico, Plaintiffs, v. The State of Colorado, Defendant, Motion for Leave to File Complaint and Complaint*, 2-3, and 5-7. This suit was ultimately settled by the states out of court. Vince Taylor, "Colorado's Snow Melt Reaching El Paso: A Status Report on No. 29 Original, U.S. Supreme Court," *Texas Bar Journal* (October 1968): 831-832, 871-872, and 874. ff. B-12.2.6.3 Tri-State Rio Grande Compact Commission 4 of, Oct 1966 thru Mar 1977, Box 6-25, Acc #076-89-0004 6-25, Records of Boundary and Claims Commissions and Arbitrations, Record Group 76, National Archives at Ft. Worth, Texas.

[26] "Report of Committee of Engineers to Rio Grande Compact Commissioners," December 27, 1937, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . New Mexico, March 3rd to March 18th, inc., 1938, Appendix No. 1, 47. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[27] Raymond A. Hill, Memo to Mr. Clayton: In re Meeting of Committee of Engineers, at Santa Fe, November 22 to 24, 1937, November 26, 1937, 3. [1937], Box 2F467, RGCC-FBCP, UTA; and "Report of Committee of Engineers to Rio Grande Compact Commissioners," December 27, 1937, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th,

21. The engineers instead focused on distributing the known available water supply to meet existing demands for that water – as Tipton put it, "to permit not only present uses of water, but also to allow increased diversion and consumption of water above Elephant Butte Reservoir by utilizing water which otherwise would spill from that reservoir." The only way Tipton and his fellow advisors found "[t]o accomplish this end" was by developing delivery schedules based on "present conditions" of flow manifesting at the Lobatos gaging station near the Colorado-New Mexico state line, and at Elephant Butte Reservoir, later the San Marcial gaging station.[28]

22. What constituted "present conditions" varied for each upstream section, but each was predicated on data and analyses from the *JIR*. For Colorado's delivery to New Mexico (Article III), those "present conditions" were reflected in the waters reaching the Lobatos "the period 1928 to 1937."[29] Stream flow data and analyses in the *JIR* had suggested a stability in consumptive water use in the San Luis Valley for much of this period, and Tipton was convinced that a state line delivery schedule on this basis would not hamper Colorado proposed developments in the valley.[30]

23. For New Mexico's delivery schedule to Texas (Article IV), those "present conditions" were reflected in the waters reaching San Marcial for "the period prior to 1930."[31] The engineering advisors initially considered a schedule based on Otowi Bridge-San Marcial

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inc., 1938, Appendix No. 1, 47. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[28] Tipton, *Analysis*, 5-6. ff. 70, Box 44-70, MCHC 1897-1987, HC. In February 1948, the Rio Grande Compact Commission adopted a resolution that, in pertinent part, changed the delivery point from the San Marcial gaging station to the Elephant Butte gaging station. "Minutes of the Ninth Annual (Nineteenth) Meeting of the Rio Grande Commission Held in El Paso, Texas," February 22, 23, 24, 1948, 5-8. ff. Opinions of Attorney Generals concerning switch of Gaging Stations, w. Factual Research, *State of Texas vs. State of New Mexico*, et al, AG No. 51-238, Box 1991/17-188, LF-TAG, TSA.

[29] Tipton, *Analysis*, 6. ff. 70, Box 44-70, MCHC 1897-1987, HC.

[30] *JIR*, 29-30; and Tipton, *Analysis*, 5. ff. 70, Box 44-70, MCHC 1897-1987, HC.

[31] "Letter from Committee of Engineering Advisers," March 9, 1938, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 7, 61-62; and "Rio Grande Compact," Article IV, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 76-78. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

relationship for the period roughly between 1912 and 1935, a schedule developed by Hill.[32] According to the *JIR*, the relationship between flows at Otowi Bridge at the head of the Middle Rio Grande Valley and at San Marcial suggested a stability in consumptive use above San Marcial for the period between 1890 and 1935 similar to that found in the San Luis Valley for the period 1927 to 1935. The report, however, acknowledged that the data of tributary inflow between Otowi and San Marcial was poor, and that the impact of MRGCD's operations on downstream flows was difficult to assess.[33] The engineers subsequently decided that a relationship between Otowi Bridge discharge and Elephant Butte inflow (excluding the months of July, August, and September) for a 1915-1937 time frame was a more accurate measure of "present conditions."[34]

24. Objections to this Otowi Bridge-Elephant Butte schedule made by the New Mexico compact commissioner Thomas McClure, prompted by criticisms raised by MRGCD's consulting engineer H.C. Neuffer, led the engineering advisors in March 1938 to return to an Otowi Bridge-San Marcial relation (excluding the months of July, August, and September) "for the period prior to 1930."[35] As later explained by Bliss and McClure, this

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[32] Proceedings of the Meeting of the Rio Grande Compact Commission . . . September 27, to October 1, 1937, 20. Untitled folder 5, Box 2F463, RGCC-FBCP, UTA.

[33] *JIR*, 42-43.

[34] Preliminary Draft of Report of Committee to Rio Grande Compact Commissioners, December 22, 1937, 5. CB-F-137-34, Box 4X215, RAHP, UTA; Tipton, *Analysis*, 6. ff. 70, Box 44-70, MCHC 1897-1987, HC; and "Report of Committee of Engineers to Rio Grande Compact Commissioners," December 27, 1937, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 1, 42-43. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[35] H.C. Neuffer, Memorandum, Subject: Report of Committee of Engineers to Rio Grande Compact Commissioners, December 27, 1937, January 6, 1938, np [1-2]. NM_00156900 – NM_00156901 and NM_00156905; H.C. Neuffer, Consulting Engineer, to Mr. John H. Bliss, State Engineer's Office, Re: Report of Committee of Engineers to Rio Grande Compact Commissioners, December 27, 1937, January 7th, 1938. NM_00054005; [H.C. Neuffer] to Mr. Thomas M. McClure, State Engineer, January 13, 1938; Thomas M. McClure, State Engineer, to Mr. S.O. Harper, Chairman, Rio Grande Compact Commission, January 25th, 1938; and "Letter from Committee of Engineering Advisers," March 9, 1938, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 7, 61. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

different time scale avoided the effects of development in the MRGCD since 1929.[36] Nevertheless, according to Bliss, "[t]he Compact recognize[d] by implications, in several of its provisions storage in Elephant Butte reservoir" – and waters for the Rio Grande Project which served lands in Texas – were "prior in right to storage in reservoirs constructed in the Rio Grande basin after 1929."[37]

25. These schedules effectively froze upstream depletions to "present conditions" that would not compromise "present uses" downstream, circa 1938. The potential for increased upstream depletions were strictly addressed through a system of credits and debits, adopted as Article VI, and were ultimately contingent on downstream uses being met.[38] Colorado, pursuant to this credits-and-debits system, was permitted to pursue post-1937 reservoir construction.[39] Similarly, New Mexico, like Colorado, could depart from its delivery schedule; it could hold water in "reservoirs constructed after 1929" pursuant to the Article VI credits-and-debits system.[40] Yet, in accordance with Article VIII, New Mexico could call upon Colorado to release the water in its reservoirs to satisfy the upstream state's accrued debits, and Texas could call upon both upstream states to release water from

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[36] J.H. Bliss, Engineer, "Provisions of the Rio Grande Compact," Santa Fe, N.M., April 2, 1938, 1. ff. Rio Grande Compact Engineer-Adviser Data, 1937-1938, Box No. 27, Accession Number 7978, John H. Bliss Collection [JHBC], American Heritage Center, University of Wyoming, Laramie [hereafter AHC]; and Thomas B. McClure, State Engineer, "Analysis of the Compact," undated, 21. NM_00164500.

[37] Bliss, "Provisions of the Rio Grande Compact," 4. ff. Rio Grande Compact Engineer-Adviser Data, 1937-1938, Box No. 27, Accession Number 7978, JHBC, AHC.

[38] "Rio Grande Compact," Article VI, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 78-79. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[39] "Rio Grande Compact," Article III, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 74-76 and 78-79. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[40] "Rio Grande Compact," Article VI, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 74-76. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

"reservoirs constructed after 1929" to satisfy accrued debits.[41] Correspondingly those debits were forgiven when "actual spill" from Elephant Butte occurred.[42]

26. The "present uses" for the apportioned Rio Grande water were left unstated in the Compact, but the positions articulated by the states throughout the Compact negotiations leave little doubt that these uses encompassed the plans Colorado had for its San Luis Valley, New Mexico's Middle Rio Grande development, and the Rio Grande Project through which Texas obtained its apportioned water. For the Project in particular, as Bliss suggested, various Compact provisions recognized its essential importance and protected it. Article IV required "appropriate adjustments" to be made to New Mexico's delivery schedule at San Marcial for "depletion after 1929 . . . at any time of the year of the natural runoff at Otowi Bridge" and "depletion of the runoff during July, August, and September of tributaries between Otowi Bridge and San Marcial by works constructed after 1937." Article VII limited the amount of water the two upstream states could store in post-1929 reservoirs to ensure a minimum amount of water in Rio Grande "project storage." Article VIII further provided for an average or "normal release of 790,000 acre-feet" from Rio Grande Project storage.[43]

27. United States compact commissioner S.O. Harper also believed the Compact was inclusive of the Project's water supply. Days following the conclusion of the Compact negotiations, he informed the Secretary of the Interior that not only was the Compact "an eminently fair and equitable solution" but also that U.S. "interests" were "fully safeguarded" in the Compact, in part as a result of the "inclusion, in the State allocations, of all water to which Federal irrigation projects are entitled."[44]

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[41] "Rio Grande Compact," Article VIII, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 80. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[42] "Rio Grande Compact," Article I and Article VI, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 73 and 78-79. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[43] "Rio Grande Compact," Article IV, Article VII, Article VIII, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 77-78 and 79-80. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[44] S.O. Harper, Chairman, Rio Grande Compact Commission, to The Honorable, The Secretary of the

28. Although the Compact permitted Colorado and New Mexico to pursue other irrigation developments while protecting the Project, it did not explicitly limit water use to irrigation. Any use of the apportioned waters was permissible, as Hill testified when deposed in the original action against Colorado in the 1960s: "subject only to the maintenance of depletions that had occurred, subject only to not increasing those overall depletions, there is a freedom in each State to store, develop, improve or do anything else within that State."[45]

THE WATER APPORTIONED TO TEXAS BY THE 1938 COMPACT WAS THE WATER TO BE DELIVERED BY NEW MEXICO TO SAN MARCIAL, SUFFICIENT TO ENABLE "A NORMAL RELEASE OF 790,000 ACRE-FEET" OF WATER FROM RIO GRANDE PROJECT STORAGE

29. The water apportioned to Texas by the 1938 Compact was the water to be delivered by New Mexico to San Marcial, sufficient to enable "a normal release of 790,000 acre-feet" of water from Rio Grande Project storage.[46] BOR pursued the Project in the early 1900s to mollify water users in Mexico, New Mexico, and Texas. Those users all protested upstream diversions in Colorado, contending that those diversions had deprived them of the flows that until the late-nineteenth century had reached their lands. Initially, an "international dam" at El Paso was contemplated to supply both the United States and Mexican irrigators. Subsequent assessment by federal engineers, however, identified a dam site at the geological formation in New Mexico known as Elephant Butte – more than 100 miles from the present New Mexico-Texas state line – as providing the opportunity to water the most land within the United States while also serving Mexico. Presented to the 1904 National Irrigation Congress

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Interior, Washington, D.C., Re: Rio Grande Compact, March 26, 1938, 2. ff. 032.1 Box No. 936, Entry 7, RG 115, NARA Denver.

[45] In the Supreme Court of the United States, October Term 1967, No. 29, Original, *State of Texas and New Mexico, Plaintiffs, vs. State of Colorado, Defendant,* Deposition of: Raymond A. Hill, Taken December 4, 1968, Denver, Colorado, 36. ff. *Texas & New Mexico v. Colorado,* w. *Texas vs. Colorado* 66-1061, Box 1989 41-240, LF-TAG, TSA.

[46] "Rio Grande Compact," Article VIII, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 80. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

in El Paso, the proposed Elephant Butte Dam received the endorsement of delegates from Mexico, New Mexico, and Texas.[47]

30. Although there were two separate irrigation districts that contracted for the water appropriated for the Project, Elephant Butte Irrigation District ("EBID") in New Mexico and El Paso County Water Improvement District No. 1 ("EP #1") in Texas, BOR treated the Project "as an administrative unit" in Clayton's words.[48] Project infrastructure was built largely without regard to state boundaries, and diversions to serve lands in Texas were made within New Mexico.[49]

31. These circumstances shaped the Compact. Both McClure and Bliss acknowledged, as Clayton had, that the "Project must be operated as a unit."[50] Consequently, as Bliss noted in recommending the Compact's adoption, "no schedule of releases from Elephant Butte Project storage" was provided aside from the 790,000-af "normal release" provision (Article VIII).[51]

32. Texas contemplated asking for a state-line delivery in the 1930s, but decided against it because of the Project.[52] As far back as the 1929 temporary compact, New Mexico

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[47] *International Dam in Rio Grande River, Near El Paso, Tex.*, 54th Cong., 1st sess., 1896, H. Doc. 125, 1-6; Guy Elliott Mitchell, ed., *The Official Proceedings of the Twelfth National Irrigation Congress, Held at El Paso, Texas, Nov. 15-16-17-18, 1904* (Galveston, TX: Clarke & Courts, 1905), 107-109 and 214-216; and B.M. Hall, Supervising Engineer, U.S. Reclamation Service, "A Discussion of Past and Present Plans for Irrigation of the Rio Grande Valley," November 1904, 3-8, and 56-57. ff. 46 Rio Grande Project. Penasco Rock Resv. Site-Elephant Butte Resv. Site, 1904-1905, Box No. 792 Rio Grande 17-46, Entry 3, RG 115, NARA Denver.

[48] Frank B. Clayton, Rio Grande Compact Commissioner for Texas, to Mr. Sawnie B. Smith, October 4, 1938, 1. Box 2F466, RGCC-FBCP, UTA.

[49] Clayton to Smith, October 4, 1938, 1. Box 2F466; and *Proceedings of Meeting Held on Friday, May 27, 1938 at El Paso, Texas, between Representative of Lower Rio Grande Water Users and Representatives of Irrigation Districts Under the Rio Grande Project of the Bureau of Reclamation*, 15. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA.

[50] Thomas B. McClure, State Engineer, "Analysis of the Compact," undated, 21-22. NM_00164500; and Bliss, "Provisions of the Rio Grande Compact," 1. ff. Rio Grande Compact Engineer-Adviser Data, 1937-1938, Box No. 27, Accession Number 7978, JHBC, AHC.

[51] Bliss, "Provisions of the Rio Grande Compact," 1 and 3. ff. Rio Grande Compact Engineer-Adviser Data, 1937-1938, Box No. 27, Accession Number 7978, JHBC, AHC.

[52] Raymond A. Hill to Mr. Frank B. Clayton, February 8, 1938. Box 2F466; and *Proceedings of Meeting Held on Friday, May 27, 1938*, 10 and 11. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA.

and Texas acknowledged that "New Mexico's obligations . . . must be in reference to deliveries at Elephant Butte reservoir [i.e., San Marcial]," as Clayton explained to attorney Sawnie Smith in October 1938. Federal control of the dam and Project works, spanning across New Mexico and Texas, anticipated to continue, defeated any effort to establish obligations for the upstream states for a specific quantity of water to Texas in 1938. "[N]either Colorado nor New Mexico," the Texas commissioner stressed, "could be expected to guarantee any fixed deliveries at the Texas line" owing to those circumstances.[53] Clayton made this same point to state representative Homer L. Leonard in August 1938, observing that the upper states' "only responsibility was to see that Texas' equitable share was delivered at the state line, or, rather, delivered into Elephant Butte reservoir, which is the point of control."[54] San Marcial was thus the *de facto* state line delivery to Texas.[55]

33. Texas concentrated on safeguarding the Rio Grande Project water supply throughout the Compact negotiations for only through the Project did Rio Grande waters reach lands in Texas. It was joined in this effort by EBID in New Mexico. The shared interest of EBID and Texas in limiting depletions above Elephant Butte reflected their mutual dependence on the waters captured and released from the dam. Clayton pointed this out to water users in Texas below Ft. Quitman in May 1938, telling them, "[a]s far as they [EBID] and we are concerned, our source is the same. If the supply is impaired above Elephant Butte, we all suffer alike."[56]

34. Water released from the federal dam to serve lands in EBID under federal contract formed a portion of the water supply to Texas, manifesting as return flows to the channel or in Project drains once those waters had been used within New Mexico. In the

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[53] Clayton to Smith, October 4, 1938, 1. Box 2F466, RGCC-FBCP, UTA.

[54] Frank B. Clayton, Rio Grande Compact Commissioner for Texas, to Hon. Homer L. Leonard, August 3, 1938, 2. Box 2F466, RGCC-FBCP, UTA.

[55] *Proceedings of Meeting Held on Friday, May 27, 1938*, 10, 11, and 15. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA.

[56] *Proceedings of Meeting Held on Friday, May 27, 1938*, 11. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA.

1910s, federal engineers and BOR officials recognized that return flows could help meet downstream demands.[57] Although such flows became of poorer quality (higher in salts) down through the Project, both Project lands in the El Paso Valley of Texas in EP #1 and lands in Hudspeth County outside the Project were dependent upon return flows by the 1920s.[58] Water users within Hudspeth County Conservation and Reclamation District No. 1 ("Hudspeth") were permitted by a federal Warren Act contract to divert water passed beyond the Project only when those waters were "available."[59] However, Project releases from Elephant Butte to EP #1 intended to improve the quality of water reaching EP #1 lands indirectly benefitted Hudspeth.[60]

35. Reliance on return flows within and from the Project explains why Texas in October 1937 asked that Colorado and New Mexico "release and deliver at San Marcial a supply of water sufficient to assure the release annually from Elephant Butte Reservoir of

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[57] United States Congress, House of Representatives, *Fund for Reclamation of Arid Lands: Message from the President of the United States, Transmitting a Report of the Board of Army Engineers in Relation to the Reclamation Fund*, H. Doc. No. 1262, 61st Cong. 3d sess. (1911-12), 106; "Water Supply of Rio Grande, from Official Records, 1912," 4-5, enclosed with A.P. Davis, Chief Engineer, Memorandum for Secretary Lane, April 17, 1913. File 8-3 (Part 4) Reclamation Service, Rio Grande Project, New Mexico, Rio Grande River, Distribution of Waters, Nov. 21, 1912 – Apr. 17, 1914, Box No. 1639 8-3, Rio Grande D-E, CCF 1907-1936, RG 48, NARA II; and Harold Conkling, Engineer, and Erdman Debler, Asst. Engr., Water Supply for and Possible Developments on Irrigation and Drainage Projects on the Rio Grande River Above El Paso, Texas, June-1919, 110-112. ff. 302.31, New Mexico. Report dated June 1919 by Conkling and Debler on Water Supply for and Possible Developments on Irrigation and Drainage Projects on the Rio Grande River Above El Paso, Texas, transmitted by letter July 15, 1919, Box 262 302.28--302.31 A. NV-NM, Entry 7, RG 115, NARA Denver.

[58] E.B. Debler, Engineer, Bureau of Reclamation, "Return Flow and Its Problems on Reclamation Projects," *New Reclamation Era* (August, 1927), 125. ff. 030.1, Box 33, General Files, 1919-1929, Entry 7, RG 115, NARA Denver, and *JIR*, 85-86, 99-104, and 403.

[59] Contract, Ilr-493, Hudspeth County Conservation & Reclamation District, December 1, 1924, Department of the Interior, Bureau of Reclamation, Contract Between the United States and Hudspeth County Conservation and Reclamation District No. 1, Providing for the Rental of Water to the District, December 1, 1924, 2. ff. 223.02 Rio Grande Water, Hudspeth County Conservation & Reclamation District, Transfer Case, Thru 1929, Box 907 Rio Grande 223.02, Entry 7, RG 115, NARA Denver.

[60] *Proceedings of Meeting, held on Friday, May 27, 1938*, 16, 17, and 25. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA; and L.R. Fiock, Superintendent to Commissioner, Subject: Protest of Hudspeth County Conservation and Reclamation District No. 1 – Rio Grande Project, May 22, 1939, 4. ff. 301 Rio Grande Project - Board and Engineering Report on Construction Features, Jan 1, 1937, Box 927 Rio Grande Pro. 246. - 301., Entry 7, RG 115, NARA Denver.

800,000 acre-feet of the same average quality as during the past ten years . . . ."[61] This was a figure that Hill had calculated would provide lands in Texas with a sufficient quantity and quality of water while also meeting the Mexican treaty obligation.[62] The *JIR* and Bliss assessed lower quantities for Texas but both appreciated the importance of return flows for lands in the downstream state. The *JIR* offered 773,000 af as a "conservative estimate," with "necessary allowances for drain flow, wastes, arroyo inflow, and "salinity control."[63] During the engineering advisors' meetings in late 1937, Bliss estimated 750,000 af as sufficient for the Elephant Butte-Ft. Quitman section, and made provision for water to Hudspeth (water that would have included return flows from upstream diversions) and the achievement of a "salt balance" down to Ft. Quitman (recognition that lands downstream relied on poor-quality return flows).[64]

36. The engineering advisors initially agreed to an 800,000-af release, linking this release to a delivery schedule based on an Otowi Bridge-Elephant Butte relationship, before revising this figure downward along with changing the schedule in March 1938.[65] As with the change to the delivery schedule, criticism by Neuffer led to this revision. The MRGCD consulting engineer believed that a 700,000-af release from Elephant Butte was "liberal," but was willing to accept as much as a 750,000 af release. Despite not making specific provision for lands outside the Project, Neuffer's own allowances for "[u]navoidable project wastes

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[61] Proceedings of the Meeting of the Rio Grande Compact Commission . . . September 27, to October 1, 1937, 13. Untitled folder 5, Box 2F463, RGCC-FBCP, UTA.

[62] *State of Texas vs. State of New Mexico, et al, Plaintiff's Case in Chief*, Volumes V, VI & VII, 1202-1206, 1220-1221, and 1235-1236. CB-F-171A thru CB-F-1716: Transcripts of TX v. NM, Vol. 1-16, Box 4X219, RAHP; and Hill to Clayton, November 26, 1937, 2. [1937], Box 2F467, RGCC-FBCP, UTA.

[63] *JIR*, 103-104.

[64] [Raymond Hill], "TEXAS COMPACT: John Bliss Estimate of Project Requirements at Elephant Butte," 12/17/37, and "John Bliss Estimate of Project Requirements at Elephant Butte," typescript, n.d. CB-F-137-34, Box 4X215, RAHP, UTA.

[65] "Report of Committee of Engineers to Rio Grande Compact Commissioners," December 27, 1937, in Proceedings of the Meeting of the Rio Grande Compact Commission, Held at Santa Fe, New Mexico, March 3rd to March 18th, inc., 1938, Appendix No. 1, 45. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver. Both the 800,000-af release and the later 790,000-af release (as discussed below) were subject to the 60,000-af Mexican treaty obligation.

below Riverside heading" and "[w]inter discharge of Project drains in New Mexico not redivertable" in that release figure would have entailed return flows for lands in Hudspeth.[66]

37. New Mexico's actions in the Compact negotiations demonstrated little concern about lands below Elephant Butte; it instead focused on the lands above San Marcial. With Texas advocating for the Rio Grande Project water supply, New Mexico appeared willing to cede EBID's interests to Texas in order to secure water for the Middle Rio Grande.[67] McClure's responsiveness to Neuffer's opposition to the higher release figure and the original schedule – both of which would have benefitted EBID – is indicative of this. Hinderlider and Clayton were critical of their New Mexico counterpart for listening to the MRGCD engineer, with the latter insisting to Harper in January 1938 that McClure "seems to lose sight of the fact that there is a very extensive section of his own State lying below the Elephant Butte dam . . . ."[68]

38. In March 1938, Texas agreed to a smaller figure of 790,000 af for a "normal release," or average release, and this was adopted as Article VIII in the Compact along with the new delivery schedule (Article IV).[69] Thirty years after the Compact had been signed, Hill explained that the 790,000 af figure recommended by him and his fellow engineers and adopted in the Compact was 730,000 af "for uses in the United States and sixty [thousand] for uses in Mexico . . . ."[70] Those "uses in the United States" were the "present uses" at the time of the Compact.

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[66] Neuffer to Bliss, January 7th, 1938. NM_00054005; and Neuffer, Memorandum, January 6, 1938, np [2-3, and 6]. NM_00156901 – NM_00156902 and NM_00156905.

[67] Hill to Clayton, February 8, 1938. Box 2F466, Box 2F463, RGCC-FBCP, UTA.

[68] Frank B. Clayton, Rio Grande Compact Commissioner for Texas, to Mr. S.O. Harper, Chairman, Rio Grande Compact Commission, January 27, 1938; and M.C. Hinderlider, Commissioner for Colorado, to S.O. Harper, Chairman, Rio Grande Compact Commission, February 4, 1938. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[69] "Letter from Committee of Engineering Advisers," March 9, 1938, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 7, 65; and "Rio Grande Compact," Article VIII, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 80. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

[70] Deposition of Raymond A. Hill, Taken December 4, 1968, Denver, Colorado, 18. ff. Texas & New Mex. v. Colo., w. 66-1061 Texas vs. Colorado, Box 1989 41-240, LF-TAG, TSA.

39. This release figure consequently constrained the Rio Grande waters apportioned to Texas. The water supply the City of El Paso obtained from Elephant Butte in the early 1940s illustrates this. Because the apportionment was defined consistent with the Project, El Paso was only able to secure this water through the acquisition of Project lands within EP #1.[71] Releases from the federal dam in accordance with Project operations would have served those EP #1 lands with water, by direct diversion and return flows, as of 1938.

40. The same Compact provisions that protected the Project against upstream depletions ensured that Texas would receive its apportionment. A 790,000-af average release from Elephant Butte; adjustments to be made in New Mexico's delivery to San Marcial for increased depletions after 1929 at Otowi Bridge and "for works constructed after 1937" above San Marcial (Article IV); and limitations on the water that Colorado and New Mexico could store above San Marcial "in reservoirs constructed after 1929" to provide a minimum amount of "project storage" (Article VII) all assured Texas some water via the Project. Article VIII, moreover, gave the Texas Rio Grande Compact Commissioner the sole authority to call for releases from post-1929 reservoirs in Colorado and New Mexico that would result in a 790,000-af release – underscoring Texas's dependence on the waters to be delivered to Elephant Butte and delivered by the Project.[72]

41. The absence of a state-line delivery requirement confounded some in Texas below Ft. Quitman who expected the Compact to apportion the Rio Grande down to the Gulf

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[71] H.W. Bashore, Acting Commissioner, to Mr. W.E. Robertson, Chairman, Water Development Commission of the City of El Paso, Jul 25, 1940; Memorandum for Mr. Stinson (Harrell), Subject: Rio Grande Project – Sale of water to City of El Paso for supplemental supply for Municipal purposes, January 17, 1941, 2-4. ff. 223.02 Rio Grande – Leases, Sales & Rentals of Water, El Paso, City of, thru Dec 1941, Box 920 Rio Grande Pro. 223.02, Entry 7, RG 115, NARA Denver; John C. Page, Commissioner, to The Secretary of the Interior, Feb 17, 1941; and J. Kennard Cheadle, Acting Commissioner, to The Secretary of the Interior, Nov 22, 1944. File No. 8-3 (Part 8), Reclamation Bureau, Rio Grande Project, Distribution of Waters, General, January 27, 1937 thru February 10, 1950, 8-3 Rio Grande-Distribution-Waters-General, Box 3623 8-3 Rio Grande-Contracts-Nelson, J.P. 8-3 Rio Grande Flood Control, Central Classified Files, 1937-1953, RG 48, NARA II.

[72] Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, 31-33; and "Rio Grande Compact," Articles IV, VII, and VIII, in Proceedings of the Meeting of the Rio Grande Compact Commission . . . March 3rd to March 18th, inc., 1938, Appendix No. 11, 77-78, 79, and 80. ff. 032.1, Box No. 936, Entry 7, RG 115, NARA Denver.

of Mexico. Yet, for Clayton the matter was clear. His "duty," as he informed lower Rio Grande water users in May 1938, "[was] to see Texas got every drop of water originating in Colorado and New Mexico that she was entitled to and to see that that water was delivered into the Elephant Butte Reservoir," and "[b]y that compact [i.e., the Compact of 1938] Texas got all she was entitled to. . . ."[73]

42. That entitlement, Clayton emphasized to lower Rio Grande water users and their representatives, was for water for lands above Ft. Quitman. In explaining to Smith in particular in October 1938 why there was no state line delivery for Texas, the compact commissioner also pointed to existing federal contracts for water from the Project – the contracts between the United States and EBID and EP #1 as well as the contract between EBID and EP #1 and Hudspeth's Warren Act contract – as providing further assurance that those lands would receive their due.[74]

43. The contracts involving the United States, EBID, and EP #1, referenced by Clayton and identified by the Supreme Court in this original action as the "Downstream Contracts," however, did not prescribe specific quantities of water to either Project district. The Downstream Contracts, executed contemporaneous with the Compact, were: (1) the November 9, 1937 United States-EBID contract, (2) the November 10, 1937 United States-EP #1 contract, and (3) the February 16, 1938 EBID-EP #1 contract. All these agreements primarily concerned the obligations of EBID and EP #1 to repay the federal investment in the Project, pursuant to the 1902 Reclamation Act, its subsequent amendments, and the 1905 act authorizing the Project.[75]

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[73] *Proceedings of Meeting, held on Friday, May 27, 1938*, 10. ff. Proceedings and Minutes 1935-1938, Box 2F463, RGCC-FBCP, UTA.

[74] Clayton to Smith, October 4, 1938, 1. Box 2F466, RGCC-FBCP, UTA.

[75] Contract Dated Nov. 9, 1937, Ilr-982, Elephant Butte Irrigation District (Adjustment of project construction charges and other purposes), United States, Department of the Interior, Bureau of Reclamation, Rio Grande Project, New Mexico-Texas, Contract between the United States and the Elephant Butte Irrigation District adjusting construction charges and for other purposes. ff. 222.- Rio Grande Project. Contracts with Elephant Butte Irrigation District, Separate Folder, Box No. 917, Rio Grande Pro. 222._222.-; Contract Dated Nov. 10, 1937, Ilr-981, El Paso County Water Improvement District No. 1 (Adjustment of project construction charges and other purposes), United States,

44. The 1902 Reclamation Act, or Newlands Act, created a federal program to irrigate the arid West through the construction of large-scale irrigation projects. Water users within these projects were required to repay the United States for the costs of construction over a period of years.[76] On the Rio Grande Project, the repayment obligation was dealt with first in a 1906 agreement between the United States and the Elephant Butte Water Users Association and the El Paso Valley Water Users Association, and then later in individual contracts to both districts in 1918 and 1920 following the dissolution of these associations.[77]

45. Agricultural surpluses in the 1920s and the Great Depression of the 1930s undercut farming prices and undermined the ability of users to meet their repayment obligations.[78] Congress thus amended reclamation law to provide relief to Project water users.[79] These amendments paved the way for the Downstream Contracts. In their 1937

Department of the Interior, Bureau of Reclamation, Rio Grande Project, New Mexico-Texas, Contract between the United States and the El Paso County Water Improvement District No. 1, adjusting construction charges and for other purposes. ff. 222.- Rio Grande Project. Irrigation Districts, El Paso County Water Improvement District No. 1, Separate Folder, Box No. 918 Rio Grande Pro. 222._222.-; and Contract between Elephant Butte Irrigation District of New Mexico and El Paso County Water Improvement District No. 1 of Texas, signed February 16, 1938, and approved by Assistant Secretary of the Interior Oscar L. Chapman, April 11, 1938. ff. 400. Rio Grande, Lands-General, 1930 thru, Box 932 Rio Grande Pro. 400.__400.08, Entry 7, RG 115, NARA-Denver.

[76] *An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands*, June 17, 1902, chap. 1093, Public, No. 161, 32 Stat. 388.

[77] Articles of Agreement by and between the U.S., acting in this behalf by Jesse E. Wilson, Acting Secretary of the Interior, and the Elephant Butte Water Users' Association of New Mexico and the El Paso Valley Water Users' Association, June 27, 1906. ff. 330-B Rio Grande. Contracts with Elephant Butte Irri. Dist., Transfer Case, Box 817 Rio Grande 330B- -348C, Entry 3; Department of the Interior, Bureau of Reclamation, Rio Grande Project-New Mexico-Texas, Contract Dated June 15, 1918 – between The United States of America and The Elephant Butte Irrigation For Repayment of Construction and Operation and Maintenance Charges; and Department of the Interior, Bureau of Reclamation, Rio Grande Project-New Mexico-Texas, Contract Dated January 17, 1920 between The United States of America and The El Paso County Water Improvement District No. 1, For Repayment of Construction and Operation and Maintenance Charges, in Department of the Interior, Bureau of Reclamation, Rio Grande Irrigation Project, New Mexico-Texas, Contracts with Water User's Organizations (Copies), Compiled November 1, 1929. 232-29 RG Separate Folder, 249-H, Contracts with Water Users, Box 716 Old Box 509-510, Code 104.RG 37 through Code 402.RG 28, Engineering and Research Center, Project Reports, 1910-55 [hereafter PR 1910-55], RG 115, NARA Denver.

[78] Donald J. Pisani, *Water and American Government: The Reclamation Bureau, National Water Policy, and the West, 1902-1935* (Albuquerque: University of New Mexico Press, 1992), 149-150.

[79] *An Act For the temporary relief of water users on irrigation projects constructed and operated under the reclamation law*, April 1, 1932, 47 Stat. 75, chapter 94; *An Act To extend the operation of*

contracts with the United States, the districts relinquished their rights to hydroelectric power revenue from Elephant Butte in order to reduce their repayment obligations.[80] The 1938 contract executed between the two districts, and approved by the United States, memorialized the historical distribution of repayment costs for storage and general project features between EBID and EP#1 on the basis of the respective irrigated acreages, permitting a three-percent expansion in that acreage in any one year "to be subject to construction charges."[81]

46. For its part, New Mexico later directly acknowledged that the waters delivered to San Marcial, pursuant to the Compact, were for the benefit of lands in Texas above Ft. Quitman. In the state's reply to Texas's 1951 complaint in the Supreme Court, approved by former New Mexico engineering advisor and now New Mexico State Engineer John Bliss, it argued that the Compact "does not attempt to make an apportionment between the New Mexico area and the Texas area below Elephant Butte." This statement was evocative of Clayton, McClure, and Bliss's observations at the time of the Compact that the Project functioned as "an administrative unit" or "operated as a unit." New Mexico with Bliss's assent, however, went further in 1951. The state asserted that "the natural dependable flow of the river below San Marcial was over-appropriated in 1906," and in the absence of Project storage "no substantial quantity of water would be available for use in Texas."[82]

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the Act entitled, "An Act For the temporary relief of water users on irrigation projects constructed and operated under the reclamation law," approved April 1, 1932, March 3, 1933, 47 Stat. 1427, chapter 200.

[80] Contract Dated Nov. 9, 1937, Ilr-982, Elephant Butte Irrigation District (Adjustment of project construction charges and other purposes), Articles 3-5, 2-4. ff. 222.-, Box No. 917; Contract Dated Nov. 10, 1937, Ilr-981, El Paso County Water Improvement District No. 1 (Adjustment of project construction charges and other purposes), Article 3-5, 2-4. ff. 222.-, Box No. 918, RG 115, NARA Denver.

[81] Contract between Elephant Butte Irrigation District of New Mexico and El Paso County Water Improvement District No. 1 of Texas, signed February 16, 1938, 1. ff. 400. Box 932, Entry 7, RG 115, NARA-Denver.

[82] In the Supreme Court of the United States, October Term, 1951, No . . . ., Original, *State of Texas, Plaintiff, v. State of New Mexico, et al., Defendants, Return of Defendants to Rule to Show Cause* [December 15, 1951], 3 and 8. ff. RG 267 Entry 26 TX v. NM #9, Box 459 1957 (Begin TX v. MN #9) to 1957, Entry 26, RG 267, NAB.

THE HISTORICAL RECORD INDICATES THAT GROUNDWATER WAS NOT CONSIDERED A SOURCE OF WATER AUGMENTATION TO THE EXISTING SURFACE WATER SUPPLY AT THE TIME OF THE COMPACT – AND SINCE AT LEAST THE 1950S THE NEW MEXICO STATE ENGINEER HAS BEEN AWARE THAT GROUNDWATER PUMPING COULD DEPLETE SURFACE WATERS BELOW ELEPHANT BUTTE RESERVOIR

47. The historical record indicates that groundwater was not considered a source of water augmentation to the existing surface water supply at the time of the Compact – and since at least the 1950s, the New Mexico State Engineer has been aware that groundwater pumping could deplete surface waters below Elephant Butte Reservoir. Investigations prior to and following construction of Elephant Butte found that the surface flow of the Rio Grande and the surrounding groundwater were hydrologically connected. United States Geological Survey ("USGS") hydrologist Charles Slichter in 1904 was the first to identify this relationship in lower New Mexico's Mesilla Valley as part of the investigation leading to the Rio Grande Project. He informed the delegates to the 1904 National Irrigation Congress that the valley's groundwater derived from the Rio Grande itself.[83] An overlapping investigation by fellow USGS hydrologist Willis Lee released in 1907 concurred in Slichter's assessment.[84]

48. An independent study by New Mexico engineering advisor John Bliss, made at the suggestion of Rio Grande Project superintendent L.R. Fiock and provided to New Mexico State Engineer and Rio Grande Compact commissioner Thomas McClure in February 1936, uncovered a "direct relation" between surface flow and the surrounding groundwater downstream of the federal dam. At certain critical points between Elephant Butte and El Paso, Bliss found that Rio Grande underflow fed the groundwater table, providing basin lands

[83] Mitchell, ed., *The Official Proceedings*, 218. Slichter subsequently reiterated this finding in his published study in 1905. Charles S. Slichter, *Observations on the Ground Water of Rio Grande Valley*, Department of the Interior, United States Geological Survey Water-Supply and Irrigation Paper No. 141 (GPO, 1905), 27.

[84] Willis T. Lee, *Water Resources of the Rio Grande Valley in New Mexico and their Development*, Department of the Interior, United States Geological Survey Water-Supply and Irrigation Paper No. 188 (GPO, 1907), 41 and 49-50.

with additional water that was recovered by project drains and returned to the river channel for use on lands downstream.[85]

49. The interconnection between the surface flow of the Rio Grande and the groundwater was apparent in the "water logging" of Project lands, which made construction of drainage works necessary in Mesilla Valley the 1910s.[86] By returning excess ground water to the stream or otherwise making it available for lands downstream, drains ensured that the water table remained in balance, that the root zones of crops were not flooded.[87]

50. Groundwater pumping had occurred in the Mesilla Valley prior to the Project but declined as users opted for surface water deliveries from Elephant Butte.[88] The Project, in turn, came to rely upon the use of return flows from upstream diversions to meet irrigation demands to those lands furthest from Elephant Butte. In the early 1910s, as completion of the dam neared, federal authorities in recognition of the importance of these return flows asserted claims "to all waste, seepage, spring, and percolating water arising within the project" with the intent "to use such water in connection therewith."[89]

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[85] John H. Bliss, "Report on Investigation of Invisible Gains and Losses in the Channel of the Rio Grande from Elephant Butte to El Paso." Feb. 1936, 1-2 and 9-12. Folder 1435, Bliss, Report on Investigation of Invisible Gains and Losses in the Channel of the Rio Grande from Elephant Butte to El Paso, February 1936, Box 55, State Engineer Reports: Rio Grande, Exps. 161-163, Nos. 1417-1437, NMSRCA.

[86] Memorandum, From: Board of Engineers: E.H. Baldwin, Rio Grande Project Supervising Engineer; L.C. Hill, Consulting Engineer; D.W. Murphy, Engineer in charge of Drainage and L.M. Lawson, Project Manager, To: Reclamation Commission, Subject: Report on Drainage – Rio Grande Project, April 7, 1915, 2. Vol. 495, New Mex.-Texas, Rio Grande, Board of Engineers Report, ff. Rio Grande, 1904, Box 474 Rio Grande (NM-TX), Entry 10 Project Histories, Feature Histories, and Reports 1902-32 [hereafter Entry 10], RG 115, NARA Denver.

[87] Memorandum, From: Board of Engineers, To: Reclamation Commission, Subject: Report on Drainage – Rio Grande Project, April 7, 1915, 2-8. Vol. 495, Box 474, Entry 10; "Report on Mesilla & El Paso Valley Drainage, Rio Grande Project, February, 1917, 2-25. ff. Report on Mesilla & Rio Paso Valley Drainage Feb 1917; L.R. Fiock, Ass't Engineer, History of Drainage on the Rio Grande Project, To December 31st, 1918, Investigations, Plans and Estimates, Surveys and Construction, Chapter VI, Department of the Interior, United States Reclamation Service, Rio Grande Project – New Mexico, Texas, Annual History – 1918, in Department of the Interior, US Reclamation Service, Rio Grande Project, Texas New Mexico, Drainage. 530-18 RG, Box 723 [Old Box 512] Code 520 RG 14 through Code 550 RG 42, PR 1910-55, RG 115, NARA Denver.

[88] C. S. Conover, *Ground-Water Conditions in the Rincon and Mesilla Valleys and Adjacent Areas in New Mexico*, Geological Survey Water-Supply Paper 1230, Prepared in cooperation with the Elephant Butte Irrigation District, Department of the Interior (GPO, 1954), 9.

[89] *Twelfth Annual Report of the Reclamation Service, 1912-1913* (GPO, 1914), 176. U.S. Department

51. There is little evidence that federal or state engineers in the years leading up to the Compact conceptualized underlying groundwater as a separate, independent supply for the Mesilla Valley or the basin. Those that contemplated the possibility of groundwater extraction to expand Project lands in the 1910 and 1920s noted that pumping would deplete the available surface supply.[90] Neither the Board, the *JIR*, nor the Rio Grande Compact engineering advisors considered groundwater as a solution to the basin's strained supply.

52. The *JIR* did make some broad observations about the interdependence of groundwater and surface flows in the basin, indicative of Slichter, Lee, and Bliss's findings. "[E]xtensive development of ground water," it noted, "would add no new water to the Upper Rio Grande Basin," and "recharge of ground-water basin would necessarily involve a draft on surface supplies which are now utilized otherwise." The *JIR* further cautioned that "redistribution of the availability and use of present supplies and the resulting effect upon the water supply of lower major units [i.e., the Rio Grande Project and beyond to Ft. Quitman]" would have to be taken into account if groundwater was developed.[91]

53. The *JIR* also discussed groundwater pumping by "cities, towns, and villages" in the basin. Although municipal water use was modest when compared to irrigation diversions for agriculture in the 1930s, it was considered "a stream flow depletion" and factored into assessments of water use for the three sections of the basin. In evaluating the Middle Rio Grande's water uses, for instance, the investigation included the City of Albuquerque because its wells were "undoubtedly a draft, direct or indirect, on the Rio

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of the Interior, *14th Annual Report of the Reclamation Service, 1914-1915* (Washington: Government Printing Office, 1915), 215; and U.S. Department of the Interior, *17th Annual Report of the Reclamation Service, 1917-1918* (Washington: Government Printing Office, 1918), 251.

[90] Memorandum, From: Engineer Harold Conkling, To: Chief of Construction, Subject: Water Supply – Rio Grande River, June 18, 1919, 17-19. ff. 302.31 New Mexico. Surveys and Investigations. THRU 1929, Box 262 NV-NM 302.28- -302.31 A, Entry 7, RG 115, NARA Denver; and D.C. Henny to Mr. J.W. Taylor, President, Elephant Butte Irrigation District, January 9, 1926, 1-2 and 10. 19260109_NMSU-EBID_02-G_001_07.

[91] *JIR*, 56.

Grande." Communities in lower New Mexico were similarly figured into the water use for the basin's Elephant-Butte-Ft. Quitman section.[92]

54. Knowledge of the interrelationship between groundwater and stream flow grew in the years following the Compact and before significant groundwater development occurred. Detailed investigation by USGS hydrologist C.S. Conover in the late 1940s and early 1950s came to the same specific conclusions for the Rincon and Mesilla valleys of lower New Mexico that the *JIR* had generally arrived at for the basin. Conover's study, made at the request of EBID to assess the use of groundwater as the surface supply dwindled in the face of drought, was provided in preliminary form to the New Mexico State Engineer in 1947, with the final report published in 1954.[93] Conover, like Slichter, Lee, and Bliss before him, noted that the Rio Grande surface flow and surrounding groundwater were hydrologically connected. The hydrologist found that the two were in a state of balance in lower New Mexico, owing to the Project's drainage system. He did not believe that extracting groundwater could then permanently augment the existing surface supply, but rather would diminish it over time – particularly for those lands further downstream that were reliant upon return flow from drains.[94] "Pumping of ground water," as Conover put it in his final report, was "essentially a change in point of diversion of an existing supply."[95]

55. There is evidence that during the 1950s drought, both BOR and EBID appreciated the connection between surface flow and groundwater that Conover had

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[92] *JIR*, 104-105. The investigation did not include the City of El Paso in this assessment because its wells, unlike Albuquerque's and others in the basin, drew upon groundwater fed by precipitation east of the city. *JIR*, 105.

[93] Chas. V. Theis, District Geologist, to Mr. John L. Gregg, Manager, Elephant Butte Irrigation District, October 23, 1947, attached to Clyde S. Conover, U.S. Geological Survey, Preliminary memorandum on ground-water supplies for Elephant Butte Irrigation District, New Mexico, September 1947, NM_00124166; and C. S. Conover, *Ground-Water Conditions in the Rincon and Mesilla Valleys and Adjacent Areas in New Mexico*, Geological Survey Water-Supply Paper 1230, Prepared in cooperation with the Elephant Butte Irrigation District, Department of the Interior (GPO, 1954), 4-5.

[94] Conover, Preliminary memorandum, 1, 8, 12-15, 20-21, and 24-27. NM_00124167, NM_00124174, NM_00124178-NM_00124180, NM_00124167, NM_00124186-NM00124187, and NM_00124190-NM_00124193; and Conover, *Ground-Water Conditions*, 2, and 132-135.

[95] Conover, *Ground-Water Conditions*, 132.

documented in lower New Mexico. A 1952 BOR study of "river loss" above El Paso, for instance, found that groundwater pumping which had expanded to compensate for shortages in the surface supply was reducing both Rio Grande flows and return flows from drains.[96] Notably, in endorsing pumping during the drought, Project officials and EBID urged those Project water users with wells to "transfer" the water they otherwise would have received from Elephant Butte releases to those users without wells rather than continue to use both surface and ground waters.[97] When the drought broke and surface flows improved in the late 1950s, Project water users shifted away from groundwater pumping once more.[98]

56. Subsequent investigations took some exceptions to Conover's findings, but did not deny the interconnection between groundwater and surface flow in lower New Mexico and were attentive to the implications of groundwater development for lands below Elephant Butte. A 1961 New Mexico State University study by Narendra Gunaji, for instance, found that drain flows recovered more quickly with the reduction of pumping following the drought than Conover had predicted. This suggested use of groundwater "as a supplemental water supply" in drought years, yet Gunaji did not recommend "continued use and re-use of ground

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[96] United States, Department of the Interior, Bureau of Reclamation, Rio Grande Project – New Mexico-Texas, River Loss, Caballo Dam to El Paso and Irrigation Wells, El Paso, Texas, July 1, 1952, Summary, Part I, A. NM_00138516.

[97] L.R. Fiock, "Rio Grande Project -- New Mexico-Texas, Water Announcement" (Department of the Interior, Bureau of Reclamation, August 1, 1951). JS000278; "Statement Issued by the Board of Directors of the Elephant Butte Irrigation District in Regard to the 1952 Water Situation" (Las Cruces, New Mexico: Elephant Butte Irrigation District, January 11, 1952). JS000280; L.R. Fiock, "Rio Grande Project -- New Mexico-Texas, Water Announcement" (Department of the Interior, Bureau of Reclamation, March 7, 1952). JS000281; L.R. Fiock, "Rio Grande Project -- New Mexico-Texas, Water Announcement" (Department of the Interior, Bureau of Reclamation, April 7, 1952). JS000282; "Statement from Elephant Butte Irrigation District Regarding the Water Situation" (Elephant Butte Irrigation District, June 3, 1953). JS000292; "Statement Regarding the Current Water Situation" (Las Cruces, New Mexico: Elephant Butte Irrigation District, March 4, 1954). JS000293; W.F. Resch, "Rio Grande Project -- New Mexico-Texas, Water Announcement" (Department of the Interior, Bureau of Reclamation, March 1, 1954). JS000283; and "Board of Directors, Elephant Butte Irrigation District, to All Irrigation Well Owners," March 11, 1955. JS000285.

[98] Narendra Gunaji, "Ground Water Conditions in Elephant Butte Irrigation District" (University Park, New Mexico: Engineering Experiment Station, New Mexico State University, November 1961), 5. JS000286; and E.R. Leggat, M.E. Lowry, and J.W. Hood, *Ground-Water Resources of the Lower Mesilla Valley, Texas and New Mexico*, U.S. Geological Survey Water Supply Paper 1669-AA (GPO, 1963), AA18-AA19 and AA24. JS000287.

water." The hydrologist instead urged EBID to "maintain, and use, all of its surface water rights to the fullest extent possible" because repeated use of groundwater would yield a supply of deficient quality for irrigation.[99]

57. A 1963 USGS report of an investigation by E.R. Leggat, M.E. Lowry, and J.W. Hood of the lower Mesilla Valley (which included a portion of the valley lands in Texas) between 1952 and 1958 indicated that "sustainable supplies" could be obtained from wells in the lower valley, but recognized that surface water applied to the land recharged groundwater, and that "the surface-water supply will be reduced if ground-water withdrawals in the valley are increased" beyond the levels of the 1950s.[100] Leggat, Lowry, and Hood warned that if surface supplies diminished and groundwater extraction expanded "drain flow will cease" and groundwater quality would degrade.[101]

58. For its part, the New Mexico State Engineer's Office ("OSE") evidenced heightened awareness of the interrelationship between Rio Grande stream flow and subsurface water beginning in the 1950s. Two years after the official release of Conover's findings, citing a "scientific investigation" of this connection in the Middle Rio Grande, New Mexico State Engineer S.E. Reynolds declared an "underground water basin" above Elephant Butte to provide for state management and control. Reynolds noted that "the waters of said basin are interrelated with the flow of the Rio Grande Stream System, so that such underground waters are a substantial source of the flow of said stream system," and that "the waters of the Rio Grande Stream System are fully appropriated."[102]

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[99] Gunaji, "Ground Water Conditions in Elephant Butte Irrigation District," 15, 27, and 36-37. JS000286.

[100] Leggat, et al., *Ground-Water Resources of the Lower Mesilla Valley*, AA25, AA45, and AA48. JS000287.

[101] Leggat, et al., *Ground-Water Resources of the Lower Mesilla Valley*, AA45. JS000287.

[102] S.E. Reynolds, State Engineer, Order Declaring the Rio Grande Underground Water Basin, November 29, 1956. ff. 245 Public Works Committee, Middle Rio Grande River - Elephant Butte Dam. 1957-58, 85th Cong, Box 6, Serial No. 6401. File 235-245, 246-254, 255-257, John Dempsey Papers, NMSA.

59. In remarks for an April 1968 symposium on "International Water Law Along the Mexican-American Border," given as New Mexico and Texas were joined in challenging Colorado's performance under the Compact in the Supreme Court, the state engineer linked his earlier action to the Compact. Reynolds acknowledged that the Compact "makes no specific reference to ground water." "However," he went on, "the inflow-outflow mechanism for determining delivery obligations makes the control of ground water appropriations in the upstream states essential for the protection of existing surface water rights in those states and the preservation of their ability to meet the compact commitments."[103]

60. In the 1980s, on this basis, Reynolds opposed El Paso's efforts to mine Mesilla Valley groundwater to enhance its municipal water supply. He declared a "Lower Rio Grande Underground Water Basin in Dona Ana County" in October 1980, and denied El Paso's applications.[104] In the ensuing litigation, *City of El Paso v. Reynolds*, the state engineer defended his decision in part on the hydrological connections between surface flow and groundwater and on the Compact. Although the federal district court in New Mexico ultimately ruled against Reynolds and expressed skepticism about the sincerity of his position, the historical record indicates that he and those in his office were aware of the problem groundwater extraction in lower New Mexico posed to the Project and thus the Compact.[105]

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[103] S.E. Reynolds, State Engineer, The Rio Grande Compact (April 29, 1968), 20-21. Folder 2062, Reynolds, The Rio Grande Compact, April 29, 1968, Box 78, Exps. 231-233, Nos. 2016-2085, State Engineer Reports: Basic/Rio Grande, NMSA; and S.E. Reynolds, State Engineer, State of New Mexico, "The Rio Grande Compact," in Clark S. Knowlton, ed., *International Water Law Along the Mexican-American Border*, Contribution No. 11 of The Committee on Desert and Arid Zones Research, Southwestern and Rocky Mountain Division, A.A.A.S. (El Paso: University of Texas, 1968): 58-59.

[104] Memorandum, To: S.E. Reynolds, From: D.E. Gray, Subject: Lower Rio Grande, September 10, 1980; State Engineer of the State of New Mexico, Special Order No. 126, In the Matter of State Engineer Order No. 126 Declaring the Lower Rio Grande Underground Water Basin in Dona Ana County, September 11, 1980, signed S.E. Reynolds, State Engineer, Received and Approved: Richard A. Simms, Special Assistant Attorney General; and State Engineer of the State of New Mexico, Special Order No. 126-A, In the Matter of State Engineer Order No. 126 Declaring the Lower Rio Grande Underground Water Basin in Dona Ana County, October 22, 1980, signed S.E. Reynolds, State Engineer, Received and Approved: Richard A. Simms, Special Assistant Attorney General. Provided by the City of El Paso; and Ira G. Clark, *Water in New Mexico: A History of Its Management and Use* (Albuquerque: University of New Mexico Press, 1987), 675.

[105] United States District Court for the District of New Mexico, *The City of El Paso*, By and Through

61. In 1982, OSE circulated a paper to the International Boundary and Water Commission (the federal agency charged with ensuring delivery of water to Mexico pursuant to the 1906 treaty) that highlighted the issue. Entitled "Rio Grande, Elephant Butte Dam to El Paso, Texas," the paper summarized the result of "[a] study of streamflow depletion in the Rio Grande Valley between Elephant Butte Dam and El Paso, Texas," plotted on four figures. A double mass diagram (Figure 1), charted "the relationship between the flow of the Rio Grande below Elephant Butte Dam and the flow of the Rio Grande at El Paso, Texas, since storage began in Elephant Butte in 1915," across three periods of time. It took special note of the third period which began in 1951, "the start of the period of lowest water supply available from Elephant Butte Reservoir" that coincided with "extensive groundwater development . . . undertaken to offset shortages to Rio Grande Project lands." "This groundwater development," according to the paper, "has changed the flow regime established

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Its Public Service Board, *Ray Pearson, Carlton C. Homan, Jr., Louie Giallanza, Clinton E. Wolf*, and *Thomas D. Westfall*, Plaintiffs, v. *S. E. Reynolds*, individually and as State Engineer of New Mexico, *Jeff Bingaman*, individually and as Attorney General of New Mexico, *Lalo Garza*, individually and as New Mexico District Attorney for Dona Ana County, Defendants, *Elephant Butte Irrigation District, The City of Las Cruces, New Mexico, and Stahmann Farms, Inc.*, Defendant-Intervenors, Civ. No. 80-730 HB, January 17, 1983. 563 F. Supp. 379; 1983 U.S. Dist. LEXIS 19988; 13 ELR 20755. Provided by Somach Simmons & Dunn. The dispute persisted until 1989 when the U.S. Court of Appeals for the District of Columbia Circuit ruled that no live controversy remained. United States District Court for the District of New Mexico, *Ray Pearson, Carlton C. Homan, Jr., Louie Giallanza, Clinton E. Wolf*, and *Thomas D. Westfall*, Plaintiffs, v. *S. E. Reynolds*, individually and as State Engineer of New Mexico, *Paul Bardacke*, individually and as Attorney General of New Mexico, *Lalo Garza*, individually and as New Mexico District Attorney for Dona Ana County, Defendants, *Elephant Butte Irrigation District, The City of Las Cruces, New Mexico, and Stahmann Farms, Inc.*, Defendant-Intervenors, Civ. No. 80-730 HB, August 3, 1984. 597 F. Supp. 694; 1894 U.S. Dist. LEXIS 24568; 15 ELR 20259; United States District Court for the District of New Mexico, *Ray Pearson, Carlton C. Homan, Jr., Louie Giallanza, Clinton E. Wolf*, and *Thomas D. Westfall*, Plaintiffs, v. *S. E. Reynolds*, individually and as State Engineer of New Mexico, *Paul Bardacke*, individually and as Attorney General of New Mexico, *Lalo Garza*, individually and as New Mexico District Attorney for Dona Ana County, Defendants, *Elephant Butte Irrigation District, The City of Las Cruces, New Mexico, and Stahmann Farms, Inc.*, Defendant-Intervenors, Civ. No. 80-730 HB, August 17, 1984. 1984 U.S. Dist .LEXIS 24276; and United States Court of Appeals for the District of Columbia Circuit, *In re Applications of El Paso*, No. 88-5357, September 22, 1989, Argued; October 20, 1989, Decided. 887 F. 2d 1103; 1989 U.S. App. LEXIS 15897; 281 U.S. App. D.C. 112; 15 Fed. R. Serv. 3d (Callaghan) 22. Provided by Somach Simmons & Dunn.

prior to 1951 such that a greater release is required from Elephant Butte Reservoir to achieve the same flow at El Paso."[106]

62. More recently OSE has recognized groundwater pumping in lower New Mexico directly threatens the Compact. An internal memorandum from 2003 warned that extensive groundwater development below Elephant Butte jeopardized the Project water supply and raised the possibility of a dispute with Texas.[107] The following year, New Mexico State Engineer John R. D'Antonio, Jr. declared a "Lower Rio Grande Water Master District" to provide for the administration of groundwater rights and safeguard "prior surface water…rights."[108]

THE BODY OF RELEVANT HISTORICAL DOCUMENTS FOR UNDERSTANDING THE INTENT AND PURPOSES OF THE 1938 COMPACT IS DISCRETE

63. The body of relevant historical documents for understanding the intent and purposes of the 1938 Compact is discrete. The water resources history of the Upper Rio Grande Basin is broad and encompasses an array of subjects of scholarly interest. However, in my expert opinion, the Rio Grande Compact proceedings and correspondence among the commissioners from the 1920s through the 1930s; records concerning the Rio Grande Joint Investigation and the resulting report; meeting notes and correspondence related to the development of the "technical basis" for the Compact; and subsequent retrospective

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[106] [Office of the New Mexico State Engineer,] Rio Grande, Elephant Butte Dam to El Paso, Texas [1982], 1. Folder 11 Correspondence and data concerning Mesilla Valley pumping. 1982., Box 1, MS 555 Joseph F. Friedkin Papers, C.L. Sonnichsen Special Collections Department, University of Texas at El Paso.

[107] Memorandum, Office of the State Engineer, District 4, May 15, 2003, File: LRG-1776, To: John R. D' Antonio Jr., State Engineer, Paul Saavedra, Water Rights Division Chief, John Romero, WRAP Director, Through: Calvin Chavez, District Supervisor, From: Erek H. Fuchs, Lower Rio Grande Basin Supervisor, Re: Emergency Application for Permit for Supplemental Wells, Local impairment analysis and issues for consideration, Applicant: Elephant Butte Irrigation District, 2-3, and 11-12. Provided by Somach Simmons & Dunn.

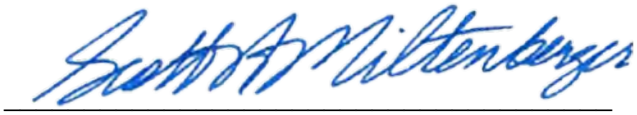
[108] State of New Mexico, Office of the State Engineer, In the Matter of the Creation of the Lower Rio Grande Water Master District for the Administration of Rights to and the Use of Ground Water from the Lower Rio Grande Groundwater Basin of New Mexico, Dated this 3rd day of December, 2004, signed John R. D'Antonio, Jr., P.E., State Engineer. NM_00018294 - NM_00018297.

assessments of the Compact deliberations by the commissioners and their engineering advisors offer the most crucial evidence for appreciating how and why the Rio Grande Compact of 1938 was drafted as it was.

64. These historical documents – most produced at or near the time of the Compact by those with direct involvement in the Compact negotiations – reveal the geographic, hydrological, political, and historical circumstances that made an apportionment of the waters of the Rio Grande challenging; the information available to the Rio Grande Compact commissioners and their engineering advisors in the mid-to-late 1930s; and the debates over how best to effectuate an "equitable apportionment" that began in the 1920s and continued into the 1930s. These are many of the same documents relied upon by the first Special Master.

65. Other materials I have reviewed, documents and expert reports produced in these proceedings as well as academic monographs and secondary works, provide further details as to the events leading to and the issues informing the Rio Grande Compact of 1938, but do not fundamentally change my primary conclusions about the Compact and which I believe are clearly drawn from an examination of its history. These conclusions are set forth in Paragraphs 5. a-d above.

I declare under penalty of perjury that the foregoing is true and correct. Executed this 2nd day of November 2020 at Davis, California.



Scott A. Miltenberger, Ph.D.

Attachment 1: Resume

Scott A. Miltenberger, Ph.D.

Partner · Historian

JRP Historical Consulting LLC

Summary

Dr. Miltenberger is a professional consulting historian, specializing in environmental and natural resources issues. Since joining JRP in 2006, he has researched alleged riparian and appropriative water rights, historical ground water rights, and Native American and federal reserved water rights in California and throughout the American West. Dr. Miltenberger has also led historical investigations of land use / ownership, survey / boundary disputes, potentially responsible parties for toxic clean-up under the provisions of CERCLA, river meanders, levee construction and performance, and flood management operations. His clients have included local, state, and federal agencies, as well as private parties. Dr. Miltenberger has qualified as an expert historian and given expert witness testimony in Sacramento County Superior Court, Santa Clara County Superior Court, and in Arizona's San Pedro-Gila River Adjudication.

Selected Professional Experience

Expert Witness Work, Deposition, and Trial Testimony

The Vineyard House, LLC, Plaintiff, vs. Constellation Brands U.S. Operations, Inc., Defendant, Case No. 4:19-cv-1424-YGR, United States District Court, Northern District of California – Oakland. Preparation of expert historian report (based on county records, and archival and library research), and expert witness deposition and anticipated trial testimony regarding the name "To Kalon," its historical association with a specific geographic place within the Oakville, California area, and the influence of H.W. Crabb, the original owner of To Kalon. San Francisco: Buchalter, APC, 2019-Present.

State of Texas v. State of New Mexico and State of Colorado, No. 141, Original, Supreme Court of the United States. Preparation of expert historian report (based on extensive archival and library research in California, Colorado, Massachusetts, New Mexico, Texas, Washington, DC, and Wyoming), and expert witness deposition and anticipated trial testimony concerning the development of the Rio Grande Compact of 1938. Sacramento, CA: Somach Simmons & Dunn, 2012-Present.

Matt Pear and Mark Pear, Plaintiffs, vs. City and County of San Francisco, a municipal corporation, Does, 1-50, inclusive, Case No.

Contact
(530) 757-2521 main
(530) 574-4559 mobile
smiltenberger@jrphistorical.com

Office Location
2850 Spafford Street, Davis, CA 95618

Education
Ph.D., United States History, University of California, Davis, 2006
M.A. United States History, University of California, Davis, 2001
A.B. History, *summa cum laude*, Colgate University, New York, 1999

Academic Honors, Fellowships, and Grants
Agricultural History Center Dissertation Grant, University of California, Davis, 2005-2006
Reed-Smith Dissertation-Year Fellowship, University of California, Davis, 2004-2005
Jacob K. Javits Graduate Fellowship, United States Department of Education, 2000-2004
Legacy Fellowship, American Antiquarian Society, 2004
Distinction, Ph. D. Comprehensive Examinations, University of California, Davis, December 2001
Reed-Smith Graduate Fellowship, University of California, Davis, 1999.
Alumni Memorial Scholarship, Colgate University, 1995-1999
Charles A. Dana Fellowship, Colgate University, 1997-1999
Phi Beta Kappa, Colgate University, September 1998 (inducted)
Phi Alpha Theta, Colgate University, September 1997 (inducted)

112CV227801, Superior Court of the State of California, County of Santa Clara. Provided expert witness testimony (based on research in federal, state, county, and municipal [San Franciso] records) concerning historical land use and urban / suburban / industrial development of Santa Clara County in the 1950s as related to the Hetch Hetchy Aqueduct Right of Way. San Francisco, CA: City and County of San Francisco, City Attorney's Office, San Francisco Public Utilities Commission, 2017.

In Re the General Adjudication of All Rights to Use Water in the Gila River System and Source. Civil Nos. W-1, W-2, W-3, and W-4, Contested Case No. W-1-11-605, Maricopa County Superior Court, State of Arizona. Preparation of expert historian report (based on extensive archival and library research in Arizona, California, Colorado, and Washington, DC), and expert witness deposition and trial testimony concerning the history of Fort Huachuca, Arizona, its changing missions, population, and water use, for the purposes of a federal reserved water right claim. Washington, DC and Denver, CO: United States Department of Justice, 2012-2016.

Modesto Irrigation District vs. Heather Robinson Tanaka, et al. Case No. 34-2011-00112886, Superior Court of the State of California, County of Sacramento. Expert witness deposition and trial testimony (based on research in state and county records) concerning the riparian status of a parcel in San Joaquin County and the historical land and water uses on that parcel. Sacramento, CA: O'Laughlin & Paris LLP for Modesto Irrigation District, 2014-2015.

Consulting Historian Services Since 2006

Historical Research and Analysis of "Cultivation," Agricultural Practices, and the Origins of California Water Code Section 1004. San Francisco: Duane Morris, 2020-Present.

Clear Lake Littoral Rights Analyses, Lake County, CA. Woodland: Yolo County Flood Control and Water Conservation District, 2019-Present.

Riparian and Pre-1914 Appropriative Water Rights Investigation of Parcels along Merced River, Merced County, CA, 2018-Present.

Investigation of Historical Water Right Entitlements within the Kern River Basin, Kern County, CA, 2018-Present.

Riparian Water Rights Investigation of Parcels in San Joaquin County, 2018-Present.

Investigation of Historical Water Right Entitlements within the Stanislaus River Basin, 2018-Present.

Riparian and Pre-1914 Appropriative Water Rights Investigation of an Agricultural Parcel in Merced County, CA, 2017-Present.

Riparian and Pre-1914 Appropriative Water Rights Investigation of Agricultural Lands in the Kings River Basin, Fresno County, CA, 2017-Present.

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Riparian and Pre-1914 Appropriative Water Rights Investigation of Sacramento-San Joaquin Delta Islands, 2016-Present.

In Re the General Adjudication of Rights to the Use of Water from the Coeur d'Alene-Spokane River Basin Water System. District Court of the Fifth Judicial District of the State of Idaho, Twin Falls, ID. Assisted in the research, document / data management, and preparation of an expert report regarding water rights claims made in the general adjudication of water rights in the Coeur d'Alene-Spokane River Basin, Idaho. Boise, ID: Natural Resources Division, Office of the Attorney General, State of Idaho, 2010-Present.

Riparian Water Rights Investigation of the Cal West-South Meridian Road Property. Marysville, CA: Stromer Realty, 2020.

Historical Research of California Public Utilities Records, 2018.

Historical Research of Military Operations at McClellan United States Air Force Base, Sacramento, CA, concerning use of chromium and chromium products, 2018.

Riparian Water Rights Investigation of Parcels in San Joaquin County, 2018-2019.

Historical Research of Water Rights for a Parcel in Stanislaus County. Sacramento, CA: O'Laughlin & Paris, LLP, 2017-2018.

Potentially Responsible Parties (CERCLA) Title Research for a Parcel in Tulare County. Rancho Cordova, CA: Geocon Consultants, Inc., 2017.

Historical Research of Native American / Federal Reserved Water Rights Claims. Humboldt County, CA, 2017-2018.

Historical Research of Water Rights acquired by the City of Santa Cruz. Santa Cruz, CA: Atchison, Barisone, Condotti & Kovacevich, 2016-2017.

Historical Research on Dams and Flood Control Operations on the Boise River. Boise, ID: Natural Resources Division, Office of the Attorney General, State of Idaho, 2015-2017.

Historical Research Concerning Reclamation District Assessments in Colusa County. Sacramento, CA: Somach Simmons & Dunn, 2016.

In Re the General Adjudication of Rights to the Use of Water from the Snake River Drainage Basin Water System, State of Idaho v. United States; State of Idaho; and all unknown claimants to the use of water from the Snake River Drainage Basin Water System, District Court of the Fifth Judicial District of the State of Idaho, Twin Falls, ID. Assisted in the research, document / data management, and preparation of several expert and consultant reports related to Idaho state water rights from statehood to the present of the more than 158,000 water claimants in the Snake River Drainage Basin, Idaho. These studies involved reservoir storage rights, appropriative water claims, groundwater use, submerged lands, hydro-electric power generation, municipal water uses, federal reserved water rights for

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military, forest, and Indian reservations, tribal water claims, and legislative histories. Boise, ID: Natural Resources Division, Office of the Attorney General, State of Idaho, 2006-2016.

Research regarding Pre-1914 Water Rights of Woods Irrigation Company, San Joaquin County, CA. Sacramento, CA: State Water Contractors and San Luis and Delta-Mendota Water Authority, 2015-2016.

Riparian Water Rights Investigation for Agricultural and Wetlands in the Cosumnes River watershed, Sacramento County, CA. Sacramento, CA: Sacramento County Counsel, 2015-2016.

Riparian and Pre-1914 Appropriative Water Rights Investigation of Agricultural Lands in the Salinas River Basin, Monterey County, CA, 2015-2016.

Riparian and Pre-1914 Appropriative Water Rights Investigation of Agricultural Lands adjacent to the Sacramento River, Yolo County, CA, 2015-2016.

Historical Research and Analysis of the Construction of Cline Falls Dam and Power Plant on Deschutes River, Oregon. Bend, OR: Holland & Knight, LLP, 2015.

Historical Research of Shipbuilding Operations at Swan Island Shipyards, Port of Portland, Oregon. San Francisco: Bassi, Edlin, Huie and Blum, 2015.

Historical Research of Land Uses and Development West of Hunters Point, San Francisco. San Francisco, CA: Bassi, Edlin, Huie and Blum, 2015.

Research Regarding Historical Background of Groundwater Pumping and Litigation in the 1950s among Orange County, Riverside, and San Bernardino Area Water interests in the Upper Santa Ana River Basin in Southern California. Redlands, CA: Thomas McPeters, Esq., McPeters McAlearney Shimoff & Hatt, 2013-2015.

Historical Investigation of Riparian and Pre-1914 Appropriative Water Right Claims for Three Parcels in eastern Contra County, CA, 2014.

Gallo Cattle Company v. Lincoln White Crane Hunter Farms; Merced Irrigation District, et. al. Case No. CV00105, Superior Court, State of California, County of Merced. Assisted in the collection of historical documentation in support of an expert witness deposition and planned testimony regarding Crocker Huffman Land and Water Company history, development of its irrigation and drainage system (later acquired by MID), and the background of a 1918 agreement to flow water from Merced County Drainage District #1 (later acquired by MID) to a private landowner. Walnut Creek, CA: Miller Starr Regalia; and San Francisco, CA: Duane Morris, LLP, 2013-2014.

Land Use History, Union Lumber Company and adjacent properties, Fort Bragg, CA. San Francisco, CA: Bassi, Edlin, Huie and Blum, 2013-2014.

Reclamation and Land Use History Investigation: Roberts Island, San Joaquin Delta, CA. Sacramento, CA: O'Laughlin & Paris LLP for Modesto Irrigation District; Kronick, Moskovitz,

Tiedemann & Girard for State Water Contractors; and Diepenbrock Harrison for San Luis and Delta-Mendota Water Authority, 2010-2014.

History of Groundwater Development and Use in Antelope Valley to Fulfill the Changing Military Missions of Edwards Air Force Base, Kern, San Bernardino and Los Angeles Counties, CA. Denver, CO: US Department of Justice, 2009, 2012-2014.

Research on a Pre-1914 Appropriative Water Rights Claim for a Ranch in Merced County, 2013.

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History of Fontana Union Water Company's Lytle Creek Diversion on the San Bernardino National Forest. Fontana, CA: Fontana Union Water Company; Rancho Cucamonga: Cucamonga Valley Water District; and Rosemead, CA: San Gabriel Water District for submission to the Chief Counsel for Natural Resources, US Department of Agriculture, 2009.

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Delta Risk Management Strategy, Franks Tract Levee Research: Historical research into the original condition of levees around Franks Tract, and collection of aerial photographs showing how the levees deteriorated over time after the island flooded, Contra Costa County, California. Benjamin & Associates, 2007–2008.

Pre-1914 Water Rights Investigation for Idyllwild Water District regarding Strawberry Creek, a tributary to the San Jacinto River. California State Water Resources Control Board, Complaint No. 33-05-01 In Re Strawberry Creek, Riverside County, CA. Sacramento, CA: Ellison, Schneider & Harris, Attorneys at Law, LLP, 2007 – 2008.

Fort Boise Military Reservation Federal Reserved Water Rights Investigation. Boise, ID: Natural Resources Division, Office of the Attorney General, State of Idaho, 2007.

Historical Property Ownership Research for a Mine in Lake County, CA. Houston, TX: El Paso Corporation, 2006

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Publications Authored in the Previous 10 Years

"Viewing the Anthrozootic City: Humans, Domesticated Animals, and the Making of Early Nineteenth-Century New York," in *The Historical Animal*, ed. Susan Nance (Syracuse, NY: Syracuse University Press, 2015), pp. 261-271.

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Attachment 2:

Library of Documents Referenced in Scott A. Miltenberger Declaration

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STATE COMMISSION OF PUBLIC RECORDS & ARCHIVES

NEW MEXICO STATE RECORDS CENTER
Publications Management Division

RULE COVER SHEET NO. _____

1. Agency's Name and Address: State Engineer
Bataan Memorial Building
Santa Fe, N.M. 87503

2. If this is a NEW Rule: Rule No.: ~~Special~~ Order No. 126-A
Rule Title: In the Matter of State Engineer Speical Order No. 126 Declaring the Lower Rio Grande Underground Water Basin in Dona Ana County.
Effective Date (if other than filing date): 10-22-80

3. If this is a SUPERSEDING Rule: Rule No.: _____
Rule Title: _____
Effective Date (if other than filing date): _____
Old Rule No.: _____
Old Rule Title: _____
Old Rule Filing Date: _____

4. If this is an AMENDING Rule:
Rule No.: _____ Amendment No.: _____
Rule Title: _____
Effective Date (if other than filing date): _____
Existing Rule No.: _____
Existing Rule Title: _____
Existing Rule Filing Date: _____

5. If this is a REPEALING Rule: Rule No.: _____
Effective Date (if other than filing date): _____
Old Rule No.: _____
Old Rule Title: _____
Old Rule Filing Date: _____

6. This Rule consists of 2 1 sheets. Update as follows:

DELETE These Sheets		ADD These Sheets	
Page No.	Dated	Page No.	Dated
		1	10-22-80
		2	10-22-80

7. The above Rule is hereby authorized by:

Signature	Title	Date
	State Engineer	10/22/80

SRC-17 9/79

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STATE COMMISSION OF
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STATE ENGINEER OF THE
STATE OF NEW MEXICO
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Santa Fe, New Mexico 87503

Special Order No. 126 September 11, 1980

IN THE MATTER OF STATE ENGINEER SPECIAL ORDER NO. 126 DECLARING THE LOWER RIO GRANDE UNDERGROUND WATER BASIN IN DONA ANA COUNTY

I. WHEREAS, the waters of underground streams, channels, artesian basins, reservoirs, or lakes having reasonably ascertainable boundaries, are public waters and are subject to appropriation for beneficial use, and

II. WHEREAS, all natural waters flowing in streams and watercourses, whether such be perennial, or torrential, within the State of New Mexico, belong to the public and are subject to appropriation for beneficial use, and

III. WHEREAS, there is known to exist an underground water basin, the boundaries of which are reasonably ascertainable in Dona Ana County, in the State of New Mexico, and in which new appropriations of water might impair existing rights, and

IV. WHEREAS, the surface and underground waters within the boundaries of this basin are interrelated.

V. NOW, THEREFORE, IT IS HEREBY DECLARED that the lands more fully described hereinafter in Dona Ana County comprise an underground water basin, to be known as the Lower Rio Grande Underground Water Basin, subject to the New Mexico Statutes, and the rules and regulations of the State Engineer:

1. Beginning at a point described as boundary monument number 8 on the United States of America and the Republic of Mexico boundary; thence westerly along said United States of America-Republic of Mexico boundary to its intersection with the west line of Section 18, Township 29 South, Range 1 West; thence northerly along the west lines of Sections 18, 7 and 6, Township 29 South, Range 1 West, and Section 31, Township 28 South, Range 1 West to the northwest corner of said Section 31; thence westerly along the south line of Section 25, Township 28 South Range 2 West to its southwest corner; thence northerly along the west lines of Sections 25, 24 and 13, Township 28 South, Range 2 West to the northwest corner of said Section 13; thence westerly along the south line of Section 11, Township 28 South, Range 2 West to its southwest corner; thence northerly along the west lines of Sections 11

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and 2, Township 28 South, Range 2 West, and Sections 35 and 26, Township 27 South, Range 2 West to the northwest corner of said Section 26; thence westerly along the south lines of Sections 22, 21, 20 and 19, Township 27 South, Range 2 West, Sections 24, 23, 22, 21, 20 and 19, Township 27 South, Range 3 West, and Section 24, Township 27 South, Range 4 West to the southwest corner of Section 24, Township 27 South, Range 4 West; thence northerly along the west lines of Sections 24 and 13, Township 27 South, Range 4 West to the northwest corner of said Section 13; thence easterly along the north line of Section 13, Township 27 South, Range 4 West to its northeast corner; thence northerly along the west line of Section 7, Township 27 South, Range 3 West, to its northwest corner; thence easterly along the north line of Section 7, Township 27 south, Range 3 West, to its northeast corner; thence northerly along the west line of Section 5, Township 27 South, Range 3 West to its northwest corner; thence easterly along the north line of Section 5, Township 27 South, Range 3 West to its northeast corner; thence northerly along the west lines of Sections 33 and 28, Township 26 South, Range 3 West to the northwest corner of said Section 28; thence westerly along the south line of Section 20, Township 26 South, Range 3 West to its southwest corner; thence northerly along the west lines of Sections 20, 17, 8 and 5, Township 26 South, Range 3 West to the northwest corner of said Section 5; thence westerly along the southern line of Section 32, Township 25 South, Range 3 West to its southwest corner; thence northerly along the west line of Section 32, Township 25 South, Range 3 West to its northwest corner; thence easterly along the north line of Section 32, Township 25 South, Range 3 West to its northeast corner; thence northerly along the west line of Section 28, Township 25 South, Range 3 West to its northwest corner; thence easterly along the north line of Section 28, Township 25 South, Range 3 West to its northeast corner; thence northerly along the west lines of Sections 22, 15 and 10, Township 25 South, Range 3 West to the northwest corner of said Section 10; thence easterly along the north line of Section 10, Township 25 South, Range 3 West to its northeast corner; thence northerly along the west line of Section 2, Township 25 South, Range 3 West to its northwest corner; thence easterly along the north lines of Sections 2 and 1, Township 25 South, Range 3 West to the northeast corner of said Section 1; thence northerly along the west lines of Sections 31 and 30, Township 24 South, Range 2 West to the northwest corner of said Section 30; thence easterly along the north line of Section 30, Township 24 South, Range 2 West to its northeast corner; thence northerly along the west lines of Sections 20 and 17, Township 24 South, Range 2 West to the northwest corner of said Section 17; thence easterly along the north line of Section 17, Township 24 South, Range 2 West, to its northeast corner; thence northerly along the west line of Section 9, Township 24 South, Range 2 West to its northwest

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corner; thence easterly along the north line of Section 9, Township 24 South, Range 2 West to its northeast corner; thence northerly along the west lines of Section 3, Township 24 South, Range 2 West, and Sections 34, 27, 22, 15, 10 and 3, Township 23 South, Range 2 West to the northwest corner of Section 3, Township 23 South, Range 2 West; thence westerly along the south lines of Sections 33, 32 and 31, Township 22 South, Range 2 West to the southwest corner of said Section 31; thence northerly along the west lines of Sections 31, 30, 19 and 18, Township 22 South, Range 2 West to the northwest corner of said Section 18; thence easterly along the north lines of Sections 18, 17, 16 and 15, Township 22 South, Range 2 West to the northeast corner of said Section 15; thence northerly along the west lines of Sections 11 and 2, Township 22 South, Range 2 West, and Sections 35, 26, 23, 14, 11 and 2, Township 21 South, Range 2 West to the northwest corner of Section 2, Township 21 South, Range 2 West; thence easterly along the north lines of Sections 2 and 1, Township 21 South, Range 2 West, to the southwest corner of Section 31, Township 20 South, Range 1 West; thence northerly along the west lines of Sections 31 and 30, Township 20 South, Range 1 West to the northwest corner of said Section 30; thence easterly along the north line of Section 30, Township 20 South, Range 1 West to its northeast corner; thence northerly along the west line of Section 20, Township 20 South, Range 1 West to its northwest corner; thence easterly along the north lines of Sections 20, 21, 22, 23 and 24, Township 20 South, Range 1 West, Sections 19, 20, 21, 22, 23 and 24, Township 20 South, Range 1 East, Sections 19, 20, 21, 22, 23 and 24, Township 20 South, Range 2 East, and Sections 19, 20, 21, 22, 23 and 24, Township 20 South, Range 3 East to the northeast corner of Section 24, Township 20 South, Range 3 East; thence northerly along the west line of Section 19, Township 20 South, Range 4 East to its northwest corner; thence easterly along the north lines of Sections 19 and 20, Township 20 South, Range 4 East to the northeast corner of said Section 20; thence southerly along the east lines of Sections 20, 29 and 32, Township 20 South, Range 4 East, to the southeast corner of said Section 32; thence westerly along the south line of Section 32, Township 20 South, Range 4 East to the northeast corner of Section 5, Township 21 South, Range 4 East; thence southerly along the east lines of Sections 5, 8, 17 and 20, Township 21 South, Range 4 East, to the southeast corner of said Section 20; thence westerly along the south line of Section 20, Township 21 South, Range 4 East to the southwest corner of said Section 20; thence southerly along the east lines of Sections 30 and 31, Township 21 South, Range 4 East, to the southeast corner of said Section 31; thence easterly along the north line of Section 6, Township 22 South, Range 4 East to its northeast corner; thence southerly along the east line of Section 6, Township 22 South, Range 4 East to its southeast corner; thence westerly along the south line of Section 6,

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Township 22 South, Range 4 East to its southwest corner; thence southerly along the east lines of Sections 12, 13, 24 and 25, Township 22 South, Range 3 East to the southeast corner of said Section 25; thence easterly along the north line of Section 31, Township 22 South, Range 4 East to its northeast corner; thence southerly along the east lines of Section 31, Township 22 South, Range 4 East, Sections 6, 7, 18, 19, 30 and 31, Township 23 South, Range 4 East and Section 6, Township 24 South, Range 4 East to the southeast corner of Section 6, Township 24 South, Range 4 East; thence easterly along the north line of Section 8, Township 24 South, Range 4 East to its northeast corner; thence southerly along the east lines of Sections 8, 17, 20, 29 and 32, Township 24 South, Range 4 East to the southeast corner of said Section 32; thence westerly along the south line of Section 32, Township 24 South, Range 4 East to its southwest corner; thence southerly along the east lines of Sections 6, 7, 18 and 19, Township 25 South, Range 4 East, to the southeast corner of said Section 19; thence easterly along the north line of Section 29, Township 25 South, Range 4 East to its northeast corner; thence southerly along the east lines of Sections 29 and 32, Township 25 South, Range 4 East, and Sections 5 and 8, Township 26 South, Range 4 East to the southeast corner of said Section 8; thence easterly along the north line of Section 16, Township 26 South, Range 4 East to its northeast corner; thence southerly along the east lines of Sections 16, 21 and 28, Township 26 South, Range 4 East to the southeast corner of said Section 28; thence easterly along the north line of Section 34, Township 26 South, Range 4 East to its northeast corner; thence southerly along the east line of Section 34, Township 26 South, Range 4 East to its intersection with the New Mexico-Texas State boundary; thence westerly and southerly along the New Mexico-Texas State boundary to a point which is the intersection of the New Mexico, Texas, and Republic of Mexico boundaries being further described as boundary monument number 1; thence westerly along the United States of America-Republic of Mexico boundary to a point described as boundary monument number 8, being the place and point of beginning.

VI. Witness my hand and official seal this 11th day of September, A.D., 1980.

S. E. Reynolds
State Engineer

Reviewed and Approved:

Richard A. Simms
Special Assistant Attorney General

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STATE COMMISSION OF
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STATE ENGINEER OF THE
STATE OF NEW MEXICO
Bataan Memorial Building
Santa Fe, New Mexico 87503

Order No. 126-A October 22, 1980

IN THE MATTER OF STATE ENGINEER SPECIAL
ORDER NO. 126 DECLARING THE LOWER RIO GRANDE
UNDERGROUND WATER BASIN IN DONA ANA COUNTY

I. This matter coming on for hearing upon State Engineer Special Order No. 126, pursuant to Section 72-2-8, New Mexico Statutes, NMSA 1978 Comp., and S. E. Reynolds, presiding as Hearing Officer, and opportunity having been given for anyone who is or may be affected by the said Order to appear and testify, the Hearing Office having considered the testimony presented at said hearing and being otherwise fully advised in the premises finds:

1. Special Order No. 126 was duly and lawfully promulgated on the 11th day of September, 1980.

2. Notice of the promulgation of Special Order No. 126, and hearing thereon, was duly published as required by law.

3. Hearing on Special Order No. 126 was duly held as required by law and pursuant to the said notice on the 22nd day of October, 1980.

4. No evidence has been presented why Special Order No. 126 should not be confirmed as promulgated.

5. Groundwaters in the Lower Rio Grande Underground Water Basin as declared by Special Order No. 126 are hydrologically related to the Rio Grande.

6. The underground waters of the Lower Rio Grande Underground Water Basin as declared by Special Order No. 126 are public waters and have reasonably ascertainable boundaries.

II. IT IS THEREFORE ORDERED that State Engineer Special Order

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No. 126 declaring the Lower Rio Grande Underground Water Basin in Dona Ana County should be confirmed as promulgated.

Witness my hand and official seal this 22 day of October, 1980.

S. E. Reynolds
State Engineer

Reviewed and Approved:

Richard A. Simms
By Jay F. Stein Special Assistant Attorney General

Richard A. Simms
Special Assistant Attorney General

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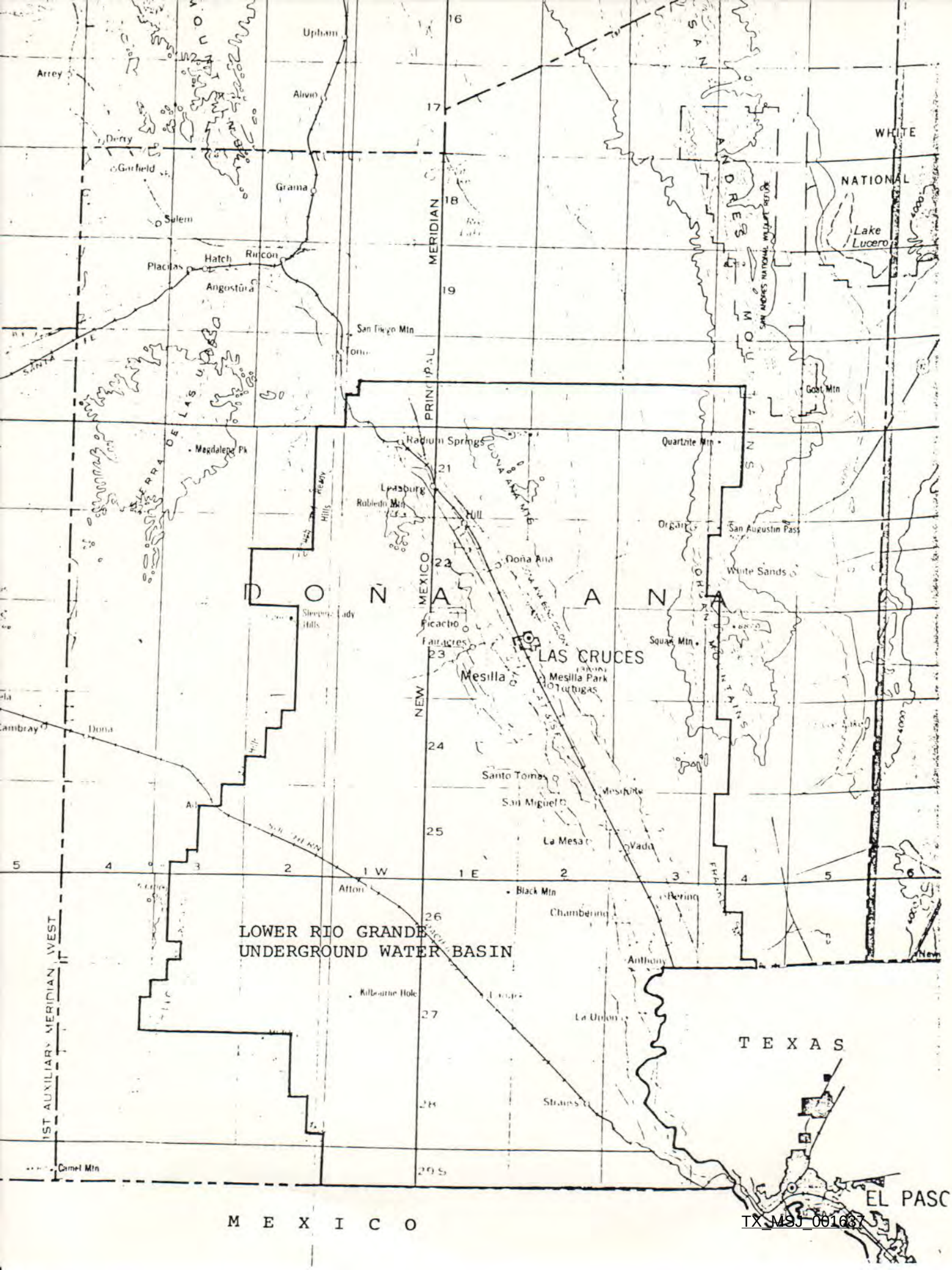

Upham
Arrey
Alivio
Derry
Garfield
Grama
Salem
Placitas
Hatch
Rincon
Angostura
San Diego Mtn
Magdalena Pk
Radium Springs
Leasburg
Robledo Mtn
Hill
Doña Ana
Picacho
Fairacres
LAS CRUCES
Mesilla
Mesilla Park
Tortugas
Santo Tomas
San Miguel
La Mesa
Vado
Afton
Black Mtn
Chamberino
Anthony
La Union
Strauss
Camel Mtn
Quartzite Mtn
Organ
San Augustin Pass
White Sands
Squaw Mtn
Goat Mtn
Lake Lucero
WHITE
NATIONAL
SAN ANDRES MOUNTAINS
SAN ANDRES NATIONAL WILDLIFE REFUGE
SIERRA DE LAS UVAS
SANTA FE
PRINCIPAL MERIDIAN
NEW MEXICO
1ST AUXILIARY MERIDIAN WEST
DOÑA ANA
LOWER RIO GRANDE
UNDERGROUND WATER BASIN
TEXAS
EL PASO
MEXICO

M E M O R A N D U M

September 10, 1980

To: S. E. Reynolds

From: D. E. Gray D. E. G.

Subject: Lower Rio Grande

On September 5, 1980, the City of El Paso, by and through its Public Service Board and others, filed suit in the U. S. District Court for the District of New Mexico against you and others seeking a declaration from the Court that Section 72-12-19 NMSA, 1978 is unconstitutional.

The City of El Paso is seeking a new ground water supply for its municipal use and if it is successful in the suit, would seek to drill wells into the Mesilla Bolson in New Mexico and pipe water to El Paso.

The principal aquifers in the Las Cruces area are the flood plain alluvium and the Santa Fe Group and they are interrelated with the Rio Grande. The Santa Fe Group comprises the upper sediments in the La Mesa Bolson (Mesilla Bolson). The source of recharge to these aquifers are precipitation on the watershed, water from the Rio Grande and return flow from irrigation. The river water and return flow from irrigation percolate downward into the alluvium and the deeper aquifers in the Mesilla Bolson. The appropriation of water from the deeper aquifers would have an effect on the surface waters of the Rio Grande in New Mexico.

There has been considerable publicity concerning El Paso's proposal to appropriate ground water in New Mexico. I am concerned that this publicity could cause a rash of speculative drilling by others in an attempt to commence the drilling of production wells before the State Engineer obtained jurisdiction over the ground water in this area. In addition, this office has received a petition from citizens in the area northeast of Las Cruces"to intervene in any manner appropriate in the matter of the utilization of this water by the City of Las Cruces." The City proposes to develop a well field north of U.S. 70 near two subdivisions and the petitioners are concerned about the effects of appropriating water from four municipal wells would have on the existing wells in the area.

Therefore, to protect existing water rights and insure orderly development of the ground water resource it is recommended that the Lower Rio Grande Underground Water Basin be declared to include the surface drainage of the Rio Grande stream system in New Mexico from the New Mexico-Texas state line on the south to above Radium Springs on the north, which encompasses approximately 1585 square miles. It

is further recommended that the administration of the basin be similar to that of the Rio Grande Basin where new appropriations of ground water are granted provided the effects of those appropriations on the Rio Grande are offset by the dedication and retirement of existing water rights.

Enclosed for your review are copies of the proposed State Engineer Order No. 126, press release and map. If the notice of declaration were published on September 18 and 25, 1980, it would be necessary to hold the public hearing between October 15 and 27, 1980.

54TH CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { DOCUMENT No. 125.

INTERNATIONAL DAM IN RIO GRANDE RIVER, NEAR EL PASO, TEX.

JANUARY 7, 1896.—Ordered to be printed.

Mr. HITT presented the following

LETTER FROM COL. ANSON MILLS, MAJOR TENTH CAVALRY, TO THE SECRETARY OF STATE, DATED DECEMBER 10, 1888.

EBBITT HOUSE,
Washington, D. C., December 10, 1888.

SIR: Agreeable to promise at our interview this a. m., I have the honor to submit the following general outline of my projected scheme for an international dam and water storage in the Rio Grande River, near El Paso, Tex., for the control of the annual floods and the preservation of the national boundary to the Gulf, and for other purposes.

The Rio Grande, 1,800 miles long, rises from an unusual number of tributaries in the very high altitudes of southern Colorado and northern New Mexico, where the rain and snow fall is extraordinary, and the ice formed therefrom in the long winter enormous. As it flows southward the precipitation gradually decreases for 600 miles, when the Mexican boundary is reached at El Paso, Tex., where there is neither snow nor ice, and but 8 inches annual rainfall; from thence 1,200 miles south, to the Gulf of Mexico, the rainfall is only sufficient to compensate for the loss by evaporation (which latter is very great), and for these reasons, the river has but few tributaries, and no increase of flow below El Paso.

The annual floods, caused by the melting of snow and ice in the mountains, take place in May and last for about seventy-five days, during which period the average flow may be estimated at 200 yards in width by 2 yards in depth, with a velocity of 5 miles per hour, although in recurring periods of about seven years it is much greater. During the remaining two hundred and ninety days of the year the average flow is perhaps not over 30 yards wide by 1 yard deep, with the same velocity, and in the same recurring periods, in the intervals between the high tides, the river goes dry for months, as it is at this time—or at least has no current, with not enough water in the pools to float the fish.

There is a present popular opinion that this want of water comes from its diversion by the numerous irrigating canals lately taken out in Colorado and New Mexico, and while it is problematical what effect this may have, if any, I am of the opinion that most of this water returns to the stream again, either through the atmosphere, by evaporation and precipitation, or by the earth, through overflow and drainage, as from personal observation I know that these seasons of flood and drought were of about the same character thirty years ago.

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After leaving the mountains the river passes through low valleys of bottom lands from 1 to 12 miles wide and from 4 to 8 feet above low-water level, of a light, sandy alluvium formed during annual overflows by sedimentary deposits from silt, which the water always carries in a greater or less degree.

In meandering along the Texan bank of the river, as a land surveyor, from the New Mexican line to a point below Fort Quitman, in 1858, 1859, and 1860, I observed that the deposit was from one-half inch to 3 inches annually, that during the floods the bed of the river was constantly changing by erosion and deposit, and that in regular cycles it shifted from one of its firm rocky or clay banks to the other, as the deposits had raised the side of the valley through which it then flowed above the level of the opposite side. Generally this change took place slowly, by erosion and deposit of matter entirely in suspension; but frequently hundreds of acres would be passed in a single day by a cut-off in a bend of one channel, and sometimes the bed would suddenly change from one firm bank to the other, a distance of perhaps 20 miles in length by 6 in width. For instance, when surveying "El Canutillo," a valley a short distance above El Paso, the river was moving westward, and about the middle of the valley, which was some 6 miles wide. Old Mexicans who had lived in the vicinity informed me that in 1821 the river ran close along the eastern bluff, where its bed was plainly to be seen, as was also a less plainly outlined bed along the bluffs on the opposite side, where the river flows at this date, and gives evidence of returning abruptly to the eastern bluffs again at the next greatest high tide, to its old channel along the bed of the track of the Santa Fe Railroad.

In another case, more recent and extensive, in the great valley below El Paso, some 12 miles in width and 20 miles long, the river, as was plainly evident at the time I was surveying the land, had made a sudden change from the bluffs on the eastern or Texan side to the western or Mexican side of the valley.

Mexicans who had been residents continuously in that vicinity informed me that this change took place in 1842.

Again, in 1884, in this vicinity, the river swept suddenly from the Mexican side, crossed the Southern Pacific Railroad, and destroyed both track and bed for a distance of 15 miles, stopping traffic for a period of three months and causing the removal of the road to hills above the valley.

Though these are the most extensive changes that came within my personal observation, similar ones are being made annually, from El Paso to the Gulf, which not only prevent the settlement and development of such of the lands as are sufficiently above the overflow (were the banks and boundaries secure), but, by reason of the river being the national boundary between the United States and Mexico for over 1,200 miles, cause fatal embarrassments to the citizens and officials of both Republics in fixing boundaries and titles to lands, in preventing smuggling, collecting customs, and in the legal punishment of all crimes and misdemeanors committed near the supposed boundary line, it being easy at almost any point in its great length to produce evidence sufficient to raise a reasonable doubt in the minds of the jurors as to which side of the line the arrest was made or the act committed.

At the last session of Congress the House passed a joint resolution (No. 112) requesting the President to appoint a commission, in conjunction with a similar one from the Republic of Mexico, to consider the matter above referred to. While surveying these lands in 1858, and prospecting for a crossing of the Rio Grande for the Memphis, El Paso

and Pacific Railroad, which was then projected—and in fact in course of construction—I examined the pass about 3 miles above the present city of El Paso, and discovered that it had solid rock bed and walls, the latter but about 400 feet apart, and that the valley above which came close down to the spur of the Rocky Mountains which crossed the river and formed the pass was from 4 to 8 miles wide, with a fall of about 4 feet to the mile, so that it would be an easy matter to build a dam in this pass and create an immense lake.

The water coming through this pass for ages has deposited at its lower end a great mass of rocks, over which is formed rapids with about 12 feet fall, and the aborigines of prehistoric ages made use of this to carry the water on to the lands below, no one knows how long ago, but it is known that the Mexicans have used it for two hundred years under most disadvantageous and unsatisfactory circumstances.

I have witnessed, each succeeding year, hundreds of Mexicans piling loose stones on the top of this drift of rocks to raise the level to that carried away by the floods of the preceding year; and it has been estimated by a federal engineer sent from the City of Mexico, that, had the labor thus expended been reduced to silver, the dam could have been built of the solid metal. The difficulty has been and always will be that there is neither bed rock nor solid earth in the bottom or banks, each being composed of quicksand.

In other places in the valley temporary willow dams 1 or 2 feet high are made at convenient places, and the water carried several miles below on to the lands that are above the usual overflow; but these dams are carried away annually and have to be rebuilt, and frequently the river bed moves miles away from the mouth of the ditch or acequia, rendering it useless; but even if these difficulties in carrying the water from the bed of the river to the lands are overcome in the usual manner, it is evident that by reason of a great overflow, say every seventh year, and a dry river in a like period, no system of irrigation for the Rio Grande can prove satisfactory that does not embrace a grand storage system sufficient both to restrain, to a great extent at least, the tidal flow and maintain a constant annual flow, especially since the great emigration and settlement in its valley is constantly doubling the demand for water.

Being on leave of absence in the city of El Paso recently, where I was a citizen before the war, having surveyed the first plat of the town and being well known to most of its citizens, I was invited by the city council to submit to it a plan for water supply and irrigation that would overcome the difficulties above referred to.

It at once occurred to me that as the Rio Grande was the joint property of the two nations and especially as the Mexicans had used its waters since time when "the memory of man runneth not to the contrary," that any plan to be acceptable and satisfactory must be international in character, and the works, both before and after completion under the joint federal control of the two nations, the more so as riparian rights in this country, so far as regards irrigation, are not well defined by law and could be best brought about in this instance by treaty stipulations between the two countries.

The matter of restraining the tidal flow by storing the water, and thus protect the constantly changing national boundary, occurred to me—if it could be introduced into the project—as likely to secure encouragement and substantial aid by liberal appropriations in money from both Governments.

And further, that El Paso, being now a city of over 11,000 population, and having every prospect of being a large manufacturing city at no distant day—there being no place within 500 miles likely to compete with it—the subject of water power ought also to enter into the problem, which of necessity is of such vast proportions as to require all incidental aid possible to attach to it to insure its success.

It will be apparent, from what has been written, that the Rio Grande is one of the first magnitude, not only in length and breadth, but for short, annual periods in devastating flow of waters, and that its general characteristics, as compared with other rivers, with reference to irrigation, are so abnormal as to require different or more heroic treatment.

I therefore projected a scheme which may be briefly outlined as follows:

To build a strong dam of stones and cement—say 60 feet high—in the pass before referred to and by submerging about 60,000 acres of land now subject to overflow and of little comparative value, create a vast lake 15 miles long by 7 wide, with a probable storage capacity of 4,000,000,000 cubic yards of water; place gates on each side of the river in the dam at the 50-foot level for wastewiers and irrigating canals to supply each side of the river and keep up a flow in its bed which would bring the water in the canals 70 feet above the streets in the cities of El Paso and Juarez, respectively.

The gates at the 50-foot level would give an available reserve of water of 10 feet over the entire surface of the lake—over 2,000,000,000 cubic yards—which would be exhausted during the long season of little flow for the purposes of irrigation and other needs, as well as maintaining a constant stream in the river beds so arranged as to exhaust the reserve about the period of annual flood, which would be checked and held in reserve for the next season of little flow, and in this manner produce a comparatively constant and unvarying flow of water for each entire year below the dam, redeeming many times the number of acres submerged above in the lake from overflow below, and fixing permanently the national boundary, the banks of the river, as well as the boundaries and titles to private lands, and making it an easy matter to collect duties and prevent smuggling, detect crimes and misdemeanors generally, arrest and punish criminals, as it is along other national boundaries.

The assumed flow given for the seventy-five days of high water will give about 6,500,000,000 cubic yards, and that for the remaining two hundred and ninety days 1,500,000,000, making an aggregate annual flow of 8,000,000,000 cubic yards. If we allow 2,000,000,000 of this for loss by evaporation and other wastes, which former in this dry atmosphere is very great, perhaps 20 inches, we have 6,000,000,000 cubic yards remaining. This should be divided into three equal parts, one for each side of the river, for irrigation and other needs, and the third for overflow, through water motors, to furnish power to the future manufacturing cities on each side and to maintain a constant flow in the river below to the Gulf, as would no doubt be demanded by the people there as their right ere they would permit the scheme to be carried out.

The 2,000,000,000 cubic yards falling a distance of 50 feet over the dam, estimating the weight of a cubic yard of water at 500 pounds, and 1 horsepower the energy required to lift 33,000 pounds 1 foot in a minute, would expend energy equal to over 10,000 horse power for eight hours every day in the year, and produce a constant stream in the bed of the river 26 yards wide by 1 foot deep, running with a velocity of 5 miles per hour, to say nothing of the probability that the

greater part of the other two-thirds would find its way again to the river bed through the earth and air, the whole flowing in a steady, continuous stream to the mouth of the river to be used as required at any season of the year, instead of, as is now the case, six-eighths of the entire mass of the annual flow going rapidly to the Gulf in the short period of seventy-five days untaxed.

Estimating the amount of water required for annual irrigation at 20 inches, the water reserved for that purpose would be sufficient for 1,000,000 acres on each side of the river—all that could be reclaimed from the desert for 100 miles below.

To carry out this project I recommended to the people on each side of the Rio Grande that they petition to the executive authority of their respective nations for the creation of a joint commission to draw up the necessary treaty stipulations to protect the work and the rights of all interested in them, the fundamental feature of which should certainly be that each nation should have the right to divert no more than one-third of the flow at any period, and that one-third of the flow should be maintained in the bed of the river, and that this international commission have charge and control of the work after completion as well as during construction.

That the legislative authorities of the two nations be asked to appropriate, after complete investigations and estimates have been made, money sufficient to complete the work, probably $100,000 for the dam proper, $100,000 for the condemnation of the 50,000 acres of land to be submerged, and $100,000 for the removal of some 15 miles of the road bed of the Atchison, Topeka and Santa Fe Railroad to bluffs above the old bed of the river, where the track now lies, subject to annual damage, and sooner or later total destruction, unless removed.

It will also be apparent that the waters of this great lake will be clear and fresh, the silt held in suspension in the current of the river being precipitated as soon as it enters the still water of the lake, doing away with the great trouble and expense now necessary in keeping the canals and ditches cleansed of sedimentary deposits, and a further great benefit derived from using water reduced in temperature by exposure for months in a warm climate far below that used in the early spring, which comes in three days from snow and ice and is immediately applied to the young and tender sprouting plants, chilling and checking their growth.

I know of no point in the Rio Grande, between Alberquerque and the Gulf of Mexico, where nature has provided both the natural basin and rim for a lake of such great dimensions, for indeed it can be made 100 feet deep if desired, and it may be questioned whether a depth of 60 feet, with 10 feet reserve to draw from, will afford sufficient storage to control perfectly the tide at its highest flow.

This project was well received by the people and has been earnestly discussed in the public press of the locality ever since, with general approbation and a disposition to endeavor to carry it out as quickly as possible; the only question exciting any general distrust being that of the sedimentary deposit in the lake, it is held by some, will shorten the life of the reservoir by filling the lake at such an early period as to render the scheme of doubtful expediency, and opinions differ very widely upon this subject, which is, indeed, a problematical one, and can only be determined, even approximately, by actual measurements of a great majority of the annual flow, for the quantity of sediment changes with flow and season.

That the bed of the river will eventually be filled, of course, is only a

matter of time, but whether in fifteen or one hundred and fifty years, can only be ascertained by prolonged, actual measurements; but, even if filled in the near future, it seems to me that the difficulty may be overcome by raising the dam, unless, indeed, that should be required too often.

The matter has already been referred to Major Powell, chief of the Geological Survey, who has sent Capt. Clarence Dutton, of his Department, to El Paso, to investigate and report on the feasibility of the scheme, but as the initial steps, should it be pronounced feasible, must come from your Department in the nature of international treaty stipulations, I have thought it proper to thus early acquaint you with the grand project.

I beg to refer you to Hon. Mr. Lanham, Member of Congress from Texas, who is acquainted with me personally and my projected scheme.

ANSON MILLS,
Major Tenth Cavalry,
Brevet Lieutenant-Colonel, United States Army.

The SECRETARY OF STATE,
Washington, D. C.

CONCURRENT RESOLUTION concerning the irrigation of arid lands in the valley of the Rio Grande River, the construction of a dam across said river at or near El Paso, Tex., for the storage of its waste waters, and for other purposes.

Whereas the Rio Grande River is the boundary line between the United States and Mexico; and

Whereas by irrigating ditches and canals taking the water from said river, and other causes, the usual supply of water therefrom has been exhausted before it reaches the point where it divides the United States of America from the Republic of Mexico, thereby rendering the lands in its valley arid and unproductive, to the great detriment of the citizens of the two countries who live along its course; and

Whereas in former years annual floods in said river have been such as to change the channel thereof, producing serious avulsions and oftentimes and in many places leaving large tracts of land belonging to the people of the United States on the Mexican side of the river and Mexican lands on the American side, thus producing a confusion of boundary, a disturbance of private and public titles to lands, as well as provoking conflicts to jurisdiction between the two Governments, offering facilities for smuggling, promoting the evasion and preventing the collection of revenues by the respective countries; and

Whereas these conditions are a standing menace to the harmony and prosperity of the citizens of said countries and the amicable and orderly administration of their respective Governments, therefore,

Resolved by the Senate (the House of Representatives concurring), That the President be requested, if, in his opinion, it is not incompatible with the public interests, to enter into negotiations with the Government of Mexico with a view to the remedy of all such difficulties as are mentioned in the preamble to this resolution, and such other matters connected therewith as may be better adjusted by agreement or convention between the two Governments.

The President is also requested to include in the negotiation with the Government of Mexico all other subjects which may be deemed to affect the present or prospective relations of both Governments.

Passed April 29, 1890.

TX_MSJ_001645

RG 48 RECORDS OF THE OFFICE OF THE SECRETARY OF THE INTERIOR

Records Relating to Reclamation Projects

RECORDS RELATING TO SPECIFIC RECLAMATION PROJECTS

1889-1907

Entry 631

Box No. 41

Rio Grande, Rouge Canyon, Sacremento Valley, Saint Mary's River, Salt River

Box No.41 Entry 631

TX_MSJ_001646

RG48 E-631

RIO GRANDE PROJECT
Contracts
Suspension of Applications for use of water of the Rio Grande

125
-190
35
40
75

TX_MSJ_001647

DEPARTMENT of the INTERIOR,
RECEIVED
DEC 19 1896
L. & R. R. DIV.
6105

DEPARTMENT OF THE INTERIOR,

J.W.L. WASHINGTON J.L.
G.B.G.

December 5, 1896.

The Commissioner of the
General Land Office.

Sir:

Your office is hereby directed to suspend action on any and all applications for right of way through public lands for the purpose of irrigation by using the waters of the Rio Grande river or any of its tributaries, in the State of Colorado or in the Territory of New Mexico, until further instructed by this Department.

Very respectfully,

D. B. Francis

Secretary.

TX_MSJ_001648

THE

STATUTES AT LARGE

OF THE

UNITED STATES OF AMERICA,

FROM

DECEMBER, 1901, TO MARCH, 1903,

CONCURRENT RESOLUTIONS OF THE TWO HOUSES OF CONGRESS,

AND

RECENT TREATIES, CONVENTIONS, AND EXECUTIVE PROCLAMATIONS.

EDITED, PRINTED, AND PUBLISHED BY AUTHORITY OF CONGRESS, UNDER THE DIRECTION OF THE SECRETARY OF STATE.

VOL. XXXII.—PART 1.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

TX_MSJ_001649

LIST

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June 17, 1902.

[Public, No. 161.]

CHAP. 1093.—An Act Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

Irrigation. "Reclamation fund" established from certain public land receipts.

Post, p. 1119.

Exception.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all moneys received from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming, beginning with the fiscal year ending June thirtieth, nineteen hundred and one, including the surplus of fees and commissions in excess of allowances to registers and receivers, and excepting the five per centum of the proceeds of the sales of public lands in the above States set aside by law for educational and other purposes, shall be, and the same are hereby, reserved, set aside, and appropriated as a special fund in the Treasury to be known as the "reclamation fund," to be used in the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in the said States and Territories, and for the payment of all other expenditures provided for in this Act: *Provided*, That in case the receipts from the sale and disposal of public lands other than those realized from the sale and disposal of lands referred to in this section are insufficient to meet the requirements for the support of agricultural colleges in the several States and Territories, under the Act of August thirtieth, eighteen hundred and ninety, entitled "An Act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts, established under the provisions of an Act of Congress approved July second, eighteen hundred and sixty-two," the deficiency, if any, in the sum necessary for the support of the said colleges shall be provided for from any moneys in the Treasury not otherwise appropriated.

Proviso. Support of agricultural, etc., colleges.

Vol. 26, p. 417.

Vol. 12, p. 503.

Deficiency.

Location and construction of irrigation works.

SEC. 2. That the Secretary of the Interior is hereby authorized and directed to make examinations and surveys for, and to locate and construct, as herein provided, irrigation works for the storage, diversion, and development of waters, including artesian wells, and to report to Congress at the beginning of each regular session as to the results of such examinations and surveys, giving estimates of cost of all contemplated works, the quantity and location of the lands which can be irrigated therefrom, and all facts relative to the practicability of each irrigation project; also the cost of works in process of construction as well as of those which have been completed.

Estimates of cost.

Lands withdrawn from public entry.

SEC. 3. That the Secretary of the Interior shall, before giving the public notice provided for in section four of this Act, withdraw from public entry the lands required for any irrigation works contemplated under the provisions of this Act, and shall restore to public entry any of the lands so withdrawn when, in his judgment, such lands are not required for the purposes of this Act; and the Secretary of the Interior is hereby authorized, at or immediately prior to the time of beginning the surveys for any contemplated irrigation works, to withdraw from entry, except under the homestead laws, any public lands believed to be susceptible of irrigation from said works: *Provided*, That all lands entered and entries made under the homestead laws within areas so withdrawn during such withdrawal shall be subject to all the provisions, limitations, charges, terms, and conditions of this Act; that said surveys shall be prosecuted diligently to completion, and upon the completion thereof, and of the necessary maps, plans, and estimates of cost, the Secretary of the Interior shall determine whether or not said project is practicable and advisable, and if determined to be impracticable or unadvisable he shall thereupon

Restoration.

Entry of irrigable lands.

Provisos. Homestead entries.

Surveys, etc.

restore said lands to entry; that public lands which it is proposed to irrigate by means of any contemplated works shall be subject to entry only under the provisions of the homestead laws in tracts of not less than forty nor more than one hundred and sixty acres, and shall be subject to the limitations, charges, terms, and conditions herein provided: *Provided*, That the commutation provisions of the homestead laws shall not apply to entries made under this Act.

Commutation not allowed.

SEC. 4. That upon the determination by the Secretary of the Interior that any irrigation project is practicable, he may cause to be let contracts for the construction of the same, in such portions or sections as it may be practicable to construct and complete as parts of the whole project, providing the necessary funds for such portions or sections are available in the reclamation fund, and thereupon he shall give public notice of the lands irrigable under such project, and limit of area per entry, which limit shall represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question; also of the charges which shall be made per acre upon the said entries, and upon lands in private ownership which may be irrigated by the waters of the said irrigation project, and the number of annual installments, not exceeding ten, in which such charges shall be paid and the time when such payments shall commence. The said charges shall be determined with a view of returning to the reclamation fund the estimated cost of construction of the project, and shall be apportioned equitably: *Provided*, That in all construction work eight hours shall constitute a day's work, and no Mongolian labor shall be employed thereon.

Contracts.

Public notice of irrigable lands, charges, etc.

Proviso. Limit of work hours. Mongolian labor.

SEC. 5. That the entryman upon lands to be irrigated by such works shall, in addition to compliance with the homestead laws, reclaim at least one-half of the total irrigable area of his entry for agricultural purposes, and before receiving patent for the lands covered by his entry shall pay to the Government the charges apportioned against such tract, as provided in section four. No right to the use of water for land in private ownership shall be sold for a tract exceeding one hundred and sixty acres to any one landowner, and no such sale shall be made to any landowner unless he be an actual bona fide resident on such land, or occupant thereof residing in the neighborhood of said land, and no such right shall permanently attach until all payments therefor are made. The annual installments shall be paid to the receiver of the local land office of the district in which the land is situated, and a failure to make any two payments when due shall render the entry subject to cancellation, with the forfeiture of all rights under this Act, as well as of any moneys already paid thereon. All moneys received from the above sources shall be paid into the reclamation fund. Registers and receivers shall be allowed the usual commissions on all moneys paid for lands entered under this Act.

Requirements of entryman.

Limit.

Payments.

Disposal of receipts.

Commissions.

SEC. 6. That the Secretary of the Interior is hereby authorized and directed to use the reclamation fund for the operation and maintenance of all reservoirs and irrigation works constructed under the provisions of this Act: *Provided*, That when the payments required by this Act are made for the major portion of the lands irrigated from the waters of any of the works herein provided for, then the management and operation of such irrigation works shall pass to the owners of the lands irrigated thereby, to be maintained at their expense under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior: *Provided*, That the title to and the management and operation of the reservoirs and the works necessary for their protection and operation shall remain in the Government until otherwise provided by Congress.

Use of reclamation fund.

Provisos. Ownership of works.

Title.

SEC. 7. That where in carrying out the provisions of this Act it becomes necessary to acquire any rights or property, the Secretary of

Condemnation for rights, etc.

the Interior is hereby authorized to acquire the same for the United States by purchase or by condemnation under judicial process, and to pay from the reclamation fund the sums which may be needed for that purpose, and it shall be the duty of the Attorney-General of the United States upon every application of the Secretary of the Interior, under this Act, to cause proceedings to be commenced for condemnation within thirty days from the receipt of the application at the Department of Justice.

Irrigation laws of States and Territories not affected.

SEC. 8. That nothing in this Act shall be construed as affecting or intended to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water used in irrigation, or any vested right acquired thereunder, and the Secretary of the Interior, in carrying out the provisions of this Act, shall proceed in conformity with such laws, and nothing herein shall in any way affect any right of any State or of the Federal Government or of any landowner, appropriator, or user of water in, to, or from any interstate stream or the waters thereof: *Provided*, That the right to the use of water acquired under the provisions of this Act shall be appurtenant to the land irrigated, and beneficial use shall be the basis, the measure, and the limit of the right.

Interstate streams.

Proviso. Basis of use.

Expenditure of funds.

SEC. 9. That it is hereby declared to be the duty of the Secretary of the Interior in carrying out the provisions of this Act, so far as the same may be practicable and subject to the existence of feasible irrigation projects, to expend the major portion of the funds arising from the sale of public lands within each State and Territory hereinbefore named for the benefit of arid and semiarid lands within the limits of such State or Territory: *Provided*, That the Secretary may temporarily use such portion of said funds for the benefit of arid or semiarid lands in any particular State or Territory hereinbefore named as he may deem advisable, but when so used the excess shall be restored to the fund as soon as practicable, to the end that ultimately, and in any event, within each ten-year period after the passage of this Act, the expenditures for the benefit of the said States and Territories shall be equalized according to the proportions and subject to the conditions as to practicability and feasibility aforesaid.

Proviso. Temporary use.

Equalization of benefits.

Regulations, etc.

SEC. 10. That the Secretary of the Interior is hereby authorized to perform any and all acts and to make such rules and regulations as may be necessary and proper for the purpose of carrying the provisions of this Act into full force and effect.

Approved, June 17, 1902.

June 18, 1902.

[Public, No. 162.]

CHAP. 1121.—An Act To authorize the Nashville Terminal Company to construct a bridge across the Cumberland River in Davidson County, Tennessee.

Cumberland River. Nashville Terminal Company may bridge, at Nashville.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled; That the Nashville Terminal Company, a corporation created and organized under the laws of the State of Tennessee, be, and is hereby, authorized to construct and maintain, for the passage of railway trains, a bridge, and approaches thereto, over the Cumberland River at any point in the county of Davidson in said State within five miles above or within five miles below the corporate limits of the city of Nashville, in said county, which said company may deem most advantageous, and which may be approved by the Secretary of War.

Secretary of War to approve plans, etc.

SEC. 2. That said bridge shall be located and built under such regulations for the security of navigation as the Secretary of War shall prescribe; and to secure that object the said company shall submit to the Secretary of War for his examination and approval a design and drawing of the bridge, and a map of the location, giving for such

Official proceedings

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TWELFTH NATIONAL IRRIGATION CONGRESS

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OFFICIAL PROCEEDINGS

EL PASO, TEXAS.

Nov. 15-18, ·1904·

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THE OFFICIAL PROCEEDINGS

OF THE

TWELFTH
NATIONAL IRRIGATION CONGRESS

HELD AT

El Paso, Texas, Nov. 15-16-17-18, 1904

COMPILED AND EDITED

BY

GUY ELLIOTT MITCHELL,
Chairman Press Bureau

BY ORDER

THE EXECUTIVE COMMITTEE

A. W. GIFFORD,
Secretary

CHARLES B. BOOTHE,
Chairman

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For Index see end of Volume.

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1905

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CONSTITUTION

OF

The National Irrigation Congress

ARTICLE I.

The Congress shall meet at such time as shall be fixed by the Executive Committee, and at such place as shall be designated by the previous Congress.

ARTICLE II.

The permanent officers of the Congress shall consist of a President, three Vice Presidents, a Secretary, and such assistants to the Secretary as the Executive Committee, consisting of one member from each State and Territory, who shall be selected by the delegation of their respective States and Territories, shall determine. The President shall be ex-officio member of the Executive Committee.

ARTICLE III.

The Executive Committee shall select its own chairman and secretary and sub-committees.

The Executive Committee shall have charge of the interests of the Congress between its sessions, arrange the preliminaries for its meetings, and take such steps as they may deem proper to bring its recommendations to the attention of the Congress of the United States and urge their adoption.

The Executive Committee shall elect its Treasurer, who shall have charge of its funds, and no indebtedness shall be incurred unless the funds are on hand to meet it.

The Executive Committee shall divide the work of each Congress into three or more sections, each of which shall have a chairman, who shall be responsible for the carrying out of the work intrusted to that section, and through whom all correspondence pertaining to that section shall be carried on.

The necessary funds for defraying the expenses incurred by the Executive Committee shall be provided for as follows: First, from the local committee at the location where the succeeding Congress is designated to be held; second, from such other sources as the Executive Committee may find expedient.

ARTICLE IV.

The length of each session shall be determined by the Executive Committee, and the election of officers shall take place at 11:00 a. m. of the last day of each session.

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ARTICLE V.

The Executive Committee shall require from the chairman of each section named in Article III, not less than two weeks previous to the date of meeting of each Congress, a list of speakers provided for that section, and a copy in duplicate of the papers to be presented in that section of the Congress, which correspondence from the chairman of each section shall be directed to the Secretary of the Executive Committee.

ARTICLE VI.

The membership of the Congress shall be as follows: Fifteen delegates from each State and Territory, to be appointed by their respective Governors; five delegates from each town and city of the United States having a population of less than 25,000, to be appointed by its Mayor or chief executive; ten delegates from each city having a population of over 25,000, to be appointed by its Mayor; five delegates from each county, to be appointed by the chairman of the governing board; two delegates each from regularly organized irrigation, agricultural and horticultural societies, societies of engineers, agricultural colleges, and commercial bodies; each member of any state or territorial irrigation commission; also state commissioners of agriculture or horticulture; the chairman of each section and the permanent officers of the Congress; also the Governor of each State and Territory, and all members of the United States Senate and House of Representatives.

At the opening of each annual session, and from time to time during said session of the Congress, the Secretary shall report the names on the official register of delegates accredited to the Congress, and such report, when accepted and approved by the Congress, shall constitute the persons so reported members of said Congress.

ARTICLE VII.

Each member of the Congress shall be entitled to one vote; *provided,* no State shall have more than twenty votes; and *provided,* when a State is represented by less than ten delegates, said delegates, if all present, may cast ten votes for said State; if some of the delegates of said States are absent, those remaining may cast their proportion of ten votes.

ARTICLE VIII.

This Constitution may be amended by a two-thirds vote of the delegates of any Congress, under the provisions contained in Article VII.

ARTICLE IX.

The Executive Committee shall have power to fill vacancies and shall make its own by-laws and rules of procedure.

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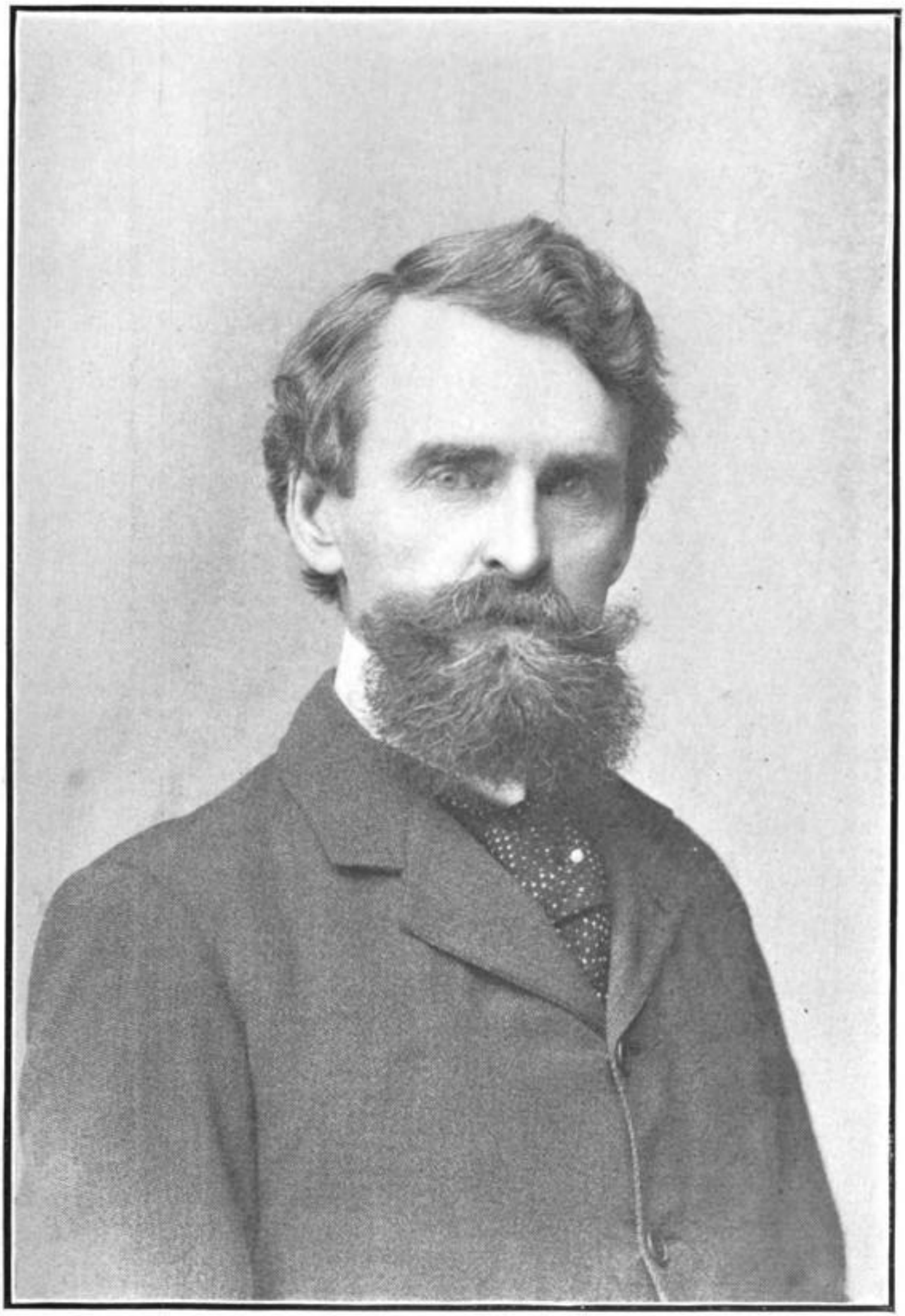

HON. W. A. CLARK,
U. S. SENATOR FROM MONTANA,
President 12th National Irrigation Congress.

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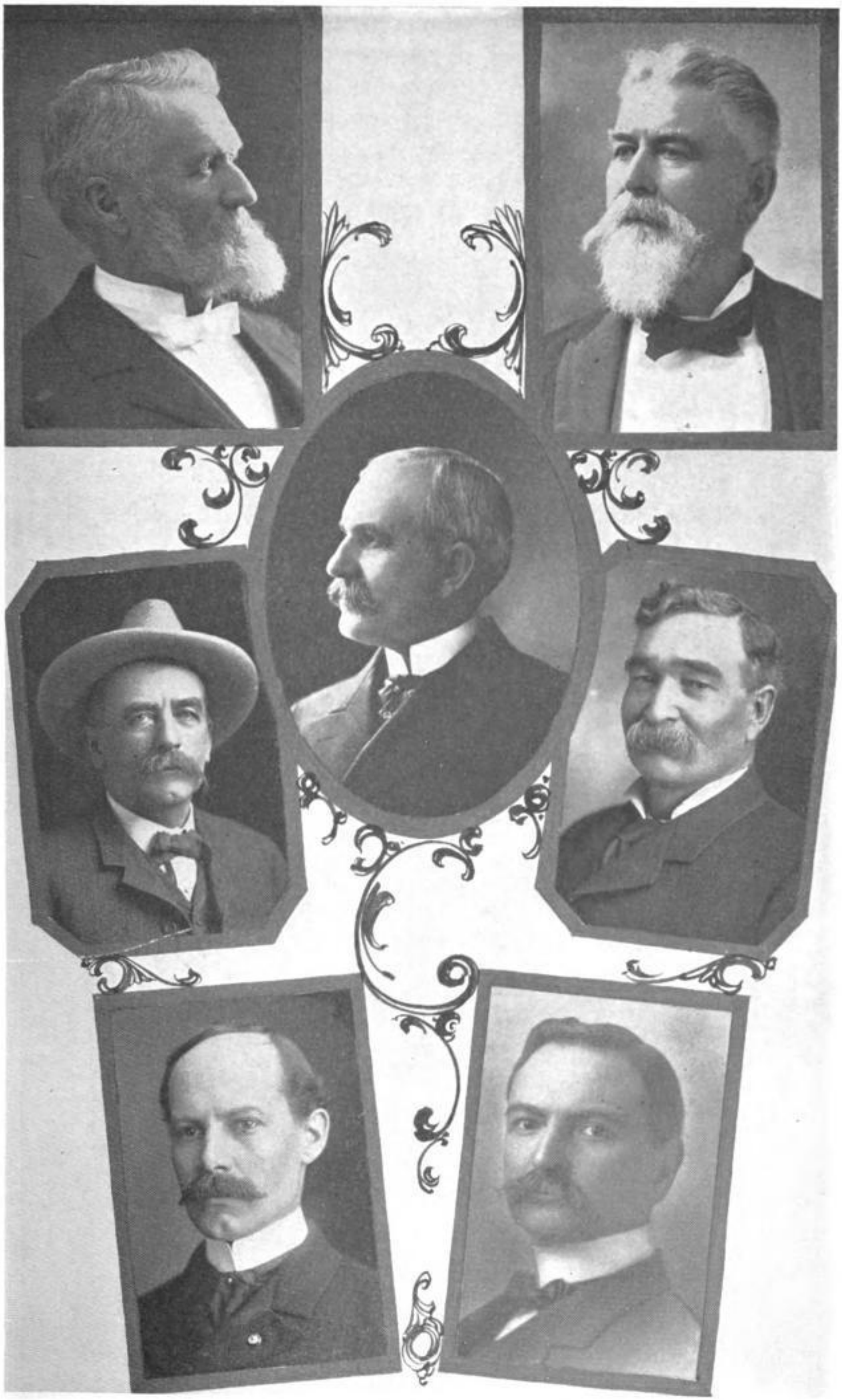

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12TH NATIONAL IRRIGATION CONGRESS

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About El Paso, Texas.

El Paso, Texas, is a city of 30,000 inhabitants, situated in the extreme western part of the State on the Rio Grande, which here separates Texas from Mexico and New Mexico.

El Paso commercially occupies a quique strategic position: there is no other city so large, so important, or so well supplied with natural and artificial advantages, within a radius of 600 miles in any direction. The nearest commercial cites of note are: on the east, San Antonio and Fort Worth; on the north, Denver and Kansas City; on the west, Los Angeles; on the south, the City of Mexico.

In the order of their importance as wealth producers for the population of El Paso and tributary territory, the principal occupations, resources, and assets of this community are: First, mining; second, trade; third, transportation; fourth, live stock; fifth, agriculture; sixth, manufacturing.

Agriculture is at present of comparatively little importance, but the possibilities of development in this industry are greater than in any other, as will be presently shown.

MINING.

Mining dominates El Paso's trade development, industry and life. It is mining that, above all other considerations, makes the basis of El Paso's wealth and prosperity permanent and certain to increase in value.

El Paso is at the center of a vast mineral zone, whose development has as yet barely begun.

The mines in El Paso's circle of commercial influence produce annually $150,000,000 in mineral wealth.

The custom smelters in El Paso's trade territory pay $100,000,000 annually for the ores brought to them for reduction; much of this money naturally flows into El Paso's trade channels, directly or indirectly, and represents a constant influx of ready cash from the great purchasing and manufacturing markets of north and east and Europe, into the Great Southwest.

Ores come to the El Paso Smelter from as much as five or six hundred miles distant, and El Paso is the primary distributing point for mining machinery, hardware and supplies for a district larger than the State of Texas.

The distribution of mineral wealth about the city is interesting to note. North and northeast, the dominant product is coal; east, quicksilver is the best known product; southeast, iron controls; south, silver; southwest, gold; west and northwest, copper.

The coal deposits are the greatest west of the Mississippi river; the quicksilver mines are almost the only ones in the United States operated commercially; the iron deposits are among the most extensive on the conti-

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nent; the silver district contains some of the world's greatest producers; the gold of northern Mexico is famous; the copper region, taken as a whole, is the greatest in the world.

TRADE.

To the casual visitor in El Paso the most prominent feature of the city's life is the extraordinary commercial activity. El Paso, the city itself, is a city of trade. El Paso is always spoken of by visitors as the busiest city of its size in the United States.

El Paso's jobbing territory, the country actually covered by her traveling salesmen and dominated by El Paso commercially, extends over a region more than 500 miles in diameter.

The jobbing trade of this city is all the time increasing. El Paso has the advantage of cheap rates in, and fair rates out. This city being an important terminal point, with a number of competing lines stretching in every direction, we get the benefit of rates usually accorded only to towns with a much larger original traffic. Aside from the question of rates, there is the even more important consideration, in some classes of business, of quick delivery. This factor is particularly important in the mining industry.

Outside of El Paso's actual jobbing territory there is a zone where there are hundreds of mines and prospects dependent on the El Paso smelter to purchase and reduce their ores. The cash received by these miners from the El Paso smelter is largely spent in El Paso for supplies. The miners often visit the city and do their buying in person, thus adding to the city's retail trade. The same is true of the live stock interests.

El Paso's retail stores derive considerable advantage from the fact that there is no other city within 600 miles that carries such costly and complete stocks of goods as El Paso's stores carry.

This city, owing to its high altitude and wonderful climate, is gaining merited recognition as a summer resort as well as a winter resort. The travel through here is always large, and the retail trade benefits from it throughout the year.

TRANSPORTATION.

The transportation interests of El Paso and the Great Southwest are of enormous importance, commercially.

Nine railroads have terminals in El Paso, six of which are great trunk lines. All the roads have numerous branches which are helping to develop the mining, stock, and agricultural country tributary to the city.

The freight movement on these El Paso lines is steady and perennial, being made up mainly of fuel, provisions, machinery and other staples always in demand, together with ores and other products of mining and live stock. Through traffic, both passenger and freight, is heavy all the year, and El Paso takes toll of it all.

The railroad pay rolls in El Paso form one of the most important sources of income, amounting to upwards of $1,500,000 annually.

A $280,000 union passenger depot to be used by all the roads is in course of construction.

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LIVE STOCK.

Large cattle ranches are found in all directions from El Paso, both in the United States and in Mexico, and the grazing industry is one of the most extensive and valuable resources of the city. Some of the lands hereabouts formerly occupied as cattle ranches have been or will be turned into farms, but stock growing will always be a leading industry in this part of the Great Southwest.

El Paso has all the necessary advantages for making one of the country's greatest cattle markets. Many wealthy stockmen make their homes, as well as their business headquarters, here. The El Paso union stock yards are connected with all the railroads, and last year took care of nearly 300,000 head of live stock. Much of the movement was from Mexico to Canada and the northern United States, but the greater part of the traffic was made up of stock moving from Texas and New Mexico ranges to California, Oregon and the feeding grounds of the Missouri valley.

AGRICULTURE.

The Rio Grande valley, both above and below El Paso, has been cultivated since the first Spanish explorers entered the country, and no doubt the ancient Pueblos had prior to that utilized other portions of the valley besides the northrn part where Coronado discovered them. The earliest Spanish chroniclers record the presence in the valley of domestic Indians, who farmed by means of irrigation dams and ditches, and well understood the extraordinary richness of the alluvial bottom lands.

It was not until the coming of the railroads and the large influx of new settlers some 20 years ago that Americans began to farm the valley on any considerable scale, or that modern methods began to be introduced. Now scores of pumping plants are at work in the valley watering thousands of acres of land.

The Mesilla and El Paso valleys are famous for their tree fruits, grapes, melons and early vegetables. Immense quantities of alfalfa are produced, but still not nearly enough to supply the home demand. This deficiency in product is true also of grain, garden truck, and some fruits, as well as poultry and fresh and canned food products generally.

Outside of El Paso there is a vast territory that would be be naturally supplied from this valley if the product of food stuffs were sufficient. It is safe to say that the valley does not now supply over ten per cent of this natural market. Yet in the valley from a point 50 miles north to a point 50 miles south of El Paso, there are 150,000 acres of cultivable land which ought to be and will eventually be brought into cultivation by modern methods of irrigation.

At the recent session of the National Irrigation Congress at El Paso, action was taken by representatives of New Mexico, Texas and Mexico that will, it is hoped, make it possible to commence soon the erection, under the provisions of the National Reclamation Act, of a vast dam or reservoir at a point 125 miles above El Paso on the Rio Grande, that will store water

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sufficient to irrigate, even in the dryest years, 180,000 acres of valley land, including some 25,000 in Mexico which possess water rights on the stream.

Water users' associations have already been formed by the people of the valley, and all the interests are working hard for the early consummation of this great project. The plan involves the expenditure of $7,200,000, which will impose a charge of $40 per acre on the land to be irrigated. But the farmers welcome the opportunity, because at the end of ten years the payments of $4 per acre per year will cease, and even that amount is much less than the cost of running a pumping plant, and not much more than has been paid to private canal companies for a service which failed more often than it supplied water.

There is no other opening in the United States for the farmer-irrigator so promising as this. Climate, soil, market, and all other conditions for successful farming and pleasant living are here unsurpassed. Under intensive farming 10 to 20 acres will support a family. It is plain that this Rio Grande valley would easily support 50,000 people engaged in tilling the soil.

Thus, while agriculture is not now among the most important local industries, its possibilities are greater than those of any other. There is room for more people in this industry without a chance of overcrowding than in any other branch of activity. There is a steady and increasing home market for the bulk of the product, and a demand impossible to satisfy, on the part of the northern and eastern markets, for our early fruits and vegetables.

MANUFACTURING.

El Paso's manufacturing industries are largely devoted to supplying home demands. The most conspicuous exception, however, is also El Paso's most important single industry—smelting.

The principal El Paso smelter has a pay roll of $60,000 a month, and maintains a community of 3500 people in an El Paso suburb. It reduces a ton of ore every minute in the year, running 24 hours a day and seven days a week.

One of the largest industrial enterprises is a dairy which is described by the world dealing directly with the consumer. This concern milks 350 to Secretary Wilson, of the Department of Agriculture, as the biggest dairy in 400 cows regularly, and delivers milk and cream to its own customers in iced sterilized bottles several times a day; it also does an extensive business in beef and dairy cattle and runs one of the most extensive alfalfa ranches in the valley. It has an important export and railroad trade.

Among the manufacturing concerns which ship goods out of the city are factories for the manufacture of office fixtures, blank books, boots and shoes, candy, carriages and wagons, brick, beer, cigars, clothing, Mexican curios, engines, boilers and mining machinery, ice, soap, lime, saddles and harness, trunks and valises, vinegar and cider.

As in agriculture, manufacturing in this locality has the vast advantage of enjoying a steady and always expanding home market, while the distances from which competing products must be brought mean heavy freight charges that would amount to a protective tariff for local industries. Steam coal is

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not expensive and other forms of power are readily available. Fine water for boiler use can be had at no great outlay.

Labor conditions generally in El Paso are satisfactory to an extraordinary degree. El Paso has never had a strike of any consequence.

ADVANTAGES TO HOMEMAKERS.

El Paso is a city that quickly becomes home to the newcomer. It is supplied with every modern convenience and advantage. The public schools are kept at the highest standard, and a certificate from them admits without examination to many of the great universities. Every important religious denomination is represented among the churches. There are scores of lodges of all varieties. The social life of the city is cosmopolitan and elevated. There are all kinds of social and educational clubs for men and women, boys and girls. El Paso has a free public library, and plenty of facilities for amusement. There are three daily newspapers with the telegraphic news service of the Associated Press. Nearly every family possesses its own home. The climate is unequaled in the world for its invigorating and curative qualities, and for its perpetual sunshine under conditions of altitude, dryness, and continual breezes that prevent any relaxation of physical energy. The spirit of the people is intensely progressive, thoroughly western. Altogether there is no pleasanter place to be found than El Paso, in which to make one's home and do one's work.

For further information apply to the Secretary of the Chamber of Commerce, El Paso, Texas.

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OFFICIAL PROCEEDINGS

OF THE

Twelfth National Irrigation Congress

FIRST GENERAL SESSION,

Tuesday Morning, November 15, 1904.

The Congress was called to order in the large convention hall at 10:30 a. m. by Senator W. A. Clark, of Montana, President.

President Clark—Ladies and Gentlemen: This 12th National Irrigation Congress will now come to order, and I will take pleasure in introducing to you the Reverend H. W. Moore, who will pronounce the invocation.

INVOCATION.

Reverend Mr. Moore—Almighty God, our Heavenly Father, the earth and the fullness thereof, and they that dwell therein are the Lord's. Thy kingdom ruleth over all and ruleth forevermore. Conscious of our dependence upon Thee, our Heavenly Father, for all that makes for wise counsel and for good conduct, we look up to Thee this morning for Thine almighty aid and guidance during the deliberations of this great National Congress. We pray that Thy blessing may rest upon the officers and upon the members of this Congress; that Thou wilt give them sound judgment, and we pray Thee that unity and wisdom may characterize all the counsels of the different departments of this Congress. We pray that everything that shall be done shall be done for the common welfare of this great land in which we live.

We pray Thee that Thou wilt watch over those who are strangers; bless those who are yet to come to us. Let Thy blessing rest upon the homes left behind them and the interests with which they are identified. We pray for the President and those who are associated with him in authority. We pray, our Father in Heaven, for all these great commonwealths of ours; for this great land that we live in, for the economical, agricultural and educational pursuits, and we pray Thee that government may so be administered in this country that this land shall be a land filled with a people, happy, virtuous, prosperous and free.

We pray that peace and good-will may characterize all the governments of the earth, and Thy name be glorified, for Thine own sake.—AMEN.

Mr. Clark—We will now hear an address of welcome on behalf of this State. I take pleasure in introducting to you, Honorable W. R. Smith, member of Congress from the El Paso District.

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MR. SMITH'S WELCOMING ADDRESS.

Mr. President, Delegates to the National Irrigation Congress, Ladies and Gentlemen:

In the name of the people of this great Commonwealth, always distinguished for their generous hospitality, I extend to you the "glad hand," and bid you welcome. All Texans to-day feel honored by your gracious presence here and their sense of pride has been quickened by the fact that you have come to partake of their hospitality while you labor to advance a cause which lies close to their hearts.

You have only entered our gates, and while you may be content to behold this beautiful and fertile valley which was the cradle of irrigation in this country, and may be satisfied with the pleasures afforded by this plucky little city, unique in the distinction of being the largest city of the largest Congressional district of the largest State of the greatest nation on earth, it is with pardonable pride that we ask you to look eastward over a distance of almost a thousand miles and behold the beauty and magnificence of a vast empire greater in territorial extent than Illinois, Ohio, New York, Pennsylvania and all the New England states combined and possessing a variety of soil and climate unsurpassed, if equaled, by any of her sister states.

We invite you to look upon her prosperous and happy population, which has increased from 820,000 in 1870 to more than three million in 1900, consisting of people from every state in the Union and from almost every country on the globe.

We invite you to look upon her white cotton fields, now producing one-fourth of the cotton crop of the world.

We invite you to look upon her vast herds of improved cattle as they roam over our illimitable prairies, adding to the world's supply of cattle more than twice as much as any other State in the Union, while at the same time taking the lead in the production of mules.

We invite you to visit our rice fields, where we are raising great quantities of rice, although we have just begun its cultivation.

We want to show you our immense crops of grain, fruits, vegetables, sugar cane and tobacco, and demonstrate to your satisfaction that the Census Department was not far wrong when it said that the value of our farm products of the year 1899 was two hundred and forty million dollars. It is more now.

We would like to have an opportunity to convince you that all the fabulous accounts you have read about our oil fields are true; that we produce enough oil in one day to run every locomotive in the the United States.

We would like to exhibit our coal, iron, marble, granite, copper, cinnabar and silver mines, which are all yet in their infancy, and point out immense sections rich in mineral resources yet undeveloped.

THE GREATEST RAILROAD STATE.

We have over eleven thousand miles of railway—more than any other State in the Union—running down to the sea and on which just freight rates are fixed and maintained by a commission chosen by our own people.

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We want you to know also that Texas is not behind in her educational advantages. The assets of our permanent school fund amount to something like a hundred millions of dollars, and annually we are using the interest from this fund, together with a liberal tax, to educate our children from the kindergarten through a splendid university.

Our laws are as just and beneficient as any ever prescribed by a sovereign power and their strict enforcement is maintaining a security and social order among our people not surpassed anywhere.

But, my friends, we also take pride in looking to the future. Great as are our natural resources, great as are the products of our industries, and great as are our institutions, greater still are the possibilities of this Lone Star State.

TEXAS AN EMPIRE IN ITSELF.

I would ask you to contemplate the fact that her great area and natural resources are capable of easily supporting a population of a hundred million. I would ask you to contemplate the fact that she can produce more cotton than the whole world is producing to-day, and in addition she can raise enough feed stuff and beef to supply the world, while the value of the products of her diversified farms if fully developed would be beyond computation.

These are only a few of the things it is possible for her to do.

NEED OF IRRIGATION.

There is but one thing lacking, gentlemen, to complete the circle of her felicities, and that is the solution of her irrigation problem, and the development of her irrigation possibilities. She already has fifty thousand acres under irrigation, but this is not much more than a drop in the sea compared to what may be accomplished in this direction. As I said before, the irrigation problem lies close to our hearts. We cannot look to the national reclamation fund, as can some of our more fortunate sister States, but we must ourselves work out our own destiny so far as this question is concerned. We have already entered upon this great work with zeal and energy.

We consider ourselves most fortunate in having this great Congress meet with us at this time. While we shall enjoy you as guests we shall also greatly profit by your experience and counsel.

Gentlemen, we want you to feel at home, and we want your stay here to be in every way pleasant as well as profitable. I assure you that our welcome to-day measures up to the greatness of this great State, and is in full keeping with the generous character of her people. Whether you come from our sister States and Territories, or from the great Republic south of us, or from across the sea, we are happy to have you as our guests.

Mr. Clark—Next in order will be an address on behalf of the University of Texas by Dr. William B. Phillips, of Austin. I now have the pleasure of introducing to you Dr. Phillips.

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DR. PHILLIPS' WELCOME.

Mr. President, Delegates of the Irrigation Congress, Ladies and Gentlemen:

I have the good fortune to hail from a city which numbers among its distinguished citizens a man of no mere local reputation. At one time, in a great National Congress, when acrimonious debate was rising every moment higher and still more high, it was by virtue of a single phrase that he poured a flood of oil upon the troubled sea, and attained more than a national reputation. So, in the language of John Webster Flannigan, of Austin, I ask: "What are we here for?" Not for office, not for any personal gain, but to set forth certain principles in which we believe and which are of economic importance to all of the country, from Oregon to the confines of Texas and from Maine to San Diego. It has been thought proper that a word of welcome should be spoken on behalf of the University of this State, because it stands at the pinnacle of the public school system, which system derives its support almost entirely from the public lands. You will remember, some few of us whose memory can go back to 1845 (I am not so fortunate myself), that when Texas came into the Union she reserved her public lands. Some years afterwards these lands were set aside as a sacred fund for the support of the common school system of this State. After that enabling act was passed, a portion of that land was also set apart for the support of the University as distinguished from the common schools, and for the support of asylums.

GREAT LAND FUND FOR EDUCATION.

That fund is now supposed to be worth somewhere between sixty-five and one hundred million dollars. It is all devoted—every cent of it, interest and principal—to the support of the common schools of this State.

At a time in its troubled history, when the fate of this State was trembling in the balance; when it had not yet made good its right to call itself an independent commonwealth; when the hearts of brave men fell fainting from despair, you will read among the earliest resolutions to this effect: "That the failure to provide for the education of the people is a just ground for revolution." That sentence may be said to be writ in blood upon the Constitution of Texas, and affixed thereto with a Bowie knife. Following along that general line the State has conserved for many years past this great fund, until to-day it promises to be the maintenance and support of generations still unborn.

The University is at the summit and pinnacle of this great fund, because it is at the head of the educational system here. There we are endeavoring to train men who, in the years to come, shall make two blades of grass grow where nothing grows now. It is into their hands as engineers and agriculturalists that we propose to devote the land that is now occupied by the ubiquitious jack-rabbit, by the vivacious but totally useless creature that we call a "prairie dog," which is now grown with lechuquilla, ojosen, tesejilla and palmilla.

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We are endeavoring there to train the men who in after years are to settle this great problem of irrigation, so that when we meet in Ogden in 1993—as I see on the program—these men will be there. If there is any one thing that distinguishes a reclamation or mining engineer from the balance of humanity it is his foresight. He has provided a program for us to live up to till 1993, when we will then visit the City of Ogden, which by that time will have more than four hundred million inhabitants.

WATER THE ONE FACTOR MISSING.

In this country we need a good deal of water; we have the good society. You know there is said to be another place, a good long ways from Texas, where there is lacking both good society and water. Here we have the good society, but we would like to have a little more water.

It is easy enough for our friends to come from the great rivers of Oregon and Washington and California, and who have harnessed Niagara Falls, and made the Sioux pay tribute to civilization; who are taking out water from the Mississippi and Missouri and are harnessing the Platte and the Salt River, to say that irrigation is a simple matter.

You have merely to take out the water that is running in the bed of the stream and carry it where you will; but what can you do with a stream that has no water in it? What can you do with a country which has a very little rainfall, and that often postponed for several years? In this country here we are shut up to one single consideration when we depart from the Rio Grande and the Pecos, and that is "the reclamation of our arid lands by system of storage reservoirs in which rainfall is to be held."

DEMAND FOR NEW TYPE OF ENGINEER.

Now, we can very easily build a dam and find a great many excellent engineers whose business it is to build dams, but I think the man is still to be born who can fill that dam with water.

Back in the East there was a good old lady, a very pious old soul, who was asked to attend a prayer meeting to invoke the divine aid in behalf of a country which was suffering from drouth. When asked to attend this meeting she said: "No, I won't go to any meeting; the United States Government has turned that whole water business over to the weather bureau, and I had enough trouble with the United States a few years ago to last me the balance of my life."

I am greatly pleased, in behalf of the University, to welcome you one and all to this great State; how large it is all of us know, what its future is to be no one can predict; but we do know, now and here, that we have no latch strings on the outside of the door to offer you; we have taken the door off its hinges and thrown it away.

Mr. Clark—We will now listen to an address of welcome on behalf of the City of El Paso, by Captain T. J. Beall. I have the pleasure of introducing Captain Beall.

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WELCOME ADDRESS ON BEHALF OF CITY.

By Captain T. J. Beall.

Mr. President, Delegates to the National Irrigation Congress, Ladies and Gentlemen:

It affords me very great pleasure, as the representative of the Honorable Mayor and Aldermen of our city council, to extend to the delegates of the National Irrigation Congress and the ladies accompanying them, a most cordial welcome to our city. In being honored in the performance of this duty, I am commissioned to say, that whatever resources we may have for your entertainment we freely lay them all at your feet, and bid you enjoy our hospitality to the fullest extent during your sojourn in our city. We fully realize that we have among us gentlemen whose presence we gladly welcome, who possess expert knowledge upon the subject of irrigation, the engineers who represent our government under the Reclamation Act of the 17th of June, 1902, which has for its beneficent object the development and extension of the great agricultural interests of the arid and semi-arid sections of our country. It is true that legislation, however beneficient it may be, does not embrace within its scope the imperial commonwealth of Texas, but extends only to the public lands embraced within the area of thirteen states and three territories of the United States. But notwithstanding our people are not the direct beneficiaries of the great work of reclaiming the public lands in which the national government is now engaged, our people feel an abiding interest in the cause of irrigation. "No pent up Utica contracts our powers" in respect to the grand work of carrying out a system of rendering fruitful desert and arid lands in a vast area of country, thus multiplying homes for the destitute, and giving employment to the people. In considering these great subjects, as patriotic citizens, we embrace within the horizon of our aspirations, the interests of the whole country, and we accord to our expert engineers who encourage us here by their presence, though not members of this Congress, a most sincere welcome. Our people sincerely trust that through the influence of this Congress there may be secured an amendment of the Reclamation Act, extending its benefits at least in part, to all the arid and semi-arid sections of our country.

EL PASO DEPENDENT UPON IRRIGATION.

The City of El Paso and the sections of country tributary to it are largely dependent for future growth and prosperity upon a broad and well-organized system of irrigation. We learn from the writings of the great Baron Von Humboldt, who explored this country in the year 1806, that when he saw the City of El Paso, which is now the city of Ciudad Juarez, the valley below was in a state of cultivation, producing fields of grain and wheat, and especially the wine grape, of finest quality, and other productions of fruit nature—apples, peaches, and pears in greatest abundance,—and speaking of its fertility and productiveness, he said, "this valley that I now look upon is as fertile and productive as the soil of Andalusia." Certainly, the City of

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El Paso and its environs, having derived such benefit from the irrigable waters of the Rio Grande in the past, cannot but feel a deep interest in the great enterprise of irrigation, the primary object for which this Congress was organized. We believe it was largely through the unremitting labors of this Congress that the National Act of 1902 was passed, and that now in Wyoming, Colorado, Nevada, and other States, and the Territories of New Mexico and Arizona, our engineering corps are engaged in making surveys for storage reservoirs and canals, by which the waste and storm waters that have passed without use to the sea will be stored and applied to the arid lands of the West, and make to contribute to the support and development of individual and national life. It is a fact well taught in history, that in those countries where fruits ripen and fall into the mouths of the people, the earth yielding forth its supplies without any human effort, you always find the lowest types of humanity.

HIGHEST TYPES OF MANHOOD.

It is in those countries where human toil and skill must be exerted to make a living out of the ground that thorough manhood is developed, and it is here you will find the highest types of mankind, standing upon the highest plane of enlightenment and civilization. And all experience teaches us that water applied by irrigation, when and where it is needed to produce a crop, is more efficient in producing productiveness of soil than when lands are cultivated and simply dependent on the accidental fall of rain from the heavens. We have millions of acres of land—sterile and desert soil—in the Great West, which only lacks the magic touch of water to make it productive and fruitful in supplying the needs of man. As the poet says:

"So in the still air, the music lies unheard,
In the rough marble beauty lies unseen;
To make the music and the beauty, needs
The master's touch, the sculptor's chisel keen.
So when on parched and thirsty soil
The irrigation falls like April showers,
'Twill fructify the virgin earth
And spread it o'er with fruits and flowers."

In conclusion, I desire again in behalf of the City of El Paso, to tender you a sincere and heartfelt welcome.

Mr. Clark—The Hon. W. W. Turney, a prominent citizen of El Paso, will now welcome you as chairman of the local committee on arrangements. I have the honor to introduce to you Senator Turney.

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SENATOR TURNEY'S ADDRESS.

Mr. President, Delegates, Ladies and Gentlemen:

It is with pardonable pride that we of El Paso have listened to what our Congressman, Mr. Smith, has said to you about the great State of Texas, all of which we and he are willing to assure you can be found to be the facts upon investigation, yet we of El Paso desire to say that, locally, we have not been able to enjoy all of the prosperity pictured by that eloquent gentleman. You must bear in mind that he lives four hundred miles to the east of us, that his district runs almost two hundred miles further east of us and that what might make him feel prosperous and happy would be very little advantage to the people of this great section.

While we are proud to be of Texas, many of us natives of Texas, and proud of her institutions and of her advancements and of her civilization, yet we feel that we have been called upon to do a work for ourselves which Texas can never do for us.

Having been a Republic, having gone into the Union under conditions different from those of any other State, her public lands are her own, and no Act of Congress can never affect them or benefit her in their improvements. We secure our support from much territory not a part of this great State. That territory is such as you are called upon by your action here this week to help benefit and help improve, and just to the extent that you will be successful in your work, to that extent El Paso will be benefited.

It was no unselfish act on our part which sent a delegation to Ogden to capture you. We care nothing about the benefits which we might secure by reason of your stopping at our hotels, visiting our places of amusement; that is of no importance. What we wanted was the result of your brains and your labor in order that you might tell us how we might benefit and improve this great country upon which our prosperity depends, and I want to say that when we received the news that this great Congress would meet here this week, it was the happiest moment in the lives of the citizens of El Paso, and to-day we have realized the fact that you have come and that you are here, and that we, people struggling for existence, as it were, will receive those benefits, not only for the present, but benefits that shall go down through all time, teaching people how they may find homes in these deserts, and teaching them how they may convert those deserts into villages, towns and cities. That is what we expect you to do, and what we know you will help us do.

A WORK OF LOVE AND PLEASURE.

Now, gentlemen, we want to say to you, that it has been our pleasure to incur the expense of building this hall; it has been our pleasure to provide some little entertainment for you; it has been our pleasure to set apart committee rooms in the court house and city halls, etc., for you, all of which we hope you will find convenient and ample. We expect you to use these. We expect you to call upon the committee whenever you feel that we may do you service in the promotion of your great work. You will find us ready at all times to comply with all your requests. We are here and you will easily

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find us. We want to say in addition to this that you will find amusement easily when you are not at work. We have been charged that we shall not interfere in any way with the work of this Congress.

Your work must be done unmolested by festivities of any kind, but we want to say that these festivities, we hope, will take place at a time when it interferes with no important work of this Congress.

You will find over the river some amusements which perhaps very few of you are going to admit that you have seen, but I want to say to you they are amusements which all of our people have seen and say little about. Say nothing about it and go see them.

El Paso, gentlemen of this convention, is proud to be so closely situated to the great Republic of Mexico—to my mind the richest mineral producing country on the face of the globe, to my mind ruled over and governed by one of the greatest statesmen, soldiers and citizens known to this or any other age. One trouble of the people of the United States is they know so little about that great country and its resources and its government. It might be very interesting to you if we had time to tell you of some of its merits, some of its laws, and some of the beneficial conditions which exist there and nowhere else. You will find them out during the time you are here, and especially if you take advantage of the trip to the City of Mexico being arranged for this occasion. There you will have opportunity to study them and to know them as we know them.

NATIONAL AND PATRIOTIC.

El Paso, as I said to you, feels interested not only in Texas, but she feels interested in every part of the country which surrounds her. As you know, it is just a step to Juarez, which is in old Mexico; just a step to the line of New Mexico; we are here, as it were, on the very point of the great State of Texas, therefore when we speak for Texas and refer to Texas, we refer to New Mexico, Arizona and the north half of old Mexico, all of which you will find are similar in almost every respect. The people, it is true, are governed by different governors and rulers; at the same time their land conditions, their necessity for water such as you are trying to give us, are just the same, and will be benefited from your efforts just the same as will we. A great Governor of Texas once undertook to write a history. He had been a Supreme Judge, had been a District Judge; had been Governor, but he proved to be not very much of a historian. He went to describe a town, and he said "A town is the center of the surrounding country." El Paso, in that respect is a town. We are the only thing you will find for six hundred miles in any direction, and we expect to keep in the lead just as we are to-day; we expect that lead to be maintained more from the efforts of this Congress than anything that has ever happened or ever will happen to us."

Mr. Clark—In behalf of the Press, that omnipresent and essential factor in the world's progress, you will hear words of welcome from Mr. H. D. Slater, editor of the El Paso *Herald,* and of the El Paso Committee. I now have the pleasure of introducing Mr. Slater.

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WHAT MR. SLATER SAID.

Mr. President, Delegates, Ladies and Gentlemen:

We have a saying in El Paso, "Live in the sun." It were an unkindness to detain you here to welcome you in formal fashion when you can see the welcome and breathe it in the very air, all about you, as you walk these streets.

El Paso claims commercial dominance over 1,000,000 square miles of territory, and we El Pasoans want you to feel that your welcome is as wide as the Great Southwest. Men and women of the Irrigation Congress, a million square miles of welcome come to you to-day from this platform.

Things have been said in few words before, in ways both concise and effective. It is related of the famous Dean Swift that on one occasion he was asked to come to a certain parish and make an appeal for funds for church extension work among the poor. On the day set for the appearance of the Dean, the church was crowded. Ascending the pulpit, Swift deliberately opened the big Bible and his sermon portfolio, and adjusted his glasses. Announcing his text, he read it twice, pausing for emphasis "He that giveth to the poor, lendeth to the Lord." Closing the book with a sweep, he removed his glasses, carefully polished them, and put them in their case. Then, straightening up, he delivered a sermon that for terseness and effectiveness has never been equaled. "My friends," said he, "if you like the security, down with the dust."

BELIEVES IN THE CONSTITUTION.

I am as much a stickler as anybody for the Constitution that our Joe Bailey discovered, but there is one serious contradiction in that immortal document. I cannot exercise the freedom of the press this morning by making a long talk without trespassing on the right of free speech that is guaranteed to the ninety speakers on your program. Being one of your hosts, I cheerfully concede the point.

So, in extending to the delegates to the 12th National Irrigation Congress the welcome of the press, I have only to say that the press of the United States is always ready to push a good thing along; and it is probably revealing no secrets if I tell you that, had it not been for the press, there would not have been any National Irrigation Congress or any national irrigation act in this generation.

HOPE FOR THE EASTERN PRESS.

Even in poor provincial New York, the editors whose ideas used to be limited by what they saw in the subway between flat and office door, are beginning to look upon the country west of the Ohio river as actually affiliated in some way with the American Republic and are giving space to articles about this El Paso Irrigation Congress almost as willingly as they describe the latest Paris modes in blankets for terriers. I note this to show how the press always leads public opinion in every community.

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In the name of the fellows who never sleep, who fear nothing but failure, who confer fame and smash the wrong, who build cities and rule the nations, who cogitate before they irrigate, who agitate before you congregate, and who get it straight while you corusticate—the men of the American press—I welcome you to the metropolis of the Great Southwest.

Mr. Clark—This closes the addresses of welcome, and we will now have the pleasure of listening to some other responses, and the first one who will address you is a man who has been foremost and one of the ablest advocates and promoters of irrigation in the United States, the author of the Newlands' bill. I introduce to you the Honorable Francis G. Newlands, Senator from Nevada.

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SENATOR NEWLANDS' ADDRESS.

Mr. Chairman, and Delegates to the Irrigation Congress:

Suddenly called as I am to respond to the addresses of welcome, I fear that my remarks will lack the felicity of thought and expression which the occasion demands. I must, however, express the warmth of feeling with which the delegates of this Congress, called from almost every State of the West, respond to the cordial and generous welcome accorded to us by the State of Texas and by the City of El Paso.

We have been interested in Texas. We have been interested in her history; we have been interested in her development. We recall the fact that Texas is the only Republic, which, by a single act, became a sovereign State of the great Union of States. We recall the fact that in the organic act which admitted her to the Union it was stipulated that if the people of Texas so demanded in the future, four great sovereign States should be carved out of this territory. And we also recall the fact that the pride of Texans in their State, its laws, its progress and its development, is so great that it would be regarded as an act of treason to-day if a Texan was to propose the division of this State to secure an increase of political power. During the recent campaign in the arid region I heard an eloquent Democratic orator comment upon domestic development as contrasted with foreign exploitations. He pointed out the vast area of territory within the boundaries of this country, the richness of its soil, the richness of its resources, the richness of its apparent and of its latent wealth, and he was urging that this great country should devote itself rather to internal improvement than to foreign adventure. And as illustrative of his subject he declared that the entire population of the United States could be concentrated within the boundaries of Texas and could there earn support. And then his face lit up with a smile, and he added, "I tremble to think in that event what the Democratic majority would be." I fear from present indications, that the party to which I belong, struck as it has been by a cyclone coming not from the East, or the West, or the North, or the South, but from all points of the compass combined, may have to resort to this method of securing dominance in the councils of the Nation. We may have to resort to the methods employed by Spain in Cuba; methods of the reconcentrado, by which we can force the entire population of the United States within the limits of Texas.

But it is gratifying to know that no process of violence or compulsion is required to increase the population of Texas. It is advancing rapidly and surely, and one of these days there will be a hundred millions of people in Texas, and in this great country of ours there will be between five hundred and a thousand millions. When we contemplate this fact, we can form some realization of the future greatness and power of this country—a power that will not have to be manifested by great standing armies, or by great fleets that float the sea, but will be evidenced by the energy, the courage and the advancement on their own soil of a great, a brave and a progressive people.

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TEXAS AND THE IRRIGATION LAW.

One of your speakers has alluded to the fact that thus far Texas has not been the beneficiary of the irrigation law, and he went so far as to assert that Texas would not be in the future. Notwithstanding the fact that Texas is not at present a beneficiary of the irrigation law, I wish to bear witness to the support and the aid and the encouragement given by Texas Representatives and Senators to this great movement. Their views were as broad as the State which they represent, and I trust that before long, Texas itself will be a beneficiary of this beneficient act. (Applause.)

I am now told that the reclamation service has in contemplation a project upon the Rio Grande, at Elephant Buttes, about one hundred miles from this place—the construction of a dam over two hundred feet high at a cost of seven million dollars embracing the irrigation of over two hundred thousand acres of land, now only partially productive and possibly not productive at all. The larger portion of that, it is true, is in New Mexico but it is immediately tributary to this State and the smaller portion is in the State of Texas itself. It is true that you have no public lands belonging to the United States in this State, but under that act it is intended to take care, not only of the lands that are now a part of the public domain, but also of the lands which have been actually settled and which lack a sufficient supply of water, and I don't see how, in principle, we can distinguish between the lands which were originally public lands of the entire Nation but are now in the hands of private owners who have settled upon them, and the lands of this State which were originally the property of the State and which now have gone into the hands of private owners.

It is a great national enterprise, intended to benefit the entire country, instituted under the constitution for the general welfare, and I don't see why in the future Texas should be excluded from its beneficient operation. In so far as I am concerned, I wish to say that I will gladly co-operate with Senators and Representatives of Texas in securing legislation in that direction.

A NEW NATIONAL POLICY.

Now my friends, just a few words regarding this act. I think few people realize how far-reaching and comprehensive it is and how it opens up a new National policy of development. In the first place the Act itself is a most comprehensive one, as relating to the subject in hand. Instead of requiring the reclamation survey to come year after year to Congress with estimates asking authority for certain work and appropriation for its gradual completion, we have, first, a fund created from the sales of the public lands throughout thirteen States and three Territories and forever dedicated to the reclamation of the arid lands. That sum now amounts to nearly twenty seven million dollars. It is a revolving fund, for as the moneys are spent upon the construction of various projects, they are gradually returned by the settlers on the lands reclaimed in ten annual installments, and thus the moneys return to the fund. Under the operation of this act within the next twenty years at least one hundred and fifty million dollars worth of work will be accom-

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plished; under this act, without further legislation the entire reclamation of the arid lands that are capable of reclamation can be accomplished.

The power is given to the Secretary of the Interior to investigate and determine what subjects are feasible and to enter without further authority upon immediate construction. No delays in construction by Congress, no delays in appropriation. The investigation can be immediately accomplished, and when the investigation is completed the work can be actually commenced; the one limitation upon the power of the Secretary of the Interior is that no contract shall be let unless the moneys for the contract are in the fund.

Thus no debts are contracted—no obligations are incurred. But the great Department of the Interior is charged with the responsibility of inaugurating these great enterprises. That work is entrusted to the geological survey—one of the scientific branches of the Interior Department, a survey that has grown up from a small beginning, composed of trained, educated, experienced men, who have become familiar with the entire country as to geology, topography, etc.—a body of men that are familiar with the face of the entire country, trained engineers, full of love of their profession, having high ideals, lifted above the prevailing commercialism which looks only to wealth as an ultimate goal, and thus this great survey has been employed in this work, and I ask that the sustaining power of the American people should be given to it; that it should be kept out of politics; that no legislation should be favored that will change its present constitution; that no administration shall be supported which will subject its appointment to political control.

If we maintain this policy, the reclamation service may be the germ of great public and governmental activity in the future in enterprises that have hitherto been regarded as belonging to the domain of private capital. Think how carefully this act has been guarded against monopoly. In this first place, as to the great public domain now in possession of the Government it guards against monopoly by providing that, as to lands reclaimed, no grant shall be made greater than one hundred and sixty acres. Thus the concentration of the lands reclaimed by the government in single ownership is avoided, and the great menace of land monopoly averted.

LANDS IN PRIVATE OWNERSHIP.

As to the lands now in private ownership and coming within the beneficient operation of this act, it is provided that no water rights can be granted to any proprietor of land within reach of an irrigation project for more than one hundred and sixty acers. He may have ten thousand, fifty thousand, a hundred thousand acres, but he can only secure a water right from the government for one hundred and sixty acres. But, you say, that is unjust to him and injurious to the country's development, that it condemns this entire area in single ownership to aridity. Not so. The fact that the waters from the irrigation project can be brought within the reach of this large holding raises its value. Purchasers of that holding in tracts of one hundred and sixty acres can secure water rights under this act. The large landed proprietor is benefitted by having the water brought within reach. He has the opportunity of making sales of lands hitherto unsalable and a purchaser can unite the water

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with the land by buying a water right from the government and thus dedicate the land to future productiveness. And so this act not only guards against monopoly in the future, but will gradually destroy existing monopoly and disintegrate these great holdings in the country without injury to any and with benefit to all.

TO PROMOTE THE GENERAL GOOD.

This gives an illustration of what the people can do when through their government they enter upon a great enterprise, no special privileges, equal rights to all, no monopoly, no concentration of wealth, the whole act tending to the distribution rather than to the concentration of wealth; and if this act can be faithfully and efficiently administered by the Interior Department, through the geological survey, we will have taken a step in the direction of solving a problem as to whether the people themselves can do things in the nature of enterprise. If this is successful we may find a practice inaugurated through this survey for the gradual building of government roads, not necessarily in competition with existing lines, or destructive of their values, but simply supplementing the present transportation system of the country, and absorbing the future growth of railroad construction in the interest of the people and not in the interest of concentrated wealth.

The attention of the American people has been called to a serious menace of the future of the Republic. During a century and a quarter of national life, this Republic, dedicated to the interest of democracy, has been developing into the greatest plutocracy that has existed in the history of the world. This has been accomplished largely through monopoly of production, and we now find that the men who have been monopolizing the production of the country are now engaged in securing the monopoly of the transportation of the country. Put these two sources of wealth under one control, and how can you hope for a fairly distributed wealth? If the great monopolies of the country are to control the transportation, if, by methods direct or indirect, they are to secure special privileges for themselves, secure rebates for themselves, accomplish discrimination against their antagonists, I ask you how long it will be before the entire wealth of the country will be in their hands? And if we can add to this the control of the finances of the country, I ask what limit there is to their power and their wealth?

I am no socialist; I am no communist; I believe that there will always be differences between men—natural differences—that the strong will always acquire more than the weak; that the intellectual will always accomplish more than the stupid; that the thrifty will always gain more than the thriftless. With these natural inequalities we must rest content, but we have a right to protest against artificial inequalities, creatd by the law or suffered under the law. It seems to me we have a new era opening to us of national activity that will demonstrate the ability of the people, through government, national, state and municipal, to accomplish great things for the benefit of all.

HONEST ADMINISTRATION OF PARAMOUNT IMPORTANCE.

To the Reclamation Service of the Geological Survey this great trust is given. Upon its conception of its high and noble duty, upon its faithful,

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honest and efficient execution of its trust much will depend. Let us see to it that it enters upon and proceeds with its work unembarrassed by faction, by partizanship or by sectional jealousies.

I am told that the great State of Texas has model legislation upon these great questions relating to artificial inequalities. I am told that there is no State in the Union that is more free from monopolistic control; no State in the Union where the people have so much power in enacting their own laws, and it seems to me that it is particularly appropriate that, in this State, which furnishes the model for such legislation, we should meet and deliberate over these great problems of national legislation which appeal to all well-meaning men in the country, in behalf of the enactment and the administration of laws that will promote the welfare, the happiness and the prosperity of all.

Mr. Clark—Gentlemen of the Convention: We have a distinguished gentleman from the State of California, its Governor, the Honorable George C. Pardee, who will now address you.

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GOVERNOR PARDEE'S ADDRESS.

Mr. President, Ladies and Gentlemen of the Convention:

I shall take but a short time and use but a very few words in expressing the obligation that the people representing the various States sending delegates to this convention must feel and do feel to the people of the greatest State in the Union for the hearty welcome which they have to-day extended to us. Such a welcome could come only from the great hearts of the people of the greatest State of this great Nation and it reminds us, from California, of the hearty welcome which the second greatest State of the Nation always gives to those who honor her with their presence on such occasions as this. Therefore it is with an especial pleasure that, representing the people of my State, I stand here to-day to express their gratification and the gratification of the Great West, the western part of this great Nation, for the hearty welcome which we are receiving here at your hands.

I notice that Maine, in the extreme Northeast of this Nation, sends her delegates here, and California we know is here, and Washington in the great Northwest, and Florida in the great Southeast also sent their delegates. The greatest State in all the Union we are meeting in, and Rhode Island—little Rhody—also has her delegates here. It seems that the people of the country realize the importance of such a meeting as this, realize the importance of the things that we are met here to-day to deliberate upon and pass resolutions concerning. It means that the great State of Texas will finally receive at the hands of this government, as has been pledged by the Senator from Nevada, such aid and such assistance as her greatness and wide extent of arid territory demands. It means that New Mexico and Arizona and Utah and California, and all the States and Territories to the north of us, here will receive that aid which will turn the vast area of deserts into a paradise.

My friends of Texas, I bring you greeting from California. I assure you of our hearty co-operation in all that we can do to make you equally participant with us in the great things which we are here to-day to deliberate upon, and which in due time will become yours with ours.

Mr. Clark—We have another live Governor here, from Idaho, who is also much interested in this question, and you will now be addressed by Governor John T. Morrison.

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GOVERNOR MORRISON'S ADDRESS.

Mr. President, Ladies and Gentlemen of the Convention:

This is an unexpected pleasure upon a very important and happy occasion, and I wish in the first place to return my thanks to the Honorable Chairman for the courtesies shown for calling me up. I am not rising for the purpose of making an address upon this occasion. I stand up for the purpose of expressing on behalf of the people whom I represent and their delegates who are here, simply our high appreciation of the gracious words of welcome which have been spoken on behalf of the good people of El Paso and the State of Texas.

We feel that we are not entirely strangers to the people of El Paso. I remember, and I thought of it when Mr. Turney was speaking, how we were captured by the cohorts of El Paso, and I am here to say to you, ladies and gentlemen, that the terms of our capitulation have been entirely satisfactory. I am glad that we are in captivity to-day. The aims and purposes of this great convention, you will appreciate, I think, are of a great interest to us. You will appreciate it the more when I say to you that the great State of Idaho, with its eighty-six thousand square miles, is about 70 per cent arid, and of that territory not less than two million acres are susceptible of a high degree of cultivation, and will, by the beneficial application of water, produce a large product for the comforts and necessities of life; hence our interest in this great convention, and we shall meet with you and take part in your discussions, hoping to take back with us something that will be of interest and benefit to our people.

As I listened to the glowing words of praise uttered on behalf of the State of Texas, I appreciated more than ever the glory and grandeur of this magnificent Lone Star State, and somehow or other my thoughts drifted into illustration and I thought of this: Over there in the heart of that metropolis of the world, London, stands the great cathedral of St. Paul, renowned for its architecture, and beauty and symmetry of design, the pride of England, and the wonder of tourists. As you pass into the rotunda you will find upon a brass tablet in the wall, this legend: "Sacred to the memory of Sir Christopher Wren. If you would see his works, look around you." So, ladies and gentlemen, I thought when these gentlemen on behalf of Texas were speaking, if you would see their works, and their glory, look around you here in the beautiful little city of El Paso. Allow me simply to expand the thought; limit it not only to Texas, but extend it to the whole United States —what a glorious country we have! And how we, as citizens, are proud of its magnificent progress and its wonderful history! When you think of the fact that the great civilization which is built up here is the greatest and noblest the world has known, that settlements have spread across this great continent of ours until more than two hundred million acres of land have been transformed from wilderness and brought into the service of man; that the civilization has reached across the Rocky Mountains to the beautiful valleys and fertile mountain slopes of the Pacific drainage, your pride of country, my fellow-citizens, must leap to the front, and you cry out, "Great are the Ameri-

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can people, magnificent in peace, triumphant in war." We have assembled here purely in the interest of irrigation. The civilization of which I have been speaking has established itself in the humid section of our country, and in the public the interest is largely centered there; but I stand here to-day to prophesy to you that the great civilization of the Mississippi valley will yet learn to irrigate, and that whole great valley will receive added benefits because of the science of irrigation which we are here to study.

THE COMING WEST.

Speak of the glory of Texas, of California and of the other States of our Union, marvelous as has been the development of the great Mississippi valley, I prophesy to you again that there will be a still more marvelous development of the Western slope of this country. The civilizations of the world have gathered around the Atlantic ocean, the wisdom of the ages has sat there. Even in its scenic wrecks may be read the history of the world to-day, and I say, fellow-citizens, that the great Pacific to the westward will yet become the great commercial ocean of the world, from which we will receive wonderful benefits. It is being written all over this country to-day that this progress is going forward. We are proud as American citizens to participate in it. Railroads will soon thread the passes of our mountains, the neck which connects the two Americas will be cut, and ships pass to and fro.

Let us then, fellow-citizens, while we glory in our individual sections, look beyond, and comprehend the whole country with its magnificent future and prospects.

Mr. Clark—I take pleasure in introducing to you Mr. C. W. Penrose, of Salt Lake City, Utah.

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MR. PENROSE'S ADDRESS.

Mr. Chairman, Fellow Delegates, Ladies and Gentlemen:

I highly appreciate the honor conferred upon me this morning in adding a few words to those that have been delivered to you. I regret, however, very much that our Honorable Governor, Heber M. Wells, who was expected to be here, is not present to respond to the addresses of welcome extended to us to-day.

I find myself here to-day among prophets, like Saul of old—prophets who have pictured the future grandeur and glory of this great Republic, and of the future benefits to be derived from the systems of irrigation that have been introduced under the laws of our country. I believe all they have prophesied will really take place, and I say "Amen" to all their projects. Sometimes the prophets of old got a little mixed in their arithmetic, and I suppose that is the reason why these figures do not exactly correspond to-day.

But, ladies and gentlemen, the people of Utah fully appreciate the cordial welcome extended to them in common with all the delegates from the various States represented here to-day, and Utah herself, smiling with pride, reaches out her right hand to grasp the glad hand extended to her from the big State of Texas, big hearted Texas. Utah is a small State, but so far as matters which affect the future of this country are concerned, she takes an interest in everything relating thereto. We were told to-day that Texas was the cradle of irrigation. I thought when that sentiment was uttered that Utah brought forth the infant of irrigation; it was her first offense.

In the year 1847, when the pioneers first entered the valley of the Great Salt Lake, came down through the mountains, the party consisted of 140 persons; a small band had preceded them two days ahead. They were sent by that great pioneer of irrigation, as well as of other works of civilization in the mountains, Brigham Young. After they entered the valley they went down and cut the brush that the rest of the company might follow with ease; they had a plow along in one of the wagons, and, descending down on a level plain, they commenced to endeavor to plough the ground and plant some seeds. But they broke their plow because of the aridity of the soil, and they then looked around for something else with which to accomplish the work, and one of them remembered that Young told them that they should go to the northeast, and there they would find a stream of water. How he knew that I cannot say, only he was among the prophets. They found a small stream of water, as he had told them, and they turned the stream out upon the land, by which they were enabled to plow the first furrows in the soil of Utah. That was the beginning of the great irrigation system that is now used not only in Utah, but in other States.

UTAH AN IRRIGATION OBJECT LESSON.

Now, I will not take up your time relating the history of irrigation in Utah, but if you want to see an object lesson in irrigation, we invite you to come and see us. We will show you what has been done by co-operative ef-

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fort, not by means of wealth, or by the organization of corporations taking up land and selling water to the people, but by the unity of efforts of the people themselves. The State of Utah is an irrigation State. We have projects on hand which, if carried out, will result in supplying the whole northern part of the State with water for irrigation under a system of distribution. By taking out the waters of the river and conducting them to the Utah Lake, a fresh water lake, by canals, then utilizing the waters of Bear Lake and Bear River, the two channels meeting together will not only increase the water supply for lands already occupied, but will bring into cultivation thousands upon thousands of acres of land not yet utilized. This is one of the projects we have in view, and we are very glad to know that we have the co-operation of the gentlemen of the government service, who have surveyed our lands and, I believe, pronounced the project practicable.

We expect much benefit through the National Irrigation Law, introduced by our eloquent friend, Mr. Newlands, and signed by the great man who has been indorsed by the people of the nation to be the head of the administrative government.

We thoroughly appreciate the favors that we enjoy from every source; we are grateful for Statehood; we are grateful that the people of the United States are beginning to understand us for what we are; that we are a part of this great Nation, though we are shut up in the mountains, and that we are now understood by our fellow-citizens in the East, and they are beginning to understand something about us. Some of our Texas friends came to see us in Ogden a year ago; we extended to them the glad hand, and now we are grateful for their reciprocal extension of that hand to us, and I say that the people of Utah are grateful for the words of welcome that have been spoken here to-day, and we extend an invitation to all our friends whenever they want to understand more concerning our resources, our capabilities, to come up and see us. We have no doors to leave open or latch-strings to leave out, but the way is perfectly clear. Come and see us; if you don't know much about us, ask our El Paso friends. I noted their energy and intelligence and their persistence in securing this Congress to meet in the city of El Paso, and I determined, if it was possible, that I would come here and see them again, and learn something about this great State of Texas, no longer the Lone Star State, but one of the great galaxy in the constellation of our country, where Utah also shines upon the same field. We are one with Texas and with all the States of the Union.

I hope that during the deliberations of this Congress nothing will be done in any selfish spirit. I desire to say that Utah has no particular axe to grind. If we have any information that will be of service to you, we shall be glad to impart it. We shall be glad to receive information from all our friends who are gathered here. We want to be one of them, and we want to learn all we can from them.

THE NEWLANDS LAW THE BEGINNING.

I indorse the remarks that have been made in regard to the progress of the nation. I understand that the Newlands Bill, as we call it in our State,

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is not a finality. It may be added upon. The people of this country can amend it or add to it as circumstances suggest. We should have a fraternal spirit in regard to all the people of this country. I know that our friends in the East are not acquainted with the needs of the arid regions of the country, but we want to extend the benefits of the Irrigation Law as it may be amended to every State in the Union, whether it be strictly in the limits now defined or not, and I am certain that the predictions that have been uttered this morning concerning the progress and welfare of this great nation, the greatest nation that the sun ever shone upon, will be all fulfilled. And I want to say still further that I foresee the time when not only will beneficient irrigation laws be passed by the country for the benefit of the people in these States of the Union, not only will this all be fulfilled, but I believe that the destiny of this great nation is to carry liberty and light and civilization to every part of this globe.

I believe that thrones will totter and nations fall, but that the principles of Democracy and Republicanism will be carried to every nation and every clime, and the time will come when, through the power and influence of this country all mankind will be free. We have a motto among us in Utah which reads like this: "Freedom, peace and full salvation are the blessings guaranteed. Liberty to every nation, every tongue and every grade." And the day will come when this will be fulfilled, and you will find that Utah, though she may be smaller than some of her sisters in the States, will come to the front with all her majesty and power and strength and intelligence, for she possesses all these things, and render powerful aid in the accomplishment of the establishment of peace, liberty and happiness in all the world. I thank you for your attention.

Mr. Clark—The program of the morning session will close with an address by the Hon. E. L. Smith, of Oregon. It had been expected that the Hon. Gifford Pinchot, Chief Forester of the United States, would be present, but his train is late. I take pleasure in introducing Mr. Smith.

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MR. SMITH'S ADDRESS.

Mr. President and Gentlemen of the Irrigation Congress:

The morning session has been prolonged so late, and there are so many subjects of vital importance to come before you, that I shall presume to keep you only for a brief moment.

For four successive days we traveled from the Columbia to the Rio del Norte, and many were the object lessons that impressed us in the country scuth of San Francisco. When we arrived at Southern California, we found a veritable Paradise. We saw the miracles that water had wrought there, for on every hand were fertile groves and fields.

As we continued our journey we came to the desert of the Colorado, and there was pointed out to us a railway constructed to bear away the harvest of that section of the country below the level of the ocean. We traversed the arid plains of Arizona, and there we saw great channels, great drainages, where the very wealth and life-blood of that section had evidently run off into waste. We were surprised at the great extent of the arid lands. The country seemed strange to us, but since we have been in this broad and beautiful city of El Paso, since we have listened to the addresses of welcome this morning, and partook of the generous hospitality of the people—a hospitality that I trust the commonwealth of Oregon will be able to reciprocate at no distant date—we feel that the hearts of the people of this great land beat warm and true, and that we are all alike, proud, happy, independent citizens of the same great and good government.

Mr. President, I thank you for the privilege of standing a moment before this great assemblage. It is an inspiration to look into the faces of the men who have come up from the South, and the West, and the East, and the North—have come to redeem the desert. May education go hand in hand with this work of reclamation, for it is the intelligence of the people that constitute their greatness in every country.

Gentlemen, in coming here I know that you have cast aside your political differences and your factional strifes in order that not a single note of discord may disturb the harmony of your labors, and I trust there will come up to you again and again, as it does to me this very moment, that grand old phrase, "how pleasant and how good it is for brethren to dwell together in unity."

Mr. Cobb—The Secretary is requested to announce that El Paso feels a special pride to-day and that this day will go down in her history as her proudest day. That she is not only proud of this hall erected by general and unselfish contributions; not only proud of the occasion, but she is proud of other and greater things, that even more than the pride that she takes in your presence is the pride in the good women of El Paso. Under the leadership of Mrs. Joseph Magoffin, a lady well known for her hospitality, the ladies of El Paso will entertain visiting ladies at the Sheldon hotel to-day from 3 to 5 o'clock. They will also present to the visitors, as well as to home people, a concert in this hall to-morrow evening. They have spared no pains to get the best musical talent, and with the melody of Mexican music will be blended the sweetness of American voices.

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Tuesday Afternoon Session, November 15, 1904.

The Congress was called to order by the President.

PRESIDENT CLARK'S ADDRESS.

Gentlemen of the National Irrigation Congress:

In the presence of this great assemblage, and in the midst of such magnificent surroundings, the delegates of the 12th Irrigation Congress, gathered here from every section of the great West, as well as from some of the Eastern States, can not refrain from expressions of satisfaction, enthusiasm and delight as they enjoy the unstinted hospitality of the good people of this beautiful city of El Paso. I am also delighted to learn that we have several visiting delegations from different States of our sister republic, Mexico; a government at whose head stands one of the greatest and noblest rulers of modern times in the person and character of Porfirio Diaz. He has shown his interest and sympathy in this cause by permitting the attendance of the National Regimental Band, of world-wide celebrity, and has likewise honored us with an autograph letter, which will be read this afternoon, conveying touching and eloquent expressions of good wishes and regret at his inability to be present.

Every promise made in the competition for the location of this meeting by the delegates of the Lone Star State at Ogden has been fulfilled beyond expectation, and El Paso, in the entertainment of its guests, has set a pace which may be difficult to follow by aspirants for future similar honors. Our warmest congratulations are due alike to our hospitable hosts and honored guests for the assured brilliant success of this Congress, which overshadows all previous conventions. Moreover, when we consider the fact that Texas is not embraced in the area available to the benefits of the Reclamation Act, all enthusiasts in the great cause in which we are engaged must be sensibly touched by the deep interest and concern in the subject so ardently manifested by the people of this city. Irrigation, however, has been widely practiced in this part of Texas, where its advantages are understood and fully appreciated, and although there is no public domain in Texas belonging to the government, the law should be so amended that government aid may be extended in a manner adapted to the different conditions existing here, as in the other States.

GROWTH OF A MOVEMENT.

The first efforts at organization for the advancement of irrigation, at Salt Lake City thirteen years ago, were eminently successful, and a movement was inaugurated which has produced happy results, beyond the fondest hopes of its founders. The most important of these is the Reclamation Act of 1902. I am delighted to see many of the pioneers of this great enterprise who participated in that meeting present here to-day. They come, no doubt, with many new ideas and broadened views, derived from study and experience, but imbued with an increased ardor and enthusiasm heightened by the inspira-

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tion of present success and glowing prospects of the future. The concensus of opinion resulting from a wide discussion of the best methods for the promotion of the cause of irrigation in that first Congress was favorable to the cession, by the government, of the arid lands to the respective States and Territories in which they occur, thus leaving the problem of their reclamation to be worked out by State legislation. However, this position was subsequently abandoned as untenable, and the conclusion was reached that only under the strong arm and auspices of the federal government could a satisfactory solution be assured.

EASTERN OPPOSITION WAS ENCOUNTERED.

Efforts to secure favorable legislation in the National Congress were met by the most determined opposition from the East and Middle West, where a strong sentiment prevailed against allowing appropriations of public funds in the interest and for the exclusive benefit, as they narrowly claimed, of the western part of this country. After years of fruitless effort, when the cause seemed almost hopeless, the happy thought, like a gleam of light in the darkness, was developed that the proceeds of sales of public lands might be set apart and used for the purpose, and the result was the present Reclamation Act, the outcome of which will be a boon of countless blessings to the present and unborn generations beyond the power of the mind of man to grasp or conceive.

Detailed reports by the officials of the government assigned to this duty, showing the progress of reclamation work, will be submitted to this Congress, which will exhibit the information in a comprehensive manner. Likewise addresses will be delivered by Mr. Maxwell, Mr. Boothe and Mr. Smythe, who are also active members and officials of the National Irrigation Association, which organization has been a valuable auxiliary to this one, and others will contribute important information, so that every corelative topic will be ably covered, and therefore I will only briefly allude to some great features of the subject.

A SPLENDID INITIAL FUND.

The aggregate of funds available in the United States treasury under the provision of the act amounts to over $23,000,000.

For convenience of administration, the reclamation service was placed under the supervision of the hydrographic branch of the Geological Survey, and a large staff of engineers selected on account of ability and experience in the various States and Territories was appointed, of which Mr. F. H. Newell was made chief. The present force comprises about 250 engineers. All reports are made to the Director of the Geological Survey, and through him to the Secretary of the Interior. The necessary preliminary work in the way of reconnaissance, measurement of flow of streams and surveys has been conducted over a wide range of country with intelligence, zeal, energy and technical skill that deserve the highest admiration and commendation for the eminent efficiency of the chief engineer and those working under his direction.

Active operations for the construction of dams and canals and other improvements are now going on in Arizona, Nevada and Idaho. For other

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projects in California, Colorado, Wyoming and Montana available sites have been selected and adopted, estimates are being made, and contracts will be let in the near future. In all these cases sums have been set aside by the Interior Department, ranging from two and one-quarter million to three million dollars each, to carry on the work when the contracts shall have been completed.

LAND WITHDRAWALS TO PREVENT SPECULATION.

In order to prevent private appropriation of land and water rights by speculators in the localities which seem to be applicable to the provisions of the law, the Department of the Interior has withdrawn from entry large areas of land in the several States and Territories, amounting to forty-three and one-half million acres, of which some three and one-half million acres have been found to be inapplicable, and have been restored to the public domain. The total amount of land available for irrigation has been variously estimated to be from fifty to sixty million acres, which, when made productive, will sustain a population of from twenty to twenty-five million people.

In undertaking to inaugurate this stupendous work, the engineers in charge were confronted with many difficulties. To begin with, all of the easily diverted waters had been appropriated by small farmers, who, by their own efforts, unaided by the capitalist or engineer, have brought millions of acres of land into a high state of cultivation, and by diligence and industry have established prosperous homes throughout the entire arid and semi-arid districts. These conditions, however, present no serious obstacles, but there are great numbers of vested rights acquired by individuals and corporations, many of them being of the intangible and invalid character, such as old unused rights of way for railroad companies, which lie in the way of proposed canal and reservoir sites. Seemingly anticipating the passage of the law, unscrupulous persons had made locations with the view to hinder and delay the progress of the work and extort money from the government. In all of these cases it is both tedious and expensive to adjust titles, although they may have no genuine merit. As the government can not proceed until all titles are properly vested in it, it is evident that rapid progress in every locality can not be expected. The work is being prosecuted in thirteen States and three Territories, and all possible projects are being examined. Some of them, which upon the surface seem easy and feasible, are found upon careful examination to be entirely impracticable, and their abandonment gives rise to disappointment and adverse criticism, which is entirely unjustifiable.

PASSED UPON BY HIGH ENGINEERING AUTHORITY.

Every project is passed upon by boards of consulting engineers before being submitted to the Secretary of the Interior for his approval. It is estimated that the work now adopted and under contemplation will absorb all of the funds now available and the probable receipts for several years to come. Numerous projects of secondary interest that have been examined can not be reached for a great many years to come, unless the government will come to the aid of the work with liberal appropriations. The reclamation fund will be

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reimbursed for every dollar expended in the course of time, by the settler, who will pay the price of the land to which he acquires title and the cost of the improvements which will be assessed to him. No returns can be expected for some years to come, and under the ten-year installment plan the reimbursement will be very slow. After ten years the receipts will be very large, and they may be re-invested in new improvements. In the meantime the aid of the government should be invoked.

In connection with the problem of irrigation, and intimately associated therewith as an adjunct and auxiliary proposition, is the protection which the great forests afford to the sources of water supply and to the proposed catchment areas. Large tracts of forest lands have been withdrawn as reserves from entry under the land laws, by the government, and a Forestry Bureau has been created and placed under the able direction of Mr. Gifford Pinchot, who will favor this Congress with an elaborate report as to the conditions of that branch of the government service, and which will be replete with interest. In the proper administration of this department, several important questions should be considered.

NATURE'S STORAGE RESERVOIRS.

Conservation of water supply is the paramount feature. Where the heavy accumulations of snow on mountain ranges are protected by forests from exposure to the sun's rays in summer and gradually melt to feed the streams, their greatest utility is realized, while denudation of the forests results in torrential waste and consequent drouths.

Protection of timber from unnecessary depredations, having due regard for the legitimate demands of the domestic consumer, the farmer and the great mining industries, as well as the protection and encouragement of the young timber growth, demands the exercise of the greatest wisdom and diplomacy, in order that the great industrial pursuits of the people may not be unduly disturbed.

Another question that demands the most vigorous attention is the ravages of forest fires that destroy annually ten times more timber than is appropriated to meet the requirements of industry and domestic consumption. Large districts in Montana and Idaho, under my own observation, were swept by forest fires during the past summer and autumn, and all efforts to even retard their destructive work were powerless until the advent of the heavy autumn rains.

The government should take vigorous action to stop, if possible, this fearful destruction, which is of annual recurrence.

REPEAL OF BAD LAWS.

During the session of the last Congress a spirited discussion was maintained during an entire afternoon, and at times acrimonious in its character, on the question of the repeal of some of our land laws, and terminated in no definite conclusions as to the prevailing sentiment of the Congress, as a decision was evaded by the adoption of a meaningless resolution by way of compromise. The question will undoubtedly be revived in this Congress. I

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feel constrained to reiterate my previously expressed opinion, that of our present land laws, the Desert Land Act and the commutation clause of the Homestead Act, have outlived their usefulness, and should be repealed in the interest of the actual settler and the small land owner. Any disinterested and unprejudiced person who is familiar with the conditions in Montana and other States, where all the water courses have passed into the control of large holders, thereby securing control of large tracts of adjacent lands, will, I believe, coincide with this theory.

The prosperity of a State is largely dependent upon small holdings of land, which insure its cultivation and consequently increased production and population. This feature has been wisely considered in the provisions of the Reclamation Act.

A COUNTRY-WIDE BENEFIT.

Sufficient has already been accomplished to arouse a national interest in the importance of irrigation. Whatever benefits one section of the Republic can not fail to benefit the whole country, and this scheme is not a sectional one, as the welfare of about one-half its entire area is involved, and the indirect contribution to the material prosperity of the other half is incalculable. The East must depend upon the West for its food supplies, and likewise for a market for its manufactured products. This is the kind of reciprocity that enriches the country, genuine American reciprocity. Why should the farmers of the Middle Western States fear competition from the far West while they produced this year little wheat for export, scarcely enough to supply home requirements, and when it has been found necessary to ship fifteen million bushels of wheat from the North Pacific coast to help supply the deficit. The area of wheat-producing territory has become inadequate to meet the requirements of our rapidly increasing population, and should there be a surplus, our Asiatic neighbors will hereafter furnish a market for all we can produce west of the Mississippi.

THE SOUTH SUPPORTS THE WEST.

The South will stand with us as allies in a common cause. Our flood waters withheld and stored, will save it millions of dollars annually in damages caused by overflow of the banks of the Mississippi river. The appropriations for river and harbor improvements deplete the United States treasury each year to the extent of many million dollars, and for whose benefit? Directly, largely the coast lines and commercial ports and cities of the East, where the money is expended; but we of the West, who contribute our share to these improvements, do not complain. With commendable pride in the advancement and glory of our entire country, we willingly concur in these expenditures. Why may we not expect from the East the exercise of equal generosity and equal patritoism in the building up of the great West? Let us point to the Louisiana Purchase Exposition, a magnificent triumph of the new century, that eclipses everything the world has ever seen, to emphasize the claims of the great semi-arid empire of the West, the chief factor and contributor to its success. There on the banks of the mighty Mississippi may

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be seen "the greatest show on earth," which has brought into competition the highest exercise of inventive genius, artistic skill, technical science and intellectual prowess of all the nations of the earth, who are vying with each other for supremacy in the great march of civilization and empire.

GREAT INTERNAL EXPANSION.

In viewing this marvelous exemplification of the world's progress, we are constantly reminded that the Louisiana Purchase, a conquest of the Jeffersonian idea of expansion, which lies largely in the semi-arid region, is in all departments everywhere in evidence with the products of its fields, forests and mines of such surpassing excellence as to forcibly demonstrate its remarkable, although only partially developed, resources. Under the inspiration of this impressive display, we are forced to reflect and wonder what the future may reveal to the coming generation when the broad areas in the valleys and on the mountain slopes of this western empire, whose parched and arid soils are rich in all of the elements of fertility, now yearning for the magic embrace of water, which they woo but can not win without the guidance of the hands of man, shall have been reclaimed and transformed into green meadows, golden fields, and happy abodes. It is an enchanting picture to contemplate to all who have a thought of the future and wish to inaugurate a policy that will insure to their immediate posterity a priceless heritage.

Mr. Clark—Next in order of business will be the report of the Executive Committee, by Hon. Charles B. Boothe of Los Angeles, California.

Mr. Boothe—Mr. President and Members of the 12th National Irrigation Congress: Recognizing the value of time to a Congress like this the report of the Executive Committee has been made brief, but it is none the less necessary.

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REPORT OF C. B. BOOTHE, CHAIRMAN EXECUTIVE COMMITTEE.

Mr. President and Members of the 12th National Congress, Gentlemen:

Upon call of the Hon. Fred J. Keisel, Chairman of the Executive Committee of the 11th National Irrigation Congress, held at Ogden, Utah, September 14 to 18, 1903, the Executive Committee elected at that Congress met at the municipal chamber in the City Hall in Ogden, on Friday evening directly following the adjournment of the Congress.

The organization of the newly-elected Executive Committee was made with C. B. Boothe, of Los Angeles, Cal., as chairman, and H. B. Maxson, of Reno, Nev., as secretary. The appointment of assistant secretary was referred to the chairman and the secretary of the committee, and Mr. A. W. Gifford, of El Paso, was selected as assistant secretary.

In conformity with the instructions received from the Executive Committee at the above stated meeting, vacancies in the list of Honorary Vice Presidents and members of the Executive Committee have been filled in all the States with the exception of New Jersey, which State refused to respond to the requests for nominations.

The completed official roster will be found on the fore page of the proceedings.

A sub-committee on Constitution was appointed, with G. A. Richardson, of New Mexico, as chairman.

A communication having been received from Secretary H. B. Maxson, of Reno, Nev., that he was ill and unable to attend to the duties of secretary, Mr. A. W. Gifford, of El Paso, was appointed secretary. and Mr. Z. L. Cobb, of El Paso, first assistant secretary.

The instructions for the Executive Committee to put into effect the provisions contained in the fourth paragraph of Article 3, and Article 5 of the Constitution, relating to the division of the work of the Congress into sections, has been carried out, and it is to be hoped will prove as successful and satisfactory to all the delegates as the committee have anticipated.

The sections with their respective chairmen are as follows:

Forestry—Chairman, Mr. Gifford Pinchot, Chief Forester, U. S. A., Washington, D. C.

Production by Irrigation—Chairman Division A, Mr. I. D. O'Donnell, Billings, Mont. Chairman Division B, Dr. E. Benjamin Andrews, chancellor of the University of Nebraska, Lincoln, Neb. Chairman Division C, Mr. Herbert Myrick, of Springfield, Mass., editor of the American Agriculturist of New York, and the Orange Judd Farmer, of Chicago.

Engineering and Mechanics—Chairman, Mr. F. H. Newell, Chief Engineer of the U. S. Reclamation Service, Washington, D. C.

Climatology—Chairman, Mr. Willis L. Moore, Chief of the Weather Bureau, Washington, D. C. (At Mr. Moore's request Mr. H. E. Williams, Assistant Chief of the Weather Bureau, was made chairman.)

Rural Settlement—Chairman, Mr. Wm. E. Smythe, of San Diego.

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Mr. Guy E. Mitchell, of Washington, D. C., was made chairman of the Press Committee.

Soon after the adjournment of the 11th Congress, advices were received from El Paso that a Committee of Arrangements had been selected there, with Hon. W. W. Turney as chairman, and A. W. Gifford as secretary, the other members being Mr. Alfred Courchesne, Mr. John W. Fisher, Mr. J. R. Harper, Mr. E. Kohlberg, Mr. Francisco Mallen and Mr. E. C. Pew, Sr. By agreement with that committee, November 15th to 18th was selected as the dates for the sessions of the Congress.

Early in September, under the provisions of the Constitution, was sent out the

OFFICIAL CALL.

The 12th National Irrigation Congress will be held at El Paso, Texas, November 15 to 18, inclusive, 1904.

All who are interested in conserving the great natural resources of the country—extending the habitable area—increasing the products of the land—insuring greater stability of prosperous conditions—making occupations upon the land attractive—the extension of internal trade and commerce, and a wider knowledge of a great economic movement which has for its ultimate object the upbuilding of an empire within the borders of a great nation, are invited to attend this Congress.

The organization of this Congress will be as follows:

The permanent officers of the Congress, including the chairmen of the sections.

Members of the United States Senate and House of Representatives.

Governors of States and Territories.

Embassadors, Ministers and other representatives of foreign nations and colonies.

Members of State and Territorial Irrigation Commissions.

Ten delegates, to be appointed by the Governor of each State and Territory.

Four delegates, to be appointed by the Mayor of each city of more than 25,000 population.

Two delegates, to be appointed by the Mayor of each city of less than 25,000 population.

Two delegates, each duly accredited by any Chamber of Commerce, Board of Trade, Commercial Club or other commercial body.

Two delegates, each duly accredited by any regularly organized irrigation, agricultural or horticultural society.

Two delegates, each duly accredited by any regularly organized Society of Engineers.

Two delegates, each duly accredited by any agricultural college, or college or university having a chair of hydraulic engineering, forestry, or other subject related to the general purpose of the Congress.

It is respectfully suggested that in the appointment of delegates, persons should be selected who are sincerely interested in and purpose attending the Congress, and that appointment be made as early as possible.

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Please have full name and postoffice address of delegates mailed to Executive Chairman, 12th N. I. Congress, El Paso, Texas, that they may receive special information which will be mailed to each delegate not later than October 5, 1904.

The work of the Congress has been so greatly enlarged through the increased interest in matters pertaining to irrigation, that the Executive Committee have decided to systematize the work of the next Congress according to the provisions in Articles 3 and 5 of our Constitution; consequently the work of the 12th Congress has been divided into five sections, their titles and chairmen being shown on this letter-head.

Each section will be conducted by a chairman who will be recognized as an eminent authority in his line, which insures a thorough exposition of the respective subjects through the presentation of papers, addresses and discussion by the most eminent men interested in forestry, irrigation, climatology and their correlated subjects.

It is confidently predicted that the coming Congress will be more highly instructive and entertaining than any Congress which has preceded it.

El Paso, the western metropolis of the Lone Star State, and on the border line of Old Mexico, is making preparation for the largest Congress, in point of attendance, which we have ever held.

A general committee of its ablest citizens, supported by the unanimous sentiment of the city, is arranging a program, for the entertainment of the delegates, which would require too large a space to print in this call, but is so unique in character as to be interesting and enjoyable to all.

A comprehensive exhibit of the products of irrigation will be installed adjoining the great Convention Hall, especially constructed for this Congress.

Irrigation in various phases will be shown, which will include mechanics and electrical machinery and appliances.

Ample hotel accommodations can be assured to every delegate.

Special railroad rates have been made to apply from all parts of the United States to this Congress, the rates being the lowest ever made to any convention. Apply early to your nearest railroad agent, so as to insure the rates being made applicable from your section.

All newspapers and other publications are earnestly requested to give wide publicity to this official call, and to impress upon their readers the far-reaching importance of this Congress.

The Vice President and members of the Executive Committee from each State are urged to make the provisions of this call as widely known as possible, and insure the largest possible delegation from their respective States.

Every State in the Union is vitally and directly interested in the subjects to be discussed in the coming Congress.

In the various sections information will be dispensed regarding the increasing of production by irrigation in the Atlantic States as well as in the Pacific section; forestry problems in New England, and along the Appalachian Chain, as well as along the Rockies and Sierras; engineering applied to protect from the devastation by floods; drainage of the submerged areas; direct-

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ing and conducting the water to its most beneficial use; climatology, with special reference to the service of the Weather Bureau throughout the United States, and rural settlement, with special reference to the disposition of "the surplus man."

THE EXECUTIVE COMMITTEE,
By C. B. BOOTHE, Chairman.
H. B. MAXSON, Secretary.

GENERAL COMMITTEE AT EL PASO,
By W. W. TURNEY, Chairman.
A. W. GIFFORD, Secretary.

Approved: W. A. CLARK,
President and Ex-Officio Member Executive Committee.

Most of the members of the Executive Committee have been active in their several States and it has resulted in bringing together a Congress, not only large in numbers, but representative in character, and generally, men of affairs in their respective sections.

The advance program which you have received indicates the excellent manner in which the chairmen of the various sections have arranged their work, and, being men of recognized authority in their various lines, of wide acquaintance with the subjects to be considered in their respective sections, it may be confidently anticipated by all that the addresses and papers which will be presented during the sessions will be of a most interesting and instructive character.

It is with great pleasure that acknowledgment is made to the Committee on Arrangements at El Paso for the generous and hearty support which they have given the National Executive Committee in every way which might concontribute to the success of the Congress. No expense or labor has been spared for the comfort and entertainment of the delegates, and in making preparations for the holding of the Congress. Uninterrupted harmony has prevailed between the Executive Committee and the Committee of Arrangements at El Paso.

At this Congress, for the first time, the organization has been formulated upon the full and comprehensive lines laid out by our Constitution.

BROADENING OF THE MOVEMENT.

The growth of the national irrigation movement has brought it into intimate relation with many subjects not heretofore recognized as closely related with the main purposes and objects of our Congress.

The passage of the National Irrigation Act has revived interest in such important subjects as forestry and climatology. It has widened and extended our interest in the great fields of engineering and mechanics. Production by irrigation has received an impulse which, in the near future, will be felt from the Pacific to the Atlantic and from the Lakes to the Gulf, and all this thought, effort and action will be directed to the extension of settlement in old communities and the building up of new communities in a

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vast desert, which but now, it is realized is filled with vast possibilities for the present and future generations of our people.

For many years each Irrigation Congress formulated new and untried policies, all of which have disappeared under the critical examination of men skilled in statesmanship and the consideration of great problems.

The 12th Congress convenes with a well-defined policy established by the Congress of the United States, and with its administration well in hand by the Executive Department of our Nation.

Matters for the consideration of *this* Congress are more largely that of the extension of the policy defined by the National Irrigation Act, and its best administration for the benefit of the people.

Through the information and facts brought together during the sessions of this Congress, and the conclusions reached after debate and discussion by the most able men in our country, the conclusions which may be arrived at will have great weight with the law-makers who represent us at the capital of the Nation.

The responsibility of each of us is great, that we shall not be swerved by any selfish purpose, nor that the resources which belong to the Nation shall be diverted from the people to whom they belong.

The foundations are being laid for an empire greater than has ever been known or dreamed of in the history of the world. We are the trustees for the present and future generations and they shall be the judge whether we have faithfully administered the trust. May we be guided by a zeal to do right, act wisely, and thus deserve the blessings of those who come after us.

Mr. Boothe—Mr. President, I have another report from the Executive Committee which I desire to present at this time, because it seems to be pertinent. The present Constitution provides for five members to be appointed by the Governors and one or two members by various organizations. We find, after two or three years' experience, it is necessary to appoint, to secure a satisfactory attendance, a good many more; for that reason the Executive Committee have decided to recommend the number that may be appointed by Governors and Mayors be considerably increased:

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REPORT OF EXECUTIVE COMMITTEE ON THE SUGGESTED AMENDMENTS TO THE CONSTITUTION.

To the 12th National Irrigation Congress:

At the close of the 11th National Irrigation Congress, a special committee on the revision of the Constitution made a report recommending that the matter be referred to the present Executive Committee and, after careful consideration, the chairman has been instructed to recommend to this Congress the adoption of the following amendments:

Whereas, No provision has been made in the Constitution for a Committee on Credentials, and the basis of representation being prescribed by the Constitution, the practice having been at several Congresses to adopt the official roster made up by the Secretary, it is recommended that an amendment to Article 2 in the Constitution be made as follows:

"The Executive Committee shall be convened by its chairman by 8 p. m. on the day preceding that on which the Congress convenes, and shall act as the Committee on Credentials and report at the opening of the Congress, and from time to time during its sessions, the names of those duly accredited as delegates."

Also an amendment to Article 4: "The President, the Chairman of the Executive Committee and the Secretary of the Congress shall constitute a Committee on Rules; and when approved by the Committee on Rules, the program submitted by the Executive Committee shall become the official program of the Congress."

Also amend Article 6 to read as follows: "The membership of this Congress shall be as follows: Fifteen delegates from each State and Territory to be appointed by their respective Governors; five delegates from each town and city of the United States having a population of less than 25,000; ten delegates from each city having a population of over 25,000; also five delegates from any county; two delegates each from any regularly organized irrigation, agricultural or horticultural society, Society of Engineers, agricultural colleges and commercial bodies; also the duly accredited representative of any foreign nation or colony; all members of the United States Senate and House of Representatives, and the Governor of each State and Territory; each member of any State or Territorial irrigation commission, and State Commissioner of Agriculture or Horticulture; the chairman of each section, and the permanent officers of the Congress."

Also amend Article 8 to read: "This Constitution may be amended by a two-thirds vote of the delegates of any Congress, under the provisions contained in Article 7."

Mr. Boothe—I move the adoption of the report of the Executive Committee.

Mr. Prince—Mr. President.

Mr. Clark—The delegate from New Mexico.

Mr. Prince—I suggest that the amendment to the Constitution be made a special order of some kind on some day after this. It is a very important

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matter, this amendment to the Constitution. The report is a good one with regard to certain matters—I suppose good as far as it goes; but it is important for us to understand and consider it. I suggest to the chairman of the committee that this particular thing, as well as other matters of importance, should be made a special order for a specific time, so we can look into it and understand it when it comes up for action.

Mr. Clark—Does the gentleman from New Mexico make a motion to that effect?

Mr. Prince—I will make the motion. I have no preference with regard to time; I will be very glad to confer with Mr. Boothe in regard to that, if he desires to appoint any particular time. If there is no objection to it, I move that we take it up at 11 o'clock to-morrow morning.

Mr. Clark—There will not be another general session until Thursday evening. All that time will be taken up by the program.

Mr. Prince—It is no honor to this city that there is no general session until Thursday evening. I don't know why there should not be, because this body is its own master, and can hold a session whenever it chooses. But, if there is no general session until Thursday evening, I move we make this a special order for Thursday evening. It is certainly as important as anything can be to come before us.

The motion was seconded by a delegate from Oklahoma.

Mr. Clark—You hear the motion, gentlemen, that the report shall be made a special order for Thursday afternoon, at what time?

Mr. Prince—Whenever this general session is.

Mr. Boothe—There is no session in the afternoon; it is Thursday evening.

Mr. Clark—No session in the afternoon.

The motion was carried.

Mr. Clark—The portion of the report which relates to amendment to the Constitution will be made a special order for Thursday evening.

The remainder of the report was adopted.

Mr. Clark—The next order of business is the reading of letters and telegrams from distinguished absentees. The Secretary will now read letters and telegrams.

FROM THEODORE ROOSEVELT, PRESIDENT OF THE UNITED STATES OF AMERICA.

WHITE HOUSE, WASHINGTON.

C. B. BOOTHE, *Executive Chairman:*

My Dear Sir—I wish it were possible for me to accept your kind invitation to attend the National Irrigation Congress to be held at El Paso.

I need not state to you the deep interest I feel in the cause of national irrigation. Irrigation is in very fact one of the means for national expansion which is most effective.

Wishing you all success, I am, Sincerely yours,

THEODORE ROOSEVELT.

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Mr. Boothe—I hold in my hand a personal communication from the President, delivered into the hands of this Congress by Mr. Pinchot, who has just arrived. If agreeable I will ask Mr. Pinchot to read this letter.

Mr. Pinchot—I was greatly honored by being made the bearer of a communication from the President to this 12th National Irrigation Congress, which doubtless would have come very much earlier were it not for the fact that we have had an election in the country.

FROM THEODORE ROOSEVELT, PRESIDENT OF THE UNITED STATES.

To the National Irrigation Congress:

It is a pleasure to send my greeting to you, both as President of the United States and as a man who has lived in the West and loves it, and is eager for its prosperity. Whatever any man or body of men may believe as to any question in political controversy, we may all unite in the great duty of internal improvement, the duty of making every foot of soil, every stream and every other resource of natural or human origin, contribute to the very utmost to the permanent prosperity of our country.

I congratulate you because you are no longer striving for what once seemed a distant hope; you are no longer engaged in a campaign of education for the passage of the Reclamation Act. On the contrary, your first great object is achieved. You have met to consider what has been and what is being done under that Act by the Reclamation Service, to consider means for giving it its largest and widest results, and to discuss the broad problems of irrigation method and practice.

It was through your efforts, and those of men like you, that the people of the United States as a Nation undertook to attack the desert, and to do away with it not only so far as there is water now for that purpose, but to the fullest extent for which water may be developed hereafter. Such an attack can be successful only when based on accurate knowledge. When the Reclamation Act was passd, the essential facts as to stream-flow had been ascertained in many parts of the United States, and the scientific basis for national reclamation, which otherwise it would have taken years to accumulate, was already in large part at hand. The fact that so much progress has already been made by the Reclamation Service is a striking example of the advantage of scientific investigation by the general government. It may be true that to the man whose interest is limited by immediate results, the admirable work of the Reclamation Service at times seems slow, but we are building for a great future, and it is far more important that the works built should be permanent and successful than that they should be completed in haste. There will be no unwise hurry, neither will there be any unnecessary delay. Most of the great problems of organization and methods have now been solved, and progress in construction and settlement is being made with increasing rapidity.

The passage of the Reclamation Law was a great step toward realizing the best use of all the public lands. For many of these lands their best use is to

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produce water for irrigation. But always, and in every place, the best use of the public lands is their use by the man who has come to stay. There are, unfortunately, in every part of our country, a few men whose interests are purely temporary, who are eager to skim the cream and go. Instead of using the forests conservatively, they would, for example, abuse and destroy the natural reservoirs upon which national irrigation depends, to the permanent loss of every agency which makes for the true development and lasting greatness of the irrigable States. Such interests can not be allowed to control.

Now that your first great object has been accomplished in the passage of the Reclamation Law, you should make yourselves the guardians of the future, and the unrelenting and watchful enemies of every attempt to waste any of the great resources in forestry, grazing, and mineral wealth, the foundation stones of a newer and greater West. For irrigation, and every other interest which you represent, the period of exclusiveness is passed. The stock interest is no longer independent of the mining interest, nor either of them independent of the irrigator. A closer interweaving than ever before is at hand, among all the great interests of the whole country. One can not prosper without the others. So the future growth and greatness of the other Western interests will depend, in the first degree, upon the development of irrigation, and the development of irrigation will depend upon the protection and wise use of the existing forests and the creation of new ones, and the proper control of the grazing. Your work for the good of one interest is for the good of all.

The following letters were read:

FROM PRESIDENT DIAZ, OF THE REPUBLIC OF MEXICO.

MEXICO, October 21, 1904.

HON. WILLIAM ANDREWS CLARK, *President 12th National Irrigation Congress, New York:*

Dear Sir—I have received the courteous and esteemed invitation which you were kind enough to extend to me for the interesting meeting of the 12th National Irrigation Congress, which will be held from the 15th to the 18th of next November, in the progressive city of El Paso, Texas.

As much for the importance of the *transcendental* matters which will there be treated of, as to reciprocate the kind consideration with which you favor me, I would take sincere pleasure in attending, if my official duties would permit; but they are absolutely the only ones which deprive me of that great satisfaction, and I must content myself with being with you in spirit, though absent from your meeting, with sincere wishes that the most complete success may crown the intelligent and patriotic work of the illustrious Congress over which you preside, and which will undoubtedly influence powerfully the solution of the many problems relating to irrigation and the forest industry. The government thus understanding, the Department of *Fomento* and some of the governments of the States of this Republic will be duly represented in that assembly by their respective delegations.

I am, very truly yours,

(Signed) PORFIRIO DIAZ.

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FROM VICE PRESIDENT CORRAL, OF THE REPUBLIC OF MEXICO.

HERMOSILLO, November 6, 1904.

MR. A. W. GIFFORD, *Secretary of the Committee, National Irrigation Congress, El Paso:*

Dear Sir—I reply to your esteemed letter, dated the 24th of last month, and thank you for the invitation which you sent to me to attend the National Irrigation Congress, which will be held in that city during the present month, and beg to advise that I am sorry not to be able to attend, notwithstanding my desire to do so. I am, with all consideration, sincerely yours,

(Signed) RAMON CORRAL.

FROM HON. PAUL MORTON, SECRETARY NAVY DEPARTMENT.

WASHINGTON, D. C.

My Dear Sir—I thank you for your letter of October 5th, inviting me to be present and address the National Irrigation Congress, to be held at El Paso, Texas, November 15-18, and regret sincerely that it is impossible for me to accept the invitation.

I have always been interested in everything that the National Irrigation Congress is trying to accomplish. I believe in saving the forests, storing the flood waters, reclaiming the deserts, and making homes out of the arid lands.

Very truly yours,

PAUL MORTON.

FROM HON. ETHAN ALLEN HITCHCOCK, SECRETARY OF THE INTERIOR.

WASHINGTON, D. C., Nov. 10, 1904.

Dear Sir—I desire to acknowledge the very courteous invitation extended to me by you to attend the 12th National Irrigation Congress at El Paso, November 15th to 18th, and to express my sincere regret that on account of the public business and the preparation of my annual report, which must be complete and ready to submit to the President before the preparation of his annual message, I can not be away from Washington at the time specified.

I am in hearty sympathy with the national irrigation movement and have taken great personal interest in promoting as rapidly as possible the reclamation of the irrigable lands and the carrying out of the manifest intention of Congress in this matter. While I can not be present personally, I will detail a representative of the department to attend the session of your Congress, which I trust will be of great benefit to the country.

FROM U. S. SENATOR THOS. R. BARD, OF CALIFORNIA, CHAIRMAN SENATE COMMITTEE ON IRRIGATION.

HUENEME, CALIF.

My Dear Sir—I thank you for, and fully appreciate the compliment extended by your letter of October 10th, in which you invite me to address the Irrigation Congress, to be held at El Paso, November 15-18.

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At this time it is impossible for me to promise to attend the Irrigation Congress. My time is so wholly taken up with matters of an official nature, both current and in anticipation of legislation which may be proposed at the coming important session of Congress, that I fear I can not take the journey to El Paso. The session of the Irrigation Congress will come just at the time when I shall be in the midst of preparations for my departure for Washington.

Reciprocating sentiments of regard, I remain, etc.,

THOS. R. BARD.

FROM U. S. SENATOR PARIS GIBSON, OF MONTANA.

GREAT FALLS, MONT.

DEAR MR. BOOTHE—I have just received your letter of the 21st, and am very sorry to tell you that I shall be unable to attend the meeting at El Paso. I have not been well this summer, and although my condition is somewhat improved since last spring, yet I feel it my duty to avoid such a long journey as I would have to make from Great Falls to El Paso.

I fully realize the importance of this, the 12th National Irrigation Congress, and you can rest assured I would not fail to be present and lend what little influence I have for the preservation of our public lands, if I could do so.

Mr. Maxwell made a very effective campaign in this State and did much good for our cause. I hope he will be able next year to again visit Montana and talk to the people in all the important towns. It certainly would contribute very much to the enlightenment of the people on the subject of preserving the public domain for homemakers.

With kind regards, I remain, Yours very truly,

PARIS GIBSON.

FROM COL. C. A. CARLISLE, HONORARY VICE PRESIDENT FOR INDIANA.

SOUTH BEND, IND., NOV. 8, 1904.

MY DEAR MR. BOOTHE—Your pleasant note of Nov. 2d reached me just as I was about leaving for a protracted eastern trip, and yet before I go, it is my desire that these few words of greeting and cordial good will shall be directed to you, and through you to the distinguished gentlemen who welcome you and to all the delegates assembled. My deep regret is that I cannot be with you in person, but it is my pleasure to notify you that we send you instead one of our distinguished associates, the Hon. E. M. Brannick, of Portland, Oregon, the vice president and general manager of the Studebaker's Northwest Company, and a gentleman in whose sagacious discernment you will find strength and wisdom.

I am mindful of the importance of such gatherings as you now have before you, through the like of which a higher and more perfect civilization, a more satisfying brotherhood of love, has come. It is but a short stretch of time and

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imagination that we look back over the developments that have come through the hardest experiences of trials and tribulations since Thomas Jefferson (the great American expansionist), fired by determination to penetrate the mysteries of the unfathomed West, the great territory that now lies gracefully within the inner realm of the most enlightened civilization.

As we follow (now in history) the trails of those sturdy pioneers inspired by Jefferson to blaze a pathway across the continent, we see Lieutenant Zebulon Montgomery Pike, the first American to explore the upper Mississippi, the valley of Arkansas and to enter New Mexico, where the Spanish governor threw him into prison as a filibuster and revolutionist. But "Pike's Peak" will forever enchant the generations to come as it has those of to-day, and of the past, a glorious tribute to a brave man.

Jefferson sent his own private secretary, Merwether Lewis, and his associate and neighbor and boyhood friend, George Rogers Clark, across the trackless forests, the deserts, and the Rockies, to the Columbia River and down to the shrine of his determined aspirations, the Pacific; and the knowledge brought by those great patriots represented much, as the world had waited more than two hundred years for such a reliable report.

Next year, at Portland, the American people will applaud the memory of these men.

I congratulate the National Irrigation Congress, as I congratulate those in attendance, the city in which you meet, the State and all in authority, for men like those before you are the men who, through unselfishness have always been found upon the firing line—such as they are the force through which our glorious Nation evolved.

May God's blessing be with you and a most perfect peace prevail. With personal regards, believe me,

Sincerely,

C. A. CARLISLE.

FROM HON. ALEXANDER O. BRODIE, GOVERNOR OF ARIZONA.

PHOENIX, ARIZ.

MY DEAR MR. BOOTHE—I have yours of November 3d, extending to me a most cordial invitation to be present at the coming Congress at El Paso, and to deliver a short address upon any subject I might choose. It had been my intention to be present during this session of the Congress, not for the purpose of delivering an address, but for the purpose of taking part in the discussion of topics. I find, however, that I am to be disappointed, as within the last few days I have had word from Mrs. Brodie, who is at present ill in the East, that she is considerably worse, so I feel that the very moment I can be spared from the Territory, it is my duty to join her.

You understand, of course, that my heart is with you in your work, and that I am a well-wisher for the success of the National Irrigation Congress.

With kind regards, to yourself personally, and sincere regret over the fact that I shall be prevented from being with you, I am,

Yours sincerely,

ALEXANDER O. BRODIE.

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OTHER LETTERS.

Letters were also read from Secretary John Hay, Secretary Victor A. Metcalf, Secretary Wm. H. Taft, Secretary L. M. Shaw, former President Grover Cleveland, Land Commissioner W. A. Richards, Commander Frederick Booth-Tucker; Commissioner John J. Terrell, Texas State Land Office; Richard H. Edmonds, Editor Manufacturers' Record, Baltimore; Hon. Chas. Scott, President Inter-State Mississippi River Improvement and Land Association and member Executive Committee for Mississippi; Hon. C. F. Huehlin, member Executive Committee from Kentucky; Mr. Joe Mitchell Chapple, member Executive Committee from Massachusetts; Hon. W. A. Kelsey, member Executive Committee from New York; Hon. Samuel Hill, Seattle, Washington, and Hon. James L. Northrup, Mayor of Johnstown, N. Y.

Mr. Clark—These letters are all very gratifying as they indicate a widespread sentiment all over this land in the interest of irrigation. The letters will be filed and published in the Proceedings of the Congress.

The next in order will be an address by Mr. Gifford Pinchot, Chief Forester of the United States and Chairman of the Section of Forestry of this Congress. I have the honor to introduce to you Mr. Pinchot.

Mr. Pinchot—I will detain you but a very few minutes, because what I will say will be very briefly said.

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ADDRESS OF CHAIRMAN PINCHOT.

The National Reclamation Act, whose passage was directly due to the personal interest and effort of the President, is of a broader national character than many people in the East realized at the time. It will give to those portions of the country which it does not directly touch, far more than the effect of that general reflex action which the prosperity of any part of the United States must have upon every other. In this case there are specific reasons, and of these the greatest is this: That the development of the arid West through irrigation will be of unmeasured importance to the East by the creation of more and greater home markets, for it is by home markets first of all that our people prosper. The Reclamation Act is a national benefaction whose blessing falls first and most plentifully upon the West, but which does not fail to bless any portion of the Union.

One of the fundamental facts that nearly every man here knows to his own cost is that there is more irrigable land, in that prosperous country we used to know as the Great American Desert, than there is water to irrigate it. Water is the measure of the value of land, and it is water that the West needs. Every addition to the water supply will extend the irigated area. When all the water now available has been put to use (and in many regions that time has either already arrived, or will not be long delayed), every deduction from the water supply will reduce the possible irrigable area. It is of the highest importance, therefore, not only to have a water supply but to keep it.

FORESTS CONSERVE WATER SUPPLY.

No argument is needed before this Congress to prove that forests conserve the water supply and vastly increase its usefulness for the purposes of irrigation. They do so by reducing evaporation, by regulating and sustaining the flow of streams, and by helping the snow water to get into the ground by seepage instead of into the air by evaporation. The forest is the first and most important factor in the water supply of the West except the water itself.

In the West the forest does not now occupy nearly all the area suited for its growth. Doubtless every man here is familiar with denuded slopes dotted with the charred remnants of forests which have been destroyed, and with great stretches of open land as to which there is no apparent reason why they should not be covered with trees. The fact is, the fire has driven the forest from vast areas upon which it should naturally flourish, and to which it may be restored by natural seeding or by extensive plantation. But it is not only the area of the forests which is reduced by fire. Very many forests are traversed by fire year after year and yet are not destroyed. But no forest can be burned without suffering in what is to you its most important function--its capacity to store the fallen rain.

TO CREATE NEW RIVERS.

The protection of the forest then protects the present supply of water. In many places continued and effective production will largely increase the steady flow of water in the streams, because many forests are now in poor condition.

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But this is only half the story. If the forests now standing are valuable for water supply then new forests created on water sheds now denuded will also be valuable. Here lies the possibility of increasing the irrigable area by increasing the water supply.

We know already that forest plantations on the open plains of the Central West are taking on the character of natural forests, are reproducing themselves from seed, and are even extending their own boundaries. Forest planting in the irrigable mountain States is still too young to afford such examples, but the efforts of nature to again cover the denuded slopes furnish ample proof of what can be done.

The importance of all this lies in the fact that the extension of the forest on denuded water sheds will unquestionably be accompanied by an increase in the available water supply. I might cite case after case from older countries to sustain this contention, cases of springs restored and streams sustained by the renewal of the forest. We have begun planting too recently to prove it here, but unquestionably man after man in this audience could furnish proof of the converse proposition, that the destruction of the forest reduces the water supply. It stands to reason that if we restore the one we restore the other. Forest fires then not only restrict the forest area but they restrict the irrigable area as well.

TO COMBAT FOREST FIRES.

What is the remedy for this age-long attack on the irrigable West by forest fires? It is a triple one. First, extension of forest reserves over all mountain watersheds of streams used for irrigation; second, a national forest service to control the forest fires and destructive lumbering, which is often their cause and nearly always their confederate; and thirdly, tree planting on denuded areas in the forest reserves.

I hold with emphasis not only that it is the duty of the national government to extend the irrigable area by increasing the low water flow of streams through planting on denuded water sheds in the forest reserves, but I also believe firmly that we are about to undertake as a Nation more extensive forest plantations than have ever been made elsewhere. There is a definite need which can be met only with the protection of existing forests and the planting of new ones, and it is not to be doubted that we shall meet it.

Mr. Clark—I regret to say that Mr. I. D. O'Donnell, of Montana, one of the Section chairmen, has not been able to be present, although he has carried on a large correspondence and succeeded in including the presence of others here who will present papers under his section. We will now pass to an address by Mr. E. Benj. Andrews, the Chancellor of the University of Nebraska, Lincoln, Nebraska, and Chairman of the Section of Production by Irrigation. I have the pleasure of introducing to you Mr. Andrews.

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ADDRESS OF CHAIRMAN ANDREWS.

Mr. President, Ladies and Gentlemen of the Congress:

The Congress meets under more auspicious circumstances than at any previous time. The cause it represents is better and better understood throughout the country. Prejudices against its work which were once very strong have been laid aside. It is matter for peculiar congratulation that the President of the United States himself appreciates the need of irrigation as a national policy and is willing to give to this great interest his support by official word and deed. The people of the East are to a great extent, and increasingly, relinquishing their attitude of hostility, caused by ignorance and misunderstanding.

A fact strongly tending to further and strengthen the cause of national irrigation is that certain technical objections to our scheme appear to have been surmounted, at least theoretically, to the satisfaction of experts. There was legitimate fear at first that comparatively little water could be stored at sufficiently high levels to enable it to flow over very vast areas in need of it. It was found, however, I believe, that the tracts reachable by proper irrigation works are indefinitely vast, much more so than one would at first suppose—sufficiently vast to make the utmost preparation for irrigating them well worth while.

It is more and more seen that the lifting of water from under the earth to pour it over fields can be made to pay in localities too high for cribbed water to reach, this form of irrigating being certain to supplement in an invaluable manner the river and reservoir work.

It is further observed that in nearly all localities, alkali, when present, can be drained away, so that with or without additional treatment the land will be rendered productive.

NO LONGER A SECTIONAL ISSUE.

The more intelligent newspapers and public no longer consider our work sectional, but look upon it in its true character as a national affair. I wish to dwell a little on this conviction and the ground for it. The making of ditches and reservoirs and the application of the reserved waters to the purpose of growing crops will certainly affect, in the first instance, special localities. But the instant these favored areas feel the touce of the living streams, produce grain and cattle and various other wealth, they will become purchasers of commodities of every kind produced in the manufacturing districts or for sale by importers, vastly enlarging the markets for all those engaged in producing or in selling. Not only will the total wealth of the country be swollen, but the profits of business will increase in every section of the land and in every department of industry.

Another consideration showing that our project is national and not sectional in its significance, lies in the fact that the vast population destined to be raised up through irrigation on the now arid and semi-arid portions of our beloved country, will be in the main perpetually agricultural, having the intelligence, the firm and vigorous physique and the intense patriotism usually

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characterizing people living upon the land and deriving their support therefrom.

To say that the reclamation project before this Congress is of national importance does by any means express the entire truth. It is of consequence to all civilized mankind.

TO CREATE A FERTILE EMPIRE.

While all civilized races are increasing in number by leaps and bounds, the areas of the earth's surface which are naturally fertile are nearly all occupied, and a considerable proportion of them tilled to about the limit of their productive capacity. What is proposed is to add a fertile continent to the earth's productive area—not a continent far from the populations to be fed, but one situated right in the midst of these populations, making its food-products available without great expense to America, Europe and Asia. It is the greatest forward step now under consideration by civilized mankind.

EDUCATED MAN OVERCOMES NATURE.

What is the distinguishing mark that separates civilized men from savages? It is this: that, whereas the savage sits down humbly at Nature's feet and waits to take with gratitude whatever gifts of life she deigns to bestow, civilized man, on the contrary, dominates nature. Within large limits he commands her. If she does not obey to his liking, he takes her by the throat and forces her to do his bidding.

The American Indians made him their chief who could trail far, find rich hunting grounds, or corn and fruit lands, and conduct his people thither. We create hunting grounds and corn lands. We coerce Nature to grow cattle and corn to our liking in amount and in quality. If we don't like the breeds and varieties at first offered, we tell Nature to make better ones and she complies.

Hitherto, at one important point, that of moisture, nature has, over vast areas of our country, mocked at us. We wanted crops and grasses. Nature said "no, you cannot get them; you shall not have them. I withhold the moisture necessary to their growth."

Again, as at so many cries before, civilization is going to have it out with Nature, and Nature has got to yield. We may still have to yield to Nature so far the means of supplying the needed moisture is concerned, not compelling her to furnish it by means of clouds and rains, the usual method; but we are going to have the moisture all the same.

Mr. Clark—I will now introduce to you, Professor Thomas Shaw, of St. Paul, editor of *"The Farmer,"* and one of the Chairmen of the Section of Production by Irrigation.

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ADDRESS OF CHAIRMAN SHAW.

Mr. President and Gentlemen of the Convention:

I had not been very long in El Paso before the Chairman of the Executive Committee laid hands on me and requested me to take the place of the gentleman from Montana, who had been appointed chairman of this division. I had not been long in El Paso, as I have said, when the gentleman requested this of me, but I had been long enough to learn something of the courtesy that has been shown by the people of El Paso to the visitors at this time, and I made up my mind that I would try and do all I could to make this Convention a success, and that when I went back to St. Paul, I would take the opportunity which I am happy to say has been furnished me of telling one hundred thousand families of the States in the Northwest of the great courtesies shown me at El Paso by the visitors of this Convention. I am requested to speak in the place of Mr. O'Donnell, who was chairman of this branch of the work, and Mr. O'Donnell is not here, and as you can understand I did not know that I was expected to take his place until arriving here at noon to-day, therefore it will be unquestionably out of place for me to take up any considerable amount of the valuable time of you gentlemen in discussing this question. I would like to say to you, however, that I have heard former Congresses criticised, not so much because of what they did, but to some extent because of what they did not do.

PRACTICAL FARM IRRIGATION PAPERS.

They accomplished a great deal of valuable work, but there is one thing I think I am correct in saying they did not accomplish; they did not give the ranchmen something practical to take home with reference to his feature of the work and I have heard ranchmen criticise the Convention because of that fact. I think, Mr. Chairman, that I had the honor of submitting to the executive committee a year ago that that question would not be overlooked at this Congress, and the next day in conversation with yourself, I found to my great delight and satisfaction, that you had been thinking, doubtless before I had, in the same direction, and then and there it was decided to give the practical ranchman something that he could take home with him at the 12th Convention to be held at El Paso, therefore I will simply remind you of the meeting that is to take place to-morrow morning in connection with this department of the work. A gentleman from the State of Texas, Dr. Phillips, I believe from the University of Texas, will talk on the practical irrigation of the public domain in this State, and I do think, Mr. Chairman, that every citizen of Texas should be so interested in a subject of that kind, that every citizen of Texas who could possibly come to that meeting should be there to-morrow morning at nine o'clock to hear that address.

GRASSES AND FORAGE.

Then will follow an address by Professor W. J. Spillman, on the growing of grass and forage crops by irrigation. I do not know of any question that can interest the ranchman more than that—the question of growing grasses

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and forage crops by irrigation. I do not know anything that would interest the man out on these ranches more than the best way in which he can sustain these grasses and crops, and I feel absolutely safe in saying this to you, that the party who is going to handle this subject, has the subject completely at his finger ends. How I came to know that so well, is that I have been tantalizing him for two years with all manner of questions on that very subject and I know from the nature of the answers he gave me, that he is going to tell you something well worth hearing. Then there will be an address on the question of irrigation by a gentleman, whose name I will not submit to you at present, for very good reasons, and there will be other addresses, so that I hope that all of those who are interested in the discussion of these practical questions will be on hand at Hall No. 1. I don't know where Hall No. 1 is, but you, gentlemen, will undoubtedly find it out. Remember, not half past nine, but nine o'clock to-morrow morning. I am told this is Hall No. 1.

I have just one thing more to say and then I am done. Dr. Andrews of the University of Nebraska, who spoke to you so eloquently this afternoon, I understand, has to go home before the meeting of this department, which will take place on Thursday.. I was requested to preside at the meeting to-morrow morning by the Chairman of the Executive Committee, but I do think it would be unfair to you, and unfair to Doctor Andrews, who has to go away, that you should not have an opportunity to know what an able chairman he makes, and therefore Doctor Andrews will preside at that meeting and make it the success it should be.

Mr. Clark—Gentlemen of the Convention: It was intended to have Mr. George H. Maxwell, the Executive Chairman of the National Irrigation Association, conduct a section on the legal phases of the irrigation question, but it was found entirely impossible for him to undertake it. He is, however, present and is to address the Congress. The next in the order of business is an address by Mr. Frederick H. Newell, Chief Engineer of the Reclamation Service and Chairman of the Section on Engineering and Mechanics.

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ADDRESS OF CHAIRMAN NEWELL.

Mr. President, Ladies and Gentlemen of the Convention:

It gives me very great pleasure to meet you, and as the hour is late I will detain you only for a moment in speaking on the subject of engineering and mechanics of which section I have the honor to be the chairman. As my predecessor has said on the platform, each chairman of section will endeavor to make his particular section as interesting as possible and I will do all in my power to present to you an interesting program, and to see that the matter is pushed forward energetically and its most interesting features given.

GREAT IRRIGATION WORKS OF AMERICA.

Engineering and mechanics as applied to irrigation is perhaps not a very attractive term to use, but in it lies the successful operation of the great irrigation works which exist now or are to exist in the future. Throughout the United States, or the Western part of it, all the irrigation engineering at present executed has been by individuals largely, and under directions of corporations, and the works already accomplished and the wonderful results testify to the work of engineers and mechanics in building the structures which now supply water to the needy crops. In our talk in this section it is hoped that we will be able to discuss the work already executed and more than that to talk about and discuss fully with you the large structures built and which are to be constructed under the terms of the Reclamation Law concerning which you have all heard about. If time permitted I should be very glad to take up State by State the work that is going on and which is projected in those States in the future, but that will be taken up I hope in the sections, and we will discuss from Arizona to Wyoming the work which is being done and which may be done in the future.

A GREAT CONSTRUCTION FUND.

The reclamation fund you have all heard about. It amounts now, as has been said by our President, to twenty seven million dollars. It has been apportioned to the different States and Territories. The Secretary of the Interior has approved the construction of various works in nearly all of them, and concerning the execution of these we wish to meet with you and discuss fully what should be done in the future.

At this time I wish to ask particularly that each State delegation would attempt to make an appointment to meet with this section and to meet with the engineers of the reclamation service at some definite hour so that we may take up in each State and Territory the work which is desired and which is contemplated, in order that you may express your wishes and opinion concerning it. The engineers here have already met the delegation from Oklahoma and Oregon, and we have an appointment immediately upon adjournment to-night to meet with the joint Oregon and California delegation to discuss the Columbia project and other projects in which they are both interested, and I hope that time will permit for us to take this up in a very brief manner at least, and I wish the chairman of each delegation would arrange

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definitely when he can meet that particular delegation and take up the features which are of interest to it. Now, without going into all the details which might be of interest, I will merely say that as engineers and as members of and all of us, and we must work together to put into effect this beneficent act ternal manner to get your co-operation and to work with you in the upbuilding of the West.

As has already been said, we are the guardians of the future, you and I and all of us, and we must work together to put into effect this beneficient act and see that the money is expended in the most economical manner to produce reclamation of the arid lands.

Mr. Clark—I will now introduce Mr. H. L. Williams, of Washington, D. C., Assistant Chief of the United States Weather Bureau, formerly called "Old Probability," and who is Chairman of the Section on Climatology. I have the pleasure of introducing Mr. Williams.

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ADDRESS OF CHAIRMAN WILLIAMS.

Mr. Chairman, Delegates, Ladies and Gentlemen:

The intimate relation that the subject of climatology bears to that of irrigation is self-evident, as the need of irrigation is due principally to aridity, which is a climatic factor.

The climate of any region is affected by such a variety of causes, both local and general, which operates so irregularly that a long and continuous series of observations, taken at short intervals of time and not far apart in space, is necessary to afford the data from which the true climate of a country or region may be established.

In the early history of the United States regular climatic observations were naturally few, being made only by those private individuals who from love of science were willing to devote the necessary time for this purpose. Systematic observations under President Jefferson's government supervision began to be made in 1817 by the Land Office Registers, and in 1818 by the Surgeon General's Office of the Army and surgeons of army posts. In 1844 the Hydrographic Office of the Navy began contributions to the work, and in 1847 the Smithsonian Institution entered the field by inaugurating a system of regularly recorded observations of the weather.

CONSOLIDATING THE SERVICE.

Soon after the establishment of the meteorological branch of the Signal Service, now the Weather Bureau, in 1870, the meteorological work of the Smithsonian Institution was turned over to that organization, and by recent instructions of the President the meteorological duties of the Hydrographic Office are to be transferred to the Weather Bureau, so that the whole system of the officially recorded observations, with the exception of those conducted by the Surgeon General's Office, is or is to be under the control of that Bureau.

A GREAT ORGANIZATION.

The Weather Bureau now maintains about 190 regular stations, where observations of pressure, temperature, precipitation, wind, humidity, clouds, and sunshine are made and recorded, and about 3500 other stations known as voluntary stations were, through the co-operation of public spirited private citizens, observations of temperature and precipitation are made and recorded, the instruments for the purpose being furnished by the government. Increasing interest as shown by requests for new stations constantly. Every State, and nearly every county in each State, is represented by these stations which occur in about 90 per cent of the counties at about 25-mile distances and the method of supervision is such as to insure uniformity and a very high degree of accuracy in the results. The Climate and Crop Service is divided into 45 local sections, each section, as a rule, covering a single State, and having for its center a regular observing station. These centers collect temperature and rainfall observations from more than 3,000 voluntary stations and publish these data in the form of monthly reports which are given a wide-

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spread distribution. During the crop-growing season (from April to September, inclusive) each section also receives weekly mail reports from numerous correspondents (aggregating, for all sections, about 14,000) concerning the effects of the weather upon crops and farming operations, these reports being published in the form of weekly bulletins.

A WEEKLY BULLETIN.

During the same season the Central Office at Washington issues weekly a "National Climate and Crop Bulletin," containing a series of charts graphically illustrating current and normal conditions of temperature and rainfall for the entire country, a general summary of the weather, and brief reports on the condition of the crops for each State. There is issued at the Central Office every Tuesday during the winter a publication entitled "Snow and Ice Bulletin," which shows the area covered by snow, the depth of snow, and the thickness of ice in rivers, etc., as indicated by a large number of reports of observations made on the afternoon of the day preceding the issue of the bulletin. This publication is of especial value to those interested in the winter wheat crop, to ice dealers, and to the manufacturers of rubber goods and other articles, the sale of which is largely affected by the presence or absence of snow and ice. Throughout the cotton, corn, wheat, sugar, and rice producing sections designated centers receive telegraphic reports of rainfall and daily extremes of temperature for publication in bulletin form, each local center receiving the reports from all others.

VOLUNTARY OBSERVATIONS.

By the co-operation of several thousand voluntary observers, many of whom have maintained local records for long periods, the Weather Bureau endeavors to collect special local data and thus perfect the records that are needed for the study of the relation between climate and agriculture, forestry, and other industries. The results of these observations appear in detail in monthly and annual reports published at the respective section centers, and in the Monthly Weather Review.

As this method has been in operation for the past 25 years with a constantly increasing number of stations, it will be seen that with all the series of observations mentioned we already have a fair basis for the determination of the climatic conditions for nearly all parts of the country and the value of the data being accumulated increases with every year.

UTILIZED BY VARIOUS BUSINESS INTERESTS.

The value of the information acquired and the facts established by these observations, not only to irrigation interests as represented by this Congress, but to nearly all business enterprises and the welfare of the people generally, is manifest. Constructors of waterworks, bridges, culverts and sewers consult the rainfall records to ascertain the maximum water flow they will have to allow for. Architects of iron and steel structures and tall buildings study the records of maximum and minimum temperatures and wind velocity, in

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order to estimate the contraction and expansion and amount of wind pressure their buidings must be prepared to withstand.

From the information as to climatic conditions made known through the reports, invalids and tourists are enabled to select the localities best suited to their health and pleasure, and manufacturers and agriculturists the regions best adapted for the carrying on of their particular industries.

TO FORECAST THE IRRIGATION SUPPLY.

By the recent extension of the system of snowfall observations throughout the mountain regions adjacent to the Great Plains, it has been made possible to forecast the probable flow in the rivers of the arid regions, a factor of great importance in irrigation. The records of the Bureau are of frequent use as evidence in courts of law for which purpose they have been decided competent by the Supreme Court of the United States.

It would be neither practicable nor desirable for the section of the Congress to which this subject is assigned to treat the topic of climatology in any exhaustive manner, and we have, therefore, chosen for the problems to be discussed such as have some special relation to the object of this meeting. While the topics are not all new the writers have brought out many new facts and ideas, and have endeavored to present them in such a manner as to make them of fresh interest.

I invite your attention to the program of the section, the meetings of which you are all cordially invited to attend.

Mr. Clark—We will now finish the program of the day by an address by Mr. William E. Smythe, Chairman of the Section on Rural Settlement.

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ADDRESS OF CHAIRMAN SMYTHE.

Ladies and Gentlemen:

I had a lovely speech—how lovely you will never know, for I shall not attempt to impose it upon you at this late hour. I know this audience is in the condition of a worthy young man in California who was waiting on a charming young lady weighing about two hundred and fifty pounds. This young couple were engaged, and their parents had impressed upon them principles of economy, so they began economy in their days of courtship by occupying a single chair. John called one night and after Mary had sat in his lap about four hours, Mary turned to him saying, "John, are you tired?" And John looked up and smiled and said, "No, not now; I was two hours ago, but now I am only paralyzed."

So, in view of the paralysis of this aduience, I shall not attempt to make a speech. I must, however, tell you a Thanksgiving story I picked up in Colorado the other day. It seems a Colorado boy was visiting a cousin in New England about Thanksgiving time, and the Colorado boy observed the very elaborate preparations being made for Thanksgiving. They had Thanksgiving in Colorado, but not on so grand a scale, and so this Colorado boy inquired of his New England cousin what was the object of it all. "Why," the New England boy said, "we thank God for the blessings of our crops." "But you don't thank God for your crops, do you?" asked the Colorado boy, and the New England boy answered, "Yes, of course we do, don't you?" "No," replied the Colorado boy, "we don't depend entirely on God for our crops; we irrigate."

Well, now, the remark was not a trivial one, it was not flippant, but was a profound one, for somebody has said, and most beautifully, "that God has never yet made a world." He has started several, including the one in which we dwell, but he depends upon man living in accordance with the laws of the universe to finish that world, and that thought applies especially to the conditions here in the arid region. It came to me with great force while I was listening to the address of Mr. Andrews, and by the way, as I listened to his expressions I was glad he had crossed the Missouri River, for he is every bit a Western man and has no business in New England.

THE COLONIZATION PROBLEM.

At this late hour I can only remind you of the section over which I have been called to preside—Rural Settlement. In other words, the Section of Colonization. All the efforts of this Congress lead to one great end, which is to make homes upon the land, and in our section on Rural Settlement we shall consider the history of colonization, the opportunities open to homemakers under the national works to be built, and we shall consider the methods of colonization. I don't want to be hoggish; not even piggish. If you want to hear of forestry or any of the other branches I hope you will hear them. I have the honor to preside over a section which excites human interest and I trust we will have a fair number of human beings to attend. Among the interesting things that we will discuss will be the history of colonization in

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Utah. I have always been an admirer of the Mormons. The Mormons were the pioneers in that arid land. They have made fertile many of the valleys in the West. I sometimes like to shock my friends in the East by dwelling upon the wonderful success of the Mormons. I say to them, "My friends, you go forth by distributing tracts in illustration of the scripture; Mormons distribute tracts of land, not printed tracts." And then I say to them, "You offer people, if they will join your church, a halo; my Utah friends offer them three meals a day in this world and a halo in the next."

TO GET A HOME.

Now, thanks to our beneficent irrigation policy, the day is coming when it is possible for a poor man to get a home upon the land without joining any particular church, and there are lessons which all can learn and particularly this Congress by attending our section on Rural Settlement and listening to the history of American colonization.

I wish I had more time. There is nothing in this world so truly uncomfortable as an undelivered speech. I have a few bad hours of indigèstion ahead of me, but I want to close as I began by saying that I trust a fair representation of this Congress will spend Wednesday and part of Thursday with us while we discuss the past and glorious future of the American colonization among the mountains and valleys of the West. We were to meet at the Presbyterian church, and that fact reminds me of the following quotation from scripture: "Thus sayeth the Lord: make this valley full of ditches, for ye shall not see wind nor rain, yet this valley shall be full of water." That text once served me in good stead at the beginning of the irrigation movement in Montana. We had a great drouth that burnt up the State and meetings were being held at which the people prayed for rain. I began an address by saying that I thought the time had come to stop praying for rain and begin digging ditches, whereupon the minister expressed surprise and I crushed him with that text, and I am glad to say that he came up on the mourner's bench, a convert to irrigation.

Mr. Clark—The Chairman of Engineering and Mechanics Section desires to invite the representatives of the Republic of Mexico to be present at the meeting of their section and to present such papers as they will. They also invite these gentlemen to meet representatives of the United States Government at 5 p. m. on Wednesday at the City Hall for the purpose of becoming mutually acquainted.

Gentleman from Oklahoma—Allow me to make a motion. I move that when we do adjourn, as I understand this will be the last general meeting until Thursday, that we meet here in this hall from one o'clock to two to-morrow for a general meeting, so that all resolutions can be read before the Congress and referred to the Committee on Resolutions.

Mr. Clark—I understand the gentleman from Oklahoma that his motion is that we have a general meeting here to-morrow at one o'clock in this hall so that all resolutions can be read and referred to the Committee on Resolutions.

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Special Session, Wednesday Afternoon, November 16, 1904.

Executive Chairman Boothe—In the absence of the President and Vice Presidents, I will call the meeting to order. The offering of resolutions is the special order for this hour. Are there any resolutions to be offered ? (After several minutes' pause.) Vice President Hall is now here and will take charge of the meeting.

Mr. Hall—Gentlemen, I understand that you have met here by previous arrangement to hear and receive the presentation of resolutions. Resolutions are now in order.

Delegate from California—As there are few members present, I move we take a recess for ten minutes. Adopted.

Mr. Hall—The time for the recess having expired, please come to order. Delegates offering resolutions will kindly announce their name and the State or Territory which they represent.

Executive Chairman Boothe—While this is a meeting, the special order of which is the offering of resolutions, it might not be out of place for the Committee on Credentials to offer their report.

Mr. Hall—I do not think it will be out of order—reports of committees are always in order. If the Committee on Credentials are ready to report, they may do so.

Delegate from Oklahoma—This being a special meeting and for special purposes, I doubt whether the committee can report unless by permission.

Delegate from California—I make a motion that the special order be set aside for the Committee on Credentials to make their report.

Seconded.

Mr. Hall—There being no objections the Committee on Credentials will make their report.

Delegate Hays made report of Committee on Credentials, and on motion the report was accepted and the committee given further time.

Various resolutions were offered by Messrs. Pinchot, Florence, Fairweather and Stephens.

Gentleman from Colorado—Point of information: Does this session here exclude any further presentation of resolutions?

Mr. Hall—I can not say if it does or not.

Executive Chairman Boothe—Replying to that question, I will say that a special order will be made to-morrow evening at the beginning of the general session for the offering of resolutions.

Adjourned.

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General Session, Thursday Evening, November 17, 1904.

CHAIRMAN: L. W. SHURTLIFF,
First Vice President.

Mr. Shurtliff—Gentlemen of the Congress, the first order of business is the presentation of resolutions.

Various resolutions were offered by Messrs. Holabird, Switzer, Linney, Pinchard and Palmer.

Mr. Twitchell of New Mexico moved that each State and Territory represented in this Congress name a Vice President and one member of the Executive Committee to be present at the opening of the session to-morrow morning.

Motion seconded.

The Chairman—Are you ready for the question? All in favor of the motion signify by saying aye. Carried.

Here a delegate from Idaho read the report of the Committee on Permanent Organization, which named the Vice President and member of the Executive Committee from various States and Territories.

Mr. Prince of New Mexico—I would like to know by what authority the Committee on Permanent Organization has taken upon themselves to name the Vice President and the member for the Executive Committee for each of the States represented here? It has never been done before. Each State has named its own choice.

Mr. Twitchell—I rise to point of order.

Mr. Prince of New Mexico—The Constitution requires the members of the Executive Committee shall be selected by the delegates of the various States. There is no other way. They are never reported by this Committee. This has never been done before.

Executive Chairman Boothe—They follow the same as was done by the 11th Irrigation Congress.

Mr. Prince—I have not the slightest objection to any name read, but I do insist that this is a precedent which should not be established. This Congress has always followed that rule, and that is that every State and Territory should name its own Vice President and one member of the Executive Committee. It is even put into the Constitution, which says that the Executive Committee shall be selected by the delegation from the respective States and Territories. Now it will appear, if this goes, on the minutes in this form as a report from this Committee, and that they were appointed by that Committee, and not by the specific States and Territories. I appeal first to the precedent that it has been enforced in this Congress that each and every Territory should name its own Vice President and its own member of the Executive Committee. I appeal to the Constitution which makes this obliga-

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tory, as to the members of the Executive Committee, and I appeal, if there were no Constitution nor precedent, to that which we all know is the best rule in this case, that each State and each Territory should select its own representatives on the Executive Committee and its Vice Presidents.

Mr. Smythe—We have a magnificent program to carry out and I think it would be well for us to defer this discussion and proceed with the program, and I move that the report of the Committee be accepted, and the election of the Vice Presidents and members of the Executive Committee be let go until to-morrow.

Delegate from New Mexico—I move that each State and Territory be represented here to-morrow morning at 9:00 o'clock, and report to this convention its honorary Vice President and member of the Executive Committee.

Motion carried.

Mr. Clark—I will ask all of these gentlemen who have addresses to present to the meeting that they come forward and take a seat on the stage, so that we will know who is expected to deliver addresses. Next in order of addresses is a paper "The Progress of Irrigation in Egypt from Its Earliest Days Until the Present Time," by Mr. Bakhati. I now have the honor of presenting Mr. Bakhati of Egypt.*

Mr. Clark—I think, gentlemen, I voice the sentiment of all when I say that we are under many obligations to Mr. Bakhati for coming here and giving us an account of irrigation on the Nile. I understand that Mr. Bakhati a few months ago could not be understood in English.

The Secretary read the following telegram:

"The President and Secretary of the National Irrigation Congress, El Paso, Texas: The National Association of Agricultural Implements and Vehicle Manufacturers, in convention assembled at Chattanooga, Tenn., unanimously and heartily send you greetings and wish you Godspeed in your progress."

Also a telegram from Mr. A. Kaplan, Louisiana Commissioner:

"President of the 12th National Irrigation Congress, El Paso, Texas: I regret my inability to be present at what I hope will be the biggest and most successful Congress ever held."

Delegate from Oklahoma—If I remember rightly, the Committee on Credentials have not made their final report, and before we vote for the election, that Committee should report so that each delegation will know how many they are entitled to before they vote. I would like to ask, Mr. President, then, how many votes each delegation has? As the Committee on Credentials has not made its final report, how are we going to decide who has a right to vote, and how many votes they are entitled to cast? I thing it would be the unanimous consent to have the Committee make its final report so that we will know how to proceed.

Delegate from Texas—I would like to know how we are going to get together to vote. I don't know that the Texas delegation has had any meeting. There are sixty delegates from Texas in the house, and while our banner

* Mr. Bakhati's address is printed on page 129.

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is over there, most of the delegates from this State have been very busy about other matters, and have not had time to get together. I think it would be well to declare a recess of a few moments so that the delegates can get under their respective banners and determine just how to cast their vote. In fact, I move a recess of five minutes that each delegation can get under its banner. Then we will get together and can caucus, and decide how we shall cast our ballots.

Delegate from Oklahoma—I amend that motion, to the effect that the Texas delegation be permitted to withdraw and decide which way they wish to vote. Amendment seconded and carried.

The Chairman—Texas delegation will be permitted to withdraw for the purpose indicated. To make things plain, I might say that if there are ten votes of any delegation present, they may cast ten votes, or a less number than ten will be allowed to cast their proportion of ten votes.

Delegate from Oregon—With the consent and at the request of the gentlemen from Idaho and the gentlemen from Oregon, I would ask that this conference to be held by the Texas delegation be held after the nominations have been made, and that will give them ample time in which to prepare their ballots.

Delegate from California—I would like to have the Constitution read as to States having more than ten delegates present. (That portion of the Constitution was then read by the Secretary.)

The Chairman—If a State has 15 delegates present, they would have 15 votes. The question has been asked by the gentleman, how are you going to know this evening how many votes each State can cast. The Committee on Credentials has made a partial report, and they intend to make a final report to-morrow, and I understand that about 70 more delegates came in since the partial report was made, and there is no one in this room who knows where the extra delegates are accredited to, that is, to what State. I should think that the Committee on Credentials should report first.

Mr. Smythe—Do I understand that if a State has but one delegate, and he is present, he can vote ten votes?

The Chairman—Yes.

Delegate from Oklahoma—I understand that the Chairman of the Committee on Credentials is now ready to report, and can read the report in a few minutes, and thus settle the matter.

Delegate from Illinois—Suppose that Illinois had two delegates; they would be entitled to cast ten votes. Supposing one of them was absent, how many?

The Chairman—If Illinois had one absent and one here, he could cast his proportion of ten.

The Chairman—The chair is of the opinion that the Committee on Credentials should report, and while it will amount to a suspension of the rules, if there is no objection the Committee will report. There being no objection, the Committee will now report.

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REPORT OF COMMITTEE ON CREDENTIALS.

The Credentials Committee reported that the Secretary's register showed the following named duly accredited delegates present.

ARIZONA

D. M. Green, Solomonville.
Geo. W. Hance, Camp Verde.
Lyman Bridges, Tucson.
Henry Warren, Holbrook.
Frank P. Trott, Phoenix.
Dwight B. Heard, Phoenix.
H. W. Bishop, Solomonville.
J. E. Thompson, Bisbee.
W. W. Pace, Thatcher.
W. Y. Price, Florence.
Kendric C. Babcock, Tucson.
Chas. D. Reppy, Florence.
F. C. Dolly, Casa Grande.
Edward N. Buck, Naco.
B. A. Fowler, Phoenix.
W. A. Wilson, Phoenix.
Frank H. Parker, Phoenix.
John P. Orme, Phoenix.
C. R. Hakes, Mesa.
R. A. Kirk, Douglas.
C. F. Joyce, Douglas.
E. R. Pirtle, Douglas.
J. M. Sparks, Douglas.
O. P. Bondeson, Yuma.
J. H. McClintock, Phoenix.
Andrew Kimball, Thatcher.
Phil C. Merrill, Pima.
Geo. Peck, Bryce.
C. S. Steward, Mesa.
J. A. Harrison, Nogales.
A. J. Davidson, Tucson.
H. B. Fletcher, Florence.
Geo. E. P. Smith, Tucson.
T. G. Norris, Prescott.
G. H. Murphy, Tucson.
L. H. Manning, Tucson.
Ed. L. Pomeroy, Mesa.
C. M. Burkhalter, Tucson.
Mose Drachman, Tucson.
W. T. Webb, Pima.
Mrs. W. T. Webb, Pima.
J. L. Waring, Mesa.
W. C. Ferris, Benson.
A. V. Grossetta, Tucson.
E. Randolph, Tucson.
Wm. G. McNulty, Phoenix.

CALIFORNIA

C. B. Boothe, Los Angeles.
John Fairweather, Reedley.
C. W. Oberlein, San Francisco.
Scipio Craig, Redlands.
Mrs. Scipio Craig, Redlands.
Wm. E. Smythe, San Diego.
J. B. Lippincott, Los Angeles.
Ferd K. Rupe, Los Angeles.
Prof. A. G. McAdie, San Francisco.
P. T. Evans, Riverside.
David DeWitt Lawrence, Imperial.
T. P. Lukens, Pasadena.
Mrs. Helen Lukens-Jones, Pasadena.
W. F. Holt, Redlands.
C. S. Chesnut, San Francisco.
Fred C. Finkle, Los Angeles.
W. C. Mendenhall, Los Angeles.
Willis M. Slosson, Nordhoff.
J. R. Braun, Los Angeles.
E. T. Perkins, Los Angeles.
P. G. Lewis, Los Angeles.
E. G. Denniston, San Francisco.
A. R. Kanaga, San Francisco.
W. H. Holabird, Los Angeles.
Geo. C. Pardee, Sacramento.
Mrs. Geo. C. Pardee, Sacramento.
Leroy Holt, Imperial.
A. H. Heber, Imperial.
W. J. Doran, Los Angeles.
John Tuohy, Tulare.
Emmet Barber, Tulare.
Mrs. John Tuohy, Tulare.
A. F. Mack, Santa Ana.
W. A. Hawley, Santa Barbara.
N. W. Stowell, Los Angeles.
A. L. Sumption, Los Angeles.
C. M. Maze, Modesto.
Fred M. Smith, Los Angeles.
A. M. Shoemake, Modesto.
C. A. Dickinson, Ceres.
Capt. W. H. Auble, Los Angeles.
J. J. Underhill, Los Angeles.
Mrs. E. H. Underhill, Los Angeles.

COLORADO.

Lute Wilcox, Denver.
J. S. J. Lallie, Denver.
A. J. McCune, Denver.
C. E. Wantland, Denver.

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COLORADO—CONTINUED.

Joseph F. Thomas, Manassa.
A. Lincoln Fellows, Denver.
E. B. Coggeshall, Denver.
Arthur F. Francis, Cripple Creek.
H. E. Storrs, Denver.
Chas. L. Michod, Colorado Springs.
Burroughs Edsall, Colorado Springs.

DISTRICT OF COLUMBIA.

Gifford Pinchot, Washington.
F. H. Newell, Washington.
Edward B. Garriott, Washington.
Geo. H. Maxwell, Washington.
Guy E. Mitchell, Washington.
Morris Bien, Washington.
A. F. Potter, Washington.
C. W. Dorsey, Washington.
J. Garnett Holmes, Washington.
N. H. Darton, Washington.
Mrs. N. H. Darton, Washington.
A. L. Dahl, Washington.
E. A. Sterling, Washington.
W. T. Swingle, Washington.
H. E. Williams, Washington.

GEORGIA.

B. M. Hall, Atlanta.

IDAHO.

Jesse B. Hawley, Boise City.
James H. Hawley, Boise City.
F. A. Sloane, Boise City.
G. A. Latham, Boise City.
J. T. Morrison, Boise City.
O. J. Turley, Boise City.
G. H. O'Day, Mosco.

ILLINOIS.

J. Lewis Draper, Chicago.
A. L. Klank, Danville.
S. H. Watson, Mt. Vernon.
G. L. Hill, Champaign.
Wm. H. Thompson, Chicago.
D. H. Anderson, Chicago.

INDIAN TERRITORY.

Herbert J. Evans, Muscogee.

KANSAS.

C. A. Schneider, Garden City.
Wm. H. Barnes, Topeka.
D. W. Baline, Pratt.
W. A. Harris, Limwood.

LOUISIANA.

W. J. Carter, New Orleans.
David Lemky, New Orleans.
C. J. Fuqua, Baton Rouge.
Henry F. Reymand (formerly of La.) El Paso, Texas.

MICHIGAN.

Mrs. W. K. Morley, Grand Rapids.
Thos. L. Hackett, Grand Rapids.

MINNESOTA.

Col. V. W. Halstead, St. Paul.
Thos. Shaw, St. Anthony Park.
John McAlpine, Duluth.
Chas. L. Hyde, Duluth.
J. Killoran, Duluth.
A. M. Chisholm, Duluth.
Geo. H. Crosby, Duluth.

MISSOURI.

M. Schulter, St. Louis.
Frank Anderson, St. Louis.
L. E. Archias, Sedalia.
L. H. Archias, Sedalia.
Geo. E. Bowen, St. Louis.
H. H. Wernse, St. Louis.
T. R. Ballard, St. Louis.
Levi Chubbuck, Skidder.

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MONTANA.

J. A. Switzer, Bridger.
Herbert Strain, Great Falls.
J. H. Anderson, Butte.
W. A. Clark, Butte.
A. B. Everett, Harlem.
C. H. Campbell, Great Falls.
Wm. Roberts, Great Falls.
T. M. Everett, Harlem.
Samuel Dinsmore, Missoula.
Austin North, Billings.
S. R. Strain, Great Falls.

NEBRASKA.

F. V. Meagley, Lexington.
F. L. Temple, Lexington.
H. C. McKibbin, Lexington.
J. S. Thomas, Lexington.
A. C. Banks, Lexington.
T. H. Boyles, Lexington.
P. Maginnis, Kimball.
T. L. Doherty, Loomis.
J. E. Smith, Beatrice.
W. H. Wright, Scotts Bluff.
F. M. Sands, Scotts Bluff.
L. P. White, Lexington.

NEVADA.

Chas. Sparks, Reno.
Francis G. Newlands, Reno.
A. E. Chandler, Carson City.
J. M. Jones, Reno.

NEW MEXICO.

Adin H. Whitmore, Las Vegas.
M. W. Browne, Las Vegas.
Chas. Ilfeld, Las Vegas.
W. S. Gillian, Mesilla Park.
G. W. Mossman, Earlham.
S. G. Kilgore, Berino.
A. H. Pearson, Hillsboro.
Eugene Van Patten, Las Cruces.
H. C. McLallen, Columbus.
M. D. Gaylord, Nogales.
J. A. Mahoney, Deming.
E. H. Bickford, Lake Valley.
W. T. McCreight, Albuquerque.
A. L. Kendall, Cerillos.
L. T. McLaughlin, Albuquerque.
H. D. Bowman, Las Cruces.
Guadalupe Ascarate, Las Cruces.
Martin Lehman, Las Cruces.
B. W. Randall, Lordsburg.
F. G. Tracy, Carsbad.
H. C. Abbott, Springer.
C. E. Linney, Santa Fe.
Pearl Baily, Chamberino.
Oscar C. Snow, Mesilla Park.
Mrs. C. E. Linney, Santa Fe.
W. M. Reed, Roswell.
J. S. Brown, Lordsburg.
A. W. Wilson, Deming.
Jay Turley, Santa Fe.
S. D. Swope, Deming.
Geo. W. Prichard, Santa Fe.
Wm. Palmer, Garfield.
Herbert B. Holt, Las Cruces.
A. M. Hove, Calsbad.
Edwin A. Chaffee, Las Cruces.
Geo. H. Webster, Carsbad.
R. E. Twitchell, Las Vegas.
J. D. Tinshy, Las Cruces.
B. L. Rodey, Albuquerque.
Theodore Ronault, Las Cruces.
M. T. Brown, Las Cruces.
R. S. Benson, Carlsbad.
Herman Westheim, Dona Ana.
W. N. Hager, Las Cruces.
Henry Stoes, Las Cruces.
W. C. Mead, Victoria.
Jesus Ochoa, Anthony.
Angel Alvarez, Anthony.
R. J. Bolles, Carlsbad.
Samuel I. Roberts, Carlsbad.
C. H. McLenathan, Carlsbad.
B. L. Sullivan, Carlsbad.
James G. McNary, Las Cruces.
Jose R. Lucero, Las Cruces.
Prof. Luther Foster, Las Cruces.
W. Rogers, Chamberino.
Nestor Armije, Chamberino.
Prof. J. J. Vernon, Mesilla Park.

NEW YORK.

Truman G. Palmer, New York City.

NORTH DAKOTA.

E. F. Chandler, University.

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OHIO

C. M. Cook, Toledo.

OKLAHOMA.

W. T. Little, Perry.
Joseph B. Thoburn, Guthrie.
F. F. Ferguson, Union City.
E. J. Murphy, Arapaho.
J. M. Hayes, Mountain Park.
J. Campbell, Mountain Park.
W. L. Fullerton, Victory.
Dr. W. Woodward, Snyder.
Joseph McNeal, Guthrie.
J. M. Cassidy, Chandler.
Jared Sater, Sr., Kenton.
J. M. Potter, Kenton.
L. A. Wykoff, Kenton.
H. H. Champlin, Enid.
F. M. Cline, Woodward.
Mark Roberts, Mountain Park.
W. R. Baldwin, Cordell.
Geo. W. Seifert, Berlin.
Frank D. Northup, Oklahoma City.
C. G. Jones, Oklahoma City.
Sidney Clarke, Oklahoma City.
E. E. Brown, Oklahoma City.
Tesse C. Davis, Frederick.
Frank Lugert, Lugert.
Jno. S. Carmack, Snyder.
A. J. Hunter, Snyder.
S. J. Morris, Hooker.
C. W. Wolfington, Hooker.
Walter Naylor, Guyman.
G. H. Matthes, Lawton.
Miss Blanche Hinckley, Watonga.
Ewers White, McLoud.
S. B. Launs, Woodward.
E. W. Kinman, Guthrie.
A. R. McLennan, Lawton.
C. S. Meredith, Lawton.
C. B. Bellamy, Lawton.
W. M. Turner, Lawton.
P. H. Haner, Guthrie.
W. W. Wolfington, Beaver.

OREGON.

C. W. Mallet, Ontario.
Miss Clara S. Carlisle, Portland.
Mrs. L. A. Carlisle, Portland.
H. C. Willis, Echo.
Tom Richardson, Portland.
Thos. G. Hailey, Pendleton.
E. L. Smith, Hood River.
A. H. Devers, Portland.
Steven A. Lowell, Pendleton.
A. K. Wilson, Portland.
E. M. Bramick, Portland.
J. N. Williamson, Priceville.
Gus Weber, Pendleton.
Frederick C. Harlow, Pendleton.
J. K. Reader, Ashland.
Mrs. A. F. Wood, Cottage Grove.
W. W. Sibrary, Portland.
J. M. Moore, Portland.
Mrs. J. M. Moore, Portland.

TEXAS.

J. A. Smith, El Paso.
J. P. Casey, El Paso.
Prof. H. P. Attwater, Houston.
P. Theaux, Houston.
H. M. Holleman, Houston.
Judge W. A. Evans, Bonham.
C. E. Kellogg, Clint.
F. M. Walker, Galveston.
G. Waldo, El Paso.
A. N. Brown, El Paso.
A. Dulchery, El Paso.
J. D. Mason, El Paso.
V. R. Stiles, El Paso.
W. R. Brown, El Paso.
J. D. Morrison, El Paso.
C. R. Morehead, El Paso.
T. S. Foster, Sweetwater.
S. P. Weisiger, El Paso.
Adolph Hoffman, El Paso.
P. F. Edwards, El Paso.
Prof. Monta Beach, Houston.
W. B. Phillips, Austin.
J. A. Gillette, Marfa.
J. C. Bird, Alpine.
Morris P. Kirk, El Paso.
A. A. Ward, Beaumont.
W. L. Malcolmson, Marfa.
Henry Warren, Dallas.
J. A. Kemp, Wichita Falls.
Clell A. Thorpe, Pecos.
G P. Lessing, El Paso.
J. A. Udden, Austin.
A. P. Coles, El Paso.
Aleck Meerscheidt, San Antonio.
Paul Stieren, San Antonio.
F. M. Edwards, San Antonio.
Jno. C. Beck, San Antonio.
G. Bedell Moore, San Antonio.

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TEXAS.—CONTINUED.

A. C. Wilmuth, Snyder.
Geo. E. Barstow, Barstow.
Daniel J. Rogers, Barstow.
Geo. E. Briggs, Barstow.
N. D. Lane, El Paso.
John Kelley, San Saba.
Joe A. Williams, San Saba.
John Hall, Lampasas Springs.
A. W. Gifford, El Paso.
W. W. Turney, El Paso.
Alfred Courchesne, El Paso.
J. R. Harper, El Paso.
Francisco Mallen, El Paso.
John W. Fisher, El Paso.
E. Kohlberg, El Paso.
E. C. Pew, El Paso.
W. Trickey, Pearsall.
R. Woodward, Pearsall.
J. J. Mundy, El Paso.
C. O. Coffin, El Paso.
Prof. T. U. Taylor, Austin.
G. M. Otis, Grand Falls.
J. M. Ingle, Abilene.
P. M. Millspaugh, El Paso.
Thos. H. Bomar, Grand Falls.
T. A. Thompson, Grand Falls.
Leonard Strable, Grand Falls
J. H. Stephens, Vernon.
Z. L. Cobb, El Paso.
J. J. Smith, Ysleta.
J. Stoney Percher, El Paso.
Felix Martinez, El Paso.
E. J. Hadlock, El Paso.
J. R. Cunningham, Abilene.
Frank Johnson, Colorado.
W. T. Lee, El Paso.
J. L. Rhead, El Paso.
B. F. Hammett, El Paso.
W. H. Winn, El Paso.
A. Starr, Dallas.
C A. Greene, El Paso.

UTAH.

John Henry Smith, Salt Lake City.
John Beck, Salt Lake City.
Miss Margaret Parks, Salt Lake City.
Roger Farrer, Provo City.
Jas. Meldrum, Provo City.
Fred J. Kiesel, Ogden.
Miss W. R. Kiesel, Ogden.
L. W. Shurtliff, Ogden.
Dr. H. J. Faust, Salt Lake City.
R. W. Young, Salt Lake City.
Andrew Knudson, Provo City.
Oscar B. Young, Provo City.
Alex Brown, Randolph.
Thos. H. Means, Salt Lake City.
C. J. Humphries, Ogden.
O. B. Gilson, Ogden.
Chas. W. Penrose, Salt Lake City.
Thos. Maloney, Ogden.
Rufus Garner, Ogden.
J. F. Pender, Ogden.
Chas. F. Middleton, Ogden.
Jos. Carlson, Ogden.
G. L. Hutchins, Ogden.
John W. Wheelright, Ogden.

WASHINGTON.

C. C. Hewitt, Spokane.
Jno. F. Greene, Harrington.
A. W. Hadley, Spokane.
C. Eugene Bortle, Spokane.
H. B. Scudder, North Yakima.

WISCONSIN.

Delbert Utter, Lake Beulah.
Thos. Barden, Ashland.
Martin Pattison, Superior.
Howard Thomas, Superior.
C. H. Callender, Black River Falls.
J. B. Stair, Lake Mills.
Chas. L. Slichter, Madison.
Gilbert Kleven, Mt. Horeb.
A. H. Peacock, Lake Beulah.
O. Greeley, Lake Beulah.
Chas. J. Maple, Milwaukee.

WYOMING.

O. Felker, Sheridan.

MEXICO.

Gen. W. D. Snyman, Chihuahua.
Guillermo Robert, Juares, Chih.
Inocente Ochoa, Juares, Chih.
Mariano Saminego, Juares, Chih.
Vicente Cordero, Juares, Chih.
Rodolfo Chavez, Juares, Chih.

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MEXICO.—CONTINUED.

Juan N. Fandoa, Chihuahua.
C. A. Mathewson, Chihuahua.
J. P. Conduit, Tlihualilo, Coah.
B. F. Butler, Lerdo, Dgo.
C. C. Gonzales, Chihuahua.
R. Anderson, Chihuahua.
Dr. W. C. Rowlings, Chihuahua.
Manuel M. Mendiola, Victoria, Tam.
Jose Duvallon, Victoria, Tam.
Carlos Arguelles, Victoria, Tam.
Ignacio R. Montemayor, Jaumane, Tam.
A. E. Graham, La Cruz Sta., Tam.
Jose Martinez, Santa Engracia, Tam.
Santiago M. Seguin, Monterey, N. L.
Wentworth S. Conduit, Monterey, N. L.
A. B. Call, Colonia Dublan.
Henry E. Bowman, Colonia Dublan.
D. C. Sutton, Sabinal, Chih.
Heleman Pratt, Colonia Dublan.
Sr. Jacobo Blanco, San Luis Potosi.
Anthony W. Ivins, Colonia Juares.
Wm. C. McCellan, Colonia, Juares.
Chas. Whipple, Colonia Juares.
Wm. G. Sears, Colonia Dublan.
Sam'l J. Robinson, Colonia Dublan.
Lic. J. N. Amador, Ciuda Juares.
Ing. P. Aguilar, Guanajuato.
Raphal de la Mora, Guadalajara, Jal.
Ignacio Carranza, Mexico City.
Alberto Guajardo, Muzquiz, Coah.
Fred Eldridge, Casas Grandes.
J. M. Pryde, Casas Grandes.
Jas. P. Dardon, Colonia Juares.
Benj. Echols, Oaxaca, Sonora.
Espiradion Provencio, Colonia Juares.
Don Romulo Escobar, Ciudad, Juares.
Ambrosio Romo, Zacatecas.
Roberto Gayol, Mexico City.
E. T. Turley, Colonia Juares.
Maxwell A. Kilbert, Mexico City.
Lic. Felipo Seijas, Juares.
O. C. Ellison, Hermosillo, Son.

OTHER FOREIGN GOVERNMENTS.

M. K. H. Bakhati, Cairo, Egypt.

Delegates were appointed under the provisions of the official call by the following:

STATES.

California.
Colorado.
Idaho.
Illinois.
Iowa.
Kansas.
Kentucky.
Louisiana.
Michigan.
Minnesota.
Missouri.
Montana.
Nebraska.
Nevada.
Oregon.
South Dakota.
Texas.
Utah.
Washington.
Wisconsin.

TERRITORIES.

Arizona.
District of Columbia.
Indian Territory.
New Mexico.
Oklahoma.

FOREIGN COUNTRIES.

Egypt.
Republic of Mexico.

COUNTIES.

Dona Ana County, Arizona.
Graham County, Arizona.
Pinal County, Arizona.
Yuma County, Arizona.
Grant County, New Mexico.
Las Cruces County, New Mexico.
Sierra County, New Mexico.
El Paso County, Texas.
Ward County, Texas.
Rich County, Utah.
Weber County, Utah.
Lincoln County, Washington.

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CITIES.

Birmingham, Alabama.
Bisbee, Arizona.
Phoenix, Arizona.
Pima, Arizona.
Thatcher, Arizona.
Tucson, Arizona.
Fresno, California.
Los Angeles, California.
Pasadena, California.
Santa Barbara, California.
San Francisco, California.
Sacramento, California.
Tulare, California.
Colorado Springs, Colorado.
Cripple Creek, Colorado.
Denver, Colorado.
Pueblo, Colorado.
Atlanta, Georgia.
Boise City, Idaho.
Chicago, Illinois.
East St. Louis, Illinois.
Kansas City, Kansas.
Henderson, Kentucky.
Lexington, Kentucky.
Kansas City, Missouri.
St. Joseph, Missouri.
Lexington, Nebraska.
Scotts Bluff, Nebraska.
Albuquerque, New Mexico.
Deming, New Mexico.
Las Vegas, New Mexico.
Santa Fe, New Mexico.
Springfield, Ohio.
Piqua, Ohio.
Portsmouth, Ohio.
Lawton, Oklahoma.
North Bend, Oregon.
Pendleton, Oregon.
Austin, Texas.
Bonham, Texas.
El Paso, Texas.
Marfa, Texas.
Wichita Falls, Texas.
Ogden, Utah.
Provo City, Utah.
Salt Lake City, Utah.
Spokane, Washington.
Walla Walla, Washington.

UNIVERSITIES AND COLLEGES.

University of Arizona, Tucson.
New Mexico College of Agriculture and Mechanical Arts.
University of North Dakota.
University of Texas.

COMMERCIAL ORGANIZATIONS, IRRIGATION ASSOCIATIONS, ETC.

Business Men's League of Decatur, Alabama.
San Pedro Valley Water Users' Association, Benson, Arizona.
Chamber of Commerce, Douglas, Arizona.
Douglas Branch of Irrigation Association, Douglas, Arizona.
Casa Grande Water Association, Florence, Arizona.
Mesa Canal Company, Mesa, Arizona.
Board of Trade, Nogales, Arizona.
Salt River Valley Water Users' Association, Phoenix, Arizona.
Association Civil Engineers, Tucson, Arizona.
Chamber of Commerce, Tucson, Arizona.
Casa Grande Water Users' Association, Tucson, Arizona.
Board of Trade, Little Rock, Arkansas.
Chamber of Commerce, Brawley, California.
Water Consumers' Association, Ceres, California.
Imperial Valley Chamber of Commerce, Imperial, California.
Imperial Water Company, Imperial, California.
Board of Trade, Los Angeles, California.
E. Whittier Land & Water Co., Los Angeles, California.
Jobbers' Association, Los Angeles, California.
Chamber of Commerce, Los Angeles, California.
Modesto Irrigation District, Modesto, California.
Board of Trade, Redlands, California.
Chamber of Commerce, Riverside, California.
Chamber of Commerce, Sacramento, California.
Merchants' Association of San Francisco, California.
California State Board of Trade, San Francisco, California.
Westminster Farmers' Club, Westminster, California.

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COMMERCIAL ORGANIZATIONS, IRRIGATION ASSOCIATIONS, ETC.—CONTINUED.

Chamber of Commerce, Denver, Colorado.
Grand Rapids Board of Trade, Bloomington, Illinois.
National Business Men's League, Chicago, Illinois.
Arkansas Valley Land & Irrigation Company, Garden City, Kansas.
Mercantile Club of Kansas City, Kansas.
Mechanics & Lumbermen's Exchange, New Orleans, La.
Board of Trade, Grand Rapids, Michigan.
Business Men's Club, Sedalia, Missouri.
Interstate Merchants' Association, St. Louis, Missouri.
Merchants' Association, St. Louis, Louis, Missouri.
Commercial Club, Duluth, Minnesota.
Public Affairs Committee, Duluth, Minnesota.
Rosebud Irrigation Company, Bridger, Montana.
Business Men's Association, Great Falls, Montana.
Chamber of Commerce, Reno, Nevada.
Refugio Community Ditch Association, Anthony, New Mexico.
Commercial Club, Albuquerque, New Mexico.
Pecos Irrigation Company, Carlsbad, New Mexico.
Carlsbad Commercial Club, Carlsbad, New Mexico.
Pecos Water Users' Association, Carlsbad, New Mexico.
Chamberino Community Ditch Association, Chamberino, New Mexico.
Community Ditch Association, Dona Ana, New Mexico.
Adelphi Club, Deming, New Mexico.
Chamber of Commerce, Earlham, New Mexico.
Community Ditch Association, Hatch, New Mexico.
Board of Trade, Las Cruces, New Mexico.
Chamber of Commerce, Las Cruces, New Mexico.
Mesilla Community Ditch Association, Mesilla, New Mexico.
Horticultural Society, Mesilla, New Mexico.
Community Ditch Association, Mesilla Park, New Mexico.
Horticultural Society, Santa Fe, New Mexico.
Board of Trade, Santa Fe, New Mexico.
La Mesa Community Ditch Association, Victoria, New Mexico.
Commercial Club, White Oaks, New Mexico.
San Miguel Community Ditch Association.
American Protective League, New York.
Commercial Club, Beaver, Oklahoma.
Commercial Club, Guthrie, Oklahoma.
Commercial Club of Guymon, Oklahoma.
Hooker Irrigation Society, Hooker, Oklahoma.
Oregon Development League, Echo, Oregon.
Commercial Club, Cottage Grove, Oregon.
Morrow County Development League, Heppner, Oregon.
Commercial, Club, Irrigon, Oregon.
McMinnville Development League, McMinnville, Oregon.
Chamber of Commerce, Ontario, Oregon.
Board of Trade, Portland, Oregon.
Board of Trade, Austin, Texas.
Chamber of Commerce, Beaumont, Texas.
Barstow Irrigation Company, Barstow, Texas.
S. W. Irrigation Association, El Paso, Texas.
Franklin Irrigation Company, El Paso, Texas.
Chamber of Commerce, El Paso, Texas.
International Miners' Association, El Paso, Texas.
Grand Falls Land & Irrigation Company, Grand Falls, Texas.
Galveston Business League, Galveston, Texas.
Houston Business Men's League, Houston, Texas.
Texas Miners' Association, Marfa, Texas.
Irrigation Company of San Saba, Texas.
Board of Trade, San Saba, Texas.
Business Men's Club, San Antonio, Texas.
Huntsville Irrigation Association, Huntsville, Utah.

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COMMERCIAL ORGANIZATIONS, IRRIGATION ASSOCIATIONS, ETC.—CONTINUED.

Chamber of Commerce, Ogden, Utah.
Ogden Canal and Water Company, Ogden, Utah.
Weber Club of Ogden, Utah.
Lynne Irrigation Company, Ogden, Utah.
Provo Commercial Club, Provo, Utah.
Randolph & Sage Co., Irrigation Company, Randolph, Utah.
Davis & Weber Canal Company, Utah.
Chamber of Commerce, Spokane, Washington.
Business Men's Association, Sheridan, Wyoming.
Department of the Interior of Washington, D. C.
Department of Agriculture of Washington, D. C.

FOREIGN.

Dublan Industrial Society.
Irrigation Projects Office, Egypt.
Board of Trade, Hermosillo, Republic of Mexico.
Colonization Company, Republic of Mexico.
Agriculture and Horticultural Society, Republic of Mexico.

The Chairman of Committee on Credentials reported that there were present 468 delegates.

Delegate from Oklahoma—I move that the report of the Committee on Credentials be received, and that the committee be discharged.

Motion carried.

The Chairman: We will now proceed for the location of the capital (laughter)—I was going to say this is a capital organization—for the location of our next meeting place. We will proceed to select the location for the next Congress. I have now the pleasure of introducing to you Mr. Hawley, of Idaho.

Mr. Hawley—Mr. President, ladies and gentlemen of the convention: I have been requested by my brother delegates of the Idaho delegation to present to you in behalf of Idaho a canditate for the honor of the next meeting of the Irrigation Congress. We, of Idaho, although we realize that we have not a State that is as great in area as California or as Texas, believe that we have one of sufficient importance to entitle our claims for this great honor to respectful consideration at the hands of this Congress. Idaho extends from British Columbia on the north to Utah and Nevada on the south; it extends from Oregon and Washington on the west to Montana and Wyoming on the east. It embraces within its area many diversified climates; many different sections which have different lines of business in which the inhabitants are engaged. We have in the north the greatest wheat-growing section in the United States, equaled only, but exceeded by none. Again in the central part of the State we have the mountains—the snow-capped mountains with their rock-ribbed sides, that seemingly hold promise in the near future to make us the equal of Colorado and Montana as a mining region. But more important than all, and comprising two-thirds of the entire State, is the southern part—the irrigated section. We have here a section that is singularly favored by nature. We are the only State of the arid region that has a sufficient supply of water for the irrigation of lands within our limits. A great tributary of the Columbia River runs through our borders from east to west, commencing at the Oregon line, making the most fertile valley in the universe. And this one valley is from 50 to 150 miles wide, and not only is the Snake River traversing this great section, but other rivers, not as

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great, but almost so, flow there. And of all this land, with the exception of a comparatively small portion, is the richest land on God's footstool, all susceptible of irrigation, and all it needs is active aid in the way of reclamation to make it blossom and bloom like the rose. Situated at the head of one of these valleys—situated where the Boise River commences and where the great valley stretches, is located the capital city—Boise the Beautiful. Commencing as a mining camp, as a convenient center for the distribution of the supplies in the days of the '60s, it gradually grew to large proportions, and the people began to talk of building up the city, in making it a place in which families could live. And finally we ascertained that the soil which had been considered worthless, was, upon the application of water, capable of growing any vegetables, any fruits that could be grown in the temperate regions of this country. And borrowing from our neighbors in Utah to the south, we commenced an irrigation system in the State, which, from a small beginning, has grown until now it is the greatest in these United States. First, my fellow delegates, taking the property near the river, and the lowlands, then ascertaining that the higher lands were better, we commenced a system of canals which cover almost the entire valley in the vicinity of Boise. We have extended that canal system until 225,000 acres of the land of that little valley are under our canals and are being cultivated at the present time. We have a city that for beauty is unequaled in the West. We have a population of earnest and active men and women. We have endeavored in that far-away country to build up a community thoroughly American in principle, one that is bound to advance as irrigation advances, and there is no limit to the capacity of production of the ground upon which it stands and which is tributary to us. We have a population at the present time of about 20,000, but we are thoroughly prepared to entertain the next Irrigation Congress. We have every facility for doing justice to as great an assemblage as has convened in El Paso at the present time. We have a city to which we can refer with expressions of pride. We are an active community, a growing community. We have expended there during the last three months over $300,000 upon our streets and our sidewalks; we do not owe a dollar of it, because we paid for it as we went. And other improvements are now in process of construction that will be finished by next September at least, costing $700,000 more. We have in the vicinity of Boise the greatest irrigating enterprises that are now being projected in the United States. At Twin Falls, but a few hours' ride, there has been taken from the Snake River by means of dams and canals, a sufficient volume of water to irrigate 280,000 acres of land, and during the next season that water will be used upon these lands. A great community is growing up in that section which a year ago was given over to the jack rabbit and coyote.

We have at Minidoka, but a few hours' ride from Boise, a great government enterprise in course of construction. The contracts have been partially let, and over 180,000 acres of the finest land will be added to the agricultural resources of the State. We have a project which is already in process of survey, and will undoubtedly, during the next year, be carried to completion, involving the expenditure of $6,000,000, which will conserve the waters of the great storms for use upon the lands that are not already covered. We have,

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within a few hours' ride, in the regions of the Snake River, 500,000 acres of land irrigated in three months. We have great enterprises there—some in completion and some in process of construction. And I say to you, my fellow-delegates, if this is really an Irrigation Congress—if we want to improve our knowledge on facts involved therein, we should take this Congress to some place where irrigation is being practically carried on and where its workings can be studied.

I have the pleasure to name Boise for your favorable consideration. Although situated in the greatest of the irrigating States of the United States, never have we as yet been honored with a meeting of this Congress. We believe that if you will come to us and hold a session there you can learn much that will be of profit to you in the future. We believe if you will meet in our midst that it will be of benefit to yourselves.

We have come here from Idaho intending, by fair means if possible, to bring this convention to our own capital city. We have refused to enter into any combination. We have absolutely refused to entertain propositions that would in any way entangle the delegation from Idaho in the future. We present the name of our city upon its merits. We have not asked reciprocity from any one. We have not asked that some State shall favor us now because in the future we will give them our vote. We have not in any way compromised the future of the delegation from our State or from any other State. And I say to you that the rule that seems to have prevailed heretofore in this convention in certain States is one that should be absolutely foreign to the conduct of this convention.

It was only last night that in the lobby of the Sheldon Hotel I heard a gentleman from one of the greatest States say to a fellow-delegate from that State, "Take off one of those badges," and he had on the badge of the State of Colorado, and a badge reading "Boise, the Beautiful, for the next Session," and I spoke to him, and he says "it is understood that our delegation is going for Portland upon to-morrow's session." And I asked him why they were so doing, and he informed me that the reason was the fact that the Oregon delegation in the Mining Congress had seen to it that Denver was made the permanent city of that congress, and they proposed to reciprocate, and they were pledged to that effect, and I say to you, when delegations to this Congress, or to any congress, who come here for the interests of the arid section, so far forget their duty to the interest which they are supposed to represent, as to trade and traffic for the sake or benefit of their own locality, that they are traitors to their cause so far as the great interest of irrigation is concerned, and I am glad to say that that gentleman from Colorado retained that Boise badge upon his breast and refused to discard it because the Chamber of Commerce of Denver had entered into a trade by means of which the Colorado vote was to be cast against us.

I simply refer to this, not in a spirit of criticism towards these gentlemen, but I believe it is my duty to make these statements. I believe that this practice of swapping votes—that this practice of trading in regard to localities—is one upon which you should stamp the seal of your condemnation here and now, because it is unworthy of this great convention. We should meet wherever it is to the interest of the cause of irrigation to have the Congress go.

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Now, my friends, what have you in opposition of Boise? As I understand it the only place, now, that is to present its claims against Boise for the next Congress is the city of Portland, in Oregon. Oregon is a great State, and Portland is a fine city. No one appreciates that more than the people of Idaho. But, my friends, Portland is the last place, in my humble judgment, to which an Irrigation Congress could go. What they want there is draining—not irrigation. Why, up in my country when we speak of an Oregonian, or one that lives west of the Cascade Mountains, we generally refer to him as a "web-foot," because it is currently reported that a man that has lived in that section for a few years, on account of the humidity of the atmosphere, develops some of the characteristics of the duck family. Now, I am not stating this as a jeer against Portland. I am simply stating that which is a matter of current rumor. If they desire to disprove it, they can do so to this Congress.

Now, ladies and gentlemen, there is an eternal fitness in all things, and while I am not so hidebound as to deny to any State the privilege of meeting with us in an Irrigation Congress; while I would like to educate the people of the entire country up to the standard of irrigation, and impress upon them the need of building up a certain section of their own communities; while I believe that it is best to give space to every State and every Territory in this Congress for the sake of educating them up to the true standard, still I am not one of those who believe in taking this Congress away from the arid region to some place that does not need it. The papers that are read before us are for the purpose of instructing us as to the practical working of irrigation matters, that they may be thoroughly understood. Can you go to Portland and learn anything about irrigation? Is there anyone there that ever irrigates, unless they do it under a roof? I tell you, there is not an irrigating canal within 200 miles of the place, so what could you learn? My friends of Oregon have promised us a great deal. If they have not promised gum boots and rubber coats, I would advise you not to forget your own, for you will need them in Portland. Now, what claim has the State of Oregon, or at least that portion of the State of Oregon, upon this Congress? I ask you who are impressed with the importance of this question, and desire the success of the reclamation of the arid lands, what single, solitary valid reason you can present for taking this Congress to a location like that? What can you learn? How can you improve your knowledge in regard to this great subject? Can you do it by observation? Will you do it simply by hearing papers read? I tell you that you can only learn by the observation of actual reclamation and the working of great irrigation projects—not merely by listening to papers being read, for you can later read them yourself just as well.

Now, my fellow-delegates, it strikes me that if we are in earnest in this matter—and I believe this is a Congress of earnest men and earnest women—we will conceive that we have a great duty to perform—to assist in building up this great inland empire. I desire to appeal to you, as honest men and honest women coming here for this great purpose, whether or not a city like Boise, situated in the heart of the arid region, situated where you

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can see practical irrigation carried on, where you can see the operation of the great enterprises that are already complete and those nearing completion, I ask you if this Congress can be taken from a locality of that kind, here in the arid region, and brought to the city of Portland, if the delegates that do that are doing their duty to the people that sent them here, and to the interests which they represent?

I would ask each and every one of you who are in doubt upon this subject, who have not absolutely made up your minds as to what way you will vote, I would ask you to call here upon this stand before this is determined such men as Professor Newell, the head of the Reclamation Department of the United States, and who is familiar with this great question in all of its details; I would ask you to bring such men as Mr. Fowler from Arizona, the father of the great Salt River section, who knows full well what Idaho is in this regard, and what the other arid States are. I would ask you to call Senator Newlands, who is versed in everything pertaining to this, and our retiring President here has a knowledge of the question in every particular. They might not like to take sides upon this question, but I believe that each and every one of them will rise in his place here and express his opinion regarding this great question, I believe that each and every one of them would tell you, ladies and gentlemen of the Congress, that it is your duty as delegates to see to it that this convention goes to Boise, instead of to rainy Portland.

But we are imformed, as I understand it, by our Portland friends, that there is another question to be considered. Away back in 1804 the President of the United States sent Lewis and Clark into that section of the contry, and they finally arrived on the Pacific Coast in 1905, and the city of Portland, in commemoration of that great undertaking, is about to start a great Exposition, and that the world is invited, and we believe that in taking the lead on this worthy matter, they are entitled to the commendation of the people of these United States. We, of Idaho, propose to help them to the utmost. We propose to assist them in every way in our power. But when they present as an argument to you that it is your duty to vote for the city of Portland because they are about to hold an exposition there, they are presenting a fallacious argument, and one which I believe you should not consider for one moment. Do you believe that this Irrigation Congress can be made a side-show to the Lewis and Clark Exposition and do us any good? Don't you know that if this Convention is taken to that place where the Exposition is being held that it will interfere most materially with the labors of the Convention? Have not these matters been before now attempted, and have they not always failed? Why here but a short time ago the Trans-Mississippi Congress was held in the city of St. Louis. I sent several delegates by virtue of my official position, and upon their return they informed me that it was a failure, simply for the reason that it was held in an exposition city, and they could not secure the attention of those who had gone there for that purpose. And the same way will it be in the city of Portland. You cannot, if attractions of this kind are going on, secure the attendance of the delegation. You cannot in Portland, no more than you could in St. Louis, prevent this exposition from interfering with the business of the

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Congress. It is something that is impossible. But while we are not in favor of sending this Congress to the city of Portland, we are in favor of assisting that city in every way, and I want you all to remember that Boise is upon the road to Portland. I want you to remember that if you go to Boise, or stop at Boise for the Congress, that it will cost you no more than it would to go to Portland to see the Exposition and the Congress together, because, so far as your transportation is concerned, I am glad to be able to inform you that it is already provided for. To-day I had a message from Mr. Burley, the General Passenger Agent of the Oregon Short Line Railway, and he informs me in this telegram that in the event the Convention is taken to Boise City, that the privilege will be extended to all who desire to go to the Exposition and who have bought their tickets, to lie over in Boise as long as they shall desire, and their tickets will be good. So you will see that if it is the Exposition that you desire to see, and also if you desire to attend the Congress, you can see them both, and see that beautiful valley and inform yourselves regarding its great irrigation projects, and you can extend your visit to the city of Portland and take in the great show as well. I understand there has been considerable question regarding this matter. I understand that it is a question of transportation. This will settle it; the telegram is as follows:

"Hon. James A. Hawley: Referring to your telegram, stop-over privilege at Boise will be allowed on all tickets—and this arrangement should be the means of securing large attendance if the next meeting of the Convention is held in Boise City."

I assure you that so far as this question of transportation is concerned, it is one that we have met to the fullest extent.

Ladies and gentlemen, I have endeavored to present our city to you as fully as possible. I believe it is to the best interests of this Congress that it should go to Boise. If you choose to come and see us, if you choose to visit with us, we will meet you with a hearty welcome; we will extend the same measure of hospitality that the citizens of El Paso have extended to this Convention. We will ask you to come in force. We will ask you to bring your wives and children, and you had better, because if you ever come to Idaho and stay three days, I don't believe you will ever go back home.

We ask you to come there to study the irrigation problems which we are solving; we ask you to go home from that Congress and pattern after those efforts we have been making to build up a great city in Idaho, and I believe if you do come, I believe if you select Boise as the next meeting place of this Congress, you will do the interests of reclamation more good, you will work more benefit for the irrigation subject, than you could by selecting any other place.

The Chairman—I have the pleasure of introducing to you Hon. T. Lovell of Oregon.

Mr. Lovell—Mr. President, Delegates of the 12th National Irrigation Congress: I hold in my hand a telegram addressed to the President of this

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Convention, from the Governor of the Commonwealth of Oregon. In language it is as follows:

"Hon. W. A. Clark, President: As executive of Oregon, and on behalf of her people, I extend a cordial invitation to the Irrigation Congress, a cordial reception and a pleasant time.

"GEORGE E. CHAMBERLAIN, Governor."

In the absence of the Governor of the Commonwealth from which I come, and in the name of her people, I bring to you a message and an invitation from the City of Roses, the Jewel of the Pacific Northwest, Portland. From Oregon, that magnificent State resting upon the Pacific, and stretching for 400 miles into the great American Desert. A city of magnificent possibilities and great resources; her mountains filled with mineral wealth, with more standing timber than any other State in the Union, situated in the zone of power, principal contributor to the reclamation fund of this nation; her agricultural features are great—a giant majestic sleeping—wanting only the influences which your organization represents, to spring forth into leadership in the battle for all that is best in the civilization in which we live—the happiness to the homes of men.

We present this invitation from various considerations. First, I appeal to that common justice which characterizes the American people, and appeal to you to send the next Convention to us, because the chronological history of this organization as displayed to you upon this banner indicates that as the standard of the life of man is measured, this Congress has lived almost a generation, and every important center throughout the great arid region has been represented, and now we ask you to come to an important section of the great inland empire of the North, the region from which I come.

It was my privilege in 1894 to stand upon the platform in the City of Denver, and appeal for this honor to come to the City of Spokane; we were defeated by Albuquerque, and we have waited a decade and now come again to ask justice for the State of Oregon. We do it now, confident of your response, because there comes at this time in the city of Portland an event commemorative of the greatest expedition which has ever been attempted, an expedition which emphasizes and forever will emphasize the grandeur and the wisdom of the administrative ability of Thomas Jefferson. That expedition of Lewis and Clark, which gave to this union 300,000 square miles of territory, out of which there has been carved three great States and portions of two others—Oregon, Washington, Idaho, Western Montana and Northwest Wyoming, came into the Union because of the wisdom of Jefferson and the ability of his engineers. Idaho, we are not engaged in any agreement or compact in voting—we recognize you as the daughter of Oregon—we are proud of you, wayward now though you be, we know you will come back to the arms of your mother, and send to the Convention in 1905 a magnificent delegation from your great commonwealth.

Not only that, but we appeal to you because we need the influence of a Convention like this. There is no State in this broad Union so utterly misunderstood as is the Commonwealth of Oregon. The great rainfall in her mountains and at the mouth of the great river of the North has impressed

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the people of the nation with the idea that we are a humid State, but the fact is that there is an arid empire within her borders; three-fourths of all our territory is dependent upon irrigation for its higher development. An area extending all its breadth and two-thirds of its length, filled with valleys arid; two ranges of mountains cross the State, the Coast range and the Cascades, and all east of the Cascades and south of the Blue Mountains and west of the Coast Range are of the same character as Idaho, Utah and Colorado, and that State needs the influence and inspiration of this Congress; the magnificent valley at the mouth of which Portland stands, the finest valley which could be found in the whole Northwest, has its wet and dry seasons, and already the people residing there are becoming impressed with the necessity of irrigation. Bring your Convention there, and there will be brought to our people the very influences which are required to raise the State to the high standard in which she belongs in the sisterhood of States.

Come to us, and show to us as teachers what we shall do to people the great arid section of that State, and to make it fertile. Teach us how to marry the mountain waters to the soil, that the result may be the disappearance of the sand, and in its place fruits, flowers, grains and grasses, and when that time shall come we will support twenty millions of people, and in every valley we will plant the standards of civilization—the church, the school, the farm and the factory.

Portland, beautiful as a dream, queen upon two rivers, with the finest fresh water harbor in the Republic, with well appointed hotels, with 150,000 people, with theaters and halls in great abundance, with a lighting system and trolley system unsurpassed anywhere, at her doorway a stream leading out to the Columbia and then to the ocean, a city standing ready with the hospitality which has always characterized her, to give you the advantages which she at this time is glad to give because of the great fair which has come to her door. She realizes the purpose of this fair is to be representative of the distinctive industries of the great West, mining and irrigation. There is no intention to make it of such magnitude as that held at St. Louis. It will be compact, ideal in its character, well appointed and so comprehensive in its scope that you can come there with your families, grasp it all in two or three days and possibly then to devote your whole attention to the Congress. Portland is able at this time to offer advantages which never before have been offered. The great trans-continental railway companies, not only because of their interest in the exposition, but because of their desire to carry homeseekers to see the great plains of the Pacific Slope, have made a railway rate which never before has been equaled, and we are sure that you can come to us from Missouri River points at a very low rate—coming over one road and returning over another. Portland proposes that you shall see an object lesson in irrigation as fine as there is in the whole Republic. Her proposition to you to-day, through me, as her representative, although not a citizen of Portland, but of Northeastern Oregon, is to say that in order that you may have this object lesson and in addition may see some of the great beauties and resources which surround her, she will charter one of the river steamers and take the delegates of this Convention, with their wives, upon a journey over the Rhine of the West. She will show to you the

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beauties of the great river of the North, the Columbia, and she will land you in a great valley whose fame is as wide as the Republic.

Now, my friends, a part of the purposes of this Congress is education; you want an object lesson, we are told, and in addition to that we want the inspiration of your work for the great Northwest. Now, in addition to that, one of the great educating influences of this day is travel, and would you like to see, as you approach the Pacific, the great grain fields, the magnificent cities and mining interests of Montana, the wheat fields of Washington, the wonderful beauties of Puget Sound? Then come to Portland over the Great Northern Road. Or would you prefer to gaze on the glories of Colorado; would you examine the wonderful and impressive civilization which has been stamped upon the valleys of Utah, a civilization to which I here and now, as the representative of my people, lay a laurel, because they have come more nearly than any other to a solution of the great agricultural problems of the age. In addition to Utah and Colorado would you see the glories of transformation of Southern Idaho, would you see the mining interests of Eastern Oregon, then come to us through the central railway lines, which reach through the Ogden gateway. Or would your preference be to traverse this commonwealth so grand and so hospitable, go across those wonderful territories which sustain a magnificent population and under the inspiring influence of irrigation are going to be a paradise; would you go through the Italy of America, through orange groves of California and look upon the magnificent city of San Francisco and feast your eyes upon their glories; then come to us over the Southern route.

Delegate from Montana—I wish to second the nomination of Portland for the next Irrigation Congress. I thought it was fully understood at the Congress at Ogden last year that Portland was to receive the Congress the coming year. In fact, I was surprised when I heard to-day that there was any competition at all. I feel that we should help this great exposition at Portland. We find that they are having a great deal of trouble in getting attractions to that portion of the country, and I think we should help them in that exposition.

Delegate from Nevada—I wish to second the motion nominating Idaho. It was my pleasure in 1900 to go to Idaho. I had with me over $250,000 from New York, London and Edinburgh, and I visited that section of the beautiful Boise River. There is no place in all the great West where there is demonstrated such practical irrigation as there is in that beautiful valley. I merely say this to show you that you will see demonstrated as you go to Boise City some of the most beautiful farms that this great continent has, and you will see an irrigation system that you can see in no other State, and all kinds of fruits and vegetables are there to be seen. I merely second the motion, and I know that Boise will give you a hearty welcome.

Delegate from Utah—On behalf of a portion of the delegation from Utah I rise to second the proposition that the next Irrigation Congress shall be held in the beautiful city of Portland. I don't intend to take up the time of the Congress this evening in advocating the claims of Portland, as they have been so well presented by the gentlemen chosen to do so. I merely

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arise to remove, if possible, the impression that has prevailed among a great many of my friends of Utah, and their relatives and friends and associates in other parts of the country, particularly in Arizona and New Mexico, in regard to a little misunderstanding that occurred at the late Mining Congress in Portland, when Utah lost what she desired, that is, that the Mining Congress be permanently located in Salt Lake. We did not quarrel with our Colorado friends because they got the Congress. We have no fault to find with Portland. A little misunderstanding arose, in which some very unpleasant reflections were cast upon Utah and its people, and a great many people were under the impression that this slur came from Oregon, and particularly from Portland. That impression has been removed. The conflict that arose was simply between two members of the Congress, and the sentiments expressed were not endorsed by the people of Portland, and certainly not by the people of Oregon. It is true that the gentleman who made these remarks was rewarded by some of those splendid roses about which we have heard, but other persons in the Congress were also favored by roses, and I wish to say that if the Irrigation Congress shall be held in Portland there will be no regrets. We have no grudge against Portland nor Oregon generally on account of that little dispute. I merely make this remark to remove the impression mentioned.

I understood at the Irrigation Congress held in Colorado Springs two years ago that in 1905 Portland should have the Congress.

Mr. Holabird of California: I wish to second the nomination of Portland. In connection therewith I might relate the following. Some time ago, while traveling, I saw sixty cars, with the exception of one car, that were great big steel cars loaded with coal. In the middle of that train there was one little car loaded with coal. Some fellow had taken a piece of chalk and written upon the small car: "Never mind, little car, don't you cry, you'll be a big one by-and-by." And I might say "Never mind, Boise, don't you cry, you'll get the Convention by-and by."

I have had the unusual privilege of traveling a great deal through the West. I have recently visited the State of Oregon. I took a long wagon-trip of several hundred miles through the most wonderful country I was ever in—Eastern Oregon. It is capable of holding a larger population than a great many other States. You could put Idaho in the center of it and not find it. There are millions of acres of vacant government land there with no strings tied to it, that any human being, under the laws of our Land Department, can enter and make a home on. And I want to say it will be one of the most interesting object lessons of your life, and I don't think any man is fit to fill a public place in America unless he visits the commonwealth of which Portland is the capital. You have no idea of its vastness and its importance. There are 500,000 acres in the valley there that are most fertile, and you can irrigate every foot of it, and it will be done by-and-by. There is a large portion of that 500,000 acres waiting for homesteaders—for the young man to go there and make a home and bring a wife with him. Few of the people of the East have never seen the great rivers and the great steamers leaving Oregon, going to all parts of the earth, and you ought to see them—you are not half educated until you do see them. You won't see

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them at Boise. I don't believe that many of you spent much time here in this city looking at irrigation work. I think you spent more time looking at the bull fights. With all the eloquence of our friend from Boise, I admire his pluck and his nerve, and I want to tell you that we have come to these conventions to listen to the lectures and learn something from the men, and I would rather listen to the lectures next year in some comfortable, magnificent building like this, and look around to enjoy something after you get out of the hall. I tell you, you will make no mistake if you go to Portland—and you will make a serious mistake if you don't.

The Chairman—If there are no further nominations, I declare the nominations closed, and the Secretary will call the roll of States, and after the roll is called, the chairman of each delegation will announce the vote which will be recorded, and the result given. There is no provision as to the unit rule in the Constitution of this Congress. So that unless each delegation should settle that question among themselves, the unit rule if not considered would not prevail. If they desire to adopt it, we will recognize it.

A delegate from Arizona—Before Arizona casts her vote she desires to explain: we have forty-six in our delegation, and we have thrashed out this proposition in order that we could reach an understanding. We have invited gentlemen from each of the delegations from the respective cities that have been spoken of to explain to us the proposition that we heard here to-night, and we have, in consequence of hearing both sides of the story, reached a ballot, and we now cast ten for each.

Ballot closed. Result: Portland, 203½; Boise City, 105½. The election of Portland was then made unanimous.

The Chairman—It has been thought proper that the following telegram be sent in answer to one received:

"National Association of Agricultural and Vehicle Mfrs., in convention assembled at Chattanooga, Tenn.: We reciprocate your friendly greeting and invite your co-operation in a movement which has become truly national in its scope and character.

W. A. Clark,
President 12th National Irrigation Congress

Adjournment.

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General Session, Friday Morning, November 18, 1904.

Meeting called to order by Mr. John Hall.

Various resolutions were offered by Mr. Smith, of California, Mr. Taylor, Mr. Chafey, Mr. Hoffman and Mr. Prince.

Executive Chairman Boothe—I ask consent for the immediate consideration of the resolution just offered by Mr. Prince.

The Chairman—It is desired that the delegates here express our pleasure and gratification to our retiring President by a rising vote unanimously on this resolution. The resolution was unanimously carried.

Executive Chairman Boothe asked unanimous consent for the consideration of the report of the Executive Committee.

Mr. Prince—I would suggest an amendment regarding the doing away with the Committee on Credentials and also the Committee on Resolutions, mentioned in the report. This matter came before this very same Congress a few days ago when the motion was made in the usual form for the appointment of these committees, and the Congress then determined that it was desirable to have these Committees on Credentials, Resolutions and Permanent Organization. It seems but a small matter, but at the same time it has been the practice to have a Committee on Credentials, which has acted and, as the Chairman of last year stated on the floor, acted with a good deal of deliberation and a good deal of care as to various matters, and so far as I know has acted entirely satisfactorily. We have heard their report this year at the session two or three days ago, and, so far as I know, their plan of procedure, which is the usual plan, has met with no objection. It is, at any rate, a democratic system that a body, when it meets, shall have its own Committee on Credentials, who shall act on these matters. I only wish to call the attention of the members of the Congress to the fact that this would do away entirely with the Committee on Credentials.

Delegate from Arizona—I cannot see how the remarks from Mr. Prince apply to this case. Here is a body of men that have been elected by their own constituents, each State and Territory has named its own Executive Committee and is posted about the business, and when you come together in Portland or any other place your organization is complete on the start. I believe there is only one thing to do, and that is to adopt the resolution.

Mr. Hoffman of Texas—I am opposed to the amendment, for the reason that a body of this kind ought to be able to pass judgment upon its own constituents, because we are the judges, through the committee appointed by each State, to decide who are delegates and who are not. You place this power of deciding who are delegates into the hands of a few men who shall meet and they are likely to see that such delegates are recognized. I believe that a body of men like this ought to have the right to decide when it meets who are its constituted members, therefore I oppose the amendment.

Executive Chairman Boothe—There never has been, during the last few years that I have been at these Congresses, a single man who has come and put his name in who was not given a seat, and I have never seen a person that has offered the least objection to anybody sitting as a delegate. When

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it comes to voting, the vote is by States, and each State decides for itself what its vote shall be. The matter of accrediting persons as delegates, putting them on the roster, has nothing whatever to do with the matter. At a matter of fact, this is a permanent organization made up of the officers and permanent members of the organization. So that really it is simply a matter to bring the names before the Convention at the opening of it. It does not affect the body or its right to vote.

Mr. Jones—This Executive Committee is composed of a member from each State, and they are to look up the credentials from the different States. I can see no objection to such an amendment as this. We have spent several days trying to find who are the Committee on Credentials.

Mr. Hays—There must always be an incentive for any movement, I fail to see the incentive in this case. For years all deliberative bodies are controlled by themselves, and why we should depart in this instance in this Convention I cannot see. The members of the Executive Committee that meets next year are selected by the delegates this year, and should not have control of the delegates next year to come. They may not be here. They may not be in Portland next year. I have talked with several members of the Executive Committee, and not one of them has assured me that he will be at the Portland Convention in 1905; no man knows, for no man has a right to say whether he will be alive one year from to-day, or at the next meeting, and I insist that it is only proper that every deliberative body should control the credentials of its own membership, and I am opposed to this resolution.

Executive Chairman Boothe—How many of the credentials that were filed in the office of the Secretary were examined by the Committee?

Mr. Hays—We have accepted the report of the Secretary, and looked over a part of the credentials. I am insisting on this proposition, that we are putting this Convention as controlling the next Convention, and that is what I am opposed to.

Mr. Young of Utah—It occurs to me that there is very little merit in the objections offered that the adoption of this proposition would deprive the next Congress of the exercise of its prerogatives. The fact would be unquestionable that the Executive Committee would merely as a committee report to the Congress. The fact of deciding as to delegates should be left to the Congress. In other words, the meeting would be held and perform its duties expeditiously and there would be no delay in our proceedings at the failure of the Credentials Committee to make a proper report. Therefore it seems to me that this proposition will tend to make the proceedings go along much quicker. I don't see why this Congress should not determine the proceedings of the next Congress. As a matter of fact, the Executive Committee will decide several matters.

Delegate from California—I have attended now four sessions of the Congress, and I have yet to see the day when a delegate presented any credentials and was ever rejected by the Congress, and I don't expect to ever see the day when any delegate from any source attends the National Irrigation Congress will be rejected. Now, in this Committee on Credentials this year there are twenty-four States represented. When they met there were ten States rep-

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resented out of the twenty-four that were in session, and never at any time did the number exceed ten States. Now, I believe the amendment would be beneficial to the Congress, but a short amendment or a word or two more added to it, I believe, would fill the bill. I would suggest, "in case of any objection to the report of the Executive Committee on membership, it could be brought before the Convention and threshed out."

Mr. Hoffman of Texas—I move you as a substitute to this amendment that the Secretary of this Convention and not the Executive Committee be the receiver of all credentials, and that he report upon the morning of the meeting of the Convention.

Motion seconded.

Chairman—We will vote on the amendment. Amendment carried.

Amendment to Article 4, offered by Mr. Boothe.

Mr. Prince—I think that by putting this proposed amendment in the Constitution that the Congress is going to tie itself up entirely. If you will read it carefully, you will see it organizes a new committee which consists of a President, Chairman of the Executive Committee and the Secretary of the Congress, and, approved by the Committee on Rules, the program submitted by the Executive Committee shall become the official program of the Congress. Now, if that only means that this is a program which can be changed by action of the Congress from day to day as necessities require, why of course there is no harm in it. It is proper that somebody should outline something in advance in order that there may be a proper disposition of matters, and that they may be considered in due order, but by putting this in the Constitution it means that this official program of the Congress becomes a constitutional matter. I don't see any necessity for it at all if the former is the interpretation that is to be given. If it is to be of any special constitutional power it cannot be altered at will. It would be putting it above and beyond the power of the Convention when it chose to change the program.

Previous question moved. Carried.

Resolution offered as to Committee on Rules lost.

Amendment offered by Mr. Boothe as to number of delegates. Adopted.

Amendment to Article 8 by Mr. Boothe adopted.

Mr. Boothe—A duty tardily performed is better than not performed at all. This bouquet of flowers on the stage was picked from the Capitol grounds in Phœnix, Arizona, and sent here by the Governor as a compliment, and I was asked to mention that fact. I wish that some expression might be made by the delegates of this Congress in appreciation of the attention which has been given to us by the Governor of Arizona.

Delegate from California—I move that a vote of thanks be sent to Governor Brodie for this bouquet, which exemplifies the beauty of Arizona as well as the results of irrigation.

Bouquet acknowledged by rising vote.

Mr. Prince—I believe it is understood that the delegation from each State and each Territory name one Vice President and one member of the Executive

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Committee, and that they do so this morning. I suggest that the Secretary call the roll of the States, in order that a response may be made.

Roll called and the names handed to Secretary.

Mr. Maxwell—Those of you who have attended these Congresses formerly note with a great deal of sympathy the absence at this time of Colonel Maxson, as Secretary of the Congress. I understand that Secretary Maxson is ill. I offer a resolution regarding him. Resolution adopted.

Chairman—The hour has arrived for the election of officers.

Delegate from Arizona—I would state that that part referring to the officers of this Congress was formally adopted last night; that part relating to the Vice Presidents and members of the Executive Committee was delayed until this morning, and has been completed, therefore inasmuch as the list of officers is undoubtedly in the possession of some one in the hall, it would seem to me unnecessary for the delay in sending for the report, and it would appear to me the proper method now would be the formal installation of the officers chosen. I have no doubt they are acceptable.

Executive Chairman Boothe—I move that the nominations sent in by the States and Territories for the offices of Vice Presidents and members of the Executive Committee be added to the report of the Committee on Permanent Organization, and that the committee be discharged.

Motion seconded. Carried.

REPORT OF COMMITTEE ON NOMINATIONS.

This committee, to whom is referred the matter of nominations of officers for the ensuing year, beg leave to report as follows:

For President, Hon. Geo. C. Pardee, of California.

For First Vice President, Hon. L. W. Shurtliff, of Utah.

For Second Vice President, Hon. J. H. Stephens, of Texas.

For Third Vice President, Hon. E. L. Smith, of Oregon.

We further recommend that the selection of Secretary be referred to the incoming Executive Committee.

We recommend that the Honorary Vice Presidents and members of the Executive Committee submitted by the delegations from each State in this Congress be adopted as a part of this report.

[NOTE.—The complete list of officers will be found on page 435 of these proceedings.]

Chairman Clark—The nomination of Governor Pardee is now before the Convention. Are you ready for the question? Unanimously carried.

Mr. Clark—Gentlemen of the Convention, I have the honor to introduce to you your distinguished next President of the Irrigation Congress, Hon. G. C. Pardee, of the great State of California.

Mr. Pardee—Gentlemen of the Congress, while I feel the greatest personal pleasure, and the greatest personal honor, for the distinction and the honor which you have to-day conferred on me, I feel, however, that it is done more as a distinction and an honor to the State which I am here to represent, than for any personal regard or for any personal distinction which may be given to me, and when I go back to my State I shall take back with

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me the greetings of this Convention, transferred through me to the State which I am here to represent—as the Senator has said, the grand State of California. There is no doubt but that every State and every Territory of this Union is both grand and great, and with the exception of all the other States and Territories of this Union, I am here to declare that California is the greatest of them all.

What more can I say to you, ladies and gentlemen of the Congress? I am deeply impressed and deeply grateful for the honor which you have to-day conferred upon me, and I shall do all that lies in my power, with your help, which I hope you will cordially extend to me, to make the next session of this Congress approach somewhat at least to the benefits which we have derived from this, and I hope that your retiring President will not forget the duty which he owes to the Congress, the duty which he owes to the irrigation propaganda throughout the United States.

Mr. Clark—Gentlemen of the Irrigation Congress, before yielding this gavel to my very distinguished successor, I desire to express to you gentlemen, members of this Congress, as well as all preceding Congresses, who are present here to-day, my deep sensibility of obligation to the members of the several Congresses of which I have been an honored member, and particularly those of the preceding one and this one, over which I have had the very great honor to preside, for their co-operation, for their uniform courtesy and respectful consideration of their Chairman upon each and every occasion. And I also desire to state to you, my friends, that my work as Chairman of two Congresses engaged in this great movement has given me great pleasure. I have realized the honor that attaches to the position to which I was elevated, and I feel this, that it has been to me a labor of love. There is nothing in the world in connection with this great work, with which I have been identified for thirteen years from the day on which the first Congress was held in the City of the Saints in the beautiful Salt Lake Valley, that I would not do to promote its interests. I have felt an abiding and an untiring interest in every step of its progress, and particularly in the progress of the legislation, which at last has brought some measure of success in working out the solution of this great problem, which is so dear to all our hearts, and which means so much to the people of this great Western Empire.

I do not intend, in retiring from the high position which I have occupied, to relax one iota of the devotion and the love which I feel and enjoy in connection with this cause. I will try to be with you at Portland, and will do whatsoever lies in my power to aid you in your Congress there; and besides I want to see the magnificent exhibition which you will establish there on the banks of the beautiful Columbia—the grand Columbia River—commemorating that great event, the advent of Lewis and Clark at the mouth of that river in 1804, where they were sent by Thomas Jefferson to explore the great Northwestern country. And in the meantime, in pursuance of my duty as representative of my State in the upper branch of Congress, I intend to secure further legislation in aid of this cause, if it is possible, and if I can get the co-operation which I believe I will have from all the Western Senators and members of the House of Representatives.

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In my address I stated to you the other day that the fund accumulated now, amounting to about twenty-seven million dollars, will soon be absorbed in this great work. There have always been laid out projects, which, if carried to their completion, and which will be carried out by the able corps of Government engineers under the direction of Mr. Newell, will absorb at least two-thirds of this fund. I do not know what we are going to get in the way of additions to this fund, in the way of proceeds of public lands, as it varies from year to year. It may be more or it may be less; but whatever it may be, it cannot, in all probability exceed five or six millions of dollars. We must demonstrate to the Eastern people that the reclamation of the arid lands of the West is a national project, and worthy of the support of all the American people, and we must enlist their aid in its development. They are spending from fifty to a hundred million dollars every year on the rivers and harbors of the East and South, and when we make an appeal for a few million dollars for something in the West, they turn their backs upon us. Now I do not propose, so far as my influence and effort may extend, that they shall do this any longer, but that they shall come to our rescue and help build up this Western country, which means so much to them, as well as to us.

Thanking you, gentlemen, for your kind and courteous consideration, I now yield to my distinguished successor the gavel which I have attempted to use with impartiality and discretion, and certainly I have used it with great pleasure to myself.

Chairman Pardee—Gentlemen of the Congress, the next order of business is the election of First Vice President. The Committee recommended the election of Mr. Shurtliff, of Utah.

Delegate from Idaho—I move the report of the Committee be accepted and Mr. Shurtliff be elected. Motion seconded; carried.

Chairman—Next in order is the election of Second Vice President. Hon. J. H. Stevens, of Texas, is named by the Committee.

Mr. Taylor of Texas—I move that the report of the Committee, on Mr. Stevens, be adopted. Motion seconded; carried.

Chairman—Next recommendation of the Committee is Hon. E. L. Smith of Oregon to be your Third Vice President.

Mr. Hall—I move the election of Mr. Smith. Motion seconded; carried.

Mr. Smith—Ladies and Gentlemen, I thank you for your kind consideration. The place was unsought by me. While I am up here I wish to convey the thanks of the Oregon people for the very kind consideration shown in selecting Portland. I want to tell you that when you come there you will find that we are your own people; you will find a beautiful city, and I want you to get acquainted with some of those old pioneers and their children—those pioneers who traveled the deserts and forests over half a century ago to save that grand land from foreign supremacy. I have no promise to make to you, but Portland's hospitality will be commensurate with her ability.

The Chairman—Gentlemen, there appears to be no further business on the table of the Secretary, save the report of Committee on Resolutions. Is the Committee ready to report?

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Mr. Smith of Utah—I desire to offer a resolution. That this Congress in every sense of the word endorse the exposition to be held at Portland, Oregon, and that the worthy work accomplished by Lewis and Clark shall be fully commended by us, and that in every way we will utilize our influence to make it a success. A hundred years have passed since the expedition of these men. We should use every effort within our reach to make this anniversary exposition a success in every sense of the word, and let us hope that the results may be all that our Portland friends expect. I make this resolution impromptu upon this occasion.

Delegate from Idaho—Idaho seconds that resolution. I desire to assure the rousing delegation that Idaho will only be second to Oregon itself in making this exposition a grand success.

The resolution was unanimously carried.

The Chairman—I take pleasure in introducing former Senator Harris of the State of Kansas, who bears a message from Kansas City to this Congress.

Mr. Harris—Mr. Chairman, ladies and gentlemen, I have no desire to detain you but for a moment. Last week I was called upon by the great commercial bodies of Kansas City to come here to El Paso and extend to you on their behalf a greeting and a message and an expression of their desire for your success and hope for your work in the future. That great State stands as a gate to the glorious and beautiful West. She is reaching out her arms to the great empire which we will see in time built up where there will be homes for American men, women and children. I agree most heartily, and I know that the sentiment of Kansas City coincides with the magnificent expression which has been uttered by the speaker who preceded me. Mr. Maxwell has been indefatigable in his work, and I am happy to bear witness to the efficiency of it. Kansas City feels that this great empire should be built to furnish homes for American men, homes upon American soil for American women, homes for American boys and girls. That is the kind of expansion we believe in back in our part of the country. Kansas City desires to say to you that whether your meetings are held in El Paso, whether they are held in Boise or whether they are held in Portland or any part of the country, she is in sympathy at all times with the work which you are furthering. She knows the kind of men who live in this great country, she knows what they have done; she has faith and hope in the future, which she will bring to pass. I thank you very heartily for the opportunity of presenting to you the best wishes of Kansas City for your success.

Mr. Kimball of Arizona—Gentlemen, I desire, in behalf of the delegation from Arizona, to call your attention to Arizona's display as you go out of the door, and say to you that, after the Convention exercises are over, we desire each member of the Congress to get an orange or lemon or one of the other of our fruits to take with you, showing to you that Arizona is at least six weeks ahead of California and other places in the raising of these products. I desire to say, also, that we want you to see the possibilities of our region, and to show what could be done by the conservation of the waters that are going to waste. We are raising at least five crops of alfalfa, and we are getting in the neighborhood of from eight to ten dollars a ton on the cars for it. We can raise two crops of peaches. I might relate a strange circum-

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stance that happened this fall. In September a hailstorm stripped our apple trees of nearly all the fruit, and we thought spring had come again when the apple trees blossomed out once more, and we have another crop of apples on our apple trees. This is the spirit of the country; this is the spirit of the people—to keep on doing and trying again. And we do hope that the good people of this entire country will not forget those things that have been said by Mr. Maxwell, which are entirely true. I want to say to you that in the valley where I live—the Gila Valley, and I also have the honor of presiding over the people in the San Pedro Valley—that all that has been said is true, in regard to the waste of the water. I am told by the pioneers of the Gila Valley that twenty-five years ago the waters laid upon the ground in abundance, and the whole country was covered with wild grass. But now that is all destroyed.

Our rains come in the fall of the year, commencing in July and running through August and sometimes to September we have nearly all the rains that come during the entire year, and we cannot conserve the water and save it to use during the drouth. This last fall we were appalled to see the rains come as they did and wash the slopes and cut out the country; where formerly there was a little cattle trail are now rivers, some of them 100 feet wide, which have destroyed farms.

Twenty-five years ago five wagons, with a little party of emigrants, came in from Utah to reclaim the grand Arizona country and help make the mining industry possible. In connection with our labors, they assisted in making the great commonwealth there.

I desire to call your attention to these facts, and ask you to get some of the products of Arizona, and don't forget the great possibilities of that territory.

Mr. Smythe—I desire to say, for the information of this Congress, that Southern Texas is still in its infancy, but an irrigated farm there has raised seven crops of alfalfa in one season.

Governor Pardee of California—Come to California and get ten.

The Chairman—I desire to give notice that at the final adjournment of the Congress this afternoon the Executive Committee will meet on this platform immediately after the adjournment.

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General Session, Friday Afternoon, November 18, 1904.

The meeting was called at 2:00 o'clock by President Pardee.

Mr. Prince—Mr. President, I have an exceedingly gratifying, as well as important duty to perform. Most gratifying because it announces what I think is the most practical act in the history of this Congress, and the most gratifying of any duty which anyone has had to perform at this great gathering here in El Paso. I ask permission to make a very brief preliminary statement.

For a number of years there has existed a diversity of opinion—no, I rather may say a bitterness of action—between those living in the Rio Grande valley with regard to the irrigation improvements which seem necessary in order to utilize the water of that river. It was a three-cornered controversy—on the north, those living in the Territory of New Mexico; to the south and east of the river, those living in the State of Texas, and on the west of the river our brothers in the Republic of Mexico. Each had its own ideas, and each was sufficiently tenacious and sufficiently powerful to prevent action on the part of the other. Each, I am sorry to say, as time went by, became more and more antagonistic to the other, so that it seemed as if harmony of action was almost among the impossibilities. But a miracle has come; that which seemed to be impossible is not only possible, but is an assured and accomplished fact. Harmony and unity of action have succeeded in the place where before was contention and bitterness. There have been frequent assurances during the course of the existence of this Congress, among all of those from all parts of the Rio Grande valley, north and central and south, and this has resulted in the adoption of a resolution which has been very aptly called "a most happy solution of a vexed question." This agreement was so perfect, that yesterday afternoon, at a meeting in this room, a resolution was adopted unanimously, by all who were present, asking that some course of action should prevail, and that the officers of the Reclamation Service should go on and do the great work which they had found it was possible to do. And since that time, in another conference, this statement, with an addendum explanatory to some extent, has been signed. I hold here the original; it has been signed by five representing New Mexico, five representing Texas and five representing the Republic of Mexico. The resolution which was adopted yesterday read: "That we heartily approve the valuable work of the Reclamation Service under the Department of the Interior of Washington, whose officers of the Rio Grande have been in New Mexico and elsewhere, and we heartily endorse and approve the proposal of building the Elephant Butte dam as a happy solution of a vexed question that has embarrassed the parties interested, providing that an equitable distribution of the waters of the Rio Grande with due regard to the rights of New Mexico, Texas and Mexico."

"EL PASO, TEXAS, Nov. 18, 1904.

"The undersigned Mexican delegates to the Irrigation Congress, have had no time to make a comparison of the two projects to store the waters of the Rio Grande, the International dam project and the Elephant Butte dam

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project, but assume, for actual purposes, that the data given by Mr. Hall in his report read yesterday at convention hall in regard to flow, sediment, evaporation, distances to bed rock, etc., are correct and that it is thoroughly practicable to bring to the site of the old Mexican dam, above El Paso, the water necessary for the areas that were previously irrigated, and that said quantity of water will be given to Mexico, without cost, at that point, surveys to be made by the engineers of the United States Reclamation Service to determine the number of acres upon the Mexican side of the Rio Grande which can be so irrigated, said surveys to be subject to the approval of the Mexican government.

"Under those considerations, the Mexican delegation endorses the Elephant Butte dam project, as explained by Mr. Hall, said endorsement to be subjected to the approval of the Mexican government, as the delegates have no instructions whatever, as stated yesterday at convention hall by the delegate from Tlaxcala, Sr. Carranza.

"JACOBO BLANCO,
"ROBERTO GAYOL,
"JOSE DUVALLON,
"YGNACIO CARRANZA,
"RAFAEL DELA MORA.

"We, the undersigned committee, representing the American side of the Rio Grande valley, heartily and unanimously endorse the above statement and presentations, made by the honorable delegation representing the Mexican republic, and through them, the Mexican side of the Rio Grande valley, subject to the approval of the United States government.

"FELIX MARTINEZ,
"A. P. COLES,
"Z. T. WHITE,
"A. COURCHESNE,
"J. A. SMITH,
"OSCAR C. SNOW,
"H. B. HOLT,
"WM. PALMER, JR.,
"R. E. TWITCHELL,
"MARTIN LOHMAN."

This document, which has been signed to-day, is, in addition to that, explanatory of it to some extent, giving it greater force and efficiency, and is signed by five representatives from the Republic of Mexico, by five from Texas and five from New Mexico, who have been appointed a committee of conference on that subject. Mr. President, this is a matter of most hearty congratulation to all who live in this section of the United States. The Rio Grande is the great river, as its name implies, of this section of the United States and of Mexico. It has vast valleys on its sides, and at certain periods of the year it brings down great volumes of water which, as matters are now, are entirely lost, which, if conserved, would add to the agricultural resources of the United States and Mexico, and now that all obstacles are removed, now that all have agreed to accept the dictum of the authorities on the subject at Washington, and to work harmoniously in order that they may be

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brought to a practical conclusion, it is, as I say, a matter of great congratulation to all of us. It is, in another sense, a matter of great congratulation to this Congress. Sometimes we are asked "why do you hold these gatherings, what do you achieve? What have you to show of the practical in the way of results for the expense and the trouble and the time and the exertion that is employed in the carrying on of these Congresses." And I say that if nothing else has been done at this National Irrigation Congress now being held in the city of El Paso, if every other moment of its time had been absolutely wasted and was soon to be forgotten, that this, which I have now the pleasure of announcing, is enough in the way of practical results to have justified the holding of this Congress, even if the expense and the trouble had been ten times what it was.

I am directed by the delegates and representatives of the Rio Grande country, in its whole extent, the three territorial divisions to which I have alluded, to ask of this Congress the endorsement of the harmonious wish to which they have all agreed, by the passage of this resolution:

"Resolved, that we heartily approve the valuable work of the Reclamation Service under the Department of the Interior at Washington, and its officers in the Rio Grande Division in New Mexico and elsewhere, and we heartily endorse and approve the proposal of building the Elephant Butte dam as a happy solution of a vexed question that has heretofore embarrassed the parties interested, providing that an equitable distribution of the waters, with due regard to the rights of New Mexico, Texas and the Republic of Mexico."

I move the suspension of the rules, that this may be received for immediate action by the Congress.

Delegate from California—I second the motion made by Mr. Prince. This is a question of great importance, and I think should be acted on at once.

Chairman—You have heard the motion, that the rules be suspended and that the Convention act immediately on this question. Are you ready for the question. Motion carried.

Resolution of Mr. Prince was adopted.

Mr. Prince—We sincerely thank the Congress for this action.

Mr. Fairweather of California—Gentlemen, I have been requested by a few members of the Congress to give a little explanation of the workings of the irrigation law of California; if it is compatible with the views of the Congress, I am willing to do so.

Chairman—Please take the platform, Mr. Fairweather.

Mr. Fairweather—Mr. President, ladies and gentlemen of the Convention; during the discussions in the various departments of this Congress it has been alluded to in some of them that if the various sections in the arid states and territories had some similar law as the State of California, it might do much good, and help them by helping themselves to get relief earlier than they will from the general government. Now, it has been generally heralded abroad that the Wright Law of California was a humbug and a fraud, and everything else that was bad. We in California, who know the beneficient effect of that law, brand that statement as a bare and bald face lie. Our law provides when a number of people in a division or neighborhood, for instance, the people interested get up a petition under the law, and apply to the Board

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of Supervisors for them to endorse that, and then they elect five or three Directors. When that is done all those within the District begin to work. Now, the Biddeford Law makes it obligatory to have a majority of the land owners, or those having title in the district, to sign the petition first. When this is done, then we go on with the workings the same as you do in a school district. We are a quasi-public corporation. The property in the district pays no taxes, because it is for the benefit of the public, and the land is enhanced in value and pays the taxes in that way to the State. We have our own officers. We elect directors; the law gives permission to elect three or five. We elect our directors, we elect our assessors, our tax collector, we levy our own taxes. It does not go through the county office in any way, manner or form. We bond our district. We have $490,000 of bonds out on our district at five per cent. They are twenty and forty year bonds; to-day the bond owners prefer the long term bond. I don't know of any bond in our district that is on the public market, and certainly there is not any bond that can be bought in that district below par.

Now, in levying our assessment for water, we levy a tax on land exactly as you assess for anything else. If I have a 20-acre vineyard or orchard or alfalfa field, and my neighbor has a 20 or 40 or 60-acre piece beside me that is growing wheat or not growing anything at all, if it is the same class of land, his land is assessed at the same price per acre for irrigation as my vineyard or my orchard. We make no discrepancy in that, and we have had very few instances where any individual kicked, for the reason that the more improvements made in going along, they add to the value of the land. Of course we are favorably located on the river, and have been working under that law now for thirteen years, and you cannot come into our district to-day and find five people to say a word against the Irrigation Law.

Under the Constitution of the State of California it allows every man—every legal voter—in the district to cast a vote. Some of your State constitutions limit the voters to property owners, and I believe it would be a good thing to allow only the actual owners of land to vote. The law says all property shall be assessed at its true value, but that is not always done, at least not in our district. The improvements are ordinarily assessed—that is, buildings. We don't call trees and vines and alfalfa improvements. For instance, if a man has got forty acres of land and a good house on it, costing $1300 or $1500, his house will be assessed at $250. If he has a barn, it will be assessed at $150. The secondary improvements on the land are not assessed very high, and do not increase the tax rate very much. The tax in our district amounts to about thirty-seven or forty cents per acre per annum, and two-thirds of the tax that is levied in our district to-day is for paying interest on our indebtedness. When that is paid off, the running expenses of our district will amount to about $10,000 or $12,000 a year, and it won't cost twenty cents per acre per annum.

We don't divide our waters—we have no locks on the gates. The law provides that every individual is entitled to his pro rata of water. He can even exchange it if he will. We seldom hear of anyone suffering from the use of too much water on his land; that is a trouble experienced in nearly every irrigated section of the world—using too much water.

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I have given you in as few words as possible the workings of the State Irrigation Law, and I thank you. If any gentleman wishes to ask a question, I will try to answer him.

Chairman—Gentlemen, I declare a recess for ten minutes.

Meeting re-called at 2:40 p. m.

Chairman—I want to announce that each speaker will now be limited to five minutes, unless granted otherwise by the Congress. The long-lost Committee on Resolutions is here. They report that they will be ready in a few moments.

REPORT OF COMMITTEE ON RESOLUTIONS.

Mr. Penrose of Utah, Chairman of the Committee on Resolutions—Ladies and gentlemen; I would apologize for this late appearance if I thought that the Committee had anything to apologize for. I wish to say we have been in session for a long time, and I beg to report the following:

The report of the Committee on Resolutions was read. (Report as made was adopted with the slight amendment offered by Mr. Finkel of California. Resolutions are found on page 125.)

Governor of Idaho—Mr. Chairman, I move as an amendment to the report of the Committee that that portion of the resolutions referring to the repeal of the Stone and Timber Act and the Desert Land Act be taken from the resolutions. Motion seconded.

Delegate from Idaho—I wish to say a few words explaining my position, and I think the position of a great many others here, with reference to this matter. While I am in accord with many of the suggestions in that portion of the resolution which we seek to eliminate, I do not believe that the time has arrived when we can safely act upon the matter; I believe it is one that should be more fully considered and should be referred to the next annual session of this Congress. We are, Mr. President, in need of funds at the present time. The main want of the people in the arid regions at the present time is money to be placed in the reclamation fund in order that the great projects may be carried on, and others that have been suggested may be made possible. Mr. President, if I recollect right, there are some ten millions of dollars that have been placed in that fund by the sale of the public lands in the year 1903, and seven and a half millions by the sale of land under the Stone and Timber Act and under the Desert Land Act. Can we safely take such action as would possibly induce Congress at this time, acting upon our suggestion, to eliminate that source of revenue, and put us back possibly in a position where we could not depend upon more than three or four million dollars a year in this fund? I say that it is a serious question that confronts us. The report of the Committee itself, in the very next resolution, says that it is necessary, in the opinion of the Committee—and with that opinion I believe we all agree—that a greater fund be raised, and we ask in the next resolution that the Congress appropriate moneys in the nature of a loan to this reclamation fund, to be repaid. I ask, Mr. President, how it will be possible to secure that money from the Congress of the United States unless we provide some means by which it can be repaid, and it is a serious ques-

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tion in my mind whether the adoption of this resolution, if favorably acted upon by the Congress of the United States, will not so impair our revenues as to render it impossible for us to obtain this money which we are now seeking in addition to that amount which we acquire from the sale of lands? You will find, Mr. President, that the Congress of the United States, in dealing with us, will want to know how the money loaned will be repaid.

Mr. Newlands—Mr. President and delegates of the Irrigation Congress, the gentleman from Idaho objects to this proposed action, not because he objects to the reform which we have in view, but because our action will tend to prevent sums of money from going into the reclamation fund, which, under existing law would go there; and he asks whether we can imperil the great work of national irrigation now advancing so rapidly by interfering with the increase of this fund through the proceeds of land sales. Now the proceeds of land sales come largely, I am told, from timber lands, and we find that the timber lands of the country are, under existing laws, going into the hands of great combinations and syndicates which hold them for future speculation and profit, so whilst we are rigidly guarding in the Reclamation Act against land monopoly in the future by providing that as to the lands reclaimed they can be acquired only in small tracts sufficient to support a family, we are adhering to a policy which is concentrating the timber lands of the country in private hands, and is gradually strengthening the very monopoly against which the Reclamation Act is intended to guard; so I say that if the fund were in danger, even if not a single dollar in the future was to be added to this fund from this source, I would favor legislation to stop this concentration of land in private ownership. But that danger is not to be apprehended. Under this very resolution it is provided and recommended that Congress should concurrently with the repeal of the Stone and Timber Act, provide for the sale of stumpage upon these timber lands, and provide that the proceeds of such sales shall go into the reclamation fund. I firmly believe that more money will be secured from the sale of stumpage than will be secured from the sale of the lands themselves. After we have sold the timber that is now upon these lands, we will either plant new forests or we will retain the lands for agricultural purposes, and then this land can be held, like the old arid domain, in trust by the country for home seekers, in small tracts sufficient to support a family. Thus if we retain the land and sell the timber we will get more for the reclamation fund than under the present system, and we will still hold the lands under the policy of this Irrigation Congress for future home seekers.

But we will assume that it is true that, temporarily, the proceeds from the sale of stumpage will not be as large as the proceeds from the sale of the timber lands themselves. We have already in that fund nearly twenty-seven million dollars, and that Act has been in operation for two years, and only about three million in all, I believe, has been expended. Under the Act the fund is a revolving fund. When twenty-four million dollars now in the fund are expended, the work does not end; that twenty-four million dollars returns to the fund through the annual payment of the settlers on the land, and you can readily see that if the fund only amounts to twenty-seven millions of dollars, that fund in the next twenty years, by the aid of

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this revolving process, will accomplish at least one hundred and fifty million dollars worth of work; so that even without an increase in the present fund we could accomplish the work, though not so rapidly, perhaps, as desired.

Now in addition to the legislation which we suggest regarding these lands, we have urged a Government loan to the Reclamation Fund so that if the Reclamation Service, after a full survey of all the projects in contemplation, find that this fund is not sufficient to meet the existing demand, they can so report; they can state how much is required—five or ten or fifteen or twenty million dollars—and we can go before Congress with the recommendation of the Reclamation Service and urge Congress to appropriate a loan to the Reclamation Fund, to be used in this work, to be expended in reclaiming arid lands; the cost of each project to go back to the fund by annual payments of the settlers and thus the Government will be reimbursed and the great work accomplished without the loss of a single dollar to the Treasury.

Now I ask whether we are in earnest in all these Irrigation Congresses in demanding that a stop should be put to land monopoly? If we have been in earnest, we have an opportunity now to demonstrate it. My friends, we have not realized yet in this country the perils of land monopoly. Why? Because we have more land than we have people to occupy it; because, though we have a population of eighty million people, we have in this country land equal to the demands of five hundred millions of people and we will yet arrive at that population, and when we approximate that point we will experience the evils of the concentration of land in private ownership. It has been the cause of more social disorder, and of more serious and bloody revolutions than any other cause in the history of the world. It was the cause of the long revolt of Ireland against English misrule; it was the cause of the French Revolution; prior to the French Revolution one-third of the entire land of France was in the hands of the church, one-third in the hands of the nobility, and one-third in the hands of the people at large. And it was this system of concentration of ownership of the lands in the church and in the nobility which led to that revolution—the bloodiest in history—and we have as a result of that revolution, in which the greatest excesses were committed, the present system of peasant proprietorship in France, which has given peace to the people and a stability to the government of that people that has never been enjoyed before.

In the Philippine Islands, the protest of the Philippine people was not so much against the tyranny of Spain as it was against the monopoly of the best lands by the Friars. Their revolution against Spain, which we aided, resulting finally in the expulsion of Spain from the Philippines, had its source in this monopoly of land upheld by the Spanish government—and you will find that in our South American and Central American States—the gradual increase of land holdings of the church led to disorder which ended in revolution against Spanish domination, and the absolute spoilation of the church of its property.

Now, we want to avoid disorder and revolutions here, not so much because it is a present danger as because it is a future danger, a danger to the peace and prosperity of the Republic. It seems to me that we have an opportunity now, without loss to this fund, to shape these laws so as to prevent the con-

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centration of lands in private ownership, and to see to it, so far as the public domain is concerned, that the prevailing system of combination and monopoly, so oppressive to the people, shall not prevail.

Chairman—Are there any further remarks, gentlemen?

Delegate from Oregon—How is the sale of stumpage going to prevent the monopoly of land, I would like to ask?

Mr. Newlands—If the government simply sells the timber on the land instead of the land, the government retains the land, and there is no monopoly. It is a monopoly of the entire people instead of a particular combination.

Delegate from Oregon—I would like to know what length of time is contemplated for the cutting off of these lands?

Mr. Newlands—That will be a matter for the administration to determine.

Mr. McAlpine of Minnesota—I wish to say a word, Mr. Chairman. The gentleman who just spoke stated that the repeal of the Acts in question would prevent a monopoly. An individual citizen of this country can go into the woods and take up the different stones, but he don't say a word against the monopoly that furnishes millions of acres of the public timber in the State of Idaho.

Mr. Newlands—Will you allow me to interrupt you? It is true that I made a reference to that, but the resolution asks the repeal of all laws permitting the issue of scrip.

Mr. McAlpine—Let that be amended first. Don't take the right of the citizens of this country from the public domain that belongs to them. This country has prospered since tne Constitution of the United States was first inaugurated, and is prospering to-day. The land belongs to the people and not to the combinations. That is what I say, the combination wants to take the public domain out of the market. Then they care little for the land laws when they use them as long as they want. The Northern Pacific Railroad got $50,000,000 worth of public domain to build 2000 miles of railroad from Duluth to the Pacific Coast. If they sold that land for $5 an acre, they would have put $150,000,000 in the treasury of the Northern Pacific Railroad. Now, if the public land is taken out of the market, those lands will increase in value about three-fourths. A citizen can go and take up 160 acres at $2.50 an acre—$400 for 160 acres of land, and if he sells it for $5 an acre he will have a gain of $400. Which is best, to put the money in the treasury of a combination or a citizen. For the year ending June 30, 1903, the Government received $4,537,000 from timber and stone. That would take 10,500 citizens of this country to enter these lands. They paid the Government $2.50 per acre for that. Supposing they sold that for $5 per acre. There was 10,500 citizens made $2.50 an acre on it. Which was the most benefit—distributing it among 10,500 citizens of this country, or putting it into the treasury of those railroads or combinations. Which is most beneficial? The combination is behind this scheme and has been for five or six years and more. Which will they do? The government received $2,850,000 for the sale of the homestead land. For the desert land there was 1,425,000 acres. They received $256,000. For the sale of these three acts of the Government which belongs to the people, the Government receives $7,644,419.

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That was set aside generally from the Northern States and other States for the sole benefit of the irrigation in the arid land States. The fund is for that purpose. It does not cause any hardship on any branch of the Government of this country to cut off that. That will take the fund away from the desert land districts. That is what is before the Convention. We have to have combinations. There are men in this country who built railroads and never got one dollar from the Government. The Great Northern Railroad was built from Duluth to the Pacific Coast—2000 miles—by James J. Hill, one of the greatest men of the United States, who has done more to open up the country than any other man. The second man to Hill, that builds railroads without going to the Government for aid is our retiring President, W. A. Clark. He is building a railroad from Utah to Los Angeles. He don't want to rob the people of their lands. It is a combination, gentlemen, we are now confronting, and I defy any man to object to one word I have said. The trouble is with the combination; the sale of the stumpage is referred to by my honorable friend, Mr. Newlands, and I ask him the question which is the best, to put the money into the combination or give it to the people. He don't answer me. There are always men that will support combinations of every kind. Some of them can be bought; some of our judges can be bought and sold to support combinations, but, gentlemen, they can't all be. I will refer you to one little matter in the State of Minnesota that was seventeen years in the Department of the Interior, before four sections of the Interior and four Commissioners. There were two little attorneys in Duluth who took the matter I refer to up, without fear or reward, and brought it to the courts of the State of Minnesota and it went to the Supreme Court in less than fifteen months, and the Supreme Court made a special order and canceled the patent. There are plenty of men in this country that can be bought and sold if the question is put right before them. I will say that this one of the most far-reaching schemes that ever went before the people of this country.

Mr. Finkel, of California—In the interest of this Convention, and the California delegation, I wish to state that hereafter if any one speaks longer than five minutes, we want to also.

I wish to say just a few words on this question. There is no real apparent difference between our friends Senator Newlands and Mr. McAlpine. Mr. McAlpine thinks that we are liable to affect the fund. I don't think that this legislation would have that effect. It would not have that effect for this season, that the stumpage off this timber land will be sold. The administration of a new law would fix the price of stumpage at such a figure that it would not enable these corporations to increase the price. In the second place, the work for which we are striving here to prevent the monopoly of land would be hindered by amending this resolution, for the simple reason that we are now accumulating funds and expending them for the purpose of distributing lands among people under the National Irrigation Law, thus introducing a new supply of lands. The new supply of land has the effect of depressing the value of all the holdings held by railroad corporations. I think this is a sufficient answer to the question. What I say is this: that every law which tends to build up a monopoly in this country should be repealed.

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I just simply want to make one amendment to this resolution not on this point.

Mr. King from Oregon—Gentlemen of the Convention, one year ago when I attended the Irrigation Congress at Ogden, I made up my mind to keep still except on the Resolution Committee, but after listening to the discussion of my esteemed friend from Minnesota in the Resolution Committee this morning for three-quarters of an hour, I cannot resist the temptation to say a few words upon this question. I am not disposed to question the motives of anyone who differs with me. I regret that I have to take sides and oppose my good friend, and while I do so, I do not question his motives. One year ago when I appeared on the Resolution Committee I was undecided about this question. I listened to the discussion of this one question at least seven or eight hours, and after listening to their discussion of this question, I was convinced that the timber land laws and other laws of this country should be repealed. The scrip question was referred to, and they said if we could offer some substitute for the desert land law, it would be upheld. We found to-day when this matter came up that amendments were made and we found that still our timber friends opposed it and said if we could repeal the scrip law and stop the further issuance of scrip we could accomplish just as much. We have brought in a resolution recommending the repeal of all acts permitting lien sections or issuance of scrip and notwithstanding we have added that, we find our friends still opposing, and I want to tell you they are going to continue to oppose it just as long as we attempt to repeal the laws. I believe it is not a question as to whether this man or that is going to profit; it is a question as to what is the best for the majority of the people. I do not question the motives of the gentleman opposing this, if he has an interest in such a question, for that interest might blind his judgment. We have resolutions here which tend to the preservation of the forests, and we should pass them. The proposition is to preserve the forests. After you sell the timber lands, give the Government a chance to own this land and replenish these forests. It makes no difference if people may have millions or billions of scrip. Do you propose, by continuing the present land laws, to continue to permit the land grabbing? If we have one wrong it is not necessary for us to continue another wrong, and what difference does it make if some man does profit when we realize that to continue the present system will continue to encourage the land grabbing of this country. In the country not wholly arid we find that much has been reserved to be taken only under the Homestead Act, and under the laws of the National Irrigation Act they must reside upon that land for five years before they can acquire title.

The Chairman—Your time is up.

Mr. Keisel—I move that the time for the gentleman from Oregon to speak be extended five minutes more. Motion seconded. Lost.

Mr. Smythe of California—The gentleman from Minnesota says there is a combination behind the demand for the repeal of these laws, and he is right—there is a combination—a combination of truth, of patriotism and of civic pride. In that combination are included the ablest and most distinguished men in the Republic. The men who have taken part in the admin-

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istration of Grover Cleveland, of Harrison, the administration of William McKinley and the administration of Theodore Roosevelt. I do not impugn the motives of those who disagree with us. There are plenty of honest men who think these laws should not be repealed. I do not say that all those who oppose the repeal of these laws are land thieves, but I do say that all the land thieves oppose the repeal of these laws. The gentleman from Idaho says that the time has not come for this legislation. When will it come? After the last acre is gone—is that when the time will come? Some time ago this Congress considered this question and demanded the repeal of these laws, and now, thank God, the question has come up to the Irrigation Congress of this year, and many of the loyal citizens of this country are on the side of the repeal. What we propose to do is not a radical innovation. It is simply a logical step in our policy. They tell us what we propose to do is merely destructive. They said we wanted to sweep away the laws upon our statute books and put nothing in their place. We now propose a substitute for everything which we would displace. But we do not insist that so far as agricultural lands are concerned, no man and no woman can acquire title to another acre save they show their good faith as home-makers by living there five years.

We have land for the man or the woman who wants to make a home. We have no land for the man or the woman who wants merely to engage in speculation. We will encourage those who wish to farm the land. We propose to sit down on those who wish to speculate.

We received a message from the President of the United States in which he referred to us as the guardians of the future. This morning by a rising vote we declared that we would be the faithful guardians of the future. My friends of the West—men and women of this Irrigation Congress—we are fighting a serious battle. We have no right to consider such a suggestion as the gentleman from Minnesota made about someone who made $200 by taking up some timber land and selling it. Those are not the people for whom we are guarding the future. We are considering the future, and in order to do that we must preserve for the home-maker the lands for farming, and as to the timber, we must get all the money we can out of it. The gentleman from Idaho says we would decrease the income. We will increase the income five or ten times from that source. We are now getting $2.50 per acre for lands that are worth far more.

Mr. Young of Utah—I believe, Mr. President, that the President of the United States has called on the gentlemen in the Department of Lands to make an investigation to know where he is at. He has been accused of being the tool of monopolies of the United States, and I don't believe it. I am a Democrat, and I voted for him because I don't believe it. Now, when these men that he has asked to make reports make their reports I believe they will tell him to leave the present land laws alone. I have lived in a community—raised from a boy—when men came to the head of the department of the Latter Day Saints, my father, Brigham Young; some came with lies, others came with soft soap and he always had to weigh what men told him for fear they would give him the suds. Theodore is in the same fix. He has asked these good men to take care of his part of it. We are going

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to hear from Theodore Roosevelt in his message to the United States, but I wanted you to hear from me too. I am here, an old man, 58 years old. I am too old to fight—never had enough wisdom to fight—but I am glad to speak a word on this question.

Previous question moved.

Chairman—Before putting the question on the previous question, I wish to state that Senator Clark has requested permission to address the Congress on this matter.

Senator Clark—Mr. Chairman and gentlemen of this Convention; I think, from the allusion that I made in my opening address, that you all know where I stand upon this question of the repeal of some of our land laws. I stand for the people that are desiring to make homes in this country and not for the land baron. I know something about this scrip business. I bought a few years ago a piece of land scrip for the purpose of locating a saw-mill on the timber land, and I found that the reservation where the scrip had been taken from had been restored to the public domain, and I was entitled to that original part of the public domain represented by this scrip. When I sent down there to find out what kind of a country it was, I found the ground barren. I think this is one of the greatest frauds of this age to allow the railroads to get scrip and sell it to the people and thereby defraud them. The homestead commutation clause gives room again for further fraud. You know very well that more than half of the homesteads in that country are commuted in fourteen months, as they are allowed by law, and how can a man who wants to avail himself of a homestead land law, and goes and moves upon it and tries to build up a farm there—how can he, from the proceeds of that barren land, acquire sufficient funds in fourteen months to pay for the land unless he is aided by somebody. And there is always somebody around to put up the money. I know a number of instances of it myself, where men have moved to land apparently in good faith to make a home there, and in fourteen months the land would be commuted and the men had the money to pay for it, and moved off somewhere else, perhaps to take up new homesteads. It is a source of fraud that should be corrected by the repeal of this act—this commutation clause.

So far as the Desert Land Act is concerned, it has enabled the grasping men of this country to acquire large domains where they get thousands of thousands of acres in one body by reason of this act, and scarcely ever work them. You can go to the State of Montana, where I live, and start in at the Yellowstone River, and attempt to cross the country to the Missouri River, about one hundred and fifty miles, and you will find that where there should be hundreds of homes and prosperous villages, where there should be towns and cities, you will find scarcely a house; instead of these you will run up against wire fences. That broad district is owned by a few men. Hence I appear before you making an earnest appeal in behalf of the actual home settler, the man who goes upon a piece of public land in good faith to make a home, where he can rear his children, and thereby contribute to his own happiness, and the prosperity of the community and State in which he lives.—Great applause.

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Chairman—The gentleman from New Mexico has moved the previous question, which was seconded in various directions. Shall the previous question now be put?

Mr. Prince—I wish to ask whether the question on which the previous question is asked is simply to strike out this one or three sections applying to the desert act and timber act?

Chairman—Shall the previous question be put? If there be no objection, the Secretary will call the roll of States. All those who vote aye on the question now before the house will vote to strike out from the report of the Committee this recommendation for the repeal of these three certain things. Those who vote no will vote to keep in the report of the Committee its recommendation for the repeal of those three certain things.

Roll call by States.

Chairman—The noes have it—63 ayes and 205 noes.

Mr. Finkel—I desire to move an amendment to that portion of the resolutions regarding a loan of the Government; I wish to put in the words "non-interest bearing" before the word "loan." I do not think we should incur any interest-bearing debt. Congress may not understand this, hence these words regarding interest should be put in. Motion seconded; carried.

Mr. Prince—I move as an amendment a substitute for the three sections with regard to the acts that have just been voted upon, the following:

"Whereas, The Timber and Stone Act, the Desert Land Law and the commutation clause of the Homestead Act have in some instances in their administration been found to result in speculation and monopoly;

"*Resolved*, That we request the Congress of the United States to make such modifications in said laws as will save the remaining public lands for actual settlers who will found homes and live upon said lands."

Congress, by its action a very few months ago, has shown, Mr. President, that it desires to take some action on the subject. It has refused to strike out the action that was proposed by the committee, which shows distinctly that it does desire some action. I submit the action which was taken last year which was very prudent and careful and judicious, and I think it is not desirable that this Congress, in the passage of any of its resolutions, should continually change its views and its standing on certain questions from year to year. It is a great deal better to re-affirm what we have done, once it is shown to be absolutely right. This was passed last year after a very long and searching discussion in which the best minds of the Congress of the United States expressed themselves. They are not here, these gentlemen, this year because they thought this matter was settled at once and forever by this Congress. Senator Teller is not here. Mr. Mondell is not here—not here because they thought this matter had been settled. That is the reason they are not here. In the first place let us re-affirm what we did then, which is in opposition to everything that is wrong in these acts and in favor of everything that is right.

Mr. Clark—I want to refer to the action of the Congress at Ogden last year. A great many members here present were there and recollect that the contention went on and a discussion was had which was, in many points,

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very acrimonious in its character, and aroused some intense feeling, and I believe, and so did the others believe, that if the Convention had been allowed to vote upon the main proposition it would have voted as they did upon this amendment—would have voted in favor of repealing these laws; but the men who were there sent by the corporations of this country, like a distinguished man from San Francisco, and several others, and the representative from Wyoming was there, and when they found that those resolutions were going to be carried by that Convention and they were afraid of the result of the vote, they trumped up the compromise proposition which does not mean anything; which was simply a makeshift and is really not a recommendation to Congress at all, and thereby we stultified ourselves by allowing the resolution to go through. But the people were tired. It was late in the Convention and they got tired with discussion, and believing that it might work out some good for the cause, they let it go through, and the men to whom the delegate from New Mexico refers are not here to-day, but they turned up in Congress. I don't know what Mr. Mondell said in the House of Representatives because I was not there, but I know that his colleague, Senator Warren, and Hansbrough from North Dakota made long arguments in the Senate chamber, opposed to this measure, and endeavored to defeat it there, so I believe these men were resting quietly, perhaps believing that this Congress will take up some such meaningless, worthless proposition, and for that reason they did not come.

I am opposed to tampering idly with this question. Let us go squarely on the proposition. Say we want these land laws repealed or not repealed; let us act manly about it and not try to put up a compromise that will be discreditable to us and have no weight in Congress.

The amendment was lost.

Motion to accept the report was carried.

Mr. Hawley of Idaho offered a resolution thanking the people of El Paso for their courtesy and hospitality which was unanimously adopted.

Chairman—I have a request from the delegate from the State of Sonora, Mexico, who wishes to be allowed a few moments for a greeting from that commonwealth. I introduce to you Mr. Ellison, of Sonora.

Mr. Ellison—Ladies and gentlemen, I have to say that I am only here as a substitute for a much more distinguished man. This man sends his regards. I exceedingly regret that such an unqualified person as myself is here in this position. It is my exceedingly great pleasure to be able to say that the very distinguished statement of your retiring President regarding us has been very impressively confirmed. I shall be brief and only consume a few moments. I hold in my hand by the courtesy of a Senator of the United States, a most wonderful instrument—the treaty of the Gadsden Purchase, which was consummated by Franklin Pearce and Mr. Gadsden; under that treaty and by that treaty we are indebted for the rich soil upon which we stand; by that treaty the State of Sonora lost thousands of miles which belonged to us. This treaty is dated at Mexico, June 30, 1853. It is signed by Mexico and the United States, passed the Senate, and is an exceedingly interesting document. It is out of the question to read it, but no more interesting document could be submitted to an audience. It concerns the entire

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border. Sonora should have been here with a delegation of 100. This territory of Sonora is intimately and closely associated with Arizona, with California and Texas, and we are interested in whatever concerns you.

I invite you to come and see us—drop over the border and see our good people and receive a most hearty welcome.

Mr. Fairweather of California—I think the press of El Paso has done nobly during this Convention by publishing very full reports. I move a vote of thanks of this Convention to the press of El Paso.

Motion carried unanimously.

Mr. Smythe of California—Mr. President, ladies and gentlemen, the closing hour of this Congress is at hand, and I have just been called upon to return the thanks of our delegates to those to whom we are so deeply indebted for the opportunities and the pleasures and successes of this event.

El Paso in 1904 will go down into the history of irrigation as one of the greatest conventions, perhaps, all things considered, the most fruitful of all the conventions which have been held in the interest of this movement, and for this result our thanks are due to the big-hearted people of Texas and especially of the city of El Paso.

Many individuals in this community have devoted months of time to preparations for this event. Among them I will mention the Hon. W. W. Turney, Chairman of the General Committee of Arrangements. I must refer to the indefatigable labors of Secretary Gifford, who has been a host to each and every one of us. Also to Mr. Cobb, the Reading Secretary. A resolution of thanks to the press is one that is well deserved. I think that never in the history of this movement has a convention been more generously treated than by the press of El Paso. To my mind it is a happy thought, because it is a true one, that for every one hundred dollars El Paso and Texas have expended upon this 12th National Irrigation Congress, Texas and El Paso and New Mexico and Old Mexico will receive a million dollars in return. I believe the years of the early future will bear out that most fully, and I want to say a few words of tribute to the very efficient and self-sacrificing and indefatigable Executive Chairman of the National Irrigation Congress. No Congress has ever had a greater Executive Chairman than Mr. C. B. Boothe, of California.

The Convention has already paid its impressive tribute to Senator Clark, who during the past two years has been our presiding officer; who has been one of the inspiring influences of this movement, and as I have listened to his speeches I have felt like telling him, "You are the noblest Roman of them all." I sought the platform this morning at the time of the election of our new President, hoping that I should have an opportunity to place his name in nomination, but the quick adoption of the report gave me no opportunity to do that. As my name was considered for the same place, it seemed the fitting thing that I should say a word to the Congress regarding him. Now, the election of Governor Pardee as President of the 13th National Irrigation Congress is not merely a personal compliment. It is not merely a compliment to a grand commonwealth. It is an action which is significant of a new era of statesmanship in California, and I hope in many Western States. It seems strange, my friends, but until this man went into the Executive Man-

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sion, we could not get a governor to mention irrigation in his message to the legislature. Governor Pardee gave it prominence in his first message. And not until he came were we able to interest a governor to the extent of securing his attendance upon a National Irrigation Congress. When we have an oasis of a governor coming in a desert of disappointment, we are glad to have you join us in giving more power to his elbow. And now, again and again and again I want to say to Texas and to El Paso, "Well done, and thank you forever."

Mr. Boothe—I desire to add one word to that statement by Mr. Smythe. The ladies who have attended this Congress have been most generously and kindly entertained here by the ladies of El Paso, and a committee headed by Mrs. Magoffin. We never have received more attention, if as much, at any place. A magnificent ball will occur to-night, at which the ladies are going to entertain, and I have been told that the husbands have been instructed to stand aside and give the boys a chance. I desire to have recorded an expression of thanks by a rising vote to the ladies of El Paso for their kindness to the delegates of this Congress. Rising vote.

Mr. Cobb, of El Paso—Mr. President, ladies and gentlemen; a few moments ago Senator Turney, that worthy citizen who has done so much for El Paso in regard to this Irrigation Congress as well as other matters, requested that I respond in a few words for him. It was after we had looked for that knightly cavalier of Texas—that eloquent orator of El Paso—Captain Beall, whom you have heard speak, and in his absence I have been requested to say to you that El Paso has been moved by your appreciation. El Paso opened her doors wide to you. El Paso gave you that welcome which comes from the bottom of her heart. But El Paso's heart is moved more now than ever before in her history by the generous expressions of appreciation from you, our friends. And in speaking for our proud city, I would not claim that we are not proud of her—I would not be worthy of El Paso if I did not proclaim her before the world as the bright jewel which gives lustre to the Lone Star of Texas. I would not be worthy of her if I did not tell you that she is the grandest, the best city in all America. The way that she has treated you is the way that she treats every man that comes to her border. You don't have to come to us as delegates. You don't have to come to us with authority or title. El Paso is great in heart and noble in spirit. We welcome every visitor, high or humble. It is the greatest town in all America, and I speak for her that spirit which has made her great. No man has come to El Paso who has done his duty but what has won. No man has struggled in her markets, in her work, no man has worked with her, but what he has risen to the pinnacle of success. I proclaim to you that we are glad to have had you as guests, and we know if you would stay with us you would be glad and proud to call yourselves El Pasoans.

There are many in this community who came here in poverty. I remember but a few years ago when I wore a pair of pants in this town which had to be hidden by an overcoat. I remember that that pair of pants is replaced by two pairs of trousers. Come to El Paso whenever you can, and you will always receive a welcome. Come to us after the Elephant Butte dam is built; come to us when that valley is fertile and irrigated. It is fertile

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now, but come when water is put upon it, and you will see a valley that is grand, you will see a sight that is colossal; you will see railroads running into the Empire City of the Southwest every three minutes.

If you appreciate what has been done for you, go away from El Paso and speak praises of her. Go away and speak of her as we speak of her. We are proud of her. We are proud that she is so good, so noble; and I tell you when America sees the progress that she will make; when Mexico has opened her resources as will be done; when our friends in New Mexico and Arizona contribute still more to their proud metropolis, El Paso; when all this is achieved in the course of the next few years, I tell you that all America will join in the sentiment that El Paso is the brightest jewel of an international diadem.

Mr. Holabird—Three cheers for El Paso.

Chairman—Three cheers for El Paso, Cobb and the patched pair of pants.

Mr. Boothe—I desire to give notice to the newly-elected members of the Executive Committee, that the Committe will meet here on this stage immediately after adjournment this afternoon, to organize.

Chairman—Is there anything further to come before this session of the Congress?

Motion to adjourn *sine die.*

Chairman—Before dropping the gavel, I wish to express for my State, if you will permit me to say, the greatest State, our great appreciation of the work which you have done here at this Congress, and also of the honor which you have conferred upon my State by electing its Governor your President for the ensuing year. Gentlemen, the convention stands adjourned.

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RESOLUTIONS

ADOPTED BY THE

Twelfth National Irrigation Congress,

November 18, 1904.

Our thanks are due to and are hereby heartily tendered to Honorable W. A. Clark for his manifold and valuable services as President of this Congress during two successive terms.

It is the opinion of the National Irrigation Congress that the National Irrigation Law should be so extended by Congress as to include the State of Texas within its provisions, in so far as to permit the Secretary of the Interior to direct engineers of the United States Reclamation Service to examine and report upon feasible irrigation projects, and, when approved according to the terms of the said law, to superitend their construction, to the end that Texas may have the benefit of the same service that is now extended to the other arid sections.

The full text of the National Reclamation Act should be printed in the official proceedings of this Congress, and all the proceedings of the present Congress should be published in book form and indexed; such published report should include the Constitution and By-Laws of the 12th Annual Session.

FOREST PLANTING.

The appropriation of funds for forest planting on denuded water sheds in the forest reserves is essential to the progress of irrigation, and we strongly urge upon Congress legislation to that end during the coming session with the view of increasing the volume of streams still flowing and restoring those which have disappeared.

We express the fullest confidence in the honesty, ability and capacity of the officials of the Reclamation, Forestry and Weather services, and commend their impartial and non-partisan administration, and our hearty thanks are hereby tendered to the officials of the Interior Department and of the Department of Agriculture, who have so ably contributed to the success of this meeting.

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We heartily commend the work of the Weather Bureau in the preparation of the Climatological Dictionary now in progress, and we bespeak for this publication the widest possible publicity.

LAND LAW RESOLUTIONS.

It is the sense of this Congress that the remaining public domain should be sacredly preserved to all the people of the United States and should be rigidly reserved for the benefit of actual homeseekers who will live upon the land and in good faith cultivate the soil. We recognize that much has been accomplished to this end; that under the provisions of the National Irrigation Law forty million acres of agricultural lands have been withdrawn from entry except under that act, and from the operation of laws which permit the absorption of public lands for private speculation, and that eighty million acres of timber lands have been withdrawn from entry in order to protect the water sheds, thereby increasing the source of water supply and conserving the public good.

REPEAL OF LAND LAWS.

In further pursuance of this wisely established policy of preserving the public domain in the interest of the entire people we urge the repeal of the Timber and Stone Act, of the Desert Land Law, and of the commutation clause of the Homestead Act.

NEW TIMBER LAW.

As a substitute for the Timber and Stone Act we favor the adoption of a bill passed by the upper branch of Congress at the last session, repealing the said act and providing for the sale of stumpage and for the application of the proceeds thereof to the reclamation fund.

ARID LAND HOMESTEAD LAW.

As a substitute for the Desert Land Law and the commutation clause of the Homestead Law we recommend an arid homestead law which shall limit the entry of any one individual to one hundred and sixty acres, which shall permit a reasonable intervening period for reclamation before requiring continuous residence; provided, however, that after reclamation the occupant shall be required to live on the land five years before securing title, as settlers are requird to do under the National Irrigation Law.

REPEAL OF SCRIP LAWS.

We also recommend the repeal of all acts permitting the selection of lieu lands, including any and all laws authorizing the issuance of any kind of land scrip, and recommend legislation for the valuation and purchase by the government, if necessary, of all lands in private ownership within the limits of forest reserves.

TO AUGMENT THE IRRIGATION CONSTRUCTION FUND.

We fully recognize that the funds now available are inadequate to the realization of the national irrigation policy upon a scale commensurate with

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the opportunities of the West and the needs of the nation, and we favor a non-interest bearing loan by the government to the Reclamation fund, to be used in the construction of projects approved by the Secretary of the Interior and to be repaid by the owners of lands benefited, in accordance with the provisions of the present law.

LOCAL CO-OPERATION WITH THE GOVERNMENT IRRIGATION WORK.

But we would not have the West depend alone upon national aid in the development of its resources, and we urge the several Western States and Territories to adopt legislation providing for the formation of irrigation districts which shall be able to raise funds by the sale of bonds, said districts to be organized only upon approval by the Secretary of the Interior, who shall employ the engineers of the Reclamation service in the construction of district irrigation works. By this means the Reclamation fund will be supplemented to the extent of millions of dollars by every State and Territory, while the benefits of national administration will be vastly extended. We commend this subject to the earliest attention of the legislatures of our Western States and Territories.

TO ENCOURAGE SUGAR BEET PRODUCTION.

It is the sense of this Congress that the irrigated lands of the arid and semi-arid West are demonstrated to be admirably adapted to the production of beet-sugar, and therefore we favor such national legislation as will tend to encourage that industry on such lands.

CONSOLIDATION OF FORESTRY WORK.

We repeat and emphasize the resolutions of previous Congresses in favor of the consolidation of all government forest work in the Department of Agriculture owing to the peculiar fitness of that department for the work, and urge the immediate passage of the bill for this purpose now before Congress.

We indorse the policy of the government in the construction of a ship canal along the west shore of the Sabine Lake, in Southeast Texas, with the view of opening to navigation the Sabine and Neches Rivers, which in addition to opening the inland fresh water harbors nearest Kansas City and St. Louis has aided in conserving the fresh water supply of these streams for rice irrigation, and we urge that similar work be extended to other localities throughout the nation, where practicable.

INVITATION TO MEXICAN DELEGATES.

The presence of distinguished delegates from our sister Republic of Mexico has strengthened the bond of friendship between the two nations, as well as enlarged our scientific and general knowledge of this continent, and in appreciation of the cordial treatment of this Congress while we were on Mexican soil by the officials of the State of Chihuahua and delegates to this Congress from the Republic of Mexico, we cordially invite the Republic of

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Mexico to send a delegation of her citizens to the National Congress to be held in Portland, Oregon, in 1905.

MESSAGE TO A FORMER SECRETARY.

This Congress extends to Colonel H. B. Maxson, whose long and zealous service as Secretary of the Congress has so closely identified him with the organization, its sincere regrets that illness should have prevented his attendance at this session and its cordial appreciation and recognition of his services as an officer of this Congress during the years he has served as its Secretary, and expresses its hope for a speedy recovery of his health.

This Congress as a whole and each and every of its members individually feel under lasting obligations to the people of El Paso for the warm welcome extended and the uniform courtesy and kindly treatment received during our stay. And we assure the people of this city that the recollections of our visit will be a life long pleasure.

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General Addresses.

IRRIGATION IN EGYPT.

M. K. H. Bakhati, Engineer of Irrigation Projects Office, Cairo, Egypt.

When you consider that Egypt is the mother of civilization you at once conclude that its irrigation is likewise the mother of the irrigating systems of the world.

I will divide the irrigation age into three epochs:

1. Irrigation as it existed up to seventy years ago.
2. Irrigation from the time of the Khedives up to the year 1880.
3. Irrigation as it has been understood from the year 1880 up to the present time.

First—Irrigation as it existed up to seventy years ago embraces a period of time extending from the reign of the Pharaohs, ancient kings of Egypt who lived four thousand years ago, up to the time of Mohamed Aly Pasha, the first Khedive of Egypt.

Irrigation was caused by the overflow of the Nile, which is the only river of Egypt; the earth would be inundated by the rising of the flood, and the remainder of the year it would be deprived of water, for there were no means of raising the low water, which flowed continually in the bed of the Nile, except by some inadequate method. The land in those days was at the mercy of the overflow. If it was good and sufficient, fine harvests were produced; if the water was low there was great scarcity of crops.

GREAT ANNUAL INUNDATIONS.

The whole land was covered with water and there remained only a few elevated portions which were chosen for habitation, forming isolated villages, and barks passed from one to the other as boats circulate between the different isles of the Antilles, and as is Cuba to-day, so was then Memphis, the capital of Egypt.

I do not condemn the systems of the ancient Egyptians, for they produced some very great results in raising the water by machines that modern science has declared war against and has set aside as belonging to the past.

The ancient Egyptians utilized Lake Moris as a reservoir to reduce the immense overflow of the Nile, and now we wish to imitate them by using this lake as a reservoir for irrigation purposes. But in examining the different strata of earth we fear infiltration, for we have on one side low lands, well cultivated and well cared for, where the level changes from eighty feet above the sea to one hundred and forty feet below.

It is not only infiltration that we have to consider, but the advantage arising from our expenditure.

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Second—The first stone in the second epoch of irrigation in Egypt was laid by Mohamed Aly Pasha, the first Khedive of Egypt, in 1833, by the construction of the dam in the Nile at the point where the river divides, forming within its two branches the delta, bounded on the third side by the Mediterranean Sea.

CONTINUED THE WORK OF THE PHARAOHS.

Mohamed Aly pitched his tent outside his residence and he remained near the great work, not wishing to leave it until it was entirely finished. He made in one year the concrete, the floor and the piers as far as the spandrel of the arches, and the second year he finished the work that Nature had called for ever since the Pharaohs changed the course of the Nile from the Sahara to the Mediterranean Sea.

With the building of this dam, Egypt entered another epoch, which is the epoch in which the true irrigation of our country commences.

Mohamed Aly constructed the dykes of the Nile, excavated the canals and built the waste gates, or regulators, for leveling the water, and by this means he was able to save the fertile land of Egypt from the annual inundation of the Nile. Since that time our minds have been centered on improving our irrigation system, and on supplying the essentials that were lacking for its completion.

In his time Ismail Pasha excavated many of the canals, of which the Ibrahimieh Canal, which is two hundred miles long, demonstrates and displays the talent of the engineers who had in charge the carrying out of the plan of this large canal, and to provide irrigation for two hundred and fifty thousand acres of land at all times of the year.

Other portions of the land which can not be supplied with water from the canals are irrigated by the rising of the Nile. The lands are divided into basins and receive water through the canals from a distance suitable for the perfect irrigation of each basin.

We commence to drain these basins into the Nile when the water from the overflow begins to abate. The lands which are subjected to this system of irrigation are planted but once a year. However, the peasants dig wells in the summer, in which the infiltrated water accumulates, and with this they are able to irrigate their land and reap a harvest of corn before the Nile overflows its banks.

SOIL DRAINAGE TO OVERCOME ALKALI.

Third—The third epoch of Egyptian irrigation is that of to-day and embraces the last twenty-four years.

It is well understood that for a land whose level surface is not exaggerated it is necessary to drain off the water which circulates in the different subterranean strata and which spoils the soil by alkaline substances which are found dissolved in it. We carry off this by means of drains. This was the first step towards placing the Egyptian soil adjacent to the Nile among the most fertile and productive soils of the world.

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We excavated many drains and changed some canals in order to do away with the use of machines for raising the water of the canals and to change the irrigation system into irrigation by gravity.

We built our dam at Assuan, 530 miles above Cairo, and stored in it a quantity of water amounting to 1,300,000,000 cubic meters, or 39,000,000,000 cubic feet, or 10,000,000 acre-feet. The great work was finished two years ago by an English contractor under a contract with a heavy bond, and we began to change the system of basin irrigation into our modern system of irrigation by canals, and utilized the water stored up above in our reservoir.

We built our dam on a grand scale, fulfilling the different technical requirements with reference to foundation and stability, and escaping the deposit of silt or sediment, which is greatly to be feared in the construction of reservoirs. We examined the different strata of the valley in which the reservoir is located and judged that we would lose nothing by infiltration. The reservoir is underlaid with granite, and granite is the material used in its construction; and it can not be denied that the dam of Assuan is the largest and strongest of all dams in the world.

We undertook to change the basin system extending over 432,000 acres, and up to the present time we have completed the work on 198,450 acres.

Three and one-half per cent of the land used in excavating our canals and drains was occupied, and the owners of the land will be reimbursed by the government.

The government assesses an additional tax of $2.00 an acre, and the peasant, on the other hand, should be able to produce five harvests every two years.

A GOOD INVESTMENT.

The government has expended $525,000 on the reclamation of 55,000 acres and realized at the end of the first year thereafter $111,200, or 21 per cent. In this way the government can realize its expenditure within five years, and the peasant can cultivate cotton and sugar cane, the primary sources of the wealth of Egypt.

The citizens of our country have water furnished to them by the government free of all charge. The land taxed by the government at $7 per acre produces three crops per year. Ordinarily the proprietor rents his land for a period of two years. The peasant can produce five different plants every two years, namely, cotton, clover, beans and maize of two varieties. He can realize from the cotton $140, two crops of maize $40, clover $15 and beans $30.

The revenue amounts in two years to $225 per acre, and he must pay rental of $70 to the proprietor of the land. I do not exaggerate when I say that a peasant in Egypt who has an acre and a half of land produces from his land cotton to the value of $280. He pays to the government a tax of but $7.50 per year.

This is not all. We raise also all kinds of vegetables and fruits, of which the date with its twenty different varieties assures a large income from its production.

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GREAT INCREASE IN LAND VALUES.

Having spoken of the productiveness of Egypt, I must not fail to speak of the price of land in our country. The price has doubled in the last three years. Formerly we paid from $100 to $250 per acre, but now it is impossible to purchase at the former price, and the lowest price at which land can be bought is $250 per acre.

When you consider that the value of the land in Egypt, comprising 7,000,000 acres, has increased in value $1,050,000,000 and more, then you can clearly judge of the actual increase of agriculture in Egypt.

And with our government well financed and with sums of money reserved for irrigation purposes, I do not hesitate to say that we wish to drain our lakes, which are situated near the sea, and we can gain by our work an added area of 1,500,000 acres.

It is true that we would lose the major portion of the silt from the overflow of the Nile in the sea, but it would be deposited on the new lands that we would gain in driving back the waves of the Mediterranean to the north.

DEVELOPMENT OF THE SOUDAN.

In Soudan, which comprises 7,000,000 acres, and which is an Anglo-Egyptian possession, we have done nothing, but all thoughts are directed to it, and all ideas are well developed for the construction of reservoirs, and with our water from the Nile and our labor we will make of Soudan another Egypt.

You will understand from all that has been said that irrigation in Egypt is expressed in these three words, "Irrigation by gravity." We are building our regulators, we are measuring our canals and drains in a manner to suit our climate, and we say to the water, which is at our mercy, "Go, water the land. You need not be raised by machines; we have commanded you to rise by our regulators."

THE VOLUME OF THE NILE.

As nearly as I can remember the silt which is found in the water of the Nile for the three months of the overflow amounts to 48,000,000 cubic meters, or 1,440,000,000 cubic feet, and with this quantity there could be constructed two dykes in the Nile from Cairo in Egypt to Kartoum in Soudan, of which the dimensions would be seven feet wide at the top, seven feet high, and the slope of the two sides would be one to one.

There could be made from this amount forty-two pyramids, each fourteen times the size of the three pyramids of Egypt. The discharge of the Nile when the water is low is 1,200,000,000 cubic feet per day and the average discharge of its overflow is 12,000,000,000 cubic feet, and the greatest overflow has reached 30,000,000,000 cubic feet. Considering that the discharge of the Nile changes every two months and that its maximum discharge is 12,000,000,000 cubic feet, and the minimum is 1,200,000,000, and that the amount of discharge after the first two months of the inundation diminishes to 3,000,000,000, we have the capacity of our Nile in one year, which is 1,458,000,000,000 cubic feet, which would cover the State of Texas, its mountains and its cities to a depth of six inches at least, if not an entire foot, or it would fill 729

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reservoirs of the size of the Elephant Butte at the lowest calculation.

In conclusion, I wish to thank you for the kind reception I have met with in the United States, and I thank the engineers who have kindly given me all necessary information concerning their methods of irrigation, and I beg you to accept my congratulations for the fine systems that you have established for irrigating your land.

And I wish to thank the honorable chairman of this Irrigation Congress for the invitation so kindly extended to me in behalf of Egypt.

And allow me to express my great admiration for the American nation, and to say as my last word *not* "Good-by," but "Au revoir."

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RURAL SETTLEMENTS.

COMMANDER BOOTH-TUCKER, of the Salvation Army.

It is with pleasure that I accept your executive officers' invitation to submit for your consideration a paper on the all-important subject of "Rural Settlements."

The fact that this plank has now been formally added to your national platform, that you have given to it so much prominence in your deliberations, and that so many expert students on the subject will be gathered together to mature definite plans, is a source of lively gratification to me. By thus bringing the question of national colonization prominently before the people and placing your imprimatur upon its importance you have demonstrated the practical character of this Congress.

It seems to me that the alliance thus formed between the kindred subjects of irrigation, forestry and colonization is of the most vital importance in order to assure the success of each. Of them it may be said as of the Swiss cantons, "United we stand—divided we fall." Not only are they naturally corelated, but I venture to say that each adds both to the dignity and feasibility of the other. Let it not be supposed, therefore, for a moment that in embodying "Rural Settlements" in this your magna charta of national requirements the progress of the kindred cause of irrigation will be impeded, but accelerated.

You will remember the old parable of the pond, the ice and the snow. Winter came, the pond was frozen over, and the ice said proudly to the pond, "I don't belong to you." A little later the snow fell and covered the ice, saying to it, "I don't belong to you." But the sun shone and the snow melted and said to the ice, "You are my brother," and the ice melted and said to the pond, "You are my brother." Gentlemen, under the genial auspices of this conference I venture to say that the snow and ice have already melted, and pond, ice and snow are saying to each other, "We are brothers!"

There are many inportant signs of the times which demonstrate that the nations of the world are waking up to the extreme gravity and importance of these subjects. The so-called policy of "masterly inactivity," which is in reality no policy at all, but that of the shiftless lazy nation, which invites calamity by failing to provide for the evil day, is being abandoned in favor of carefully organized plans based on scientific principles and often attaining mammoth proportions.

PROFIT OF GOVERNMENT WORKS IN INDIA.

India we are told has expended something like $125,000,000 on its colossal irrigation enterprises, combining with it a systematic plan of rural settlements and colonization, which has in the last nine years resulted in placing 800,000 persons on part of its once arid and abandoned lands. The fact that the government has not only been able to meet all interest payments and carrying charges, but to make a clear annual profit of three and one-half million dollars, surely speaks for itself and requires no comment.

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Second, perhaps, in this remarkable march of the nations should be placed the great advances which, thanks to the energetic action of this Congress, have taken place in arid America.

While last, but not least upon the list, is the remarkable action of New Zealand in its expenditure of some twenty million dollars under its Advances to Settlers Act. Here the possibilities that lie before systematic colonization have been demonstrated in an altogether remarkable manner, as will be seen from the copies of the act and the official reports upon its operation which I have taken pleasure in submitting to your delegates for their consideration.

The fact that the State of Oregon has invested some four million dollars of its school funds in advances to the farmers of that State at 6 per cent, and this without incurring, as I understand, any losses, seems to me to further demonstrate the safety and wisdom of a policy which shall extend to our rural districts and would-be bona fide settlers a system of credit, without which our commerce and trade would languish and be compelled to yield the palm to the other nations of the world.

FARM COLONIES IN THE UNITED STATES.

Our own Salvation Army farm colonies bear out the same deductions. Crippled as we have been by lack of capital we have nevertheless been able to establish three farm colonies with a total acreage of 3000 acres and a population of 530 souls. With a total expenditure of about $300,000 the repayments have amounted to about $50,000. On our California colony a thirty-acre tract was recently sold at the rate of $155 per acre, while one of our Colorado farms has just changed hands at $115 per acre, and the owner says that he would not sell it for $200 per acre.

On our townsite in Colorado lots have been selling at an average of $200 per lot, or $3200 per acre, while the business turnover for the year amounts to about $200,000.

A working people's sanitarium for consumptives has been established under the supervision of an expert physician, where for popular prices good treatment and excellent climatic advantages can be obtained within the limits of any working man's capacity. It is hoped that ultimately the sanitarium will constitute a home market for the colony, while the colony will provide light work and outdoor employment for the patients.

Gentlemen, it seems to me that the experimental stage has been passed, and the time has come for action on an extended scale.

TO ENACT A COLONIZATION LAW.

By following the lines which have been laid down by the most successful workers in this field it seems to me we shall minimize the risks of failure. What these lines should be I have indicated in the draft of a colonization bill, which was prepared after the last session of your Congress by some eminent lawyers. That draft was submitted to the late Senator Hanna and met with his approval, and was to have been introduced by him. After his death the late Senator Hoar took charge of the bill, and it was referred to the committee on public lands. Copies of that bill have been submitted to the dele-

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gates of this Congress for such action as they may deem to be desirable. You will see that it follows in a general way the New Zealand act, with such modifications and adaptations as appear necessary or desirable. In brief it proposes:

1. The formation of a colonization bureau with a commissioner in charge under the Secretary of the Interior.

2. The collection and distribution of information regarding lands suitable for colonization, so that the would-be settler can get reliable data.

3. Loans of $500 to $1500 in cash, live stock or materials to enable poor but worthy families to make homes for themselves upon the public lands.

4. The issue of bonds to the extent of $50,000,000 for the purpose of providing the advances to the settlers, not more than $5,000,000 to be issued in any one year, thus enabling Congress to put a stop to the expenditure should the plans not answer.

I have no doubt that upon this outline you, gentlemen, will be able vastly to improve. I trust that in some form or other that bill may receive your endorsement, and that the "ipse dixit" of this Congress, which carries so much weight in the counsels of our nation, may go forth with no uncertain sound in favor of the organization and establishment of rural settlements on a national basis.

I thank you for this opportunity of expressing my opinion on this vitally important subject. It has been with a profound sense of my own insufficiency and with no particle of desire to dogmatise that I have written. But I feel that I must not transgress the limits of your patience lest you should be tempted to follow the example of the cannibal tribe in Africa, who when asked by the parent society in America what had become of their missionary who had mysteriously disappeared, replied, "He gave us so much advice that we ate him!" Lest the editorial scissors of your Executive Committee should deal similarly with this article, I would conclude with one little incident.

There is in a Salvation Army home for convalescent workers a pet dog which seems to have wonderfully imbibed the spirit of its leaders in that when its meal is served it will not touch the food till a bevy of neighboring sparrows have joined in the feast. Gentlemen, millions of human beings, our fellow-citizens, are watching this Congress. In making it possible for them as honest home-owners and genuine homesteaders to partake in your great irrigation banquet by means of a properly organized system of rural settlements it appears to me that you will secure the approval of your conscience, the admiration and support of all good men of every party, and the co-operation and blessing of the Almighty.

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THE WATER SYSTEM OF PASADENA.

HELEN LUKENS JONES, Pasadena, California.

The system employed in obtaining water for use in the city of Pasadena, California, is an estimable one, in that it practically demonstrates what it is possible to accomplish in a locality where there exists no surface stream flow.

Pasadena, in a way a celebrity, since her pictures and praises have been tossed like confetti far and wide, needs but brief introduction. During the fall and winter, when winds and snows and floods and cold make the East bristle with discomforts, Pasadena becomes the Mecca of the tourist. Vast is the contrast between her disposition and appearance and that of frigid Eastern cities. She is circled, entwined, entangled in flower gardens. Her houses peek merrily from behind veils of roses and jasmine. She is always laughing and good natured. She has a soul—a soul of sunlight and gladness. Association with her—life in her genial atmosphere—is ever a delight. Like a bright-eyed bird she snuggles in a nest formed by encompassing hills and mountains, a nest known as the San Gabriel valley.

THE WATER SOURCES.

To the north, within three miles of the city, loom the rugged flanks of the Sierra Madre Mountains. It is the grouping of underground water currents from this water shed that constitutes Pasadena's water supply. In no single instance is there a visible stream-flow. Of the 601 miner's inches developed for use in the city, every drop comes from underground filter beds, most of which are located in the Arroyo Seco, near Devil's Gate, under the old river channel and its adjoining mesa, all within three miles of the city. Because of this complete underground system Pasadena's water has been declared by experts to be equal if not superior to that of any other city in California.

At present, to use an expression explanatory, the city is divided into three parts, namely, east, west and north, and the water system is controlled by three companies, which are managed on a basis profitable to stockholders as well as satisfactory to consumers. The city is negotiating for municipal ownership, believing the advantages will be greatly increased by combining the three divisions into one system under one management. The city has abundant capital for such undertaking, and under municipal ownershinp the facilities for more extensive water development would be exhilarated.

The area supplied by the system is twelve square miles and the consumers number 20,000. In all there are ten wells, ranging from 150 to 700 feet in depth. Six of these are bored wells, worked by means of compressed air pumps. The other four are dug wells with steam pumps. There are five reservoirs for storing water, with a united capacity of 85,000,000 gallons. Floors and sides of these reservoirs are cemented and they are tightly roofed. This condition, and the fact that all water is carried in closed iron pipes, excludes all notion of impurities, and the water when it reaches the consumer is

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as crisp and sparkling and crystal clear as when it left its home in the underground gravel. Not only does the covering method permit purity, but it prevents evaporation and waste, a most important and necessary precaution in regions where water is limited and difficult to acquire.

ECONOMY IN WATER USING.

Seven years ago the water companies of Pasadena found it absolutely necessary to initiate a meter system to prevent misuse and waste of water by consumers. If a man must pay for every inch of water he uses he is vastly more cautious in regard to the amount than if given unlimited freedom. The new scheme worked admirably, in fact very shortly after its inauguration the storage supply increased notably and remained uniform, where previously it had fluctuated in a fashion alarming for the good of the community. Four thousand meters, aggregating approximately $60,000, have been installed. Ninety per cent of these are known as five-eights meters. The remaining ten per cent are larger. A number of consumers are still without meters, but in time all will be supplied.

According to the last annual report the cost of operating the entire system, including the mechanism of the three companies, was $45,700. The receipts amounted to $86,799, showing a net profit of $41,099. The most extensive developing paraphernalia is located at and near Devil's Gate, a jagged pair of rock crags that picturesquely dig their toes into the bottom of Arroyo Ceco, northwest of Pasadena. Here is an $11,000 water plant, also an underground tunnel 4500 feet in length. This tunnel runs to a submerged dam founded on the bedrock, where it received the underground flow of water arrested by the dam. The depth of the tunnel below the surface averages 160 feet. In this tunnel wells have been sunk from which is attained purest water from deep subterranean strata by use of compressed air pumps. The plant used at this point consists of 100 horse-power high-pressure water-tube boiler, Leyner compound steam engine and two-stage air compressor, air receiver 36 inches by 8 feet, exhaust steam condenser and the necessary boiler feed-pumps. This machine has a pumping capacity of 1800 gallons per minute. Oil is used for fuel, thirteen barrels of which are consumed every twenty-four hours. By using a condenser not more than three per cent of the water is wasted, showing that the method is one of economy. The mouth of this tunnel is closed and cemented and a gate used to release the water required. From the plant the water enters a 22-inch pipe, and by means of gravity is distributed in the various reservoirs and thence to the consumers.

To further illustrate the economic methods of Pasadena it may be well to mention the fact that under municipal management a remarkable sewerage system has been inaugurated, whereby all sewerage is utilized for irrigating a 460-acre farm owned by the city. The produce from this farm, including walnuts, grain, corn, pumpkins, alfalfa and stock nets the city a luxurious sum.

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"UNITED WE STAND."

C. EUGENE BORTLE, Secretary The Inland Empire Association,
Spokane, Washington.

Irrigation is really in its earliest stage of infancy in this country; when we stop to review in our own minds the expensive and ofttimes profitless undertakings in other lines we marvel at the shortsightedness of those individuals who have tramped over countless wastes of arid lands to eventually sink their fortunes in an uncertain project which held out anticipations of sudden riches. Where these same expenditures might have been devoted towards a far better purpose in turning these arid lands into veritable gardens of productfulness.

We have only to look back a few years and see the Yakima Valley one sage brush desert, occupied only by roving bands of Indians and the howling coyote; her sparce growth of bunch grass providing grazing through the winter months to a few thousand sheep. Little was ever known of its true value to the agriculturist and horticulturist until surveyors had gone over the valley and discovered how feasible it was to irrigate large portions of the lands lying in the valley and along the lower benches of the hills. To-day after years of ceaseless work the Yakima Valley is a veritable Garden of Eden, as famous as the renowned valley of the Nile. Its fruits and other products rank among the finest in the world. Her products shipped to Oriental ports alone are no small part of the immense quantities that are shipped from all of the Pacific States combined and her products shipped all of the way to the Atlantic coast have been the means of advertising the whole State of Washington.

The wealthy ranchers throughout the Yakima valley have reaped their riches from the narrow confines of small irrigated tracts of land which would prove in the Eastern States, where they are compelled to depend on the provisions of nature's rainfall for moisture, a starvation income.

The banking institutions of the city of North Yakima are carrying the largest amount of deposits of any other city of like population in the West. These deposits are placed there, not by the commercial interests of the city, but by those same tillers of small acreage tracts.

Wenatchee, which sets nestled along the shores of the great Columbia River, is another instance of what can be accomplished by irrigation. The altitude of a little over 700 feet above sea level will not permit of a sufficient amount of rainfall to be of any benefit to the lands for agricultural purposes, and as the topography of the country is such as to make irrigation feasible and the canals easy to construct, much has been accomplished in the past few years to transform the Wenatchee valley into a marvel of productiveness. Some of the most prolific yields of fruits are raised in this valley, whose soil is composed of volcanic ash and the vegetable wash from the hills which has accumulated for ages past, forming an inexhaustible quality of soil. With the application of water from their ideal irrigation system this is truly a great lesson to take from irrigation.

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NATURAL STORAGE RESERVOIRS.

Eight small lakes situated on the edge of irrigable lands in the Spokane valley forms a natural reservoir for the storage of waters and supplying 60,000 acres of land in this valley, thereby forming a means of support to at least 30,000 people. So successful has been this undertaking that the people have required better transportation facilities for their produce, and as a result electric lines have been constructed, running through the thickly populated sections of the irrigated district. Telephone lines have been run which lead to all long distance points; the mail is delivered daily to the doors of the residents and they are provided with as many conveniences as if their homes were situated in the city of Spokane.

To live nearer the soil is in most popular favor at this time, and people are beginning to see, the great benefits to be derived from a residence on a ten or twenty-acre tract where the boys are given the opportunity to get the out-of-door environment which the close confines of the city does not allow. They are here given the space to make men of themselves and learn the true value of out door farm life, which can be carried on to-day without any privations to hinder as in years gone by, when our closest neighbor lived a mile away and a doctor could not have been reached in case of an emergency without a ride over rough country roads of twelve or fifteen miles.

To inform a new arrival from the East that some of the irrigated lands were producing from $200 per acre upwards to even $500 would immediately arouse that man's skepticism, but they are nevertheless true facts and can furthermore be proven by a visit to almost any one of the irrigated districts of the State of Washington.

These are only instances of what has been accomplished in our own vicinity and what can eventually be realized throughout the now arid portions of our great State. As one gazes over the map our eyes wander to the great bend of the Columbia River, known as the "Big Bend Country." Three million five hundred thousand acres of this vast domain are irrigable, and 1,000,000 acres can be irrigated at a probable cost of $30,000,000; a large sum to be sure, but when we take into consideration that many times this amount of money is being sunk at the bottoms of our eastern harbors and along the waterways where but only a few individual vessel-owners are reaping the benefits therefrom we at once turn over in our own minds the immense evolution to be wrought if the same amounts of moneys were being devoted towards arid wastes of our great inland West.

SMALL ACREAGES UNDER IRRIGATION.

It has been demonstrated that from ten to forty acres of land under irrigation in this country is bound to occupy a man with assistance of others to handle and do justice thereby; stop a moment and figure how families would profit and prosper on 1,000,000 acres of irrigated land.

Then a few figures would evidence the fact that they would require the output of great manufacturing industries, and think what an army of employes it would necessarily demand the services of.

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With the millions of acres of irrigable lands lying out in the parched and bleeching sun only waiting the application of moisture to have them give forth profits to the needy and industrious, we wonder how this change of conditions can be brought about.

It would be a useless waste of time for one man to attempt the change, or for even a number of men, but with the combined efforts of thousands of men throughout the United States, men who represent the wealth of the largest commercial enterprises and who have come to realize the fact that the needs of the country demand available government domain be utilized to provide for the masses who are compelled to seek their residence and occupation at their different trades in the congested cities, they are ready to give every aid and attention towards remedying the present condition. With the ending of the fiscal year June 30, 1901, there went into effect one of the most broad-minded and humane laws in the history of our nation. The provisions of this reclamation law we are most of us familiar with, yet it stands open to-day awaiting with her accumulating millions the proper legislation to have granted to ourselves a sufficient amount with which to carry out such projects as the government has found feasible for irrigation in the Northwest.

At the irrigation convention held in Spokane October 5th, many important matters were discussed, among which were means suggested whereby more interest could be brought to bear among the people who are to realize the direct results of contemplated projects to be carried out by the government. Among the many prominent speakers on this occasion was George H. Maxwell, the Executive Chairman of the National Irrigation Association. During Mr. Maxwell's address he stated that "the money for developing the water courses of the West so they can be made to water the countless acres of arid land must come from Congress. If you would get any appropriations from Congress you must unite your forces and reach the Congressmen through their constituents.

The national association is not a channel to get the Reclamation Service to do this or do that. It has nothing whatever or will it have anything to do with the engineering of the work. But when the Secretary of the Interior shall name any irrigation project as feasible and should be carried out, we are for it, whether it be in the Arizona desert, in the great plains of Montana or in the Big Bend country. It is then our job begins and we at once start out to get money from Congress.

TO INTEREST THE EAST.

We go to our Eastern connections and then we will get the money. We have the International Harvester Company, the International Implement Company, the National Board of Trade, the National Manufacturers' Association, and all of the great manufacturing bodies of the East behind us that employ hundreds of thousands of men and turn out hundreds of millions of dollars worth of manufactured articles every year. What makes markets for them is good for the constituents of their Congressman, and applies the leverage.

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You want to develop the State of Washington, and they want it developed. You want an organization in this State that will combine every interest in the State. If you go to work, every irrigation system that can be built will be built as fast as you can place settlers upon the land. It is up to you.

Mr. Maxwell's visit gained a great amount of interest in the National Irrigation Association, and had the effect of organizing the Northwest Section of the National Irrigation Association, embracing all of the State of Washington and the northern part of the State of Idaho.

The objects of the Northwest Section is to co-operate in the work of the national association to bring about effective laws towards benefiting our own local sections of arid lands which the government surveys have proven to be feasible.

The great amount of interest already manifested in the work warrants the belief in the minds of its officers that the Northwest Section will have at least 1500 members one year hence.

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EARLIEST ATTEMPTS IN MODERN IRRIGATION.

A REMINISCENCE.

BISHOP WM. C. MCCLELLAN, Colonia Jaurez, Chihuahua, Mexico.

Writers and speakers frequently give to Utah the credit for being the pioneer in the great irrigation movement, and this credit no doubt is largely deserved, but in my mind there is no question but that the irrigation microbe was carried to Utah from the valley of the Rio Grande.

The writer was a volunteer in the United States service in 1846, under the command of Colonel P. St. George Cook. We had been ordered to California, and in October of the year mentioned we found ourselves at Santa Fe, which place we left on the 21st of October and continued our march down the Rio Grande valley. At a point a short distance above where Rincon now stands the writer, with forty-nine others, most of whom were invalids, was detached and sent back under command of Lieut. W. W. Willis to Pueblo, Colorado, where other detachments had been sent for the winter.

On this return trip we took our slow and tedious march for the second time along the winding banks of the Rio Grande, and were thus given excellent opportunities for observing the Mexican people, and especially their style of farming, not only on the river, but in the smaller valleys toward the Taos Mountains. The irrigation idea was a new one to us, and we were not a little surprised and interested in noting the miles and miles of canals that had been constructed and the many acres, otherwise barren, that had been made productive by this system.

EARLY NATIVE CANALS.

We found canals along almost the entire route from Santa Fe to Socorro, some of them of great length, and in places very heavy work had been done in making deep cuts, or in building earthen aqueducts of considerable height and length. And how all this labor was done and all these results achieved with the tools then in possession of the natives was an unanswerable question with us all then, and indeed remains so with me to the present day.

While irrigation was not going on when we were there, owing to the lateness of the season, we could plainly see how it was done, in fact the manner of preparing the ground with bordering ridges and of flooding it, etc., was very much the same as that still in practice in the neighboring State of Chihuahua. From these irrigated fields were produced wheat, corn, chili, melons, pumpkins, grapes and some inferior apples and peaches.

In May, 1847, the detachments that had been wintering at Pueblo took up their line of march toward the West by way of old Fort Laramie, where we struck the trail of the Mormon pioneers, and followed it until the 27th of July, when we came upon the first body of Mormon pioneers encamped on the ground where Salt Lake City now stands. They had arrived there three days before.

Here was an ideal place for putting into practice the A, B, C's of irrigation, as the waters of City Creek canyon could easily be made to run east, south or west; and before the end of July these waters had been diverted from their channel and were moistening the parched soil on the south and west; and

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there and then, I believe we may say, was launched a movement that has since been the salvation of Utah and surrounding States, and must eventually prove the redemption of all the mighty West.

And let me now take the liberty of correcting a statement that appeared in an El Paso paper a few days since, to the effect that much of the responsibility and consequently the credit for the early irrigation successes in Utah rested with me. Candor compels me to say that I took no part whatever during the first few years, for as a young man I was so disheartened with the forbidding sunflower and sage-brush desert that I did not think it worth an effort at reclamation, and my greatest desire was to get away from the scene of desolation that surrounded us. This I succeeded in doing about the 16th of August, when I left Salt Lake Valley determined never to return.

But there were those whose judgment was better than mine; those who saw into the future with a clearer light than I did. They determined to remain, and with the running streams as their allies to conquer the desert and wrest from it the necessities of life, and with the push that even then characterized the Americans, and under the direction of the astute mind and leadership of Brigham Young, they were victorious.

METHODS BORROWED FROM THE RIO GRANDE.

While personally I did not assist in this work then begun, I have no doubt that others of our party who remained were invaluable helps, and possibly leaders in this work, as a result of the ideas they had borrowed from the Mexicans along the Rio Grande.

After three years spent in Iowa I became converted to the doctrine of irrigation, and securing an outfit I returned to Utah. And there I found land that three years before had been covered with black crickets now producing fine crops of potatoes, etc., and many canals had been built, most of them small and easy of construction. My faith in the cause of irrigation was strengthened and I began learning about it, and working for it. Soon after I took an active part in an irrigation scheme that furnished homes for about 100 families, and since then, in one way or another, I have had more or less to do with problems of arid soils and irrigation, and I must say that in a degree I sense the feeling of honest pride that comes to men who have battled with the desert and with the drouth and subdued them through their own necessities and for the benefit of their fellowmen.

In traveling along the Rio Grande a few years since I was led to reflect upon the great changes in conditions. Where the water was waist deep in 1846, and that was said to be a dry season, I could have crossed dry shod at the same place and same season of the year fifty-four years later. No doubt we all understand how much of this change has been brought about by using the waters of the tributaries for irrigation purposes, thus helping to dry the river.

It is devoutly to be hoped that the contemplated schemes for the storage of waste waters in this region may be crowned with complete success, and it seems to me but right to express the wish that your neighbors across the Mexican boundary line may be, on some terms, permitted to share in the benefits thus obtained, as in the past they have no doubt been sufferers.

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Engineering and Mechanics Section.

CHAIRMAN: FREDERICK H. NEWELL,
Chief Engineer U. S. Reclamation Service.

Wednesday Morning Session, November 16, 1904.

The meeting was called to order at 9:00 a. m., November 16th, by Chairman Newell. Upon his request, Mr. H. N. Savage acted as secretary. There was a brief discussion as to the purpose of the conference and concerning the program of the proceedings.

Mr. Newell—We will listen to a paper by Mr. Savage on "Reclamation Work in the State of Washington."

Mr. Savage—Mr. Chairman, Ladies and Gentlemen: My paper was prepared since coming here, because after arriving I found that I had been scheduled for a paper on irrigation in Utah and that Mr. Doremus, State Engineer, had also been put down for one on the same subject, and I decided to shift to Washington. I have selected the Palouse Project as the subject for a little talk, because it is one of the latest investigated and developed and is up for final consideration at this time.

RECLAMATION IN THE STATE OF WASHINGTON.

H. N. SAVAGE, Supervising Engineer.

It has been the policy of the Reclamation Service during the field season of 1904, to concentrate its work as far as practicable upon one principal project in each State, with a view to bring it to the point of construction with as little delay as possible. The preliminary surveys and investigations are carefully prepared, and from them plans are developed, comprehending the projects in their entirety, for the consideration of the consulting and supervising engineers.

In Washington attention this season has been given chiefly to the southeastern part of the State, where the engineers have located apparently a feasible project, known as the Palouse project. This scheme contemplates the irrigation of 100,000 acres of land lying between the Snake and Columbia Rivers in Franklin County, which are sufficiently low to be reached by a gravity canal diverting water from Palouse River. It is proposed to divert the water by a low dam near Hooper Station, and convey it by means of a canal about six miles long through the divide and into Washtucna Coulee. The proposed cut involves an excavation of about 600,000 cubic yards of gravel and small boulders. An alternative plan consists of building a dam 140 feet

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high across the Palouse River, constructing it of the material taken out of the cut through the divide between that river and Washtucna Coulee. This would require the removal of a few miles of the Oregon Railroad & Navigation Co. track and the acquisition of the area to be overflowed by the spillway. By increasing the height of the dam a few feet, sufficient storage could be obtained to regulate the flood run-off of Palouse River.

Washtucna Coulee, a part of which it is proposed to utilize for storage purposes, is a narrow basin extending from the Palouse river valley to within one mile of Connell. That portion of the Coulee extending from the rim of Connell 15 miles east to Silver Lake, is the proposed reservoir site.

INCIDENTAL POWER DEVELOPMENT.

From the cut through the divide into the coulee it is proposed to construct the canal on a minimum grade for a distance of 7,800 feet to the town of Washtucna, where two drops aggregating 83 feet can be used for developing power. It is estimated that the minimum flow of Palouse River during the irrigation season, with the storage available in Rock Lake, would be 350 cubic feet per second, which would develop 2,500 horse power. From Washtucna for about 10 miles the coulee is comparatively flat, but for the remaining distance to Washtucna Lake, about 1½ miles, there is a drop of 78 feet where over 2,000 additional horse power can be developed when desired.

At the west end of this coulee it is proposed to excavate a channel through the divide into Esquatzel Coulee, building a dam at the summit of the divide, which will give an available storage of 210,000 acre-feet. By increasing the height of the dam 43 feet, a storage capacity of 255,000 acre-feet could be obtained.

South of Connell lies Esquatzell Coulee, down which it is proposed to construct the main distribution canal from the storage reservoir to the irrigable lands. The Northern Pacific Railroad now occupies this basin and the Oregon Railroad & Navigation Co. Washtucna branch extends through the entire length of Washtucna Coulee.

NOW A BROOK; AGAIN A TORRENT.

The Palouse River varies in volume from 17½ to 15,000 second feet, and has a drainage basin of 2,200 square miles, most of which is uncultivated. On Rock Creek, one of the principal branches of the Palouse River, is a natural lake nine miles long, which can be converted into a storage reservoir with a capacity of 75,000 acre-feet, by the construction of a dam 37 feet high across the outlet. The total discharge from the lake during the season 1903-04 was 91,300 acre-feet. The discharge of Palouse River during the season 1901-02, the lowest run-off year recorded, was 341,000 acre-feet. During 1903-04 the discharge was 637,000 acre-feet. It is estimated that 100,000 acres can be irrigated by gravity under the Palouse project, assuming the duty of water to be 3 acre-feet per acre per auunm. Along the line of canal from Washtucna reservoir down Esquatzel Coulee, there is a considerable fall which can be utilized for pumping water to additional lands lying between 600 and 750-foot contours, if required.

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The estimated cost per acre for developing this project is from $35 to $40, and the scheme is considered desirable at those figures.

Mr. H. A. Storrs—I would like to ask if the railroad companies have agreed to move their track at their own expense?

Mr. Savage—They have not. In response to our inquiry, they have stated that they would bear such expense in moving their tracks as the traffic expected to result from this development warranted. Negotiations have been carried on for some time, and the indications are that the companies will do what is fair in the matter.

Mr. Storrs—What is the expense involved?

Mr. Savage—About $200,000. I might add that the conditions prevailing in this project for power development seem to be worthy of very special notice. Throughout Washington there are a number of electric railways being projected. A number are already in operation and are proving to be very profitable. Many small towns are putting in electric plants and there will be a demand for the power which can be developed from this project as soon as everything is settled. The power will have to be transmitted but a very short distance, and these small towns will grow rapidly. The junction of the two rivers which are navigable insures also a big development in municipal manufacturing enterprises.

Mr. Storrs—Will this power be available at all seasons?

Mr. Savage—Throughout the year. At least 4,500 horse power will be available constantly the year round.

Mr. Newell—The next paper is by Mr. G. H. Matthes, who has had charge of the work in Oklahoma. A great deal of his attention has been diverted from the strictly reclamation work by the instructions of the Secretary of the Interior. I might say that in Oklahoma a fund has been created in three counties, amounting to about $700,000, by the sale of lands, and that this fund is to be expended by these counties in certain structures, jails, court houses, bridges, school houses, etc., and that work has been put under the charge of Mr. Matthes, so that he has not been able individually to give as much of his time to the reclamation work as we had hoped; nevertheless, he has had excellent assistants and has not neglected the study of the Territory.

[Mr. Matthes presented a paper on "Investigations in Oklahoma"; it is here omitted as it is printed in the Third Annual Report of the United States Reclamation Service.]

Mr. Newell—You have before you the paper of Mr. Matthes on conditions in Oklahoma. It illustrates one of the unfortunate conditions that we occasionally run up against, that is, when our first investigations show that a project seems feasible and looks good, but later investigations develop the fact that it is very difficult of execution. It is intended to put into Oklahoma immediately the best reconnaissance men the service has developed during the last few years, to make a continued and thorough study of the Territory for other opportunities. We will continue to keep at this thing until we do build something in Oklahoma. It is possible that a modification of the first ideas of the Otter Creek project and the North Fork project may be

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reached which will make these projects appear in a better light, but it is fair to state that our first conclusions are disappointing.

A delegate from Oklahoma—I would like to say that taking the government reports of the rainfall in the region investigated you will find the rainfall very short. Another thing I would like you to investigate is the underflow of Otter Creek. There is an underflow of the North Fork where I investigated 150 feet across and about 2 feet deep. The underflow of Otter Creek is 156 feet across and about 5 feet in depth. It runs back almost to Granite Mountain. The underflow of that creek is much larger than the overflow. I think the underflow would counteract the loss by evaporation.

Mr. Newell—The matter of underflow is always very interesting. I have made a computation. If we estimate it at 156 feet wide, 5 feet deep, and moving at the rate of 10 feet per day, we get less one-tenth of a second foot with a ¼-inch pipe. We are apt to get very big notions of an underflow because we fail to bear in mind the fact that it is moving so very slowly. We must not attach much weight to an underflow.

A delegate from Oklahoma—I would like to ask if it would not be practicable to give us a beginning with the North Fork, give us a reservoir there and then if it proves practicable, extend the works to include Otter Creek.

Mr. Newell—That is an excellent suggestion and one which, since I have been in Oklahoma, I have been thinking of seriously. We started in with Otter Creek as our leading or initial point. The proposition now is to put some more good and experienced men in there and tell them to simply start out with that as their starting point, and see if they cannot discover a feasible site there, or if not, an alternative. We are going to hammer on this line until we get something that will stand the scrutiny of the men who will have to pass upon it ultimately.

A delegate from Oklahoma—What would be the cost per acre of putting in these works?

Mr. Matthes—The cost per acre as computed from the original project was $13.20. It is now very certain that it will be greater. If we have to cut down the size of the reservoir, we will have to increase the estimated cost per acre.

A delegate from Oklahoma—Was the cost to irrigate included in your estimate per acre, or was it simply the cost of construction?

Mr. Matthes—The computation was made on the basis of the cost of the complete works, including lands, damages, etc. The cost of maintaining the works and conveying the water to the lands was not included.

Mr. Newell—That amount of $13.20 I think is too low. Of course, when you take into consideration the bringing of the land under subjection, the price will have to be raised. In these computations it has been the tendency of the engineers to raise the estimated cost. For instance, the people of Las Vegas will be down here to try to convince us that $57 per acre is not too much to pay, but they will have a pretty hard task to convince us that it is not too high for them to pay, and in Oklahoma I think it will be necessary to raise the amount very materially.

Mr. Mendenhall has made considerable investigations in this matter of underflow in California, and I will ask him to give us in general the results of

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his conclusions, those which are most interesting to us. The underground supply, of course, compared with that on the surface is always very, very small. It is hard to form a comparison between the two. If I remember right, an ordinary irrigated farm of 80 acres will require almost as much water as a city of ten thousand population. About the same comparison might be made between the waters underground and the waters on the surface.

This study which Mr. Mendenhall has been making of the underground waters of California is typical of other parts of the United States and gives us the result of a very thorough and careful examination of conditions which have been puzzling the people there for many years.

The engineers of the Reclamation Service and Geological Survey have been carrying on two distinct, yet very closely related lines of work. This work of Mr. Mendenhall's is not under the Reclamation Act, but comes under the related work. Mr. Mendenhall is what is known for convenience sake, the Division of Hydrology.

I will state for your information that the work of the Geological Survey in its relation to irrigation and reclamation is divided into a number of divisions. There is the work of the men who are measuring the streams in all parts of the United States; there is the work of the men who are studying the wells and underground waters, and there is the work of the men also who are studying the quality of the waters and its relation to irrigation, such as ascertaining the alkaline contents of the water and its possible effect upon the crops; yet all of this work comes right down to the question of the industrial development of the whole United States. Here in Texas we have been studying the flow of the rivers, the opportunities for development, the quality of the water, the underground conditions, and all such matters that will lead to a larger and better use of the resources of the State. Under the Reclamation Act we can not expect to go into actual developments in the work in Texas, but we can study the conditions, and the suggestion has already been made by Senator Newlands and others that it may be proper to allow the expenditure of a portion of the funds in Texas, especially in connection with the Rio Grande, and this is a point on which I think the people of the State may appropriately express their wishes and desires.

Mr. W. C. Mendenhall—I might say, as a preface, that in Southern California we are studying the conditions in a community, which, although not an old one, is densely settled and one in which our resources have been highly developed. Our object is to determine whether the underground waters may be further developed so the people themselves may know how much more land they can reclaim in safety.

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THE UNDERGROUND WATERS OF SOUTHERN CALIFORNIA.

W. C. MENDENHALL, Geologist, U. S. Geological Survey

The greatest population and the highest cultural interests in Southern California are concentrated within a wide diversified valley that extends inland 80 miles from the Pacific Coast at Santa Monica, and is effectually screened from the Mohave and Colorado Deserts by the San Gabriel and San Bernardino Mountain Ranges. These high groups protect the land on their Pacific slope from the climatic extremes of the deserts, and at the same time wring from the ocean winds the moisture with which they are laden, and which in the form of perenniel streams, makes possible the high state of cultivation that has given some of the adjacent agricultural lands values of from $500 to $2,000 per acre. Yet the rainfall is low—from 10 to 20 inches in the valleys—and this, and its concentration within a few months of the year, are conditions which demand irrigation to insure crops even of grain and hay, and make it imperative for the much more valuable citrus lands, walnut groves and gardens.

The practice of irrigation was begun early in the century by the Missions, before a general settlement of the country by the Mexicans or the Americans. Short and simple ditches, which usually took their water from the Cienigas, the perpetual springs, and served a small acreage about the ranch houses, sufficed for the simple agricultural needs of this pastoral period. The construction of permanent works of a better character began before the Civil War, and was most actively carried out during the seventies and eighties. The famous Riverside Colony was founded in 1870, its existence depending entirely upon the successful construction of a large canal, which carried the flowing waters of the San Bernardino Basin to a strip of desert mesa north of the Santa Ana River. By the construction of other canals built about this period, the mountain waters as they came down the canyons to the margin of the low-lying tillable lands, were gradually diverted, and the acreage under cultivation extended. Such flourishing colonies as Anaheim, Pasadena, Pomona, Ontario, Cucamonga, Highlands and Santa Ana owe their foundation to the diversion of these surface waters.

THE WASTE OF THE FLOODS.

By 1880 the available flowing waters had been generally diverted and utilized, and the limit seemed to have been reached to the amount of land reclaimable from this important source, but the stimulus of the very high values reached by the California citrus lands, and the comparatively small acreage under cultivation as compared with that reclamable if water were available, combined to induce a most thorough examination of all possible sources. After the appropriation of the normal stream flow, there remained two additional possibilities sufficiently inviting to enlist the attention of capital and skilled service. Because of the high gradients of the California river beds, and the steep slopes of the mountains where the greater part of the rainfall

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occurs, as well as because of the fact that a large part of the annual precipitation falls during heavy storms of moderate duration, there has always been a heavy loss of water through run-off during floods. If this could be saved by impounding reservoirs, a great gain would be affected. But the generally constricted character of the San Bernardino and San Gabriel mountain canyons has been unfavorable to the construction of reservoirs. Actually but two important projects have been completed; the Bear Valley dam, whose stored waters have added the flourishing Redlands colony to the reclaimed areas; and the Hemet dam, less favorably situated as regards rainfall, and less successful therefore in the matter of acreage redeemed. Another project, the Arrowhead, is under way after years of patient observation of rainfall and run-off, hence eventually there will be a further addition to the waters conserved in this way.

The second attractive possibility for the development of additional water lay in the development of the great underground reservoirs. It had been found in the sixties and early seventies that the boring of wells in certain moist land areas was followed by flowing water, and when the surface supplies had all been appropriated, engineers turned their attention to these lands and to the storage sites as the two remaining sources which promised most in the way of increasing the available supply.

THREE THOUSAND ARTESIAN WELLS.

The Gage canal system, completed in 1886, has depended from the first almost entirely upon underground waters, and its 7500 acres of splendid citrus lands are an example of what may be done with them. Since this experiment the development of underground waters in Southern California has continued, until now there are nearly 3000 artesian wells and about 1600 pumping plants representing a capital of about $3,500,000 and a combined production of at least 400 to 500 second feet continuous flow.

This development, although under way for thirty years, was given a great forward impulse by the series of dry years which began a decade ago. The previous ten years had been years of abundant rainfall, the precipitation being well above the average, although this vital fact was not generally recognized by water users. As a consequence the acreage brought under cultivation during those years exceeded the amount which the ditches depending upon surface streams could serve when the dryer period came on. The most important and valuable of California crops are perennial plants, citrus and deciduous fruits and walnuts which can be rapidly adjusted to fluctuations in the water supply. A grove which does not come into profitable bearing until five years after planting, represents by that time considerable capital. If the water fails it for a season, that capital is lost. Hence great energy has been displayed in the development of water as the surface supplies have dwindled under the influence of the drought. There are few important irrigating systems whose supply has not been augmented during the ten years past by the boring of wells whose flowing or pumped water is used to make up the deficiency in stream flow. And in addition much independent irrigation has been undertaken whose supply is well water entirely.

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A large part of this is new land, not under cultivation previous to the beginning of irrigation from wells; a smaller proportion was moist land cultivable without irrigation before the dry period, and retained in the cultivated class since only by the installation of wells. The reclamation of lands in this way has been most extensive, naturally in the artesian areas, and in those other low-lying lands bordering the artesian basins, where water could be obtained near the surface and at but slight cost by pumping, but it has been practiced in a more limited way where higher, warmer and more valuable lands have enabled the horticulturist to lift water to greater heights, and to pay the resulting higher charges.

UNDERGROUND WATERS THE SAVIOR OF SOUTHERN CALIFORNIA.

It has been fortunate indeed for Southern California that she has had large bodies of subterranean waters to draw upon. This fact has enabled her to come safely through so trying and generally fatal a combination of circumstances as a decade of heavy rainfall, and consequent exaggeration of her most fundamental asset, accompanying such a rapid industrial development as to constitute a boom of the first order. The reaction from such a combination is usually utter stagnation. The worst fault of our Western American business character is its cheerful, careless optimism. We will believe any tales however false, that flatters our community pride and promises fortune; we will have nothing of any facts, however absolute, that set a limit to our resources. Here in the Southwest we might well parody the well-worn motto of the court of Louis XV, and say, "After us the drought." But Southern California has not as yet lost any extensive areas of her reclaimed lands, although the deficiency of rainfall at Los Angeles for the past eleven years has aggregated twenty-six per cent of the average, and during that time, and at present she has been steadily increasing her acreage.

The geologic relations which have made this condition possible may be briefly outlined. The valley of Southern California is not a normal stream valley, carved by stream action and adjusted in width, depth and alignment to the volume and course of the stream. It owes its character entirely to other agencies, those agencies being crustal movements. This diversified low land may be best described as a series of deep, irregular crustal troughs, parallel to each other and to the Pacific shore line, plunging to the northwest and abutting in this direction against the granitic San Gabriel range. At the foot of this range the ridges separating the troughs are lowest, and a practically continuous valley extends from Santa Monica to San Bernardino. Farther south the separating ridges rise higher, and the valley is broken by mountain chains and groups. As these troughs and their separating ridges have formed by geologic processes, the previously existing rivers have maintained their way across them from the higher mountains where they rise, to the sea, and in maintaining these courses have cut canyons in the ridges and have filled the troughs with the sands, gravels and clays that are due to their erosive action. The result is a series of deep bedrock valleys filled with alluvium, across which the rivers flow. These conditions give rise to cer-

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tain peculiarities in the habits of the rivers, peculiarities which it happens adapt them in a wonderful way to man's needs as an irrigationist.

BECOMES A LOST RIVER.

The Santa Ana River is the most imporant of these Southern California streams, has the largest drainage basin, the longest course and exhibits these beneficent peculiarities in the great perfection. It will therefore be briefly traced as an example of the type. It rises in the higher San Bernardino Mountains where rainfall is abundant, and has attained a volume of from 25 to 50 second feet when it reaches the first of the filled geologic troughs at the mouth of its upper canyon. Here it promptly sinks in the coarse debris and percolates slowly below the surface, protected perfectly from evaporation and contamination until it reaches the lowest point in the rim of this depression. This rim forces it to the surface, and it flows across it as a living stream, the waters which escape diversion sinking again in the gravel filling of the second trough. After a short subterranean course it is forced out again by the impervious rock at Riverside Narrows, and continues to flow over the surface through the Santa Ana Mountains until beyond these it reaches the inner edge of the greatest of the troughs, the Coastal Plain, in which it sinks. Below Santa Ana it rises once more in a series of strong scattered springs and escapes to the sea.

This hide and seek habit is characteristic of the rivers of this valley, and is as ideal an adaptation to the needs of the arid land horticulturist as though definitely planned by man for his own benefit. The lower rims of the rock folds force the water to the surface at very convenient intervals for diversion, and meanwhile not only is the water in its underground passage saved from loss by evaporation, but the irregular spasmodic supply at the canyon mouths is converted into a uniform flow which is unaffected by individual storms and responds but slowly to prolonged wet or dry periods. These basins are, therefore, not only storage reservoirs, but are most effective regulators as well, and go far to bring about that most important desideratum in irrigation practice, uniformity of supply. An additional important economic factor is introduced by the presence of artesian conditions along the lower margin of each of these storage basins.

The material with which the rock basins are filled is alluvium, river deposited sediment. Each stream issuing from its mountain canyon carries with it the products of its erosional activity there. Debouching upon the plain, its velocity is checked and the heavier fragments are dropped. At the lower margin of any particular basin, where the velocity of flow is least, the finest materials are laid down as clay sheets. These have the original slope of the stream bed and are limited in their extent upstream. In this direction they gradually become coarser until they are no longer impervious. The waters entering the valley at the canyon mouths and percolating seaward below the surface through the more porous strata are entrapped beneath these sloping clay blankets, where, under the weight of the waters behind them, they accumulate pressure. Then when the impervious clay cap above them is pierced they flow.

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AN ARTESIAN BASIN OF 250 SQUARE MILES.

These cheap artesian waters are well distributed in Southern California, and have been important elements in its development. The original area of the lands under which they were found was about 375 square miles, but it has suffered a shrinkage of 33 per cent during the last fifteen years and now measures only about 250 square miles.

Since these artesian basins are unlike the normal synclinal folds in porous rock which have come to be regarded as the type, so they have special characteristics which bear directly upon their usefulness.

In the first place, being in wholly unconsolidated and generally coarse material, they have a high transmission capacity. So freely does the water flow through them that individual ten-inch wells have in a few cases yielded six or eight second feet of water. Such wells do not fail because the water supplied at the head of the alluvial fan can not reach the boring, as has been the case in the Denver basin, for example. On the other hand, flowing so freely they draw down the supply at a very rapid rate, but can be restored if closed for a time, while a new supply is allowed to accumulate.

The fact that the water bearing strata lie approximately parallel to the surface, and that the highest are very near it, facilitates development to such an extent that ranchers in many instances have found it more economical to sink a well for each ten acre lot than to distribute from a single central well. This condition encourages the multiplication of wells and the draughts upon the artesian supply.

It is these great rock basins, with their filling of saturated alluvial wash which constitute the important underground reservoirs that have not only tided the region over a long period of low rainfall, but have actually made possible constant additions during the dry period to the reclaimed lands. These great natural reservoirs more than compensate for the lack of sites for effective artificial storage. Their actual capacity is to be expressed in cubic miles rather than in smaller units. The San Bernardino basin has been explored by the auger for over 1000 feet, and is roughly estimated to attain a maximum depth of 3000 or 4000 feet. The alluvial filling about Pomona and Chino, and that east of Pasadena, above the Paso de Bartolo, is known to extend below sealevel. The great Coastal Plain basin has been explored for 1300 feet, and its depth, were it known, would probably be found to run well up into the thousands. With a surface area of 775 square miles and on the basis of 30 per cent of voids, a very impressive but utterly valueless estimate might be made of the amount of water stored in it.

Now while, as I have stated, the underground reservoirs have proven of incalculable value to Southern California during the decade just passed, and have not only carried the country through this period, in spite of the fact that the greater part of its earlier development was carried out during and upon the basis of a decade of excessive rainfall, but have actually permitted a continual increase of acreage under irrigation, it is not to be expected that this result has been attained without affecting the water level in the reservoirs.

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UTILIZING ALL THE WATER.

Water levels have, in fact, declined notably, artesian areas have shrunken, and pressures in wells still flowing have decreased markedly. The thing which causes most surprise is that these shrinkages have not been more violent. The underground supplies have been attacked in front and rear. The summer, and a part of the winter flow of the mountain streams is diverted at the canyon mouths and used for irrigation, where formerly all of it sank into the gravels and joined the underground supply. A few storage reservoirs have been built which hold a part of the winter flood waters that are now and always have been the chief source from which the ground waters are replenished. Thus not only has the supply been less during the past decade because of drouth, but is has been further curtailed because of diversion and storage. In addition to this indirect attack, the great number of artesian wells and pumping plants which have been put in have directly attacked the quantity of stored waters. It is estimated that of the 225,000 acres under irrigation in the valley of Southern California at present, two-thirds are dependent upon developed underground waters, about 400 to 500 second feet of which are used while the surface streams supply but 200 or 250 second feet. These relations are not fixed, there being a large acreage which is irrigated with surface water when this is abundant, but with well water when the streams are low. But the irrigation from developed water alone is increasing, while that from streams is at a standstill, or is shrinking, the flow of certain important streams which are due to rising ground waters having diminished during recent years.

The shrinkage in artesian areas is brought out graphically by the accompanying map, upon which fourteen areas are shown in which flowing water is or has been found. These combined artesian areas originally amounted to 375 square miles; they now cover about 250 square miles, a loss of 33 per cent, most of which has taken place within ten years. One great water company, whose supply of 40 second feet was originally all artesian, except about six second feet, now pumps at least 75 per cent of the total. The water levels in wells in important water-bearing lands tell the same story. Maximum declines of 60 or 70 feet within the past four years are of record. Declines of 25 or 30 feet are not at all rare.

These of course are the phenomena to be expected during a period of drouth. The critical point with the California irrigationist who is dependent upon underground waters, is to determine how much of it is due to the dry period and how much to development. Obviously this is a difficult point. The amount of water returned to the gravels each year is scarcely capable of direct estimate, at least with the data now available. The greater part is contributed of course during the winter floods, but the measurements of these are difficult, and but few attempts have been made to estimate them.

Observations upon the fluctuations of the ground water level are perhaps of more value. A system of such observations has been begun by the survey, but it will have to be continued for a considerable period before its results furnish a safe basis for conclusions. At present we have only two or three

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sets of observations within the valley which extend far enough back to be valuable. Fortunately for our thesis, their evidence is harmonious. I have selected for discussion the profile of the water level in a well near Anaheim, on the inner edge of the Coastal Plain. Pumping plants are numerous in this vicinity and are being rapidly increased in number, so that the phenomena exhibited by this profile may be accepted as typical of those neighborhoods where most pumping is being done. For direct comparison with it a rainfall chart has been prepared in which the departures from the average are shown for each year, since it is with the relation of each year's rainfall to the normal that we are especially concerned.

It will be noticed that from the time when the observations began in 1898, the declines were continuous and regular throughout the dry period, which was interrupted during the winter of 1900-1901 by an excess of rainfall. During this winter the water level raised two feet, but the gain was more than lost before the beginning of the next rainy season. The decline then continued, although irregularly, until the winter of 1902-1903, another year of excess in precipitation. Here again the profile shows a rise, but again it was more than lost before the end of the year. Since that time the decline has been rapid.

FACING A SERIOUS PROBLEM.

The significant thing about this profile—and such other measurements as we have exhibit the same phenomena—is that years in which the rainfall has exceeded the average have failed to stop the decline, although they have checked its rate. With present developments then the decline will continue, rapidly through years of deficiency, less rapidly through years of average rainfall, slowly through years of slight excess, and will cease only with an amount of excess greater than any that we have had in a decade. This is a sufficiently serious showing to call for a halt in the development of underground waters. It does not necessarily mean loss of land now reclaimed, because it is recognized that the proportion of water available for the restoration of the underground supplies, increases at a rapidly accelerating rate as the rainfall itself increases, that is, where a precipitation of fifteen inches may add little to the underground supplies, with a fall of twenty inches, nearly all of the last five may prove effective for this purpose, and a precipitation of twenty-five inches, well distributed throughout a long wet winter, may restore the continuous declines of half a dozen years of deficiency.

But the evidence is quite sufficient to show that it is time to stop increasing indiscriminately the number of wells for reclamation of virgin lands. There is grave danger that the splendid subterranean reservoirs which have carried communities through the past decade without distress, and have responded so fully to every demand made upon them, may be overestimated. Such supplies are everywhere peculiarly liable to over-valuation for several reasons. Among them is the fact that if the total quantity of stored water be estimated, the figures are so great that thoughtless users immediately conclude that such supplies are inexhaustible. They forget that actually it is only a very small part, often no doubt only one or two per cent of this great amount, which is, or with present methods, can become available. Again,

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the fact that these great bodies of gravel are efficient regulators of the supply through rainfall, responding but slowly to periods of drought or periods of excessive precipitation and showing but slowly the effects of over-use, leads many to suppose them wholly independent of those controlling factors, and so encourages them in their campaign of over-development. As a matter of fact, close, careful and continual observations should be made of fluctuation in ground water levels, as development proceeds, and these when compared with rainfall measurements, will give a safe, scientific basis for the regulation of the acreage irrigated from ground waters.

Meanwhile, development must proceed with extreme caution, for obviously nothing worse can happen to a community than to be forced to abandon lands which have been reclaimed at a great expenditure of time and capital.

Mr. Newell—Mr. Mendenhall has given us briefly the result of years' of very careful work. He has called attention to a serious condition which exists in that locality, where a field possessing ideal conditions may have its underground waters drawn upon by so many wells as to imperil the value of the entire area. The striking thing to me is the rapid decline in the area of these artesian fields. A fact we should emphasize to the people of California and others interested in that there is a limit to the artesian and underground waters, and without alarming them, we should suggest that they should exercise wise and prudent forethought, and if necessary, enact State laws to guard against over-development and total destruction of the field by putting down too many wells, and thereby kill the goose that lays the golden egg.

Mr. Fred C. Finkle, of Los Angeles—Having devoted about 18 years to practice as a hydraulic engineer in Southern California, I am thoroughly familiar myself with these conditions, and what applies to Southern California applies to a great extent to other portions of California also. Within the last few years it has become generally recognized among engineers that these artesian springs, as well as other basins that are not artesian, have been drawn upon to a greater extent than they can sustain. For many years it has been that the man who had the longest pump rod would deprive others of their share of the water, but now the Supreme Court has changed the aspect of the law so that no longer can a man go in irrespective of the rights of others and draw out the underground waters so as to destroy the old supply; yet it will require a great deal of time to restore the normal conditions.

GRAVEL BEDS HOLD THE WATER.

An interesting thing which we will observe by the topographic map exhibited by Mr. Mendenhall is that in all of these basins and between them and the mountains are large beds of gravel, sand washes from the various streams. The supply of these basins comes from the floods which come from the foothills and fill the lower levels. The floods carry enormous amounts of silt, which is caught by these gravel beds, thereby preventing the percolation of the water through them and thereby preventing the full benefit from

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accruing which would otherwise come from these artesian belts and storage basins.

I am not so optimistic myself as some of the people of my section of the country, but I do believe if the people will listen to reason and cease their developments—the courts will probably enjoin some of the recent developments—that in a reasonable time all of these basins can be restored practically to their normal level, but this can not be accomplished without the assistance of the courts. As to the value of these basins, Mr. Mendenhall has dwelt almost entirely on their value as water supply for irrigating lands. They possess another great value, that of sub-irrigating the lands overlying them. When the water stands within a few feet of the surface, as it does in these artesian basins, the underground water feeds the alfalfa and other products in that section; so these waters in their original state serve two purposes, they first sub-irrigate the products and then furnish waters for irrigating other lands in the foothills and arid districts of the State.

Mr. Newell—Gentlemen, the next paper on the program is by Prof. E. F. Chandler, State Engineer of North Dakota.

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SPRING FLOOD MEASUREMENTS IN NORTH DAKOTA.

E. F. CHANDLER, State Engineer.

It is not my intention to treat a topic so broad and so long as one might infer from the title printed in the program ("River Floods and Water Supply of North Dakota"), but merely one special phase that may force itself on the attention of those making stream measurements in as northern a latitude as North Dakota, a topic, however, concerning which I have not happened to see anything published.

This is the casual relation existing between the early spring floods—or rather, the first high water of the spring—and the ice which then, after holding the river all winter in a grasp of iron, is melting, breaking up, and floating down.

It is a characteristic of North Dakota streams that quite frequently there are two well-marked high-water stages during the season, the first, early or late in April, the result of the melting of the snow, may be almost certainly expected. Then, there being no mountains to hold heavy snow banks through the spring and no forests to delay the run-off, the water promptly slides off the prairies into the rivers and, even where the fall is as slight as in many of these prairie streams, it has soon run by and is gone. Afterward comes the second rise, the "June rise" as it is termed, which can not be predicted with certainty, but which usually occurs, following the rains, in late spring or early summer.

It is the April rise that is likely to give the highest water. If irrigation is in view, this early flood, though not needed for immediate use, must be stored for later use and is the most assured source of supply. Thence measurements of its quantity are made.

Perplexity not infrequently follows in the mind of the hydrographer because of a serious and sometimes apparently causeless discrepancy that may be found between these measurements and those at later season high stages. I believe that the rule may be safely laid down that, on prairie streams of as sluggish a nature as these, when the ice first breaks up and goes down, the height of the water on the river gage for several days, or for a week or two, must be assumed as due not entirely to the quantity of water being discharged, but in part to the ice; for this seems to have a tendency as it catches on the banks and increases the friction to retard the speed and raise the water more or less, even when it is running freely down the river without forming any visible jam or barrier.

STREAM GAGES NOT ALWAYS ACCURATE.

If a rating-table, based on later season measurements, is to be applied in the computation from the gage-height record of the season's run-off, it is necessary to reduce the gage-heights or deduct a very considerable per cent from the assumed discharge during the first portion of the flood following the spring break-up. Unless an unusual number of discharge measurements have been made at that season (which may be hardly convenient for an engineer who has charge of a number of gaging stations on different streams, all

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of which are apt to have this brief spring rise at nearly the same time) one has not sufficient data to obtain a comprehensive idea of the precise amount of this correction each day for every stream, and it is largely a question of judgment, an estimate. Yet such an estimate must necessarily be made, for the records for those few days may denote the highest water of the whole season, hence be of proportionate importance. This past spring the floods were somewhat unusual, it is true; but there was scarcely a stream in the region but had at least a third of its total run-off for the year within a single month in the early spring, and in some cases four-fifths of the total run-off passed in less than a month.

A few illustrations may be of interest.

On the Pembina River, a small stream of eighty feet width, a spring measurement made while the channel was covered across with lodged or floating ice cakes at some points, although clear and open at the point of measurement, gave at a 12-foot depth of water a discharge 20 per cent less than the rating table, equivalent to subtracting 2¼ feet from the gage height. This rating table, by the way, checked perfectly with a still higher measurement a week later.

On the Red River, at Grand Forks, a spring measurement made while occasional ice-floes were still running down the stream and lodging against the shore gave a discharge of 21,000 second feet instead of 27,000 second feet expected from the gage-reading, a discrepancy on a total depth of 36 feet equivalent to a difference of 4¾ feet.

A measurement under similar circumstances eighty miles further up the same stream, at Fargo, a few days later, produced a 30 per cent discrepancy, indicating that out of a total depth of 13 feet the ice had raised the water 2½ feet.

At the same time on the Cheyenne River, near Fargo, a discrepancy of 22 per cent, equivalent to 3½ feet out of the 16 feet depth of water was found; but this was not unexpected, for the ice-floes were lodged across the channel a short distance below.

On the Red Lake River, at Crookston, Minn., a measurement made when the ice seemed to be all gone except narrow strips fringing the bank, and when considerable inspection discovered no gorge or barrier below, gave only 6000 second feet discharge instead of the 10,400 expected (an expected figure confirmed by still higher-stage measurements the following week), equivalent to 5⅓ feet fall from the 16 feet depth. An autumn low-water measurement at the same place, made with the temperature falling toward zero, and a driving snow storm covering the river with a layer of snow-sludge and shell-ice sliding along the surface, gave results 25 per cent too small, equivalent to a difference of nearly one-half foot on the 3½ feet depth. I suspect, however, that anchor ice was forming on the bottom of the channel a little further down, diminishing the cross-section somewhat.

SLIGHT FALL OF STREAMS.

All these streams have only a gentle fall, meandering through level valleys whose general descent is about one foot per mile, or less than two feet

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at most, and in the clay and silt of this level prairie they have eroded comparatively narrow channels of from twenty to fifty feet depth. With a maximum velocity of not more than three or four feet per second under any circumstances, and of one and a half feet to two and a half feet per second in all the cases mentioned above, the current does not often drive the ice-floes together with force enough to cause any conspicuous ice jams where the ice is gorged together into a huge dam. But the influence of whatever barriers there may be extends a proportionately greater distance up the stream to retard the flow and raise the gage-height. And, furthermore, if I interpret the data right, the mere presence of the jostling ice cakes in the stream, when they form so considerable a portion of its volume as the three-foot and four-foot ice-floes and bergs of North Dakota may do, by making one layer of the stream so to speak more viscous, retards the flow and raises the water disproportionately.

Mr. Newell—The paper by Mr. Chandler, dealing with ice conditions, is one which some of us can not appreciate very much, especially in the southern part of the country. The ice proposition, however, is one with which the engineers have to deal and is very important. In all of our structures in the North we must take the ice situation into consideration, such as its volume, duration periods, its thrust, ability to overturn structures, etc.

Mr. Storrs—There is one important feature, which applies to the western portion of North Dakota at least, and which differentiates the conditions Prof. Chandler refers to. In the western part of the State we have many small streams which, during the flood season, come down the coulees and wash in considerable volume. An examination of these small streams shows that it would be exceedingly valuable to conserve their waters by storage and thus obviate the necessity of pumping. The waters can ordinarily be stored above the upper benches and can, therefore, supply water to the lower areas which can now be developed only by pumping. Even if the amount of water that can be stored is small and variable, it is very valuable, because it will save pumping to the higher level, which is extremely expensive. In seasons whenever there happens to be an abundance of water it may be unnecessary to pump to these higher tracts at all. In that respect it is distinctly different from the conditions in Oklahoma, where there is only a variable supply from the streams, there being no reservoir such as we have in North Dakota, where we have the Missouri River to draw on and a pumping plant at hand to make up any deficiency in the run-off in the small streams.

DEVELOP SMALL RESOURCES.

Mr. Newell—The matter is very important to the people in North Dakota. There the matter of reclamation is a problem of developing smaller resources. We hope to be able to develop a method of pumping which will be applicable to that State and others in a similar condition. The fall of the ground is not sufficient to take the water by gravity ditches out of the Missouri River.

Mr. Storrs—It is barely possible that there may be some such favorable localities but I have not run across any yet. The hills—you can hardly call

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them mountains—in that State do not conserve the snowfall to any extent. The streams are small and the run-off from most of them is limited. It is possible that if a favorable reservoir site could be found some power could be found to draw the water from the reservoir, but that would be quite unreliable, and I should think, in any case, would only supplement to a small extent the pumping by means of a steam plant. Steam plants are especially inviting in that State because of the abundance of a cheap grade of coal, called lignite, making it quite economical to do the pumping by means of using coal for fuel.

Mr. Newell—That illustrates the condition of the Reclamation Service, where we do not have one thing we have another. It so happens that in North Dakota we have large quantities of this lignite, and tests are now being made in St. Louis of the efficiency of the coal from North Dakota and other parts of the country and the best way to utilize it for pumping in irrigation. They are testing it by direct fire, steam boiler, by putting it in a gas producer and testing it also by making briquettes of it, which can be handled commercially, but the tests so far indicate that the gas producer may be the way in which we can best use it and put it into effect. This is one of the innumerable ways in which the engineer and business man must overcome the effects of natural conditions.

EXPERIMENTS WITH COMPRESSED AIR.

A Delegate—Have they ever tried the compressed air system?

Mr. Newell—Not that I know of.

A Delegate—I will state that where I live they have just put in a compressed air plant and are making quite a success of it. They say they can lift the water by compressed air in large plants more cheaply than they can by pumping. This plant is run with oil as fuel. We purchase oil at the wells at about 15 cents per barrel, or a cost of about 50 cents per barrel at the plant, which makes it a very cheap fuel. At present they are demonstrating what can be done with compressed air. I think that in large plants it would be by far the cheaper method of lifting the water. It is much cheaper to have one large plant than to have numerous small plants, because one large compressed air plant can be utilized to lift water from a great many wells. This plant when completed is to cost $16,000, and the parties have entered into a contract with the owners of the land whereby the latter are to purchase enough water to irrigate 13,000 acres of land at a cost in construction of the plant $16,000, and about 40 to 60 cents per acre for each irrigation. It seems to me that whereas in Oklahoma or the Dakotas, or other places where they have to irrigate by pumping, that it is important to look into this matter to ascertain if they can not produce the water more cheaply by means of compressed air plants than by the construction of these large irrigation works and reservoirs, where the water can be obtained at a depth of say less than 150 feet. I do not know what the area is in North Dakota that they have irrigated, but it seems to me that under the conditions it would be very expensive for them to irrigate from wells by pumping.

Mr. Finkle—Is it a system of direct lift?

Delegate—Yes, sir.

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Mr. Finkle--If so, I would state that that system has been used by us in Southern California for a great many years and it is now being used where the wells are scattered over a wide territory. I have made some very careful tests of that system and I have found it to be very inefficient in the matter of fuel. Air compressors do not usually have an efficiency in a warm climate of more than 50 per cent. Then again the free air discharged into the well loses a good deal of its force, so about the best results I ever obtained was about 30 per cent, and in many cases only got as much as 20 per cent of our actual power, so we do not look upon that system with a great deal of favor in that country. Mostly all of the pumping plants there now are either gasoline engines or electric motors, the electricity being obtained from the water powers in the mountains.

Mr. Newell—It is understood that Mr. Fred C. Finkle will favor us with a discussion of the subject of "The Most Economic Type of Hydraulic Power."

THE MOST ECONOMIC TYPE OF HYDRAULIC POWER.

Mr. Finkle—I was not advised that I should speak before this gathering until last evening, so that I have not prepared any paper, and whatever I will have to say to you this morning will be in the nature of rambling remarks.

In Southern California we are dependent more on the underground waters than upon any other source. The streams are limited in their flow during the irrigating season, and reservoir sites are very scarce, and with few exceptions we do not expect much from that direction in future. We are blessed in another way. Although we lack reservoir sites we have a precipitous fall in all of these canyons, which can be utilized for the development of electric power. I am satisfied that some of our rivers have falls as great as 350 feet to the mile. While the streams are small, we sometimes obtain considerable horsepower from them. I may mention one stream on which I constructed a power plant for the Edison Electric Company of Los Angeles, known as Milk Creek, where 24 second feet of water flows in average years. We have constructed a power plant on it by means of less than seven miles of conduit, which gives us about 4000 horsepower available. The fall at the station being nearly 2000 feet, which registers about 840 pounds to the square inch at the nozzles. These plants are used for irrigation, light and street railway operation.

POWER CONDUITS.

One of the most important questions we engineers have had to meet is the proper design and proper materials for constructing power conduits. In early days our power conduits were constructed mostly of cheap materials, generally wooden flumes which were hung on the sides of the mountain, and every storm that came up they would be broken or damaged by rolling boulders or land slides above them, so the engineering profession has been compelled to give a good deal of study and investigation to the matter of designing something permanent. You can realize the utter importance of having an uninterrupted service in a power plant. It is not only necessary where you are furnishing power to light cities, and run electric railways, but also where you are pumping water for domestic use and irrigation. These disasters to the

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early and crude power plants were very bad and caused the whole matter to be looked upon with suspicion and investors were not eager to put their money in the securities of these power plants. From my own experience I have come to the conclusion that there are two available methods, but before I outline these to you I wish to state briefly the conditions usually encountered in building conduits, referring particularly to California. The waters in California are all diverted at the base of the mountain ranges and distributed over the bench lands, so that power plants in the valleys practically do not exist. We have only one power plant in the valleys, and that is on Mill Creek, known as Mill Creek No. 1, which diverts the water at the mouth of the canyon and carries it two miles. All of the other structures are in the mountains, where you have to contend with vertical bluffs and steep sides of the mountains, scantily covered with vegetation, and when the heavy rains occur in the winter, landslides come down these mountains and almost any kind of structure exposed on the surface would be very undesirable.

MODE OF CONSTRUCTION.

The mode of construction which I have now practically decided upon is a concrete and cement pipe. We make this pipe in two-foot sections by mixing the ordinary gravel and sand which we find in the waters and screen through a coarse screen with one part of Portland cement. The pipe is laid in trenches dug to a depth sufficient so the pipe will be below the influence of land slides and to prevent it from being broken by rolling stones coming down the mountain. In some places we find it impossible to excavate these trenches on account of the vertical bluffs and in those cases we construct a tunnel. These pipes are laid on a uniform grade and the grade is usually determined by the velocity that is safe to give the water in your pipe, as it is not advisable to make the velocity greater than 5 feet per second, as to make it greater would have a tendency to wear the pipe. The joints are made by means of a cement collar put on the outside, made half of sand and half cement and covering the entire circle of the pipe. This collar is put on by men wearing rubber gloves, who press it down carefully. Inside of the pipe we plaster the joint with cement and this makes it a perfect joint. We now have three power plants which have been constructed in this manner and they have proven an excellent success, having had no interruptions in the service of any of them. One of them has been in use six years and that is a thing that never has occurred when flumes or other surface structures were used. In Southern California we have developed all of our smaller water powers and have had to go farther north. The Kern River is now the principal source from which new developments are being made.

POWER DEVELOPMENT BY TUNNELS.

The Edison Development Company is developing a plant on the Kern River. It will develop an enormous amount of land and give us 28,000 to 35,000 horse power in Los Angeles. This quantity of water is so great that a conduit of the nature I described would not be possible. A conduit 48 inches in diameter I have never found to be successful. For this particular purpose

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we are driving a tunnel 9 feet wide and 9 feet high in the rough. When lined with concrete inside it will be 8 feet wide with a water carrying cross section of 7 feet in depth, the upper part being arched over in a circular form to sustain the formation. We find that by the use of this tunnel, we shorten the line which would be occupied by a flume from about 14 miles to 8½ miles. Although the tunnel will cost more than a flume, it will be a perpetual thing when constructed. A tunnel of this character if driven through the rock will be a thing which for all practical purposes we may say will endure forever, while a flume under the very best conditions is only good for 15 or 20 years. Besides, the other objection which I mentioned, namely, interruption to the service, is a vital matter. Companies which built flumes in the early days have abandoned them and built tunnels. There was one company at Bakersfield which originally built a flume and had so many interruptions that within three or four years after the flume was built they drove a tunnel. For a large flow of water the tunnel is the most economical form of power conduit. The problems an engineer must meet are cross section and grade to be adopted for each particular grade. As to the grade to give such a tunnel, what governs me almost entierly is the velocity which the concrete work inside such a tunnel would stand. My reason for concreting these tunnels is that in this way you can save considerable on the first cost of the work and you reduce the co-efficiency of roughness. My method of concreting is to use 4 parts of crushed rock and three parts of sand to one part of cement and lining and covering the bottom with three to four inches, plastering the whole surface with a mixture of 1 to 2 sand and cement, applying, say, ¼ of an inch to give a smooth surface and prevent percolation through the cement. By means of this construction the co-efficiency has been reduced as low as .01 and in other cases it has been as high as .012. If the work is very poorly done it might run to 013, but I have never had a case of that kind in my experience. Of course the first investment in a power plant is made greater by means of this class of work.

TUNNELS VS. FLUMES.

In California where timber is quite abundant a flume can often be constructed very cheaply, but by figuring the cost of maintenance of such a plant, the loss to the company by interruption to its service and consequent loss of reputation, etc., and cost of renewals, which are very great on all timber structures, I find that the figures I have prepared show that although higher at first the other system is cheaper in the end. I deem this subject one of consderable interest to the Reclamation Service for unquestionably will they meet with problems of this nature, and what I have said in regard to the economy of a power company of course applies fully to the Reclamation Service wherever the plant is for power purposes, and where it is not for power purposes it applies to a considerable degree. Of course many of us in our first practice as irrigation engineers had to do more or less timber work in the arid part of the United States. The companies often allowed us only a certain amount of money to do the work and many of the land schemes were dependent upon the revenue derived from the sale of lands,

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and the habit grew up among the hydraulic engineers of the West of doing a great deal of timber work. The results have not been very satisfactory. Many of the systems are in such a condition that they have to be re-constructed or give very inefficient service in the future. In irrigation it is possible to forego the use of the water for a short time when a break occurs in the canal or conduit, but it is not possible in the case of power; and I might state that the development of power is what first called our attention to the necessity for doing permanent work, and this necessity is now coming to be recognized by engineers engaged in reclamation work. I am pleased to see that the Reclamation Service is planning to do good and permanent work. Not being connected with the Reclamation Service in any way, I know very little about their plans except what they see fit to give out from time to time. I know that it is not advisable to advertise their plans at all times as there are speculators in the country who are always willing to take advantage of the government as well as the people.

ELECTRICAL POWER DEVELOPMENT.

I would state that in Southern California at the present moment as near as I can remember there is something like 3000 horse power (electrical) developed from water, used for lifting water for irrigation and that is all done in a valley which is about 100 miles in length and an average width of not over 20 miles. There is a good deal more power than that employed but it comes from gasoline engines, which are used to a great extent, the electrical companies not being able to supply the demand. A good many of these gasoline engines will be replaced in the near future when some of the larger electric power plants are completed. On the Kern River, which is within 40 miles of Los Angeles, it is possible to develop 70,000 to 80,000 horse power, which will be available for use in that vicinity. This power will not, of course, be used for pumping water to any very great extent, because we have practically reached, if not overreached, the limits to which water can be pumped at the present time, and there are many other uses to which it can be applied, such as electric light plants, and the electric railway systems, which are becoming very numerous, joining all the small cities and towns in a perfect net-work. We have just passed through a period of dry years and that fact taken in connection with the excessive development has caused a depletion of the underground supply of water, and the curtailing of some of these excessive developments. We have hopes, however, that with the return of wet years in that section all the water that is needed for irrigation can be obtained, ultimately, in Southern California.

Mr. Newell—The matter Mr. Finkle has brought up is interesting to all engineers. The matter of permanent construction is one that must appeal to all of us. Construction up to the present time has been of a temporary character. The work of the reclamation engineers is largely in the line of good and permanent work. We have been experimenting on the construction of large cement pipes. We have been experimenting on the construction of pipes larger than 48 inches. We have been endeavoring to ascertain the practicability of constructing this pipe 6 feet in diameter, especially for pres-

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sure conduits to take the place of flumes so that we would not be compelled to use the wooden box trough or the wooden pipe, which has been used very successfully and largely in the West.

PUBLISHING ENGINEERING DETAILS.

Mr. Finkle has referred incidentally to the fact that the plans of the Reclamation Service were not widely known, and I think it only proper to state that in all matters of engineering detail we desire to have the widest possible dissemination and discussion, but in matters of advice to the Secretary of the Interior, our instructions are very positive and direct, that we are employed to work for him and no one else and our advice is to be given to him and not the public. I have noticed occasional squibs in the papers to the effect that they cannot find out anything. That is really a compliment to us. If anyone wants any information if he will write to the Secretary he will probably get it. In all matters of engineering that we can we want to take the public into our confidence and get suggestions from them.

TUNNEL DISCUSSION.

The subject of tunnels is an extremely interesting one to us, particularly in connection with such tunnels as we are building in Nevada and especially on the Gunnison and in the Montrose Valley. In the latter, under the direction of Mr. Fellows plans have been made for a tunnel 30,000 feet in length and 12 feet in the clear, lined throughout in order to increase the velocity to a point of safety. I think the velocity figured on is 10 or 12 feet per second. The work on that project has now advanced to a point where the bids have been received, and I think you may be interested to know that the bids have ranged from $2,600,000 to $1,000,000, and all made by men who are experienced in the work. The contract has been let and is now ready for signature.

Mr. Fellows--I have been particularly interested in what Mr. Finkle has said. I am not prepared to discuss the very able remarks he has made, but I have been asked to deliver a paper later in regard to tunnel estimates, in which I propose to cover some of the points he raised, particularly in reference to decreasing the size of the tunnel and the increasing of the velocity through lining. In referring to the tunnel which Mr. Newell has described, we have been criticised by some of our principal citizens who have said that the Reclamation Service was going so far as to propose to line this immensely long tunnel so as to make a pretty job of it, make it look nice and give it a pretty finish. It has been asserted by some of our citizens that we could reduce the cost of the tunnel one-half by leaving off the lining. As a matter of fact, as Mr. Finkle has stated, the result of adding the lining is exactly the opposite. In the tunnel we have used .012 as our co-efficient of friction, thinking that to be on the safe side. In the unlined section constructed by the aid of machine drills we have used rougly .030, and it is my recollection that the discharge of the tunnel without lining would have been about 485 cubic feet per second and with the addition of the lining the same size tunnel

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decreased in size by the amount of lining would have a discharge of 1300 second feet, thus considerably more than doubling the capacity of the tunnel by the addition of lining with an increased cost of about 25 per cent. This illustrates the necessity for concrete lining, which reduces the cost and is advantageous in every way. We find that in certain portions of the tunnel it will not be necessary to line the upper side of the tunnel by placing an arch in it, and in that section the lining is to be left out, but wherever the lining or support is necessary for the maintenance of the tunnel the lining will be included.

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Wednesday Afternoon, November 16, 1904.

Chairman Newell—Regarding Mr. Bien's paper on the proposed State irrigation code, I might explain in advance that when the Reclamation Act was passed there was a great deal said in the papers on the necessity of reforming the State laws in accordance, and in the winter of 1902-3 we had many inquiries from every State and Territory asking advice as to what changes should be made in the State and Territory laws so as to conform with the Reclamation Law.

Our invariable answer was that we did not advise any changes whatever at present or until we knew more of the practical workings of the law. We have now had 2½ years' experience with the irrigation law and are better qualified to say in what way the State and Territorial laws might be improved with reference to that experience.

The States of Oregon and Washington appointed commissions to consider a State irrigation code and at their invitation Mr. Bien and myself met these commissions in joint session at Pendleton, Oregon, and Walla Walla, Washington, and at their suggestion and request Mr. Bien drew up a code to serve as a starting point for laws that may be beneficial. Copies of this code have been sent out to persons everywhere who indicated that they were interested in the matter. With this brief statement as to why we are interested in the matter, I take pleasure in introducing Mr. Morris Bien.

PROPOSED STATE CODE OF WATER LAWS.

MORRIS BIEN, United States Reclamation Service.

The simplest form of regulation of the use of water is best exemplified by the present laws of the State of California. These declare the principles of priority and beneficial use and provide that claims to the use of water shall be recorded in the form of a notice of appropriation and shall be perfected by application to a beneficial use.

The form and theory of these laws was developed by several of the States, which followed in general the California laws and elaborated upon the methods established in that State.

DECREES OF WATER IN EXCESS OF SUPPLY.

The operation of these laws places no restraint upon appropriations of water. The courts in passing upon the claims of the appropriators, having scant information concerning the amount of water available for use, with no guide to the quantities which should be applied in the cultivation of crops, and confronted with the excessive claims of the parties, have often adjudicated rights to the use of water many times in excess of the amount carried by the stream.

The knowledge obtained during recent years concerning the discharge of streams and the use of water have caused such decrees to become exceptional in present practice. Nevertheless the need for a more careful regulation of the appropriation and use of water has been apparent for many years.

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MODERN STATE WATER LAWS.

In 1890 the State of Wyoming enacted a code of water laws providing for a thorough supervision of the utilization of the water supply of the State through a State Engineer and State Board of Control who adjudicate rights to the use of water in the first instance, and Division Superintendents and water masters, who have immediate charge of the distribution of the water in the various water divisions.

Nebraska subsequently adopted a code of water laws substantially the same in principle as those of Wyoming.

Idaho, Utah and Nevada in 1903 at the last session of their legislatures adopted codes of water laws based upon those of Wyoming with, however, a number of important modifications dictated by the experience of Wyoming and the development of irrigation practice.

OREGON AND WASHINGTON IRRIGATION COMMISSIONS.

At the sessions of the legislatures of Oregon and Washington, in 1903, the governors were directed to appoint commissions to prepare and submit draft of a code of irrigation law.

At the joint session of the two commissions with the Chief Engineer and other members of the Reclamation Service held last August, the fundamental principles of a modern irrigation code were discussed. There was also some consideration of the provisions which should be incorporated in such a code to facilitate the operations of the Federal Government in carrying on the work of constructing the irrigation systems contemplated by the Act of Congress approved June 17, 1902 (32 Stat. 388), known as the Reclamation Act.

As the conditions in the two States were similar it was deemed advisable for the two commissions to work in harmony and to prepare codes which should be as nearly identical as the conditions would permit, in the hope that by co-operation the commissions would be able to submit to the respective legislatures a code which should be an expression of the most advanced development of irrigation law.

PREPARATION OF DRAFT OF STATE CODE.

At the conclusion of the joint session of the two commissions, I was requested to prepare a draft of a code of water laws to form a basis of discussion by the commissions. The draft was prepared in a few weeks and widely distributed among those interested, for comment and criticism.

A number of valuable comments and suggestions have been received, enabling me to formulate amendments which a subsequent careful study of the draft had shown to be advisable, besides suggesting important changes and improvements.

I desire particularly to express my obligations in this matter to Messrs. F. I. Dunbar, Secretary of State of Oregon; A. E. Chandler, State Engineer of Nevada; Clarence T. Johnston, State Engineer of Wyoming; L. G. Carpenter, State Engineer of Colorado; D. W. Ross, Engineer in charge of the work of the Reclamation Service in Idaho, and T. A. Noble, Engineer in charge of the work of the Reclamation Service in Washington.

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PROVISIONS NEEDED IN STATE CODE.

A State code of water laws should provide for the appropriation, adjudication and apportionment of the waters of the State, and divides itself naturally into four branches.

First—A declaration of the fundamental principles upon which the right to use water shall be based.

Second—The adjudication of rights to the use of water claimed under the previous laws, thus determining the unappropriated public waters.

Third—The regulation, control and determination of the rights to water to be subsequently acquired.

Fourth—The regulation and control of the distribution of the water, rights to the use of which have been established.

PROPOSED CODE FOR OREGON AND WASHINGTON.

In discussing these branches of the subject the important features of procedure in the proposed code for Oregon and Washington will be described.

Under the first heading the fundamental principles are few and well established; namely, that all the waters within the limits of the State belong to the public and are subject to appropriation for beneficial use, except from sources of supply which are navigable; that the beneficial use of water shall be the basis, the measure and the limit of the right; that the use of water is a public use, and private parties may exercise the right of eminent domain for the acquisition thereof; and that water used for irrigation shall be appurtenant to the land on which it is used.

ADJUDICATION OF RIGHTS.

Under the second heading, providing for the adjudication of rights claimed under prior laws, it is now generally conceded that the final adjudication must be by the courts. The codes of the different States contemplate various forms of procedure. In the code proposed for Oregon and Washington, a State Engineer, appointed for six years by the Governor, subject to confirmation by the Senate, is to make a complete hydrographic survey of a stream system, obtaining all the data necessary to determine the amount of water available and the rights of the parties entitled to the use of it. This material is turned over to the Attorney General of the State, who is required to enter suit promptly for the determination of the rights of all parties and to prosecute the same diligently to a conclusion. In all suits for the determination of the right to the use of the waters of any stream system, all who claim the right to use such waters shall be made parties. In all suits involving the determination of water rights, the Attorney General is required to intervene on behalf of the State, if in the opinion of the State Engineer the public interest requires it.

PROCEDURE FOR APPROPRIATION OF WATER.

The third subject, namely, that of the regulation, control and determination of rights to the use of water to be acquired, is placed in the hands of the

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State Engineer. The procedure proposed is substantially the same as that adopted in the other States having a modern irrigation code with some differences of detail.

The principal feature to be noticed is that before any work looking to the construction of an irrigation system is commenced, and after the State Engineer has passed upon the form and substance of the application, the intention to appropriate the water shall be published in a newspaper circulated in the community. After such publication the State Engineer will approve the application if no valid objection is presented.

LICENSE TO APPROPRIATE WATER.

When the construction is completed, the works are to be inspected and approved by the State Engineer, who will then determine their capacity, which will limit the amount of the appropriation. Afterwards, when the water is applied to a beneficial use, the State Engineer makes a further inspection, whereupon he issues a license for the appropriation of the amount of water which has been applied to a beneficial use. A time limit is fixed for completion of construction and for beneficial use.

DISTRIBUTION OF WATER—WATER COMMISSIONERS.

For the distribution of the water, which comes under the fourth branch, the States are divided by the law into four Water Divisions by drainage areas, each under the supervision of a Water Commissioner appointed by the Supreme Court of the State. Their functions being the distribution of water under judicial decree or appropriation, they may be regarded as, in a sense, officers of the Court. The four Water Commissioners with the State Engineer constitute a Board of Water Commissioners, of which the latter is president. The Water Commissioners each serve six years, their terms being so arranged that a new one is appointed every two years. This board has general supervision over the waters of the State.

DISTRIBUTION OF WATER—WATER MASTERS.

The actual work of distributing the waters of those entitled to use them is done by water masters appointed by the Water Commissioners with the approval of the State Engineer. Each water master has charge of a water district set apart by the State Engineer as found necessary from time to time. The operations of the water master are under the supervision of the Water Commissioner, and their acts are subject to appeal to the State Engineer.

The cost of the water distribution is borne by the water users. The general expenses of the State Engineer and the Water Commissioners are paid by the State. The greater part, if not all, of this expense will be returned to the State Treasury by the fees collected by the State Engineer and by the repayment of the cost of hydrographic surveys by the parties to the suits for adjudication.

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RELATIONS TO RECLAMATION SERVICE.

Special reference should also be made to the features of the draft relating to the work under the Federal Reclamation Act.

In order that the State may obtain the full benefit of this work and prevent serious interference with, and perhaps the entire abandonment of the projects to be investigated, it is provided that the water supply for such projects shall be reserved from general appropriation until the investigations of the Reclamation Service shall determine the precise amount required for the project, the remainder being then released from such reservation.

It is also provided that State lands coming under such projects shall be disposed of in harmony with the plans for the disposition of the lands of the United States, and that lands required for the Reclamation project, for irrigation works shall be transferred to the United States without charge.

In all sales of State lands hereafter, the conveyance is to reserve right-of-way for ditches or canals constructed by authority of the United States.

DUTY OF STATE.

The theory of these provisions is that the State regulates the appropriation of the water, exercising this power and holding the land in trust for the public, and when the interests of the public are so directly involved as in these large irrigation projects, and when, further, there is no element of individual speculation or profit in the construction of the works, which are for the purpose of establishing the maximum number of homes on the land, it is the duty of every State to which the Reclamation Act is applicable, to assist with every resource under its control.

MISCELLANEOUS PROVISIONS.

It will be of interest to review several of the other provisions of the draft.

Units of measurement are established; the cubic foot per second for the flow of water and the acre foot for volume. The miner's inch is fixed as one-fiftieth of a cubic foot per second, unless a different ratio has been agreed upon by contract, or established by actual measurement or use.

The amount of water which may be appropriated for irrigation is limited to one cubic foot per second for 70 acres, or its equivalent.

WATER FOREVER APPURTENANT TO LAND.

While it is conceded that water used for irrigation must be appurtenant to the land, the fact must be recognized that conditions may arise to make it impracticable or uneconomical to continue to irrigate a particular tract. Provision is made so that the use of water may be severed from the land, after application to the State Engineer, due publication of notice of such intention and approval by the State Engineer. Similar provision is made for a change in the nature of the use to which the water is applied, or in the place of diversion, storage, or use.

SEEPAGE WATER.

The subject of seepage water is one that has given much trouble, and provision is made for the appropriation thereof in the same manner as other

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waters, with the requirement that the appropriator must pay reasonable charges for storage or carriage to the owners of the irrigation works from which it comes, provided that the seepage can be traced to such works beyond reasonable doubt.

All decisions of the State Engineer or Water Commissioners affecting a substantial right are subject to appeal to the courts.

MODERN CODE FOR OREGON AND WASHINGTON.

The Commissions of the States of Oregon and Washington in working upon this subject, have before them an opportunity to make a definite advance in the development of irrigation law, and the character of the men comprising them justifies the hope that they will prepare a creditable work and assist in making the State laws of the arid region an exposition of the high development which is found to be the invariable accompaniment of the irrigation community.

It will be impossible, of course, to consider every section of the code. Many of those present have seen the code and have examined it. What I wish to do is to call your attention to the main points embodied in this draft and also to a few amendments which have been made and to some important changes that have been suggested by those who have had an opportunity to examine it.

The keynote of the entire draft is contained in the first section, which I will read as amended:

"Section 1. Waters of the State Public Waters.—All the waters within the limits of the State from all sources of water supply belong to the public, and except as to navigable waters, are subject to appropriation for beneficial use."

The next section proclaims the fundamental principle of the irrigation law that the beneficial use of water is the basis, the measure and the limit of the right.

STATE ENGINEER.

It then takes up the establishment of the office of State Engineer, giving his duties and requirements of his office. One point that has been questioned in this connection is the requirement that the State Engineer shall not engage in private practice. The code provides that the State Engineer shall receive a salary of $3000 per annum and shall not engage in private practice.

Question—What is the objection to that?

Mr. Bien—Of course a first-class engineer will make more than that, and the idea of some is that the State may get a better man by allowing him to engage in private practice that would not interfere with his duties. It appears to me, however, that the State will get better service from a man who devotes his entire time to the State's business.

Mr. Fellows, of Colorado—What you have said is probably true. It is difficult to put the salary higher than $3000 and yet it would be hard to secure the best talent for that amount. For that reason it may be well to pay the State Engineer the salary mentioned and allow him to engage in private

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practice, but I do not think he could do that without compromising himself in many ways. Things would come up that he would have to pass upon as a State Engineer and in which he might be interested privately. I do not see how it would be possible to successfully permit the State Engineer to engage in private practice. This is simply a suggestion.

Mr. Finkle, of California—While it would be undesirable to have the State Engineer engage in private practice for fear that he might be tempted to favor private parties, I think that the salary might be raised to about $5000, which would enable the State to secure a man of reasonably good ability to take the office. I should think that would be nearer right than $3000.

Mr. Bien—This code was drawn with a view to the conditions in Oregon and Washington, and while I think that the State will need better talent when it begins an irrigation system than at a later period, yet I think it will be difficult to get most legislatures to make the salary $5000. In States like California, for instance, there would be little trouble on that point, and the legislature would doubtless make the salary $5000, or more.

Senator F. G. Newlands, of Nevada—What salary is paid in Utah?

Mr. Bien—I think it is $3000.

Mr. Finkle—What is the rule in Utah and Idaho?

Mr. Bien—They do not engage in private work.

Mr. Chandler, of Nevada—Speaking from the standpoint of the engineers: In legislating for any other position it is seldom, if ever, provided that the occupant of the office shall not engage in private business, and I hardly see why a man engaged in public business should not be allowed to engage in private business. Of course if he does not perform his public duties properly and satisfactorily, it is the duty of the Governor to remove him. I think it would be casting a reflection upon the office of State Engineer to make any such requirement. We do not put it in when district attorneys are appointed or when men are appointed to other State or municipal offices. I can see considerable advantage in eliminating the requirement. The only State irrigation code having that particular clause is that of Nevada. It is not mentioned in any other code and in no other position perhaps do men do more effective work than is done by the engineers in other States. Mr. Johnson, State Engineer of Wyoming, works not only a good many hours of the day but a good many in the night. Engineers must be honest and capable men in their line of work. If they are that kind of men they will necessarily fulfill the duties of their office. If they are not, the sooner they engage in private work the better for the State.

Mr. Newell—The subject under discussion is one of great interest to all of us, and I would like, for the sake of argument, to take the other side from my friend, Mr. Chandler. I think the moral effect of that clause is good because it will tend to raise and keep the salary of the State Engineer higher. If he is put in office and notice served upon the people that that man is not going to do private work, they will then give him a fair salary. There is too much tendency to say, "Give him $2000 and he will make enough on the outside to pay him." That is just what we want to avoid. My experi-

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ence leads me to the conclusion that a public official, especially in engineering work, should not do private work and that his energies should be required, both by law and custom, to be devoted exclusively to the business of his office. I fully believe that a second-class man who devotes all his time to the subject is a great deal better than a first-class man who gives some of his time to private affairs. By putting it in the form of a law that he has no outside interests I believe it would result in his getting a better salary and in protecting him from the influences that might affect his office.

JUDICIAL FUNCTIONS OF STATE ENGINEERS.

Senator Newlands—The State Engineer is often called upon to discharge almost judicial functions. In many of the States he is a member of the Board of Control. Mr. Chandler in our State has discharged his duties most acceptably to the entire State. He is now inquiring into the Carson River matter, which involves the determination of priority of right and amount of water to which each claimant is entitled. Of course his determination is not final. He simply makes up a list of water rights and gives his views as to the prior rights, but his moral position would be very much affected if it were known that he were employed by any of the private interests in irrigation work, construction work, running lines or ditches, or any work of that kind. It would be regarded as an indirect method of controlling his judgment. In all of these States men who have vested rights and claims, which are often very much in excess of the water which they actually use, are in a state of great apprehension as to the determination of these questions by any board or party. In the State of Nevada it has been almost impossible to amicably adjust or pass upon any question of water rights. The people would prefer to fight the decisions rather than submit the matter to any tribunal except the courts. Now, as long as the people in these States are in a sensitive condition, it seems to me of the highest importance that the law should guarantee them that the State Engineer is absolutely impartial and unbiased and free from interests of every kind. As to salary, I think that is a matter to be determined by the financial condition of the various States. In some States all salaries are exceedingly low. The compensation, I imagine, should be adjusted according to the prevailing standards and according to the area of the State. It is very important that the State Engineer should not engage in private practice.

HYDROGRAPHIC SURVEYS.

Mr. Bien—The first definite step to be taken under the law is the adjudication of existing water rights. It is provided that the State Engineer shall make a hydrographic survey of the stream systems and obtain the data necessary to establish the rights of parties interested. This information when obtained is to be furnished to the Attorney General of the State, who is required within sixty days to enter suit for the adjudication of these rights, bringing in all persons who are interested in the same source of water supply.

It is also provided that in all suits between parties all those interested in the water supply in controversy shall be brought into the suit, and further, that in any case in which, in the opinion of the State Engineer the interests of the

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State are affected, the Attorney General is required to represent the State in the litigation. The costs of these suits are divided between the private parties interested in proportion to the water rights adjudicated, and similarly, the court is authorized to order a hydrographic survey of the stream system when considering rights on that stream and this cost is assessed against the parties.

It may be that in some States it would be better to have the State bear the entire cost of these adjudications. There are a great many reasons why the State should, but I think the controlling principle will be the State Treasury.

WATER RIGHTS—METHOD OF OBTAINING.

The next step in the matter of water rights is in making application for the water. This code follows largely the precedents established in Wyoming, Utah and Nevada and requires application to be made to the State Engineer in such form as he may provide.

When the application has been made in proper form notice is published in the district where the water is to be used, stating the nature and amount of the proposed water right, thus allowing all parties whose rights may be affected, to present to the State Engineer at a certain time any objections they may have to the approval of this right. It is the duty of the State Engineer to decide whether there is unappropriated water available for this right. If there is, he approves the application, and it then becomes a permit to appropriate water and after that the applicant may begin his construction.

The law requires that the work shall be completed within 5 years from the date of the permit, and at or before that time the State Engineer is required to inspect the works and determine their capacity. This capacity will limit the amount of water which can be appropriated under this permit. Within three years after that time it is required that the water shall be applied to a beneficial use, and then another inspection is made in order to determine the amount of land that has been furnished with water and upon that inspection the State Engineer issues a license to appropriate water to that extent.

The right is then fixed, and if there are no other applicants—as there probably would not be, because all parties interested having had an opportunity to object—the right to appropriate this water will probably be unmolested throughout the life of the application, which, of course, is as long as the water is used for beneficial purposes.

The code provides that any decision of the State Engineer which affects substantial rights shall be appealable to the courts.

STATE WATER DIVISIONS.

There is a provision also for the division of the State into water divisions, and after considerable discussion it was thought that four water divisions wherever it was possible would be the best, because the four Water Commissioners selected in these divisions, together with the State Engineer form the Board of Water Commissioners, which is equivalent to the Board of Control in other States. The Water Commissioners appoint Water Masters to have charge of the distribution of water in each water district. The water

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districts are determined by the State Engineer. The Water Masters are appointed by the Water Commissioners, subject to the approval of the State Engineer. The idea is that the State Engineer should have control as far as possible of the entire machinery relating to the appropriation and diversion of waters. The Water Masters are the officers with whom the appropriator comes in contact, and in case of a disagreement the appropriator may appeal to the Water Commissioners and from them to the State Engineer, whereupon the State Engineer is required to fix a time when he will hear and determine the questions involved.

SALARIES—HOW PAID.

The State Engineer and Water Commissioners are paid by the State. It is believed that the fees of the office of the State Engineer and the repayment by parties to suits of the cost of hydrographic surveys will return to the State a large proportion, if not all, of the appropriation. The work of the Water Masters is paid for by the appropriators. The Water Master renders his account, approved by the Water Commissioner, and in that account is required to state the amounts chargeable to each ditch or appropriator. The county pays this account and assesses and collects it in the same way as it collects taxes.

MISCELLANEOUS PROVISIONS.

That is, in general, the system outlined in this code. The remainder relates to a number of important miscellaneous provisions. The first is the establishment of units of measure, the cubic foot per second for the flow of water and the acre-foot for the volume of water. It provides also for a ratio between the miner's inch and the cubic foot per second. It is, of course, understood by engineers that the miner's inch, as measured by the crude methods generally in use, may vary almost indefinitely. I think that the ordinary methods of measurement practiced in various parts of the country will cause the miner's inch to vary 1/30 to 1/60 of a cubic foot per second. Where it is not otherwise provided the miner's inch shall be considered as 1/50 of an inch per cubic foot. In California there has been legislation making it 1/50, and that is an advantage because it is easier to compute. The range is so great that we are just as likely to be at an average at 1/50 as at 1/40.

Mr. Finkle—We are very much confused about the matter in California. We did have it 1/50 before March 23, 1901, when the legislature passed another act providing for a standard miner's inch of 1/40.

Mr. Bien—When an appropriator of water fails to use the water beneficial there must be some means of determining when his rights shall cease and after which abandonment will be presumed.

It is also provided that in making adjudications or in issuing permits to appropriate water the amount allowed shall not be in excess of one cubic foot per second for 70 acres or the equivalent. That is the rate that has been most generally adopted in the States.

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WATER APPURTENANT TO LAND.

The water being appurtenant to land for irrigation purposes, we often find conditions when it is not possible to use the water on the land beneficially for various reasons. Under these conditions it would be a waste of valuable property to require this water to be continually applied to this land or be abandoned. By application to the State Engineer, the publication of notice, and the subsequent approval of the State Engineer the water may be transferred to other land. It is desirable that the transfer shall be made only after the fullest investigation, and it is believed that the procedure outlined will give an opportunity for investigation and examination that will prevent any injustice. A similar procedure is provided for a change in the place of use or method or nature of use of any water which has been appropriated.

APPROPRIATING SEEPAGE WATER.

The question of seepage water has given a great deal of trouble. The code provides that the seepage water shall be subject to appropriation in the same way as other water, through an application to the State Engineer, but that the party desiring to appropriate this water must pay a reasonable charge to the person owning the irrigation works to which the water can be traced without a reasonabe doubt. The permit to appropriate this water is not given until the State Engineer is satisfied that the proper arrangements have been made.

CO-OPERATION WITH RECLAMATION SERVICE.

The next point is the relation between the State and the Reclamation Service in the operations required by the Federal Statutes. It is, of course, understood that for a great many reasons the work of the government must necessarily be slower than that of private parties, and also that the government is ready to spend whatever sums may be required for the most advantageous development of the water supply it should have ample opportunity to investigate the water supply and surrounding conditions without interference by speculators who are continually taking advantage of this proposed work. For that reason it is impossible for the government to say just how much water is necessary for any particular enterprise it would undertake. The State itself being vitally interested, and whatever control it has over these waters is for the benefit of the public, so it was deemed proper that the State should reserve the water necessary for the Reclamation Service for general appropriation until the amount needed could be definitely determined, after which the surplus would be open for general appropriation.

The State is able in other ways to assist in the operation of the Reclamation Service. First, by providing that all public lands belonging to the State shall be sold with the reservation of a right-of-way for canals, etc. constructed by the United States. The United States has done that with its own lands sold since 1888. It has also provided that a right-of-way over any lands of the State shall be granted to the United States in connection with its reclamation operations.

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SALE OF STATE LANDS UNDER RECLAMATION PROJECTS.

Any lands belonging to the State which are within the limits of withdrawals for reclamation projects shall be sold in harmony with the system pursued by the Federal Government, the idea is that individuals should not be permitted to buy this land in enormous quantities. The Federal Reclamation Act prohibits the sale of water rights for more than 160 acres to any one person. If parties are allowed to take State land in unlimited quantities the government will have considerable difficulty in adjusting their claims to the Federal law when work is undertaken.

That is a review of the important points of this draft, and if there are any questions to be asked regarding it, or any points for discussion, I would like to hear them.

DISCUSSION.

Mr. William E. Smythe, of California—How does that law differ from the Wyoming law?

Mr. Bien—The main difference is that the Wyoming law constitutes the Board of Control a judicial tribunal. This code leaves it to the courts; the State Engineer collects the data and the Attorney General brings the suit.

Delegate—Is the State Engineer appointed by the Governor?

Mr. Bien—Yes, sir; and the Board of Control is formed by electing one member from each of the four districts.

Delegate—Does this code recognize the private ownership of the water apart from the land?

Mr. Bien—No, sir.

Delegate—Does it make any provision for regulating the rights of companies supplying water?

Mr. Bien—It provides that no appropriator can have a right for more water than he can use. Any surplus water shall be held in trust by the water company for those who may have an opportunity to use it.

Delegate—In Mexico all interstate streams are absolutely controlled by the Federal Government; the State governments have nothing to say. I think this is one of the greatest sources of difficulty in the United States. It is one of the difficulties we have to contend with in Texas.

Mr. Bien—That question is not touched upon in this code. Under our Constitution it is a question for the courts to decide. I think any action which the States may take will not affect the matter. It may complicate it, but it cannot affect the ultimate conclusion. The question is now before the Supreme Court of the United States in an action between Kansas and Colorado. What the relation of the States may be to interstate streams is a judicial matter as conditions now exist. It is hoped that the Supreme Court in passing upon that case will make a definite settlement of the matter.

Mr. Finkle—There are two points which I would like to mention. The first is as to the time of the completion of the works and also the time of beginning work. We had some difficulties in California on the latter point by reason of the forest reserves. The government would not permit an appropriator to go into the forest reserve and go to work until permission was ob-

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tained from the Secretary of the Interior. As the law of California formerly stood there was no provision touching the matter, so we had an act passed through the legislature two years ago which corrected the difficulty and which provides that surveys for the proposed work must begin, if within a forest reserve, within sixty days after permit is granted and that actual work of construction must begin within sixty days after permission is obtained from the Secretary of the Interior. That brings me up to the other point. You provide five years as the time for building the works complete?

Mr. Bien—The State Engineer is authorized to make an extension of three years for physical causes.

Mr. Finkle—I was going to suggest that it would appear unreasonable to allow small works that much time, and that it would perhaps be proper to make the limit in proportion to the cost of the works, say one year for every $100,000 invested.

It has also occurred to me that the matter of appropriation should be definitely stated. As I understand the law there is no right to appropriate except on public lands of the United States. I judge it must be the law everywhere, because the whole theory of appropriation is based on the act of Congress passed in July, 1866.

VARYING DUTY OF WATER.

Delegate—In making a limit in the allowances of water, do the reclamation engineers take into consideration the immense difference in the requirements of different parts of the country? For instance, in California it will not take very much. At the experimental station in Arizona several years ago the bulletin reported 6 feet practically for crops of alfalfa. Our experience here is almost parallel and we know it positively because we have to pump the water. Different crops require different amounts of water. Corn, for instance, requires about two feet. In making an estimate of how a dam, for instance, can cover 180,000 acres of land, how much is allowed for each acre per annum? Our evaporation here is 80 inches and our rainfall 8, practically nothing.

Mr. Bien—The allowance of water in each project is carefully estimated according to the local conditions, according to the best data that can be obtained and according to the peculiar conditions of each case.

Mr. Newell—As Mr. Bien has stated, in every project we study the local conditions in that particular area. Mr. Means, the soil expert, studies the method of use and the proper means of developing it, the kind of products for which it is best suited, etc. One man may plant one kind of a crop and one another and we cannot anticipate what that will be, but we make an allowance to cover all the probable conditions and include it in our estimate, whether it is one, two or six feet. Of course when a country is developed and when we have 50,000 or 100,000 acres under irrigation, we all know that conditions will change greatly and that less water will be required. In our preliminary estimates, we will presume, for instance, that a dam will hold two million acre feet of water and that that will probably supply 180,000 acres of land, but a lot of that land one year will not require as much as the other

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part and in determining the average we must take the experience of engineers of past generations.

Mr. Savage—I think we all realize the importance of the discussion. Mr. McCune of Colorado is here and we would like to hear from him.

FORMER STATE ENGINEER DISCUSSES QUESTION.

Mr. McCune, of Colorado—I think Mr. Newell has covered the point with regard to the state engineers, still I am satisfied that it would be difficult to get that salary arranged, at the same time it might be difficult to get the best talent for the salary suggested, so the man taking the office must have some public spirit, be something of a martyr, so to speak, for I do not see how he can engage in private practice and do the office justice. In regard to the use of water, we have many problems coming up and it is difficult to decide all of them. They have to be worked out as we go along. The duty of water and the question of abandonment are problems that are giving us a great deal of trouble. As to the question of abandonment, I think the time might be fixed at five years. In the matter of the completion of the works, in one case it might require five years, in another three, and in other cases it might be necessary to give more time. It is a difficult matter to fix and I don't see how it can be worked out except as we go along.

Mr. Savage—We have present some of the members of the various commissions in Oregon and Washington, and I would like to hear from some of them.

VITAL POINTS IN CODE.

Mr. Hailey, of Oregon—It seems to me that the vital point in this bill is some law by which we can determine the rights of the appropriator and the limit of the appropriations; some law, for instance, whereby all appropriations are recorded in one place and so that over-appropriations can not be made. I was reading an address this morning delivered by a lawyer in California, and he cited statistics showing how in three or four of their drainage basins they had appropriated under the present California law enough water by their written appropriations to irrigate all of the irrigable lands west of the Mississippi River and north of Texas. I do not know how that would apply in Louisiana. We might extend California all over the western country by soaking it so that it would swell up as rice does in Louisiana. It is just that kind of expansion we want to stop. We want a man to have what he is entitled to. We want to adopt some feature which will have a tendency to do away with litigation. You gentlemen, who live in States where they have the most laws governing water rights, know that this is where they have the most litigation and instead of the water users being rich it is the water lawyers who are getting rich. If a man is going to spend all his substance in trying to build up a home in lawsuits, he will not have any home to live in when he gets through. I approve of the provision which makes the state engineer a disinterested party. He should be nothing but a state officer and have no other private interests. If a man can work for Uncle Sam and exclude his private interests he can do just as much for Texas, Oregon, California or any of the States as another. If he is working that way with no private interests he will be disinterested just like our Su-

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preme Court judges and he will try to arrive at the truth in all things and in so doing avoid a great deal of litigation and he will perform his duty not only as an experienced man, but also he will do it with a technical education.

ABSURD COURT DECREES.

The article I referred to cited an instance where a court on the testimony of the farmers in the community gave to one man twenty feet of water when his ditch would not carry over eight. If they had had the advice of an expert engineer the court would not have done that. I think if we had these two fundamental principles in our laws, one defining the right to take water and the other cared for through the State Engineer, we would have the essential requisites of a good law. No law as drafted in the first instance will cover the whole ground. If it would, there would be no occasion whatever for a meeting of this Irrigation Congress. If the National Irrigation Act, which is one of the most complete laws ever drawn, were self-acting, you would never call this Congress together, but we are pushing that same thing all the time and that is what we will have to do to improve on this law. Washington expects to do the same thing. The code was drafted at our request simply because both States are situated almost identically as to water rights. The eastern portion of our State has some arid land and the western portion has plenty of water, sometimes a little too much, and we asked Mr. Bien and Mr. Newell to draft with their experience what they deemed to be the main feature of a law, and so far as I have heard from Washington and our own people, they are highly pleased with this code.

Mr. Savage—We have with us one of the irrigators up in that country who likely will have to work under that law, and we would like to hear from him—Mr. Mallett, of Vale.

Mr. C. W. Mallett, of Oregon—The gentlemen from Wyoming, from Louisiana and others, together with Mr. Hailey, have nearly destroyed my case. I have got to invent something new or keep still.

As to paying the State Engineer, I heartily agree with the majority opinion in regard to that matter. It frequently occurs that I call to my aid my neighbor, or my neighbor calls me to his aid in performing work, and I am sure that if I were in his employ he would certainly raise my wages after a time if I would give my whole time and attention to his benefit. I know if I call on my neighbor for assistance, I would rather raise his wages if he would give me his whole time and benefit of his knowledge. I feel the same way about the State Engineer. We want his whole time and impartial services.

As to the amount of water necessary to irrigate a given tract of land, or in other words, as to the duty of water, it is a question of utmost importance from the standpoint of an irrigator to determine how much water is necessary to set aside. It may be 2 acre feet, 3, 4, 5 or 6. The aridity of the climate, the soil and kind of crops produced all have a modifying influence on the amount of water absolutely necessary. In eastern Oregon the best that can be done is to flood the field to a depth of six inches at each irrigation. In the beginning of the reclamation work it would require three

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or four irrigations during a season, and ordinarily there would be necessary nearly an acre-foot at each irrigation.

Mr. Hammond, of New Mexico—I notice that it has been stated that the basis of estimating the service of water is one second foot for 70 acres of land. I take it that that is the amount that is needed under the most adverse conditions. Is it to be understood that it is not conceived that there is any land or conditions which would under any circumstances require more than one second foot per 70 acres of land? I do not know what the maximum would be in New Mexico, for in that territory the service of water varies greatly.

Mr. Bien—One second foot for every 70 acres of land is, according to all general practice, ample for practically all conditions. It is suggested as the maximum. In a great many cases the amount allowed would be less.

READJUDICATION NECESSARY.

Mr. Switzer, of Montana—In the State of Montana all adjudications up to this time have allowed one second foot of water to 40 acres of land, which is very wasteful. Is there any provision made in this code whereby old water rights may be adjudicated in the light of more modern knowledge?

Mr. Bien—I think the courts would have to attend to that. I think that it is possible when the courts have had considerable experience in irrigation litigation they may review these old decisions and decide that such an amount of water is a waste, and that a party could not acquire title to water that is wasted. The principles which are developed by experience would open an opportunity possibly in the future for the courts to review such decisions, but the law can not change the decisions where a right is involved.

Delegate from Fresno County, California—In Fresno County, California, we go on the basis of one foot of water for 160 acres. I do not think there is one in a hundred that gets that much. I am satisfied that in our State we have done too much irrigating and have used too much water. In my orchard I have irrigated only once each year during the last four years and I find the results very satisfactory. I made up my mind to irrigate in that way and my neighbors said, "Your trees will die." I said, "Then let them die."

WASTEFUL METHODS OF IRRIGATION.

Delegate—Is there any provision made by which those who use too much water can be prevented from using more than they actually need? If there is not, there should be such a provision. In Tulare County, in the San Joaquin Valley, California, we have men who use water to the injury of their land. They have water-logged their land until they can not raise crops and they still use water. They use so much water for fear if they do not each year they will lose the right to use the amount of water they claim for appropriation, and by that method they have prevented others from having water who actually need it.

We have streams in California—the Tule River is one of them—where the sand is from four to twelve feet deep and the under-flow in the summer time becomes enormous. We can dig down in the sand and find water two feet below the surface of the sand and that flow of water will perhaps be twelve

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feet deep, but no one can get the use of that water because we have no submerged dams and these parties who claim the prior rights will take out all of the water they can get, when others further down the stream are suffering for water.

As to the amount of water that we require, on an average one acre foot is sufficient, although there are many fields that do not require any water at all. I have a small vineyard that has not been irrigated in six years and produces better than others that are irrigated every year. In sections of the country near the rivers, where the early appropriators have used so much water they have drawn the alkali to the surface and now can not produce anything but salt grass, and very little of that, whereas twenty years ago they produced pretty good crops. There should be some provision in the law regulating these conditions, and there is no State in the arid region which needs this law more than California. In my seventeen years' residence there I have seen the need of such a law. I have seen the owners of riparian rights claiming the water when they could not use it, to the detriment of those who could use it to great advantage. I have seen others who wanted to use the water at times of the year when they did not really need it. A great many of them have not tried to educate themselves along the line of beneficial use. The matter of the use of water is one along the line of which the people have to be educated. There are many sections near Fresno where they have not used any water for several years, and they would be glad if the ditches were taken out, because they are an injury to the land and the crops they grow there and they will have to begin to drain very soon. Some of them have already commenced to drain. It seems to me that the regulations regarding the water being used beneficially should be very strict.

Mr. Bien—The fundamental principle of the entire law is beneficial use, and this is a matter of education, and the courts must prevent waste. There is also a provision that in the distribution of the waters by the water master they shall be so distributed as to prevent waste.

In regard to the duty of water, the idea was to provide for a maximum amount. The local conditions and a great many other things will change this amount, and it is really one of the most important duties of the State Engineer to gradually raise the duty of water by means of his adjudication and passing on these appropriations, and when he has established the proper sentiment, there is no doubt but what the courts will follow and ultimately waste will be cut out in that way.

PAID SENTRYMEN GUARD WATER.

Mr. W. E. Smythe, of California—There is no section in the West so greatly in need of an intelligent and enlightened irrigation law as the State of California. It is true that we have had more water in the court houses than we could put on the land. We have had almost a civil war in trying to divide private waters. On the Tule River I have seen erected on the headgate of the canal a sentry box like State penitentiaries have, and I have seen in the balance sheet of that company for its annual expenses an item of $1500 for guards, guns and ammunition. That is the kind of barbarism we have had in place of the civilization we talk about in California, and yet in

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spite of these conditions it has been impossible to bring about any reform. The only remedy is more water. The people can not see any remedy in more law unless you accompany the proposed legal reforms with means of supplying more water for the irrigation of their lands.

It seems to me that Mr. Bien has produced a composite photograph of the water laws and has utilized the strong features, avoiding the weak, and I think that something like that can be adopted in most of the States, but in California it will not be adopted unless accompanied by means of providing more water. Of course the ideal system of irrigation would be a national system under the present law, if a sufficient amount of money were available for the purpose, but it seems to me that the amount of money now available is sufficient only for an experimental policy. We have not anything like money enough to meet the needs of the arid region. We have $27,000,000 now in the reclamation fund.

POTENTIAL GREATNESS OF COLORADO RIVER.

We could use every dollar now in the reclamation fund upon one single river of California, or, rather, it belongs to five States, one territory and a foreign country, that is the Rio Colorado. According to the estimates of Mr. A. P. Davis by the application of that money we would make homes for a new population of 1,500,000 in Southern California and Arizona, but that $27,000,000 must be divided between sixteen States and Territories. The present fund represents the accumulation of more than seven years of the receipts of the land office, which amount now to about $500,000 a year. Under the present wise law the expenditure may be concentrated for a time in one locality, but every ten years it must be equalized between the States and Territories coming under the Reclamation Act. $500,000 a year for this western country is a mere bagatelle. I would like to suggest a method of supplementing that fund. You have heard of the district irrigation law, commonly known as the "Wright" law, although most of our people have become impressed with the idea that it is the "wrong" law. The law seems right to me, as it joins inalienably the right of land and water. It undertook to furnish us water at a little cost, but the difficulty was that it fell down on its administrative side. It put into the hands of communities of farmers matters which they did not understand how to handle, and of the forty-seven districts formed I think perhaps only four or five may be said to be successful. The rest had failed for various reasons, but the cause of their failure can be summed up in the phrase, "Lack of supervision." The trouble is not with the fundamental character of the law; the trouble is in carrying it out. They traded their bonds, which represented mortgages on their homes, for water rights which existed only in the imagination of promoters. They were wrecked by their district and other officers mostly. Large sums were expended in works that never were completed and are now going to decay. My suggestion is, let us amend the district irrigation law in California and let other Western States adopt such a law, but let it be provided before a district can be formed that the Secretary of the Interior, acting through the United States Reclamation Service, shall investigate and approve that project as plausible in its engineering, economic and financial features.

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NATIONAL SUPERVISION OF LOCAL DISTRICTS.

If we had had such a provision for national supervision, not a single district in California would have been a failure. The government would have investigated these projects and proved most of them as being unplausible, and the people then would not have voted the bonds and the banks would not have bought them. On the other hand, if the Reclamation Service had recommended it, the people would have gladly voted these bonds. I would like to have it provided that not only shall the Reclamation Service investigate and report on the districts, but that the engineers of the service shall also be charged with the actual work of construction. If you build these canals, our farmers can operate them successfully, but they are not fitted to pass upon the feasibility of these projects. In other words, I propose a method by which California can supplement the reclamation fund available for expenditure by from fifty to one hundred million dollars. We can safely say that for every dollar we get out of the national treasury we will put four dollars into the irrigation work. The money can be paid by the lands that are to be irrigated. We will have to pay 4 or 5 per cent interest on our district bonds, but I believe it is the feasible method. The National Irrigation Act is extremely elastic and under it the Secretary of the Interior can do almost anything, and he would be able doubtless to make the investigations at the expense of the reclamation fund, but the large element of cost would be represented by the proceeds of district bond sales placed at the disposal of the Reclamation Service and expended under their direction.

Now, if you will go before the people of California and say two things, first—we propose more law, and second—more water, then I believe we will get the law, but as long as it presents itself in the aspect of a destructive measure, a measure to bring everybody into court and prompt litigation, I believe there is no probability of its being adopted in our State.

As to this matter of the duty of water, the duty of water varies with the conditions, climate, soil and crops, also the customs and even the traditions of the country affect the amount of water that is applied to the land.

WATER AND LAND INSEPARABLE.

I believe that in a few years we will have no such thing as a private work of irrigation, that is, a work of irrigation owned apart from the land. We are going to establish the principle that the man who owns the water shall also own the land and the air. Unless we adopt that principle we can not have true, economic freedom in this country, and I am sure that this irrigation movement is not going to stop short of that point. I believe that we are going to see, as is already the case in the Salt River Valley, a natural merger of all the irrigation works in a watershed, into one comprehensive system. The nation will be able to let us have the money necessary for the works at the head of the streams and we must devise for ourselves a method of providing the moneys necessary for building the works of distribution and the great pumping works and drainage systems—for drainage is the handmaid of irrigation, and nothing is more certain that if you put the water on the land you must get the water off. We are going forward in the evolution of

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our irrigation systems until we have one splendid, magnificent, comprehensive system of works. When we reach that point it will be possible for every watershed to settle for itself the question of the duty of water. If they want one cubic foot per acre per second, they can settle it on that basis, and if they want six times as much on the Rio Grande, they can also arrange it satisfactorily. It is free water and the water should be used in its natural watershed. We want to bring the thing down to a matter of home rule. We want the aid of the nation in constructing these works, but when constructed we want them to be administered by the little democracy living in these little watersheds. People use various quantities of water, not only because their crops differ, but also because the soil differs. You can often throw a stone from one kind of soil to another, and then, people differ as to the amount of water that is required. When you have it merged into one single system, you can provide a certain minimum amount of water for which a party will be charged. Everybody should pay for the insurance they get from an irrigation canal, and in addition let them use what they think they need and let them pay for it. On that basis you can adjust it with actual equality. I want to say that if there ever was a body of men fit to lay the foundation of a great civilization, we have them in the Reclamation Service as organized to-day. Let the States help this work hand in hand, and be sure that when you ask for more law that you give them more water at the same time.

GOVERNMENT AID TO DISTRICTS.

Mr. Newell—Mr. Smythe has a touch of genius in his suggestions. It gives us some relief as to how we are going to construct many of these works, especially where private land is involved. On the spur of the moment it strikes me that the suggestion is worth all the trouble that Mr. Smythe has taken to come here. If under a State law districts can be formed, we have enough money in the fund, and probably always will have, to make the necessary investigations and bring the projects to a point where actual contracts can be let. That is feasible, for we are able to call upon the district, the men interested under the State law, to vote the bonds necessary to pay for the contract. These bonds would simply bear interest from the time the money was needed to pay for the construction. It would then enable this work to progress on what seems to me admirable lines, because the men who must pay for the works ultimately could on security of their own property advance the money as needed at a low rate of interest, as it is to be assumed that while the credit of the United States might not be behind these bonds, yet I believe it would bo so considered in financial circles and it would give these bonds a standing in the market which an irrigation bond has not now.

Mr. Emmett Barbour, of California—In our county we have formed a district, and on the basis of about $7 per acre have secured all the water we need. The bonds are paid up and it costs us $1 per acre for the first irrigation and about 50 cents per acre for the second irrigation. I think we are now in as good standing as any district in the State.

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Mr. W. A. Ward, of Texas—In the irrigation company I am interested in, we wanted more money to extend our plant and we issued bonds, and although we made over 50 per cent profit last year, there is no profit for the bonds.

Mr. Fairweather, of California—We have 138,000 acres of land. Our bonded indebtedness is $492,000. The water tax in our district does not exceed 45 cents per acre per annum. Two-thirds of our water tax to-day is paying interest at 5 per cent on those bonds. When these bonds are paid off by the next generation and the district is clear of debt, the water tax on our district land will not exceed 15 cents per acre.

Mr. Newell—Gentlemen, I notice that Governor Ahumada, of Jalisco, and staff, escorted by the Executive Committee, has just entered the room, and we will take a recess for five minutes to extend him our greetings. (The Governor addressed the convention in Spanish, wnich translated, is as follows:)

GOVERNOR AHUMADA'S ADDRESS.

Governor Ahumada, of Jalisco, Mexico—I desire to thank you for the invitation which you have extended me to be present amongst you, and to say to you that I regret very much my inability to address you in English. I am pleased to see such a large assemblage of delegates, and I trust that your efforts for the reclamation of the arid lands as well as the storage of our flood waters will meet with success. I am here as Governor of Jalisco to assure you that you will have the co-operation of my State and the entire Republic of Mexico, as I realize your efforts are conducive to the benefit of the joint countries. I desire to especially thank the Executive Committee for sending me the invitation to attend the Congress.

It has been twenty-five years since I first lived among you. For the past twenty-five years I have had the pleasure of living among Americans and Mexicans on the frontier, during which time I have observed the good feeling which has existed between the two people, and the relations between them have been cemented more and more closely each year. It is gratifying to appear before you as a friend of the American people.

Although my duties have called me away from the office of Governor of Chihuahua to assume the governorship of the State of Jalisco, I note with pleasure that the feeling of friendship which exists on the frontier has extended also to the State of Jalisco. The people here are not only interested in your deliberations, but the people down there are also interested in what you are doing, and I can say to you unconditionally, that we will co-operate with you in any of your undertakings that we are able to assist you in.

In conclusion, I desire to say that I trust that your deliberations may prove beneficial alike to both countries, especially in your deliberations regarding the reclamation and irrigation of the arid lands. I trust that you may be able to get at the matter as easily as possible, and that will be by taking the easiest way.

Mr. Newell—We will now be favored with a description of the Klamath Project in Oregon and California, by Mr. J. B. Lippincott.

Mr. Lippincott introduced an elaborate map of the Klamath Project and explained it in detail, accompanying his address.

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THE KLAMATH PROJECT—STATUS OF INVESTIGATION, 1904.

J. B. LIPPINCOTT, Supervising Engineer U. S. Reclamation Service, Los Angeles, California.

The basin of the Klamath River was visited by Mr. John T. Whistler, Engineer U. S. Geological Survey, in October, 1903, and reported upon under date of November 2, 1903. Mr. H. E. Green, Engineer U. S. Geological Survey, also visited this basin in October, 1903, and reported thereon in a communication entitled, "Report of Reconnaissance of the Country Lying on Either Side of the Boundary Line Between California and Oregon in the Klamath and Ashland Atlas Sheets of Oregon, and the Shasta and Modoc Lava Beds Atlas Sheets of California." These reports were preliminary and were considered sufficient justification for a further investigation of this section during the present summer.

In the latter part of June, 1904, Mr. J. B. Lippincott, Supervising Engineer, made an extended trip through a portion of the basin of Klamath River and Lost River Basin with Mr. T. H. Humphreys, Assistant Engineer. No extensive surveys had been made at that time, Mr. Humphreys having spent his time in acquainting himself with the general situation. The basin of Sprague River, which lies largely in the Klamath Indian Reservation, has not yet been explored, but it is stated currently that there are large areas of excellent land in this reservation that may be reclaimed. This report is therefore based very largely upon general information received from Mr. T. H. Humphreys and upon a personal reconnaissance of J. B. Lippincott, Supervising Engineer, aided by the topographic maps of the Geological Survey. The data based upon the surveys now being made is not now available.

Permanent gaging stations are being established by Mr. Humphreys at Keno, on the Klamath River, at the Horse Fly reservoir site on Miller Creek, at the Clear Lake reservoir site on Lost River, a gage rod and evaporating pan in Tule Lake, near Merrill, and a gage rod in Klamath Lake, near Klamath Falls. The record will be maintained of the flow of Link or Klamath River at Klamath Falls, Mr. Whistler's gaging station on Lost River, in Langell's Valley, will be abandoned, also the gaging station in Lost River at Olene.

GENERAL LOCATION.

The principal streams of the Klamath basin are Williamson River, Sprague River and Lost River. The drainage is quite singular. Lost River at present does not flow into Klamath River, but into Tule Lake, which has no outlet. The general situation is in Klamath County, Oregon, and in Modoc and Siskiyou Counties, California. The State line to a singular extent divides this basin between the two commonwealths. For instance, the Clear Lake reservoir site lies in California, but the water impounded therein can best be used in Oregon. The Horse Fly reservoir site is situated in Oregon, and this water can best be used in Orégon. A diversion conduit from the Upper Klamath Lake will serve lands both in Oregon and California. The

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falls of the Klamath River are in both California and Oregon, and this power can best be used for the pumping of water onto lands in California. Klamath River is navigable in a portion of its course and is so used commercially. Upper and Lower Klamath Lakes are commercially navigable and are cut in half by the State line. Tule Lake is navigable but only to a slight extent so used, and is cut by the State line. We therefore have an interstate situation, both as to water supply, power and irrigable lands.

This immediate region has no railroad, the nearest station being Pokegama, from which a stage drive of some 30 or 40 miles is made to Keno and from that point the Klamath River is navigated by means of a gasoline boat to Klamath Falls, which is the county seat of Klamath County. Two railroads are now being projected into this region, one from Pokegama and the other coming in from California and known as the Weed road. Both these railroads are built primarily for lumbering purposes.

THE KLAMATH RIVER.

Sprague River and Williamson River are the two principal tributaries of the Klamath. Williamson River is fed by some very large springs, the water supply apparently coming in large part from the country around Crater Lake. Sprague River drains the region northeasterly from Klamath Lake.

These streams flow into Klamath Lake, which covers 67,220 acres. If the marginal swamp lands are included it becomes 94,000 acres. The river is therefore regulated by this large area of lake and swamp. From the Upper Klammath Lake the stream falls abruptly about 56 feet and is called Link River. At Keno the lower rapids of the Klamath River begin. This Link River also supplies the Lower Klamath Lake, which covers 29,400 acres with water and 88,300 acres of water and marginal swamp. The lower lake acts as an additional regulator and the fluctuation in river height at Keno probably does not vary over two or three feet.

On October 25, 1903, Klamath River was measured at Klamathon by Mr. H. E. Green at its low water stage, and the volume discharged was 2000 second feet. It was stated at the time that the river was lower than at any previous time for twelve years. The low water flow of Link River in 1904 was 1773 second feet. The Upper Klamath Lake may be used as a storage reservoir if desirable. An examination of the map which accompanies this report will indicate at a glance the extent to which this stream is interstate.

The elevation of Klamath River near the Southern Pacific crossing at Klamathon, according to the topographic sheets of the Geological Survey, is less than 2200 feet. The elevation of the River at Keno is 4086 feet, as determined by levels run from Klamathon, which indicated a fall of about 1900 feet in a distance of 40 miles. Near the mouth of Falls Creek there is a drop in the river of 400 feet in two miles, as indicated by the topographic map on the Shasta quadrangle. With a low water flow of 2000 second feet, this 400-foot drop would develop 91,000 theoretical horse-power. Beginning at a point about six miles below Keno in a distance of 10 miles the map indicates a drop in the river of 800 feet. This would be sufficient to produce 181,000 theoretical horsepower with a flow of 2000 second feet. From

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this it will be seen that the opportunities for power development on the river are very great, and it will be shown later that there is the possibility of using this power for irrigating arid lands.

It appears to be feasible to make an excavation near Keno in the channel of the river at the head of the rapids, where the river drops 60 feet in a short distance, by means of which the water can be drawn off of the marshes surrounding Lower Klamath Lake, as well as from the Lower Klamath Lake itself. This difference in elevation probably could be made sufficient so that the flood waters of Lost River which are not impounded in the reservoir sites on Lost River could be turned into the Klamath River and away from Tule or Rhett Lake. The advantage of such a proceeding will be treated of later.

LOST RIVER.

Lost River is an interstate stream, which flows to a material extent through Clear Lake. Horse Fly reservoir site, on Miller Creek, tributary to Lost River, has a drainage area above it roughly estimated at 200 square miles. Its elevation is 4792 feet. The basin is fairly well timbered and apparently has a fail rainfall and winter stream flow. The reservoir basin is very flat and swampy and it is estimated that the area of the valley is about 3500 acres, and that a dam of 50 feet high would give a capacity of 100,000 acre feet. The river flows through a narrow canyon of basaltic rock at the dam site. The land under this reservoir site is largely public and has been withdrawn for a reservoir. The site is of very substantial importance.

Clear Lake reservoir site is situated on the southern branch of Lost River, and above Clear Lake the stream above the lake is known as Willow Creek. The drainage area of Willow Creek, as obtained from the topographic sheets, above Clear Lake dam site, is 577 square miles. The area of this lake as shown on the topographic sheet is 12½ square miles, or 8000 acres. It is estimated that a dam that is 40 feet high at dam site below the lake would probably hold half a million acre feet and this estimate is here endorsed. The dam site is in a canyon of volcanic rock. Apparently there are excellent spill-way opportunities and probably the dam could be best constructed of earth and loose rock. There is a very pronounced public opinion to the effect that the principal supply for Lost River comes down Willow Creek. The grades into Clear Lake are very singular. Willow Creek in flood discharge overflows into Clear Lake, but at the same time a large portion of this water passes down Lost River. When the creek falls Clear Lake begins draining into Lost River and discharges through its in-take channel. The area of Clear Lake, according to land office surveys, is 9200 acres. The area of adjacent swamps, according to survey, is 15,000 acres. The drainage basin above the lake is covered by a sparse growth of pine trees. The elevation of the lake is 4533 feet, according to the contour maps. The rise of the lake during the past winter would indicate an in-flow of about 150,000 acre feet additional to the discharge of Lost River, which was continuous during the in-flow period.

Lost River discharges into Tule Lake, the area of which is 90,000 acres. During the past winter the lake had a net rise of seven feet, indicating an

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in-flow of 830,000 acre feet. The past winter, however, was one of unusual rainfall. The evaporation in this region is believed to be about 3½ feet. As this lake maintains an area of about 90,000 acres, this would indicate a mean annual net flow of Lost River of 315,000 acre feet. This agrees with a statement as to the usual annual rise of Tule Lake. There is the opportunity, both at Clear Lake and Horse Fly Valley to hold over water from wet to dry years. It would seem reasonable to expect that 200,000 acre feet annually might be obtained from these two reservoir sites. The water from these reservoir sites would naturally be used on Langell Valley, which contains about 12,000 acres of irrigable land; Poe Valley containing 10,000 acres; Swan Valley, 30,000 acres; Alkali Valley, 20,000 acres, or 72,000 acres in all, in valleys lying under these two reservoir sites and above Klamath River. These areas are gross and only roughly approximate and probably will be increased by a detailed investigation. It would seem reasonable, however, to consider that these two reservoir sites can irrigate all the underlying agricultural lands in the valleys named. There is practically no public land in Poe Valley, some public land in Langell Valley, and quite a large amount of public land in Alkali and Swan Lake Valleys.

As previously stated, the flood waters not impounded in Horse Fly and Clear Lake reservoirs could be diverted into Klamath River and away from Tule Lake.

BUTTE VALLEY.

Butte Valley is in California, adjacent to the northern line of the State and in Siskiyou County. It is roughly estimated that this region contains over 100,000 acres of agricultural lands, and that there are some 10,000 or 15,000 acres of government land in the southern limits of the valley. The elevation is about 4200 feet, between 150 and 200 feet above the level of Lower Klamath Lake. Butte Creek and Antelope Creek flow into this valley. The midsummer water supply, however, is quite small and is used for irrigation. There would be an abundant water supply for pumping from Lower Klamath Lake, and a great abundance of power obtainable from Klamath River for lifting this water into Butte Valley. The question as to whether it is commercially feasible to do this is not yet estimated upon, but the withdrawals of public land along the Klamath River for the purpose of generating power pending this investigation are believed to be justified.

TULE LAKE.

Tule, or Rhett Lake has an area of 90,000 acres. The lake is supplied from the in-flow of Lost River. Tradition states that in years past the lake has been almost dry and that teams have crossed over very considerable portions of this area, and that sage brush stumps are found in the lake. If Lost River water can be mostly impounded in reservoirs and the surplus diverted into Klamath River by lowering the outlet of the river at Keno, and by throwing a levee across Lost River, there practically will be no other supply into Rhett Lake, and with an annual evaporation of 3½ feet, it is believed that the lake would rapidly shrink in area and uncover a large area of land. It is a fresh water lake. This lake is interstate and navigable, but only slightly

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so used. The margin of the lake is meandered by the land office. If the lands that are uncovered are public lands that could be disposed of under the Reclamation Act, they could be very easily irrigated by means of a diversion canal, either from the Klamath River or from Lower Klamath Lake. This is a subject that will require legal opinion. Tule Lake is an interstate navigable lake and could only be drained by Congressional permission.

LOWER KLAMATH LAKE.

Lower Klamath Lake has a water surface of 29,400 acres and a swamp and water surface of 88,300 acres. If the outlet from the lake at Keno can be lowered, as previously suggested, the greater portion of this swamp land can certainly be drained and probably a large portion of the lake bed itself. This lake is interstate and navigable, and used commercially for navigation. It is a duplicate of the Tule Lake situation, and if these lands can be drained they can be readily irrigated from the Klamath River. The swamp lands are all in private ownership, title having been conveyed by the State.

The areas of the beds of these two lakes that might be uncovered, as suggested, of course are not definitely known as yet and is being determined by survey, but it would seem within reasonable limits to say that there might be from 50,000 to 75,000 acres of public lands so reclaimed.

KLAMATH INDIAN RESERVATION.

Klamath Indian Reservation has not yet been investigated, but it is reported that there are large areas of irrigable lands therein and this will be made a subject of future study. Particular attention is called to the fact that the State of Oregon has a claim pending in court for the swamp lands shown as the Klamath marsh on the Klamath quadrangle, which lands are in the Indian Reservation.

EXISTING CANALS.

A canal has been constructed from Lower Klamath Lake near the State line, for the irrigation of the north shore of Tule Lake. This is the largest canal in the district. The manager of this canal is Mr. Adams, postoffice address, Merrill. I have talked with Mr. Adams and other owners of the canal, and they state that all they wish is water for their lands, and that they will be pleased to have the government enter this field and to turn over their canal systems to them.

Another canal diverting water near Klamath Falls carries between 600 and 1000 inches of water. This ditch irrigates the lands between Klamath Falls and Lost River. The ditch was constructed some years ago, has passed through bankruptcy and is now irrigating some 5000 or 6000 acres of land. There are one or two small irrigation ditches in Poe and Langell Valleys.

About January, 1904, the Klamath Canal Company was organized for the purpose of constructing a canal from the Upper Klamath Lake towards Tule Lake. This would parallel the largest existing canals in this region, being some 10 or 15 feet higher in elevation. This Klamath Canal Company is being managed by an engineer of the name of W. K. Brown. They have

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entered into contracts to furnish water to land owners southeasterly from Klamath Falls and along the existing canals. They are proposing to furnish this water for $10 an acre, with $1.00 per acre annual rental. Their water contracts are severe. At present this corporation is constructing a tunnel 4x7 feet in section out of the Upper Klamath Lake, the intention being to widen this tunnel to such dimensions as may be required by the contracts that are ultimately entered into. They have purchased some land and succeeded in signing up for water for about 20,000 acres of land. Their field of operation, as previously stated, is situated between Klamath Falls and Tule Lake, covering an area of some 60,000 acres. This canal company at present is very active along promotion lines, and is working quite a force of men on the tunnel in question. They began work on their canals about the first of August. They express very great dissatisfaction and regret over the fact that the Reclamation Service is making investigations in this section, as it will interfere with their program, and have endeavored to have orders issued to suspend the surveys. The principal men of this region, outside of this corporation, are of the opinion that public irrigation works are desirable. Numerous petitions to this effect have been presented to the service. The Reclamation Service will not proceed unless the people of the region desire it. The withdrawals made were for the purpose of giving the Reclamation Service an opportunity of investigating the country sufficiently to determine whether there was any occasion for the construction of public works here. These withdrawals were considered necessary, as the Klamath Canal Company were filing on streams and endeavoring to file on the Horse Fly and Clear Lake reservoirs, which filings, if perfected, might prevent the federal government, or, for that matter, any other irrigation enterprise, from doing business in this region.

It would hardly seem reasonable that the Reclamation Service should stand aside for a corporation that was not irrigating an acre of land, and that did not have a mile of ditch or canal constructed, and leave to this corporation the reclamation of over 300,000 acres of land lying in three counties and two States, the source of water supply being both interstate and navigable.

LAND WITHDRAWALS.

It was deemed advisable to withdraw, at least temporarily, all public lands in the Clear Lake and Horse Fly reservoir sites, and the public lands along Klamath River for power, and also to withdraw such townships as contain public irrigable lands. An examination was made of abstract records in Klamath County, Oregon, and only such townships withdrawn as contain public land.

If the beds of these navigable lakes are public lands, as is believed to be the case, it will probably be possible to reclaim 100,000 acres of public land in addition to over 150,000 acres of private land under this project.

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SUMMARY.

The following is a very rough estimate of the gross irrigable areas:

Irrigable from Clear Lake and Horse Fly Reservoirs.

Langell Valley	12,000 acres	
Poe Valley	10,000 acres	
Swan Valley	30,000 acres	
Alkali Valley	20,000 acres	72,000 acres

Irrigable from Klamath River.

Between Klamath and Merrill	60,000 acres	
From Merrill to Carrs	10,000 acres	
Bed of Tule Lake	50,000 acres	
Bed of Lower Klamath Lake	20,000 acres	140,000 acres
Butte Valley, irrigable by pumping		100,000 acres
Total		312,000 acres

The water supply is believed to be adequate for this irrigation.

RECOMMENDATION.

It is recommended that pending these investigations and reports, the segregation previously made should be maintained and that no further rights of way, particularly to reservoir sites, should during that time be granted to any applicants of this region. Surveys should be vigorously made to determine the vital facts upon which final judgment must be rendered by the Secretary of the Interior.

Mr. Newell—This brings up matters of policy and matters in which citizens of both Oregon and California are interested. I therefore suggest that we give the matter full consideration while it is before us, as it is one of the very big questions the Congress will have to consider.

Mr. A. King Wilson, of Oregon—From the explanation we have heard it appears that the only question before us is how we can assist in promoting this project, and I have to offer a resolution in order that we may have some written record. The resolution is as follows:

"Whereas, unusual opportunities exist for the reclamation of large areas in both the States of California and Oregon in the basin of the Klamath River, and

"Whereas, the public interest and sentiment of the citizens and land owners of said section is desirous of having these works built in an extended and comprehensive way by the U. S. Reclamation Service and not partly constructed by water selling corporations; and

"Whereas, the irrigable lands and their water supply are divided by the Oregon and California State lines; and

"Whereas, the engineers of the Reclamation Service are now making investigations of the extent and cost of said reclamation, including the drain-

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age of large interstate lakes, which work may call for special legislation from both Congress and State Legislatures.

"*Therefore be it Resolved,* by the California and Oregon delegations to the National Irrigation Congress, in joint session assembled, that the Secretary of the Interior is hereby respectfully requested to diligently prosecute said surveys, and if the said Klamath Project proves feasible to build the same as an interstate enterprise; and

"*Be it further Resolved,* that the representatives in both Congressional and State Legislative bodies be and hereby are respectfully requested to lend their aid and assistance to the Reclamation Service in passing such acts as may be found requisite."

Mr. Fairweather, of California—We have heard something of this subject before. Of course the California people read and know something about what the press and people are doing in the State, and at the meeting of our California delegation yesterday morning we undertook to discuss a few subjects and I introduced a resolution, but I am instructed by the California delegation to say that they decided that with all the powers they have now, or will have in future they will stand by the Reclamation Service in everything it has done in the past or may do in the future. We have that confidence in the government men who are now doing the work that we wish them to know that California will stand at the back of the Reclamation Service, and we do second with all our powers the resolution now before the house.

Mr. Newell—The motion is before the section on the adoption of the resolution. It has been moved and seconded. What is your pleasure?

Mr. Finkle—I am heartily in favor of this resolution and the reclamation work, but it seems to me that we ought to adopt this resolution here and not present it to the general convention. It seems that it only concerns California and Oregon and the reclamation people, and if we adopt it here unanimously that lends it all the force possible and puts us on record before our respective legislatures and the legislative branch of the government of the United States.

Mr. Newell—All in favor of the resoultion, signify it by saying "aye." The resolution is adopted.

Delegate—I move that the resolution as adopted and the action of this joint session be reported to the chairman of the Irrigation Congress tomorrow night and let them pass on it and adopt it. It is only a question of adding to it all the force we can get, and if the National Irrigation Congress will endorse it—it is an interstate proposition—it seems to me it will give it more strength, because when we do that we will be getting some of the men who are in Congress of the United States to endorse by their action what we as mere representatives of our respective States are endorsing.

Mr. Finkle—If we do that it opens the door for everybody to come in with resolutions recommending all kinds of enterprises to the Reclamation Service, and if they adopt one of them they will have to adopt all. We all have faith in the reclamation engineers and know they are people who are able to pass upon a project, and I don't think we ought to have the Congress pass upon it.

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This is a project in which two States, Oregon and California, are interested. This is our excuse for this joint meeting to recommend it to the Service. The Reclamation Service through their representative who has spoken endorses this project if the people of Oregon and California can come together on it, and we have shown that we can come together on it, but we should not take it to the Congress simply for the precedent it would establish.

Mr. A. H. Devers, of Oregon—There is such a committee and all resolutions that may come before the Congress are first presented to the committee. I presume that that committee is competent to take care of and pass upon all resolutions. I believe it is necessary to give this resolution all the force that it is possible to give it. If the Resolutions Committee of the Irrigation Congress thinks it worthy to be presented to the Congress, let them do so and give it all the prestige they can. I move that the resolution be presented to the Committee on Resolutions of the National Irrigation Congress.

Motion is seconded.

Mr. Fairweather—Oregon and California have agreed on one proposition. We have adopted this resolution, and we have thus done all that we can do in this Congress. We have agreed in this resolution to do all in our power to aid the Reclamation Service and do what we can with our State legislatures. There was a resolution introduced this afternoon before the Congress of a like nature as this, affecting a part of our State—I don't care to mention it—but the California delegation feels strongly that the resolution now already passed by us is entirely sufficient and we hope that the Oregon delegation will withdraw their objections and allow this division of the Congress to pass this resolution and not carry it any further.

Delegate from Oregon—I will withdraw my motion and say that California with her gold and Oregon with her grain will stand by this resolution and the Reclamation Service until that scheme is carried through.

Mr. Newell—The paper by Mr. Lippincott has been presented and discussed, and I understand that all objections to the resolutions as passed has been withdrawn.

I will say that the Reclamation Service is pushing its work forward as rapidly as possible and hopes to soon have all the necessary data upon which to proceed. If it is thought wise by our friends in Oregon and California to assist us their support will be a great aid to us. The matter of public policy is one in which we need your support. We are the servants of the people. We must get the facts and you must do the work based on a knowledge of those facts.

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Thursday Morning, November 17, 1904.

Chairman Newell—The session will now be in order. You will first have the pleasure of listening to an address by Mr. H. A. Storrs.

IRRIGATION DEVELOPMENT IN NORTH DAKOTA.

H. A. Storrs, Electrical Engineer, U. S. Reclamation Service, In Charge Irrigation Work in North Dakota.

Surveys and examinations of the entire arid or semi-arid portion of North Dakota have been pushed systematically and energetically by the Reclamation Service to discover a locality where the natural conditions offer a fighting chance of working out a feasible irrigation project. But the topographic features of the State are distinctly unfavorable to the storage and diversion of water from its streams, and while its neighboring State in the West offers a dozen possible projects, many of them evidently feasible, North Dakota seems to possess few, if any, possibilities of large irrigation projects.

The Missouri river affords an abundance of water, but the irrigable lands along its banks exist either in small tracts at low elevations, or in extensive plains at high elevations above the river. The lower lands are not sufficient in extent at any location to warrant the enormous expense involved in damming and diverting the waters of the Missouri. The higher lands could be reached only by dams of great length and height or by large canals several hundred miles long. Neither of these methods is considered feasible, in view of the unfavorable topographic features presented and the enormous expense involved.

The smaller streams are flat in slope, variable in flow, devoid of favorable reservoir sites and hemmed in by high banks of earth, all of which conditions are unfavorable to storage or diversion of irrigating water.

PLANS FOR PUMPING.

This season, however, it was determined to ascertain whether it would be feasible to pump water from the Missouri River for irrigating the inviting bench lands which extend for many miles along its banks. The Reclamation Service has been unwilling to resort to this method of securing irrigating water, on account of its presumed high cost, if any cheaper or simpler method could be discovered. The feasibility of any pumping project is not assured until it is demonstrated that the value of the lands and crops will warrant the necessary expenditure for pumping machinery, canal system and annual operating expenses. These expenditures must be borne by those who receive the benefits of the irrigating water, since every dollar expended by the government for such purposes must, soon or late, be returned to the Reclamation Fund. For this reason it is really the people concerned in any such project who, by agreeing to co-operate with the government, decide that the project shall be considered feasible.

The engineer can determine the natural conditions, the cost of irrigation

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works and their maintenance and operation, and can present figures showing the cost per acre for irrigating a proposed tract of land. It then rests with the land owners to decide whether they will agree to pay what is required to install and operate the proposed irrigation works.

IRRIGATION EDUCATION NECESSARY.

The people of North Dakota have much to learn regarding the value of irrigation. Almost no irrigation has been attempted thus far, and the majority of farmers have had no opportunity to see what has been accomplished in other States. Undoubtedly when the facts are presented to and understood by the people, they will be as ready to accept the conditions and secure the benefits resulting from reclamation projects as have been the farmers in Montana and other western States.

As a result of preliminary investigations not yet completed, the Reclamation Service will soon present to land owners in the vicinity of Bismarck, in Buford-Trenton and possibly some other localities, the proposition to erect pumping plants at these places, provided the people will agree to pay the costs of obtaining water in this way.

WILL BE UP TO THE PEOPLE.

These costs promise to be but little if any higher than for many of the projects in other States, where an annual charge of three to four dollars per acre is required during the first ten years. This amount pays for the irrigation works in ten annual installments, in accordance with the terms of the Reclamation Act, and also pays the cost of operating expenses during the first ten years. During subsequent years the anuual charge covers only maintenance and operating expenses.

In projects involving steam pumping plants, the operating expenses will probably be greater than on gravity systems. These operating expenses, however, will be proportional to the amount of water actually pumped. Consequently in years of heavy rainfall the operating expenses will be small The pumping plants are really a reserve, to be called upon to supply the deficiencies of rainfall and run-off. By storing all the flood-waters of small streams within the area covered by the project, the run-off may materially lessen the quantity of water which has to be pumped.

CHEAP IRRIGATION.

In general it may be stated that the pumping works and canal systems for the two projects examined would be paid for in ten annual payments not exceeding two dollars per acre each. The maintenance charges would amount to about one dollar per acre and would be practically constant whether much or little irrigating water was used. The operating expenses would, however, vary according to the amount of water actually used and would amount to little or nothing during years of abundant rainfall. During dry years when as much as two acre-feet per acre might be used, the total for maintenance and operation would approximate two dollars per acre. The pumping plants will have the capacity to deliver two acre-feet per acre for the

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entire tract during an irrigating season 100 days in length. This amount is probably the maximum that will be required if economy is exercised in the use of water.

TWO OBJECT LESSONS.

The Buford-Trenton project includes about 18,000 acres and the Bismarck project about 15,000 acres. The latter may be considerably extended after the surveys are completed and the results studied. Possibly it will be thought advisable to erect a central power station convenient to the coal supply and transmit the power electrically to the pumping plants, thus saving transportation of coal to pumping plants located at a distance from the railroads. The land owners along the Missouri, and possibly other rivers in the State, will soon have an opportunity to signify their desires regarding the construction of national irrigation works within the confines of the State.

Mr. Newell—Gentlemen, the subject which Mr. Storrs has just presented is a very attractive one, particularly to all parts of the arid region. If it will be found practicable to pump water for irrigation at a price comparable with that furnished by gravity canals, the limit to which we can extend the development of the West becomes a very broad one. The most notable advance in the last twelve months has been in the conception and the use of the gas producer and the gas engine for pumping plants, by which we cut out the old steam engines, and instead of utilizing the coal for the purpose of making steam in the boiler, and then furnishing the steam to a steam engine, and this engine furnishing the power to operate the pumps, we burn the coal in a gas producer; the gas thus obtained is used at once in the gas engine and there applied directly for the production of the necessary power for raising the water. The problem which Mr. Storrs has been dealing with, that of pumping water from the Missouri River in particular, is one that is applicable all over the West. We have before us a number of engineers who have had more or less experience in pumping, and I believe this opens out one of the widest vistas of development which has yet been presented. I see before me Mr. Finkle, and will ask him for a few remarks.

PUMPING IN SOUTHERN CALIFORNIA.

Mr. Finkle—Mr. Chairman and Fellow Delegates: I have certainly been very well entertained by the able address which Mr. Storrs has just delivered; he has presented the subject in such a comprehensive manner as to leave but little more to be said by anyone. In Southern and Central California we have resorted to a very great extent to the pumping of water for irrigation. The pioneer portion of the State in this respect is Southern California, notably the counties of Los Angeles, San Bernardino, Riverside and Orange. I have not at hand the figures to give you the exact results of these operations, but in a general way I may state that there is approximately about three thousand electric horse-power applied to pumping plants in this region of California, in addition to which there are numerous individual plants operated by steam or gasoline. The success of these operations has been attended by a very rapid extension of the work all over the water producing sections

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of the southern end of the State of California, and at the present time no one doubts the profits which are derived from such operations. The only element of uncertainty is the supply of water which is available for such extensive operations. Yesterday, in this section Mr. Mendenhall dwelt upon this subject at length, and I had the honor of making a few remarks upon the matter, pointing out how the danger could be averted to some extent by curtailing the use of the water in all necessary operations as far as practicable and adding to the stores of water in nature's own reservoirs. There are many sections of the arid regions not so vitally interested in this as California. I wish to state that pumping in California is yet in its infancy, and I desire to mention one or two notable examples. The Kaweah River, which flows through the county of Tulare, has upon it two power plants, and a great portion of the power derived from these plants is now applied to the pumping of water in the vicinity of Visalia, Tulare, Exeter, Porterville and other settlements. Some of these settlements are orange growing districts and produce the earliest fruit in the State of California, which does not, to any extent, come into competition with the later fruit of Southern California. Fields of alfalfa and other crops are produced in this same manner. Also, near the city of Fresno there has been constructed an electric power plant on the north fork of the San Joaquin River, which is also supplying power for similar purposes. The capacity of this plant is so limited, however, that enormous projects are in contemplation on the Kings River by the Kings River Power Company. We will be able to develop, on the Kings River, approximately one hundred thousand horse-power, a portion of which will be devoted to the pumping of water for irrigation purposes in the great San Joaquin valley.

NOTE OF WARNING TO ENGINEERS AND PROMOTERS.

In closing my remarks I desire to say a few things in the way of precaution to the engineer and promoter relative to the development of irrigation by pumping. In the first place, of course, an inspection is necessary of the ground waters which are to be applied for the purposes of irrigation in the different localities in the arid regions of the United States. These ground waters are sometimes impregnated with salts, which if applied to the land would cause the destruction of the crops. It is therefore necessary to make a careful chemical analysis of the water to be applied in any locality before any extensive enterprise is entered into. In the San Joaquin valley we have found localities where the ground waters would be unfit for irrigation, but the greater part of that valley is underlaid with waters suitable for such purposes. In Southern California we have no difficulty of that character as the waters are all very nearly free from salts, the only mineral which is carried to any extent being calcium carbonate, which, in moderate quantities is harmless. The salts of sodium are the ones which we dread the most, particularly sodium carbonate or black alkali. This subject cannot be discussed in detail to-day, but I desire to state in this connection that the Reclamation branch of the United States service has in its employ experts who are entirely competent to deal with this stage of the question, and the cities

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in the arid West in the localities where the government is doing test work need have no fear that this feature will not be carefully looked after. Also, there is another feature equally as important. From the address made by Mr. Storrs we see that this feature has received its careful attention; of course this being the foundation of success or failure, it can in no case be overlooked. The question of the crop which can be grown by irrigation, the prices at which this crop can be sold, and the cost of production on the one hand and the cost of supplying the water on the other must be carefully determined by qualified experts; when this is determined the scheme may be safely recommended if it is found to be feasible. In this regard we again have the assistance of the able engineering corps which is combined with the Reclamation Service of the United States, men selected for their special fitness in these lines of work, who have devoted a life-time, almost, to those questions, and by the work so far accomplished show that they are devoting their energies to determine which schemes of reclamation are feasible. Now, we need not think that the reclamation of arid lands will stop when all the schemes which are to-day considered feasible have been developed. The history of every old nation shows us that as a country grows, as population increases the demand for production increases, and with these demands for production enterprises which would not be commercial in ages past become profitable. Therefore, I expect to see that the reclamation of arid lands in the United States will continue for centuries. I expect as the population increases the cost of production will diminish from natural causes. In this manner, enterprises where it is now considered impracticable to pump water for irrigation, will become entirely feasible, and it is hard for any one living in the present day in this country, unless he has visited the older sections of Europe to realize the extent of the possibilities to which this may be extended.

There are many others here who have ideas upon this subject, and as this is a gathering where the ideas of the many may be an estimate of the whole, I desire to thank you for your attention.

Mr. Newell—Gentlemen, in the remarks that Mr. Finkle has made he has touched on two very important considerations, the first is the quality of water from underground pumping plants, and that, as he has stated, is being studied quite thoroughly--by two different divisions of the work. The other point that Mr. Finkle has made is the economic, and there is where we must give a great deal of thought and attention. That question is not to get water on the ground or cultivate it, but the question is, will it pay in a given soil and climate to cultivate the ground intensively; what are the crops and markets which will enable men to succeed under the conditions? There is a subject which opens up a wide range of discussion, whether, in a given locality a project is feasible from the human side.

We have with us as guests and friends and associates in this work several of the engineers from the Republic of Mexico. We appreciate their presence; they have been very kind to come here, and one of them, Mr. Robert Galor, Commissioner of Public Works of the City of Mexico, has consented to appear and say something of his work, although he is very apologetic as re-

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gards his ability to speak in English before a public audience, yet I trust he will at least come forth and present himself to the audience. I take pleasure in introducing Mr. Galor.

DRAINING THE MEXICO BASIN.

Mr. Galor—Mr. Chairman, Ladies and Gentlemen: I was invited by Mr. Newell to say a few words about my work in Mexico. It will give me pleasure to do so. The City of Mexico is situated in the bottom of a basin which has no outlet to the sea, and it is about seven thousand feet above the level of the sea. Since the times of the Aztecs the city was flooded a good many times with very heavy water. The Indians began the work of the drainage of the valley, but did not succeed. The Spaniards came afterwards and met with some measure of success, but their works were not sufficient to drain the valley. Afterwards the Government of the Republic of Mexico started several times to do this work in order to save the city from the floods. In 1886 our government started the work and pushed it with great vigor until it was finished about eight years ago. The works consist of a canal thirty miles long and at the end seventy feet deep and twenty feet wide. After the canal there is a tunnel six miles long and three feet in diameter. As soon as these works were completed we were able to build the sewers of the city. A lake was formed from storing the rain water of the valley. The drainage works are large enough to include the waters of the lake as well as the soil water of the city. We started the construction of the drainage and for that purpose I was put in charge as chief engineer of the construction of the sewers. I came to this country and had the pleasure of meeting several of your ablest engineers, who gave me very good ideas, which I used in making the plans for the sewerage of the city.

In 1896 we started the construction of these sewers and they are now finished. The system of sewers that we use is a combined system. I was particularly interested in giving a good system of flushing, and I think we succeeded, because we can flush our sewers every day in five hours and thirty-seven minutes with only twenty men. All this water and the refuse water off the houses goes to the main drainage canal, and through the tunnel. A company was formed in order to use this water for developing electric power and use the water for irrigation. As the tunnel is constructed on a steep grade, they erected three power plants in which they generated electric power, and they sent this power to Pachuca, which is one of the largest mining places in the Republic of Mexico. This city is lighted by power generated with this refuse water of the City of Mexico, and a great number of mining places receive power from this source. As soon as the water leaves the power plants it goes to irrigate a large portion of very dry land, where formerly they could not get crops one year out of five. Now they get crops every year because they irrigate all these lands with very rich water, the refuse water of the city. I think this is one of the most complete and best schemes for the use of water, as we take it from the upper lakes that are on the southern side of the City of Mexico and use it on the dry lands. At the same time we have a complete system for the drainage of the city.

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Mr. Newell—We have to thank Mr. Galor for his kindness and for the very interesting facts he has put so concisely before us.

For the benefit of those in the back of the audience, or room, I will say that Mr. Galor is chief engineer of the sewerage system of the City of Mexico. He has devised and constructed a system of drainage or sewers for that city, discharging through a tunnel and power is developed from the use of that water, and the power transmitted and used for electric lighting and pumping, after which the water is turned out on the dry lands and used in irrigation, producing good crops, and the seepage or return waters go back into the streams in a naturally filtered and purified condition by their use in irrigation. It is an ideal system and I hope that the description which Mr. Galor has given out may be translated and published in our proceedings, at least in the proceedings which will go to the engineers. We will learn a great many lessons I think from the practical experience which Mr. Galor has had.

As the next paper on the program I will call upon Prof. Thomas Taylor, Professor of Civil Engineering at the University of Texas, who has been co-operating with us in Texas in the study of the water supply and development of the water resources of the State for irrigation and power. For the information of our Texas friends who have the idea that because the reclamation fund is not applicable in Texas, we are not working in Texas, I think it is only fair to say that the Geological Survey has been spending a considerable amount of money in Texas for many years; is systematically studying this State as it is all parts of the United States, preparing the topography and maps of Texas; is studying its geology; studying its water, and studying the opportunties of development, and if opportunities offer we will co-operate in every way in utilizing the waters for the irrigation of land whether in Texas or in any other part of the country. Professor Taylor will speak to us briefly on his investigations of power for pumping water for the irrigation of rice.

Mr. Taylor—Mr. Chairman: Before I commence I wish to precede my talk with this motion: I move a vote of thanks to Mr. Galor for coming so far and having the courage to address us in our own language.

Mr. Holabird—I take pleasure in arising to second the motion, not only to extend our thanks to the individual, but to the Sister Republic for sending him and giving us the knowledge of this treble use of the water.

Motion carried unanimously.

Mr. Newell—The management has requested that I give notice that the Rural Settlement section is holding a session on the second floor of the Court House. It has been feared that perhaps some one has wandered in here thinking he was in the Rural Settlement section, and if so we will warn them that this is not the proper place. I will do all in my power to give Mr. Smythe an audience, and ask every one to go over and listen to them if he so desires. We want to be fair in this matter and give the other section a chance.

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POWER FOR PUMPING WATER FOR RICE IRRIGATION.

PROFESSOR THOMAS TAYLOR, of Austin, Texas.

Mr. Chairman and Gentlemen of the Convention:

This paper could well have come as a discussion of Mr. Storrs paper, because it is on a similar subject. It is not a new topic at all; it is a continuation of the general subject of pumping water for irrigation purposes. The statement was made day before yesterday that in Texas there were fifty thousand acres under irrigation. The gentleman stated only one-sixth of the truth. There are over fifty thousand acres irrigated for general crops. There are two hundred and twenty-five thousand acres of rice irrigated in Texas, making in all nearly three hundred thousand acres, or as some estimate three hundred and twenty-five thousand acres under actual irrigation in Texas not under ditch. The majority, or nearly all, or I might say ninety-five per cent of the rice irrigation is done by pumping, strictly. There is only one that I could call a ditch or canal plant in Texas, which derives its water from tapping a stream by a dam, which is located at Del Rio. There is only one plant in Texas that develops its power by water, that is at Cuero. The ninety-five per cent then in Texas is from pumping direct; ninety per cent of this is from the use of the centrifugal pump. Now as to this, as I said, it is a continuation of the paper by Mr. Storrs—almost right in line with it. I believe I got the statement right, that it required two acre-feet generally as an average there to irrigate the crop. If I understand, that statement was that each season you had to cover the land with about two feet of water.

RICE GROWING IN TEXAS.

In rice cultivation we have to put on more, because rice is a marshy crop; it is used to growing in a swamp. Now, instead of taking the rice to the swamp, or taking the mountain to Mahomet, we went and got Mahomet and brought him to the mountain. Now, instead of taking the rice down on the coast and growing it in the marshes and bayous, we simply brought the marsh up on the table land by pumping. We put a dam around the land to be cultivated and we pump on the inside of that and that makes our marsh there; this is briefly rice irrigation. Now, rice irrigation you know—just briefly I will take up the Japan method; I have read this paper but will repeat just a few words of it. A few facts were given; the Japan farm has an average size of about a quarter of an acre. This room is about the size of a Japan farm, of which there are nine million in Japan, or about 3,000,000 acres. Those of you who have been used to planting tobacco know that you have to put your seed out in a seed-bed before you start. They put theirs in a seed-bed and then go out onto the farm and plant it out by hand, putting about two hundred thousand stalks on one acre, and every one put down by hand. Now, you can imagine the condition of a man's back when he gets through with an acre. Notwithstanding that, Japan produces to-day eleven times more rice than the whole United States. In addition to this there are three Japan colonies in Texas to-day on our rice farms; at Del Rio; at Webster; at Garwood, and I can say, as I said yesterday, they are displaying the same energy in

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rice irrigation in Texas that they are now displaying in scaling the walls of Port Arthur. Now, instead of putting two feet per acre on their ground in Texas and in Louisiana, which is the Carolina method, we have got to put about three feet on unless it rains, and this is an uncertainty. We have got to put three feet of water on the ground. We start and sow the rice like we do wheat. We plow the land like we do for wheat; then we sow it with a drill exactly like we do barley. The only difference is this: it is laid off in farms where the difference in level is about six inches; they are dyked in and the water is pumped on these after the rice is up a few inches, and it stands there for about ninety days. Every particle of rice should be covered at the roots from two to six to eight inches, and it ought to stand there for sixty to ninety days; this is the modern method. Mr. Storrs spoke of the number of plants and said that pumping was in its infancy. Well it is in its infancy in Texas and Louisiana, but I must say it is a pretty robust infant.

SIZE OF PUMPS.

Now, as to the size of these pumps: last summer I walked through the suction pipes of one of these pumps. I stood in one and the upper part of it was two feet above my head. That gives you just a faint conception of what we are doing, and that very large engines are required to do this work. There are five hundred, in round numbers, well plants in Texas irrigating rice by using the small centrifugal pumps. I made a tabulation last night and this morning of the number of big canal systems. There are in operation to-day in Texas, or were this last summer, exactly forty-one, irrigating from 500 to 16,000 acres per system. Now, on each acre per each minute that you irrigate you ought to put seven and a half to nine gallons of water. In Texas we estimate gallons per minute; we have to keep to that language or the people will not understand us. On every acre every minute you have got to put about seven and a half to nine gallons; say seven and a half gallons; that means for ninety days just three feet that you have got to put on there. Now I make no excuse for the technical part of this because that is what this section is. If we let X represent the number of acres to be irrigated and Y the lift in feet, there are two factors, and only two in rice irrigation, as there are only two in all irrigation plants. The first is, how much do you want to irrigate, that is in pumping plants; the second is, how high have you got to lift the water; of course these are the fundamental factors. When you know these two an engineer can tell you how much power you have got to put behind the machine to drive it. Now, the theoretic horse-power or the actual horse-power in operation: If you multiply the number of acres you want to irrigate by the lift in feet, and divide that by 440, you will get the number of horse-powers that you have got to have for pumping. Roughly speaking, then, if you multiply the number of acres you want to irrigate by the lift in feet and divide by five hundred, you have a still more conservative estimate.

Now if a man is going into this business he should always make the manufacturer guarantee the goods. I know a lawyer down in Texas that almost had his license taken away; he was over the average. He went to buy a horse and

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the professional horse-trader told him a long tale about the horse; the lawyer took it all down and says, "Come across the hall," and then said "will you please swear to that." He stepped back. "No, sir, I may be a Texas horse-trader, but I won't swear to that; I am too old a bird for that." But you can do this, and the reputable makers of large centrifugal pumps as well as small ones will guarantee them, and they go from one inch to sixty inches in diameter—they will guarantee them, but never go into it unless they do guarantee them.

COST OF PUMPING.

Now, as to the cost, it is found in Texas you can get water from the big canal systems at two bags of rice per acre, about three hundred and sixty pounds; in average figures then that will mean five or six dollars per acre per season. You can get the water for that or pump it yourself, and on the small well plants they actually irrigate for less than that. A well plant where it has got a lift of not over twenty feet will uniformly produce better results than the big pump canal systems. Now, that is roughly the substance of the investigation of the amount of power necessary for the irrigation of rice in Texas and in Louisiana. Why do I say in Texas and Louisiana? Because in the old Atlantic States they are still using what we call the Carolina method. Briefly, then, what is the modern method? It is simply to produce a marsh on the highlands by pumping the water up there, and there is but one gravity plant in Texas, one water power plant in Texas, and all the rest are power plants, pure and simple.

Mr. Newell—It is very impressive to learn what has been done in Texas in pumping, the enormous development which has taken place there quietly with the assistance of the engineers and other persons interested. The lessons given by Professor Taylor of the excellent results accomplished should encourage us all to consider pumping as one of the great developments of the future. The cost, I expect, will show up larger than that of gravity canals, but we must recollect that the gravity canals built by private enterprises all over the country have taken the cream of things. You cannot go along and repeat and take out ditches now as you did ten or twenty years ago, and so pumping plants come now into direct comparison with the later ditches, which we must build at larger expense. In this connection it may be of interest to some of us to know that in a telegram just received I find it stated that at St. Louis, at the coal testing plant, in what is known as the mining gulch, near the mineral building, we have just completed a most successful run on North Dakota lignite in gas producing.

DAKOTA LIGNITE AS A GAS PRODUCER.

That is quite significant because of the fact, which will be appreciated by our North Dakota friends, that the North Dakota lignite has been considered hardly worthy of taking into account in the development of the country, but it is found that in this experimental plant that by utilizing that lignite as a gas producer we get results which are superior to that of bituminous coal. We hardly appreciate it until we understand that in that State hundreds of

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thousands of acres are underlaid with this lignite, which has been considered very inferior to bituminous coal. If this is true it means an enormously increased value to that whole State and its industries.

Professor Taylor—I omitted one thing, that is the advantage of pumping from surface wells as over canal systems. We have in Texas an irrigation law, so-called, and law they say is a science, but if our irrigation law is a science, why, it is one of a rather peculiar brand. Now we have in the courts a term known as the Texas rule. That Texas rule is that the latest decision of the Supreme Court in regard to the upper and lower proprietor, the present Chief Justice decided this, almost word for word: That if the water could be used, that if irrigation was necessary for agriculture in the locality where the contest occurred, the upper proprietor could take all of the water out of the stream and not leave sufficient for the lower proprietor for the same purposes. He can force him to leave enough for domestic purposes, but not enough for irrigation purposes. The well proprietor has the advantage; he is away off from a lake, away off from any stream; he has a farm of one hundred and sixty acres, digs his well, and for twelve hundred dollars can put down a good pumping plant, irrigate only thirty-five acres of rice, spend nine hundred and seventy dollars in doing it, take in only one crop and clear twenty-three hundred dollars on thirty-five acres. Now, we are not all doing that; that is one of the best, but I am only going to give you the best; we will do our own washing at home—not here. I always advise a man to put in a well plant, why? Because injunctions cease from troubling him, and irrigation laws are forever at rest on the well plant farm.

Mr. Newell--The Texas rule has the advantage of simplicity, for the fellow first up the stream can get all the water; just think what it would do for us in other parts of the arid region. Now we have left five minutes before the stated order of the day, and the only thing I have on the program is an address by Mr. Holabird on errors to be avoided in the management of irrigation systems. If Mr. Holabird will speak to us for five minutes we will ask him to do so on the errors to be avoided in the management of irrigation systems.

ERRORS TO BE AVOIDED.

Mr. Holabird—Mr. Chairman, Ladies and Gentlemen: This is a little bit of a surprise. I really have not very much time to even think about it, as I think Mr. Newell will concede that. My observations, having some experience in the management of irrigation enterprises and in observing the working of irrigation enterprises, lead me to form some conclusions, and I believe they are reasonably correct. First, a given amount of water in one—I will not name the enterprise; it is a great irrigation enterprise, possessing a great deal of natural merit, both in the land and climate—the company allotted to the land altogether a quantity of water. The land not all being farmed or occupied, each water user was allowed to use all the water he wanted. Instead of accumulating his water, which we will say was thirty miners' inches, and using it at stated periods by a schedule, he was allowed to use two or three hundred miner's inches all the time. Finally financial disasters overtook this large corporation and they were in very great trouble. It was necessary

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to repair the ditches; it was necessary to sell more land in order that the income from water rentals might be sufficient to maintain the ditches and keep the company alive. It was ascertained that there was no surplus water, because the few water users on these vast areas were using from two to ten times as much water as they were entitled to, and when I suggested taking it away they threatened to mob me; so you will see it is dangerous. In the first place it teaches the farmer a very bad practice, of making him believe that he has a prescriptive right to water that he never can own and should not be allowed to use to his detriment, because my observation is that there is more damage to crops by the abuse of water than from the lack of water; you will find that universal throughout the West without exception. When you talk about water—large quantities of water to a given quantity of land, why, the orange growers of California who produce twenty-eight thousand car-loads of fruit per annum, would think themselves wonderfully supplied with water if they had one California miner's inch to ten acres. The other danger is in not having a schedule, and that will end my brief talk. I believe that all distribution—I am speaking now from the point of the manager and not of the engineer—of water should be distributed under a schedule. I do not think it is wise; it will not work out well to let Mr. Jones telephone in to the water man and say "I want some water to-morrow for my north forty." I believe it is best to make your schedule, and tell Mr. Jones and Mr. Smith the very day and the very hour and the very minute this water shall be turned on, and when it shall be turned off. This is very important indeed.

WASTEFUL METHODS OF IRRIGATION.

One of the most beautiful valleys in California, and I regret they are not represented here so far as I know, is Owens Lake Valley, in Eastern California; it is one of the gems of the western continent. In the early days they took the water falling from the high Sierras and appropriated it, as we call it. There are scores of little farms in there using two and three hundred miner's inches of water. They irrigate when they want it and when they do not want it the water goes to form lakes; the result is they are filling the valley full of lakes or ponds. That shows the folly of giving a farmer more water than he actually needs and letting him have it to go to waste and ruin the country and ruin his own crops.

Mr. Newell—The time has arrived for the special order of business, which is of peculiar interest and importance to the citizens of this beautiful city, and the inhabitants of the neighboring country on both sides of the line.

I wish now while I think of it to announce that at 12:00 o'clock the committee of organization is to meet here in this hall.

THE RIO GRANDE.

The subject which has been assigned for 10:30 is that of the Rio Grande, the wonderful river which flows—sometimes—by your city; the river that rises in the State of Colorado is of great importance to the southern part of that State, flows through New Mexico, is the fount of life of the greater part of that territory, forms the State boundary between Texas and New Mexico

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for a little distance, and then for many miles forms the international boundary between the State of Texas and the Republic of Mexico. The use of its waters is, of course, of prime importance—of vital importance—to the citizens of the State of Colorado, Territory of New Mexico, State of Texas, and last, but not least, the Republic of Mexico. You are all familiar—those of you who are interested in the subject—with much of the past history of this river, and the discussions which have gone on concerning its use. I think it is not necessary to mention, and in fact from the view-point of the engineer we wipe aside all of the past, and simply consider, and have the right as engineers simply to consider what are the best conditions of the river and what are the best uses of its waters irrespective of all territorial or social or human interests. Starting out, therefore, with this consideration solely, as to the river itself, what would be its ideal use without reference to State, county, or territorial lines; then, with that starting point, which is as far as the engineers will go, we simply say, here are the facts. Now, it is for your consideration as citizens, as statesmen, to say what shall be done with the river, but it is for us to inform you, as clearly and impartially as possible, what we consider are the physical facts which must be taken into account in any of the problems, and the best use of the waters of the stream. There are before us in the audience, representatives from New Mexico, from Texas and from Mexico. There are members of Congress and others who must give the last word to this matter, and we wish, in presenting this as engineers, to confine ourselves strictly to the engineering features, and let you draw your own inferences and reach your own conclusions without any intimation one way or the other, as far as we can, as to what we consider to be the best solution, other than that which is based on the facts.

The Secretary of the Interior, who has charge of the expenditure of the reclamation fund, has authorized, among other investigations in the West, a study of the Rio Grande in the same way that he has authorized the study of the Colorado and the Arkansas and the Platte and all the other great streams in the West, and we will report to him the facts, which we find, with such recommendations as may seem desirable. He has gone still further, I think, in official publications and intimated that both the Secretary of the Interior and the Secretary of State hope to see, through the expenditure of the reclamation fund, some solution possibly, about the question confronting us on the Rio Grande. The passage of that law, creating the funds which are available for construction put an entirely new basis upon the consideration of the Rio Grande, and many of us who may have formed opinions in the past, must of necessity recast them on the basis of the facts which have been carefully considered and brought out and given during the past season. These are engineering facts simply, they are based upon careful measurements made by Mr. W. W. Follett, who has devoted practically his life to the study of the Rio Grande, and worked up by him in connection with Mr. Hall, our supervising engineer for the Rio Grande district.

I now have the pleasure of introducing Mr. B. M. Hall, who will speak to you briefly on the subject of his studies of the Rio Grande. Many of the most important matters to be considered by Mr. Hall can only be made

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comprehensive by diagrams, and it will take a little time to display these. These are diagrams which can only be understood by careful personal examination; they are not of a nature to be displayed largely in a hall. I might say that this paper was prepared originally to be read at a small session of the engineers, where we could get together in a small body and see the diagrams, and we had no expectation of the popular interest in the matter until, we may say, this morning, when it seems that a large number of people wished to hear the reports and calculations of the engineers. Therefore the diagram which was prepared for our own personal and direct inspection may not be wholly intelligible, and we will ask those interested to see Mr. Hall later so that they may see them. We also have a large number of drawings, which can be inspected at any time, here or in Mr. Hall's office a short distance away.

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PAST AND PRESENT PLANS FOR IRRIGATION OF THE RIO GRANDE VALLEY.

B. M. HALL, Supervising Engineer U. S. Reclamation Service.

The Rio Grande rises in the State of Colorado, and flows south through the entire length of the Territory of New Mexico to the north boundary of Texas, near the town of Anthony. From this point "The Pass," about four miles above El Paso, Texas, it forms the boundary between New Mexico and Texas. At "The Pass" it becomes the boundary line between the United States and Mexico, and continues as such for about 1300 miles to the Gulf of Mexico.

So far as its history is known it has always been a torrential or storm-water stream, subject at times to great floods, and at other times to periods of minimum flow when its bed was dry, or carried an insignificant amount of water along certain parts of its course.

Above El Paso it has a length of about 900 miles, and a drainage area of about 38,000 square miles. In this section its ordinary flow, or what is known as its permanent water, comes almost entirely from a comparatively small area in Colorado and upper New Mexico, where there is a heavy snowfall in the mountains.

The country through which it flows is very fertile, but the rainfall is so meager and so erratic that it is an arid desert, and no crops can be raised without artificial irrigation.

EARLY IRRIGATION IN RIO GRANDE VALLEY.

Before the middle of the sixteenth century the Spaniards entered the valley of the Rio Grande in New Mexico, and there found the Pueblo Indians living in towns, cultivating the land, and bringing water onto it by irrigating ditches, many of which are still in use to this day. A Spanish colony was established at Chamita, New Mexico, in 1598, and at Santa Fe in 1605. The latter colony existed until 1680, when they were driven out by the Pueblo Indians. Spanish supremacy was again established in 1692. From that time to near the middle of the nineteenth century the Rio Grande Valley in New Mexico was under the dominion of Spain and Mexico, and was settled up by Spaniards and Mexicans, who irrigated and cultivated the lands. In the excellent report made by Mr. W. W. Follett in 1896 to the International Boundary Commission, he says: "While quite a large native population has come into the Rio Grande drainage in New Mexico since the construction of railroads in 1880, it is confined principally to the towns, and to-day fully 90 per cent of the irrigating in this section is done by Mexicans and Indians." In the same report Mr. Follett says: "The El Paso Valley was occupied by Spaniards over three hundred years ago. In the year 1600 El Paso del Norte (now called Juarez) was an important town, and records are in existence over two hundred and eighty years old which refer to the Acequia Madre of El Paso del Norte as being in use." In speaking of his investigations in El Paso Valley, Mr. Follett says: "From all I could learn, I should judge that in former years some 40,000 acres of land were tilled in this valley, more than half of which was on the Mexican side of the river."

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SCARCITY OF WATER.

During recent years there has been a great scarcity of water in the Rio Grande, in New Mexico and in the El Paso Valley of Texas and Mexico. The deficiency of flow at El Paso brought about a complaint from the Republic of Mexico. The question by a protocal, dated May 6, 1896, was referred to the International Boundary Commission for a full investigation and a report upon the following points:

1—The amount of water of the Rio Grande taken by irrigation canals in the United States of America.

2—The average amount of water in said river, year by year, before the construction of said irrigation canals, and since said construction.

3—The best and most feasible mode of so regulating the use of the waters of said river as to secure to each country concerned, and to its inhabitants, their legal and equitable rights and interests in said waters.

On November 25, 1896, this Commission, composed of Col. Anson Mills for the United States, and Señor Don F. Javier Osorno for the Republic of Mexico, having before them the full and complete report of Mr. W. W. Follett, United States Engineer for the Commission, reported as follows:

1—The increase in the acreage irrigated from the Rio Grande in the State of Colorado from the year 1880 to the year 1896 was 197,000 acres. The increase of acreage irrigated in New Mexico during the same years was 3000 acres, making a total of 200,000 acres.

2—The flow of the river at El Paso has been decreased about 200,000 acre feet of water per annum by the taking of water for irrigation by canals constructed in the United States of America; the great mass of these waters consisting of flood waters utterly unavailable for irrigation without large reservoirs.

3—As "the best and most feasible mode of regulating the use of water, and securing to each country and its inhabitants their legal and equitable rights in said waters," the Commission recommended that the United States government should buy all necessary land, pay all damages, and construct at its own expense an international dam at "The Pass," about four miles above El Paso; submerge 25,565 acres of good land in the United States with water; extend the Mexican boundary upstream to the dam site, giving Mexico 98 acres additional territory in order that one end of the dam may be on Mexican soil; deed one-half of the dam, the reservoir and the water supply to the Republic of Mexico, and in some way prevent the construction of any large reservoirs on the Rio Grande in the Territory of New Mexico.

The Commission estimated the cost of this project at $2,317,113.36.

As above mentioned, Mr. Follett estimates that about 40,000 acres of land had prior rights under the old canals in El Paso Valley, and was deprived of irrigation by the act of American citizens on the head waters; and that something more than one half of this 40,000 acres lay on the Mexican side of the river. As the restoring of these ancient water rights is the primary object of the proposed expediture of $2,317,113.36, the cost of the project would be $57.92 per acre. However, it will be shown further along in this paper that the proposed resevoir could be made to irrigate 55,000 acres

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in El Paso Valley, which would put the cost per acre at $42.12, provided the estimate of the Commission is a correct one. There is every reason for believing this estimate too low, but aside from the monetary cost per acre for the land to be irrigated, there is another item of cost to be considered. The reservoir would cover 25,565 acres of good valley land with mud and water, and would cause marshes to form in the low flat valley at the head of the lake amounting to perhaps 15,000 acres additional, making a total destruction of about 40,000 acres of land in Mesilla Valley, which is just as near to El Paso, and just as valuable as any of the land that would be irrigated.

WOULD HAVE LEFT NEW MEXICO OUT.

While the published report of the Commission and its engineers plainly sets forth the fact that increased irrigation in Colorado caused shortage of water in Mexico, Texas and New Mexico, their recommendations not only leave New Mexico out of all the benefits to be derived from a project inaugurated for the purpose of making up this shortage, but give part of her territory to Mexico; cover up another part of it by the proposed reservoir, and distinctly ask that the government shall prevent the construction of any other large reservoir on the Rio Grande in the territory of New Mexico. The only reasonable explanation of these extraordinary recommendations lies in the probable fact that the Commission had no alternative plan for consideration, and thought that the plan recommended was the only possible plan that could be adopted for restoring the water to which Mexico laid claim by virtue of ancient prior use. Indeed they were confronted at the time with the prospect of an Elephant Butte dam in New Mexico, not under government management, but to be constructed, owned and operated by a stock company of private capitalists, whose plans contemplated the construction of a comparatively low dam, without sufficient storage capacity for irrigating a large area above and having a surplus for Mexico. At that time the United States government had no Reclamation Service. Now that conditions have completely changed, and there is an alternative plan which claims to be able to accomplish just as much for Mexico, and a great deal more for the United States, it becomes necessary to compare these two plans, and choose between them.

The alternative plan, suggested by the U. S. Reclamation Service, is to build a storage dam opposite Engle, New Mexico, across the Rio Grande at a point about a quarter of a mile below the site selected by the old Elephant Butte Company, and a third of a mile below the Elephant Butte, which is a conical mountain peak rising abruptly from the river bank to a height of about 500 feet. At this site it is proposed to build a dam that will form a reservoir 175 feet deep at its lower end, and 40 miles long, with a storage capacity of two million acre feet, that will impound enough water to furnish 600,000 acre feet per annum, and irrigate one hundred and eighty thousand acres of land, distributed as follows:

110,000 acres in New Mexico.
20,000 acres in Texas above El Paso.
50,000 acres in El Paso Valley below El Paso.

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With the above brief statement of the U. S. Reclamation Service project we will proceed to compare it with the International Boundary Commission project, in a spirit of fairness, and with the object of arriving at the best solution of the question before us.

In considering these projects, or any other plan of water storage on the Rio Grande, it is well to keep in mind the following facts:

1st—While the floods on the river are enormous, they do not come with any regularity, and the total flow in some years is less than one-tenth of the total flow in other years.

2d—Any reservoir constructed on the river will stop all the silt that comes down the river in suspension. Hence a small reservoir will accumulate as many acre feet of mud per year as a large one until it is filled with mud.

3d—All of the water that comes down the river is needed for irrigation. We can not afford to waste any of it.

These three conditions make it imperative that the reservoir should be as large as possible, and as deep as possible; having a capacity for carrying a supply of water over from year to year to equalize the yearly inequalities, a surplus capacity for mud accumulations, and a surface for evaporation that is as small as possible in comparison with the quantity of water in storage.

Mr. Newell—The next short discussion or presentation of facts on this subject will be by Professor Schlicter. He has made a very careful and thorough study of the question of the underflow in and about this city. This investigation was made for the purpose of setting at rest the questions which come up at all times as to how large a quantity and the quality of the water which is believed to be moving beneath the surface of the ground in the apparently dry river channel. Professor Schlicter has during the past few years developed and put to practical use very ingenious devices for measuring the rate of movement of water under ground, and he has been able to demonstrate the fact, which we before suspected, that the waters are moving underground in these apparently dry river channels, but that they are moving very slowly in many places. The quantity is restricted and the quality varies very much from that of pure water. Professor Schlicter has made these investigations for the purpose of furnishing material for comparison, and will give us briefly the results of his examination.

RIO GRANDE VALLEY UNDERFLOW.

Professor Schlicter—Ladies and Gentlemen: I had the very great pleasure this summer of co-operating with Mr. Hall in one or two of the secondary problems connected with his very difficult investigations upon the Rio Grande project. I will report in a very few words upon the investigation of the underflow in the pass above the city. The point selected for this investigation was the exact line of the proposed international dam. Accepting the Mexican borings at this point as correct the greatest depth to bed rock here at this point is eighty-six feet, and the total width of the sands at the level of the channel of the river is less than four hundred feet. The first point that we investigated was the determination of the slope of the water through the

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pass. We found by running the levels that the average slope of the water at this point in the river was considerably less than four feet to the mile, being no greater than three and six-tenths feet to the mile. This first part of the investigation was very discouraging, for we expected to find a very large flow of water through the gravels, as the flow of water through gravels is controlled by the head under which it flows, as well as the flow of water through pipes or through streams themselves. We began the investigations by making borings to various depths, and we found that at this point the sands were very uniform. There was an absence of boulders and of broken rocks; finding only occasionally layers of silt. The sand might be described as a large-sized cement sand or planter sand, quite free from silt except in occasional layers. The layers of silt increased as depth was penetrated until they became quite numerous at greater depths. The velocity of the ground waters through this pass was found to be exceedingly moderate, as might have been anticipated from the slight slope which the water possessed. The velocity in no case exceeded three feet in twenty-four hours, the lowest being a little more than two and a half feet in twenty-four hours, and I should say it is slightly less.

SALINITY OF UNDERFLOW.

But one surprising feature that developed in these investigations was the increasing saltiness of the water as the depth penetrated increased. The amount of common salt in the water at ten feet is about one hundred parts in one hundred thousand, but this continued to increase with every foot of depth, but quite slowly, and at a depth of between thirty-five and forty feet the amount of common salt took a sudden jump and increased enormously, so that at a depth of sixty feet the amount of common salt in the water was found to be about two per cent, or two pounds of common salt to one hundred pounds of water. Not only did the common salt increase, but the alkalies and other salts in the water showed an even greater tendency to increase. These, at a depth of between thirty-five and forty feet suddenly increased and seemed to increase almost indefinitely, until at a depth of fifty feet the total salts in the water were found to be just short of five per cent, or about one pound of salts to three gallons of water, which is considerably stronger—not quite twice as strong as the water of the ocean. An estimate can be made from the cross section of the gorge as to the amount of underflow, the amount of water that passes through the gorge. Before passing to that I will say that it is of course very difficult to measure the rate of movement of these very strong waters, but at a depth of forty-two feet the apparatus worked very well, and we waited many days in our tests, and we found that at that depth the motion of the water had ceased altogether, which corresponds, of course, with the sudden change of the character of the water, where the water was found to suddenly increase and the amount of salts dissolved in it, that was the place where the motion of the water ceased altogether. So, taking the cross section of the gorge, and assuming that I am mistaken in regard to the lack of movement of the water at great depths, the total amount of water flowing through the gorge is less than one and one-half second feet, or taking the area in which we know the water moves, and

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accepting as a fact the area in which we know it does not, the total amount of water flowing through the gorge is one and one-tenth second feet, barely sufficient to irrigate, I suppose, from sixty to seventy acres of land.

SOURCE OF SUPPLY MESILLA WELLS.

I will not take up your time with any further matters except one point I observed in the Mesilla Valley, near Mesilla Park and Las Cruces, where we succeeded in measuring the amount of water lost by the river and contributed to the gravels. As the results of the investigation at that point, I think we have established that the source of the water that is used by the pumping plants is the river itself; that the origin of the ground waters, or the supply of ground waters which are used by the pumping plant, is the water contributed by the river itself or lost by the river. A number of test wells were put in places and observations were made upon these about every week by Professor Tinsley of the Agricultural College, who extended the observations through the time of the heavy floods. We found that before the flood, or during the very low stage of the river, the river was contributing a very small amount of water to the gravels, but at the time of the flood and silt that is deposited on the bottom of the channel is scoured out by the heavy flood, and during that period the river loses for each mile of its channel seven and one-half second feet of water; that is the maximum contribution of the river during the floods for each mile of its channel it loses seven and one-half second feet. For the entire five weeks of these observations the loss of the river to the gravels was an average of a continuous flow of three second feet for each mile of the river.

These cover, I think, sufficient points that directly bear upon the proposed dams and storage reservoirs.

Question asked of Mr. Schlicter—For the benefit of myself as well as others more deeply interested in this matter, Mr. Hall in his table there shows that the overflow in the Elephant Butte dam will be nothing. Now, the first question that I want to ask is this: If there will be no overflow in the Elephant Butte dam, naturally the Elephant Butte dam would catch and retain all of the water, and I therefore want to ask, the first question, would there then be any river at El Paso?

Mr. Schlicter—It seems to me that that question is not directed exactly at the right person. I understand that the water is to be allowed to flow down the channel of the river, and that the diversion dams will take it out, although this is a question that does not belong to me.

Question—Well, that question probably does not pertain to your discussion, the next question that I want to ask probably will; and that is, if there is no overflow from the Elephant Butte dam, and we obtain the water for our pumping plants from the river, will not these pumping plants exhaust the water below and the pumping plants cease to exist?

Mr. Schlicter—Very likely that would be the case. If the source of supply is cut off and you continue to pump, there must be a depletion of the stored waters, which occurs at the present time during every irrigation season. Water levels are very greatly lowered by pumping plants.

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Question—As I understand it, you propose to bring that water down the river channel, is that true, Mr. Hall?

Mr. Hall—The water that you get now in the river, that is underneath the river bed and in the valley lands comes from the rains on the high lands and from floods down the river, and from the water that is flowing in the river at certain periods. The under gravel gets saturated. We estimate that when we get in that storage dam, that instead of injuring that condition we will better it. You will still get all of the rainfall that comes below the dam; of course you will have the floods originated below the dam—they will not be disastrous floods—but you will at all times have a wet river bed and considerable water flowing in it, while at present you have a river bed that is dry for five months—and longer this year—and I suppose the conditions ought to be better because of the percolation from the river bed more or less and there is always a flow from the rain-fall on the mesa.

Mr. J. L. Rhead—I just want to mention a fact, that I believe one point has been lost sight of, that is the fact that the water stored in the Elephant Butte reservoir would be distributed over the lands of the valley, and the pumping plants would be thereby benefitted in place of being injured. In place of being fed by the water of the river they will be fed by the distribution of the water over the lands.

Question—I should like to ask a question, Mr. Hall. Your table shows that the flow at the upper location—at Elephant Butte, is greatly in excess of the flow of the river at this lower point. Professor Schlicter's discussion gave us to understand that the sub flow at any point in the river was very small comparatively. I should like to ask as a matter of information what becomes of the water which flows at the upper point, and not at the lower, if it does not become sub flow?

Mr. Hall—We have not followed that up; we expect to find that out; all we know is that it was true.

Mr. Hoffmann—You will probably have to "go below" to find it out, Mr. Hall?

Question by Congressman Stevens, of Texas—I started to ask Mr. Hall this question: I believe you reported that fifty thousand acres shall be irrigated below the city of El Paso. You do not state whether they shall be equally divided between the State of Texas and Territory of New Mexico, or make any recommendation.

Mr. Hall—I thought it was best for us as engineers to leave that to you, gentlemen.

Mr. Stevens—As a rule of law, as well as common sense, the party getting up a document—a legislative body or court—should construe it and not leave it to other parties who do not know what their intention is.

Mr. Hall—I made a calculation in the paper which I did not have time to read. The opinion that I had upon the question was that it would be better for the State Department and the Congress of the United States to settle that question. We have troubles enough of our own.

Mr. Stevens—I desire to ask another question: I find a statement, Mr. Hall, in your report, to the effect that the Water Boundary Commission pro-

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vided, in a bill I presume, or in a report, that no reservoir should be built at any point in New Mexico.

Mr. Hall—That was given the preference in their recommendation. They did, however, give an alternative, which I did not mention. It was their expressed desire that no dam be allowed to be made on the river above, but if that could not be prevented, then they give an alternative.

Question—The language in the report that I desire to draw your attention to is this: In the first part, speaking of the Water Boundary Commission, you say that they distinctly ask that the Government prevent the construction of any other large reservoir on the Rio Grande in the Territory of New Mexico. Now the bill, which was formulated by that committee, and that satisfied both the United States and Mexico, and was recommended by this Commission, which you seem to in some measure criticise, is this: it is a bill to provide for the equitable distribution of the water of the Rio Grande between the United States of America and the Republic of Mexico. The second object is for the purpose of building an international dam and reservoir on the said river at El Paso, Texas. Now, the misconstruction, as I understand it, is this: You stated it was the object and purpose of this Commission to prevent the building of any other dams above here in New Mexico? The bill states this distinctly, the first section of the bill. "Be it enacted by the Senate and Congress of the United States of America that nothing of the Acts of March 3d, 1891, shall be so construed as to authorize an appropriation and storage of the waters of the Rio Grande in the Territory of New Mexico, to which others have right by prior appropriation." Now that has been left out in the calculations in the newspaper statements and in the criticisms of myself and other men who have advocated the building of this international dam from the beginning, and my object in arising here is to defend ourselves against the statements published in New Mexico and advocated in Congress. We have never asked or sought to prevent the building of dams in New Mexico, and all we ask now is, that the water that has heretofore been appropriated by this valley and Mexico shall be continued to be appropriated by us.

Mr. Hall—I will state that I made no criticism upon Congress nor any bill that has been introduced in Congress. I simply wished to show by that statement the recommendation of that Commission, and I quoted the language of that recommendation as to their preference. They stated that the Government should be asked to prohibit the building of any dam in New Mexico if possible, but if they could not do it, to do something else.

Delegate from California—It seems to me that Mr. Hall has answered in his paper the question raised by Mr. Stevens to a great extent by saying that the building of one large reservoir would be much better than the building of small ones, several, one above the other, owing to the silt question.

Hon. B. S. Rodey, Congressman from New Mexico—On behalf of New Mexico I desire to state now, that notwithstanding this report and this agreement, that the remaining portion of New Mexico does not waive any of its rights in reference to building dams, nor any of its claims to have dams built up at a later date. Myself and Brother Stevens have for the past six years fought this out in Congress and I hope it is to be settled here to-day.

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Mr. Stevens—I am glad to know that Mr. Rodey has the common sense to recognize the fact that we do not want all the water of the river in the international dam, but that we are willing to divide with New Mexico, but that we do want the water that we have had the right to appropriate heretofore. (Applause).

Mr. Rodey—We have been scared to death for about ten years by Brother Stevens. I believe the whole matter can be settled now, but we never have given up our rights to the waters that fall in our dishpan. We are good citizens and are liberal, but we don't give up the waters we need.

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Thursday Afternoon, November 17, 1904.

The meeting was called to order at 1:30 p. m., Chairman Newell presiding.

Mr. Newell—Our program calls for a paper by Mr. Thomas H. Means, Engineer of the Reclamation Service, on "The Necessity of Draining Irrigated Lands."

Mr. Means—I have not attempted to prepare a paper on this subject, but have gotten together a few ideas on the necessity of draining from the standpoint of the growing plant in the hopes that some discussion would be provoked and bring out a great many more thoughts, perhaps, than I could by a more lengthy paper.

Most of the agricultural plants which we use now are the result of thousands of years of selection and development. They are almost without exception plants that are adapted to growing in moist soils, but not wet soils or in standing water. A few of our plants, as rice, are adapted to growing in water, but we can say that generally our agricultural plants cannot grow in standing water. The roots of these plants require two things for their proper development. The first and foremost is water; the second is air, and if we exclude either of these from the roots they will not develop as they should. Most of us do not consider that air is essential to the growth of the roots of plants, but you might almost as well cover a plant to its top with water as to cover the roots entirely with water and exclude the air from them. We have aside from the roots, a number of friendly bacteria in the soil and all of them require moisture and air for their proper development. One of the most useful families of plants, the legumes, have a faculty of obtaining from the atmosphere through the activity of bacteria, the nitrogen necessary for their development, and leave nitrogen in the soil. This nitrogen is obtained through the myriads of nitrogen bacteria in the soil, and these bacteria can not exist there in the absence of moisture and air and perform their proper functions. Where air is excluded and moisture is in excess a different set of bacteria or denitrifying organisms seem to flourish and undo the good accomplished and turn loose their nitrogen. So for the benefit of the plants themselves as well as the bacteria we must have both air and water. However, every drop of excess moisture in undrained soil is damaging to the plants growing in the soil. Undrained soil not only prevents the proper growth of the roots, but is usually cold from the fact that there is a greater evaporation on the surface. The cold soil naturally prevents the development of the roots and the development of plants from the roots.

We also have certain chemical changes which take place in undrained soil. In the arid country the development of alkali takes place. This sometimes occurs in the soil as a result of decomposition, but I have known a great many instances where it has developed from the fact that the soil was not drained. You will notice in districts where black alkali occurs around the edge of the plants there will be a black ring of sodium carbonate, resulting from the undrained condition of the soil. In the eastern regions sour soils develop in undrained fields. The same thing is also seen in the West, though western

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soils usually contain a large excess of carbonate of lime, which has a tendency to prevent the formation of acid.

IMPORTANCE OF DRAINAGE.

The most important feature in connection with undrained soils in the West is the development of alkali. We have in all of the soils and rocks a certain amount of soluble matter, either present as such or forming by the processes of rock decomposition. This accumulates at the point where the water evaporates and leaves all the alkali there at the surface where it can do the most harm. The development of alkali is a most serious problem confronting the irrigation farmer because it prevents crop growth. Drainage, applied either artificially or existing naturally, prevents these conditions from occurring or if they exist, greatly aids in reclamation by removal of the alkali. We know it is possible by drainage to reclaim alkali lands and to improve the soil and allow the friendly bacteria to develop and grow, and that it is possible by this means to obtain the nitrogen from the atmosphere which is useful to the crops that produce it and the following crops.

Drainage also prevents the formation of black alkali. There have been seen some marked cases of this, where the simple drainage of the land has prevented, or, as one might say, neutralized the black alkali, and the last but not least effect is that drainage warms the soil. These are some of the points we want to consider from an agricultural standpoint. They appeal to the engineer because he is trying to irrigate lands for the use of the agriculturalist. A great many points I might bring up, but I think they can better be brought up by some discussion.

Mr. Newell—The remarks of Mr. Means are now before you on the necessity of draining irrigated lands. That matter which Mr. Means has discussed briefly and so well is one of the most important in the work of the irrigation engineer, that is, to provide drainage or consider the necessity for drainage at the same time he considers the necessity for irrigation. We have all seen the ruin and blasted hopes due to the lack of provision for drainage and the destruction by alkali closing up the pores of the soil. There are a number present who probably know something about that, and I would like to hear from Professor Forbes, who has done such good work in Arizona.

THE DATE PALM A WATER FEEDER.

Prof. Forbes, of Arizona—I might cite an exception to Mr. Means' rule that all soils must be drained, of which he has given one exception—the case of rice. I will give another. I have just returned from a trip into Lower California, where I went largely for the purpose of hunting up a plantation of date palms I had heard of down there. Among other conditions I have found in that oasis, I found great numbers of date palms, thousands of them ranging up to 200 years in age, growing in a water-logged soil and bearing fruit. My companion and I dug some 18 wells from one end of the water-logged strip to the other, ranging in depth from two to ten feet, and found that water came all the way from one foot to within two inches of the surface of the soil, and in that sub-aqueous strata we found the ground matted with date

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palm roots. That is interesting as it shows that water-logged soils have their uses and their utilities. It is possible that in regions like the Colorado River where there will probably be undrained lagoons for many years their utilization may be brought about.

Mr. Newell—That is an exceedingly interesting matter, as in some parts of the country it will be practically impossible to drain lands because of the fact that they are beneath the general level of the water. The whole subject of drainage is one that is impressing itself upon us more and more. The Reclamation Act provides for the control of water to reclaim the land, but we have rather read into the law that it includes drainage, which is involved in the reclamation of a great deal of the better land we have to deal with.

Mr. Barbour, of California—For two years I was employed to construct canals and lay off lands for irrigation. The lands were laid off first from the main canal by running contour checks, starting from the main canal and running contours, dropping down from each check from 3/31 to 4/10 from one to the other. After the checking had been done, we put in a system of irrigating ditches from the main canal, and between the irrigating ditches we had drainage ditches, which we carried down to sloughs or else made other ditches to carry off the surplus water and take it back into the main canal again lower down, and in that way we drained off a great deal of land where there were spots of both black and white alkali. There were spots there which at first would not grow vegetation but in two or three years it produced in abundance grain and alfalfa.

AN INTERESTING EXPERIMENT.

In talking with Mr. Miller one day he gave an instance of an experiment he had made. On the San Joaquin River he had about ten thousand acres of alkali land that would produce nothing. He had heard of the government's experiments in draining the alkali out. He built a large canal through the center of the tract and on either side of the canal was a slough. He built irrigation ditches from that canal in both directions. He carried these ditches out a certain distance so that they would not come quite to the slough and then built drainage ditches between the irrigating ditches to carry the water off to the slough. He irrigated the land and as soon as it was dry enough plowed it up, let it lay about two months, irrigated again and plowed it up again. He then let it lay until the next spring, when he irrigated again and plowed it up again. He let it lay again for about two months and repeated the process. The third season he put in wheat on the alkali land and got the largest crop that he ever raised anywhere. The fourth year he put it into barley and the fifth year into alfalfa, and said that it was the best alfalfa that he had on any of his ranches. Now this was land that would not grow any kind of vegetation. It was perfectly waste. Not only that, but he reclaimed about 3000 acres of that lake bed by running this alkali into the sand of the lake bed. As a matter of fact he reclaimed about thirteen thousand acres of land by that experiment. He said he got his first idea of reclaiming this land from reading of Government experiments.

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Mr. Newell—We have a paper, as the next number on the program, by Mr. Fellows, on "Estimate on Tunnel Work."

Mr. Fellows—I wish to state that what I have to say with regard to estimates on tunnel work will be limited to irrigation work only, as that class of tunnel work would necessarily be considered by itself to a certain extent. At the same time, the rules applicable to one form of tunnel must necessarily apply to the others also. What I have written must be considered as general as well as relating more particularly to the irrigation work.

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ESTIMATES ON TUNNELING IN IRRIGATION PROJECTS.

A. L. FELLOWS, District Engineer U. S. Reclamation Service.

I first became intimately concerned with tunnel construction about eighteen years ago, in connection with an irrigation project in Southwestern Colorado. In this project, the lands to be reclaimed were separated from the river which was expected to furnish water for their irrigation, by a divide rising to an elevtion of several hundred feet above the river bed. The tunnel forming part of the irrigation system as constructed, was 5400 feet in length, with a cross section of 7x9 feet. My connection with this project was that of Assistant Engineer, and there I learned principally what *not* to do.

As is common with corporate enterprises, the amount of money available was decidedly limited, and it was generally considered that money that could be saved in surveying was economy for the project. As a matter of fact, in this particular case I have estimated that three-fourths of the actual cost of the project would have been saved by careful and thorough engineering.

The tunnel was constructed of considerably greater length than was necessary and was left unlined, in spite of the protest of the Assistant Engineer, on the theory that it was more economical to give it a heavy grade and to leave the tunnel unprotected, than to construct lining that might serve as protection.

RESULT OF FALSE ECONOMY.

This tunnel may today serve as a typical, horrible example. The roof has caved in until there are, in places, rooms of from 16 to 30 feet in height. The finer material has been washed out to some extent, but the bulk of the material broken down from the roof is left as a menace to the maintenance of the tunnel and an impediment to the flow of the water. It would cost more to-day to put this tunnel in good repair than to construct a new one. I cite these conditions simply as instances of things to be avoided in tunneling, or, in fact, any other kind of engineering work.

My attention was first drawn to the Uncompahgre Valley Project, of which the Gunnison Tunnel is an integral party, by its similarity to the project which I have just instanced, and in its examination every effort was made to avoid the mistake that had been made in the first project.

The importance of thorough surveying, with reference to any class of engineering, cannot be over-estimated, and this importance is particularly well illustrated in the survey of the Gunnison Tunnel Project which I am now discussing. As a matter of fact, mistakes did creep into the early part of the work, and had the project been constructed as at first contemplated and as the earlier surveys seemed to indicate was the proper method, it would have been done at an increased cost of several hundred thousand dollars. In my opinion it is safe to say that surveys amounting, at the outside, to not over $8,000 in cost effected a saving of not less than $200,000 in construction. This refers to the construction of the tunnel alone, and not in any way to the increased efficiency of the project as a whole, with reference to which it is estimated that the cost has also been lessened by at least another $100,000, and perhaps by twice that sum, through the change.

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FACTORS CONSIDERED.

The best location for a tunnel having been decided upon in a general way, the details must be worked out with the greatest of care. The amount of water to be carried, the amount of fall available, the best alignment for the tunnel, from both topographic and geological standpoints, the cross section, co-efficients of friction and velocity of flow, are all to be determined as exactly as possible.

The alignment may depend upon a variety of both topographic and geologic conditions. The shortest line may be the best, but it may also be affected by the character of the formation to such an extent that a longer line through better formation may be preferable. It is true that one cannot tell what conditions he may meet with in a long tunnel, but, with reasonable care, the probabilities may be ascertained and many uncertainties done away with, at least withinn reasonable limits.

At first thought, it would seem that the natural location for a tunnel was always where the line was the shortest, but the very causes which have made such a location the shortest line may also be of such a character as to prevent easy construction and possibly provide contingencies which will very materially increase the cost of construction. A saddle between hills often owes its existence to the fact that the erosion which has taken place has been caused by the softness of the rocks at that particular point, or possibly to the fact that there is a fissure at this location which has rendered erosion easy, but tunneling difficult.

The grade to be given the tunnel, as is the case in the grading of canals, syphons, etc., will depend upon the conditions. If there is sufficient flow available, the tunnel should be given enough grade to carry the amount of water desired at the maximum velocity that will not erode the tunnel lining, this being, of course, for the purpose of decreasing the cross section to as great an extent as possible.

The co-efficients of friction depend upon the surface of the tunnel, and will range from 0.010 to 0.012 for smooth concrete, up to 0.030 to 0.035 for the ordinary rough rock walls in machine-bored tunnels.

The velocity is dependent upon the grade which can be given. In my plans, I have assumed that the lining can withstand a velocity of approximately 12½ feet per second, without injury. This high velocity would not be possible if it were expected that the water to be conveyed through the tunnel would carry a great amount of silt, but, in the project which I am now considering, the amount of silt carried is usually inconsiderable.

Assuming that the location of the tunnel has been made with the necessary care, we are ready to make an estimate of the cost of construction. In the course of my investigations with regard to this subject, I have compiled considerable data concerning the cost of construction of tunnels in different localities, much of which, however, I regret to state I am unable to incorporate in this paper, as it was given to me confidentially and is, therefore, not to be disclosed. It is sufficient to say, in this connection, that the cost per cubic yard of material to be removed may vary from a very small sum, amounting

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to perhaps not more than $2, up to almost any figure. My suggestions with regard to estimates can be, therefore, only general, the details necessarily being worked out separately for each individual project.

MAKING ESTIMATES.

The kind of estimate to be made will depend very largely upon the stage of investigations. For example, in the earlier stages, when general knowledge only as to cost of construction is desired, it is quite common to accept figures concerning cost shown by actual construction under as nearly similar conditions as possible in the region in which the project is located. This estimate may be based either upon the cubic yard or linear foot. I have found no very clearly defined idea as to the proper cost per cubic yard in making estimates. Some authorities state that $5 per cubic yard in long tunnels is the time-honored basis for estimate; others state that $6 is more nearly correct; and still other figures are given by other authorities.

Probably the more usual practice is to determine as nearly as possible the cost of similar structures in the vicinity; for example, in the preliminary investigation with reference to the Gunnison Tunnel, I found that tunnels of about the same size and in conditions apparently more unfavorable than those surrounding the construction of the Gunnison Tunnel, had cost, for excavation alone, from $20 to $30 per linear foot. In the two tunnels most nearly like the proposed Gunnison Tunnel, of which I have knowledge, the proprietors, who had done the construction work themselves, without the intervention of contractors, informed me that while the excavation had cost them somewhat more than $20 per linear foot, they were certain that under as favorable conditions as they knew to exist with reference to the proposed Gunnison Tunnel, $20 per linear foot would be ample. Later investigations have demonstrated to my satisfaction that these estimates were not too high, but in general, those made in this way can be considered as approximate only.

As investigations proceed more nearly to completion and final estimates, before letting contracts, are desired, it becomes necessary to consider the probable cost much more in detail, and then the only proper way of making an estimate, in my opinion, is on the basis of a contractor's bid. Plans must be drawn, showing the different varieties of cross section to be used, with the amount of lining necessary for different degrees of hardness of the geologic formation, and the probabilities with reference to the finding of water in great or small amounts, must be determined. In the specifications for the Gunnison Tunnel, an effort was made to do away with all uncertainties, so far as the water to be encountered was concerned, by incorporating proposals with reference to the amount of water to be pumped, thus putting the burden directly upon the government, and not upon the contractor and thence indirectly to the government.

DETAILS TO BE WORKED OUT.

The first details to be worked out with care are those relating to the furnishing of power for construction. A water power, if available, may often be preferred to power derived from the use of coal or oil, unless these are extremely low in cost. This subject has been most ably treated by Mr. H. A.

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Storrs in his valuable paper, and need not be gone into at this time. I desire to say, however, that in general I am sure that the Government would save money by constructing the power plant itself, instead of leaving this for the contractor to do. It would lose nothing thereby, as the cost of establishing a power plant is well known among contractors, and they would almost invariably allow for the cost of such a plant, with probably some additional allowance, if they were satisfied that sufficient power would be furnished.

In the matter of the establishment of a water power plant, a number of instances which have come under my observation have led me to believe that the saving to the contracting party may be several times the cost of the power plant; in other words, the contracting party is practically losing nothing and may have considerable to gain by itself establishing the power plant. In making the estimate, the cost of depreciation upon the plant must, as has been shown by Mr. Storrs, depend upon whether the plant will be entirely used in the construction of this individual project, or whether there will be considerable salvage. In most cases there should be a salvage of from one-half to one-third of the original cost of a new plant. This has an important bearing upon the estimates, as the cost of the plant is a very considerable proportion of the entire cost of construction. Estimates with reference to the cost of a power plant may generally be determined with reasonable accuracy through the aid of the engineering supply companies, which are always glad to furnish preliminary estimates.

THE LABOR PROBLEM.

The next item to be considered in detail, is that of labor, and here, too, conditions will vary widely in different localities. It is usual for contractors, in making their estimates, to determine the cost of operation per day as the first step, the amounts paid for labor being different in different localities. In estimates for a 12x12 tunnel which I have in my possession, I find the following items in computing the cost of excavations at one heading for one day, the number of employes varying with the number of shifts:

Compressor engineers	2 to 3.
Compressor firemen	2 to 3.
General foreman	1.
Shift foremen	2 to 3.
Time-keeper	1 or 2.
Machinist	1 or 2.
Blacksmiths	2 to 3.
Drillers	8 to 12.
Helpers	8 to 12.
Muckers	14 to 21.
Trackmen	2 to 3.
Dump men	2 to 3.
Light men	2 to 3.
Nippers	2 to 3.
Stable men	2 to 3.
Pump men	2 to 3.

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4-horse teams	1 or 2.
2-horse teams	1 or 2.
Locomotive engineers	4 to 6.
Brakemen	4 to 6.

To these are to be added the cost, varying in the different localities, as before stated, for fuel, water, power, oil, repairs, carbons, depreciation of plant, insurance on men, pumping water, bond and incidentals not otherwise accounted for, the last item amounting usually to about 10 per cent. of the total cost.

The estimates made by the contractors will probably not vary very widely, generally, as to cost per day. The crucial question is as to the amount of work that can be done in one day. For example, in two bids in my possession, the contractor who made the higher estimate of cost per day, has assumed that he could do not to exceed 12 feet of work at each heading per day; while the other makes his estimate on the assumption that he can complete, on an average, 18 feet per day in each heading, this decreasing the cost per linear foot in the second case very considerably.

LINING.

The lining will naturally depend upon many different conditions. In some localities where material for making brick is at hand, it may be thought best to line the tunnel with brick. In others, where construction is intended to be temporary only, the lining may be of timber, with a board surface to facilitate the flow of the water. In the project under consideration, it was decided that concrete should be used, and in making the estimates with this end in view, the following items were taken into account, the cost of a cubic yard of material in place being computed: Labor, crushing stone or transportation of gravel, or both, as the case may be, sand, forms, placing forms, cleaning bottom of tunnel, drayage, cement sheds and depreciation on equipment. To the sum of these items should be added also the cost of cement, although where, as in this case, the cement is furnished by the United States Government, its cost will not be included in the contractor's estimate.

TIMBER.

The amount of lumber used per linear foot may be easily computed and is to be added where timbering is necessary.

The summing up of the various items enumerated above, reduced, according to the best judgment of the engineer, into cost per linear foot for different classes of work, will give his estimate of the actual cost of construction. Where it is expected that bids will be asked, however, a profit to the contractor must be added. Few contractors will estimate on less than 20 per cent. profit, and ordinarily 25 per cent. will be accepted as a reasonable basis.

It is not expected that in a general discussion upon such a subject as this, it would be possible to cover all conditions that may arise. Only general rules can be laid down and all details must be worked out separately for each individual project. Where the plan outlined above is followed, however, it will, in general, give a close approximate idea of what should reasonably be

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expected as bids by contractors. The engineer must use his best judgment in making these estimates and endeavor to cover all details. Difficulties of an accidental nature that may arise should not be included, excepting in the insurance and contingencies as above provided for. The contractor may perhaps make an additional allowance for unforseen emergencies, but the fact is generally recognized that although a contractor may possibly make his estimates on the worst possible conditions, the contracting party may do the work himself and thus avoid the extreme conditions on which the contractor's basis is estimated.

In conclusion, I desire to deprecate a too common tendency to over-estimate. It appears to me to be as much of an error to over-estimate as it is to under-estimate cost, and while reasonable allowance for contingencies should be made, it is not, in my opinion, good engineering to make an additional allowance after the allowance for contingencies has once been made. I have known of instances where estimates had to pass through several different hands and each individual felt it incumbent upon him, even after expressing himself as satisfied with the details, to add some lump sum for unexpected emergencies "so as to be on the safe side." I appreciate the fact that engineers are often criticised for under-estimating, and I deprecate this fault as fully as any one can, but the point which I desire to make is that after the engineer has stated what, in his opinion, is the proper estimate, that amount should be adhered to and neither added to nor subtracted from, unless some good reason for the change is shown.

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Forestry Section.

CHAIRMAN: GIFFORD PINCHOT,
Chief Forester Bureau of Forestry U. S. Department of Agriculture.

The first paper presented was by Prof. George L. Clothier.

FOREST PLANTING AND FARM MANAGEMENT IN THE MIDDLE WEST.

GEORGE L. CLOTHIER, Assistant Forest Inspector U. S. Bureau of Forestry.

Since the first settlement of the treeless prairies of the Middle West, forest planting has been practiced by the farmers of the region with more or less success. In no other part of our country has tree planting been so universal, because climatic conditions have forced farmers to plant for protection. Not only has the tree planting idea taken hold of farmers, but every city in the region that takes any pride in its appearance has planted shade trees in such abundance that towns located on a bald prairie thirty years ago now seem to be buried in a forest.

Although forest planting has been popular in the prairies, it is very seldom that one finds a farm forest plantation that was wisely conceived or that was planned with reference to the benefits which the remainder of the farm might receive from its presence. Throughout this region, the best development of the country requires that the soil moisture be conserved during the long summer drought which is a recognized feature of the climate. It is a well known law of physics that air in motion has a very much greater power of evaporation than still air. Anything that will retard the movement of the air currents near the surface of the ground will reduce the rate of evaporation from the soil in proportion to the retarding effect. For this reason windbreaks have a powerful influence in reducing evaporation and consequently in the conservation of the soil moisture. Forest trees make the most efficient windbreaks, because of their height and flexible yielding character which causes them to act as a cushion to lift the air currents and keep them at a considerable distance above the ground.

Professor F. H. King, found by experiment that a windbreak reduced the evaporation for a distance in front of it equivalent to more than 16 times its height. Twenty feet from the hedge on the protected side, the evaporation was only 60 per cent as great as three hundred feet away where the influence of the windbreak was not felt.

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LOCATION OF THE FOREST PLANTATION.

No prairie farm is complete without its forest plantation, but since a forest is the most permanent thing that can be planted on a farm its location should be chosen with great care. The forest should be so placed as not to interfere with the convenient division of the farm into fields. Where the windbreak effect is the most important advantage sought, it will generally be found advisable so to distribute the forest plantations in belts on the borders of the fields as to afford protection to the whole farm. A good plan is to plant strips five rods wide on the windward side of the farm, as for instance, on the South and West, and single lines of trees every 30 rods apart, crossing the farm as nearly as possible at right angles to the path of the destructive winds. The single lines of trees will serve as boundaries to the permanent fields and may be used as living fence posts upon which to fasten wire fencing.

Good farm management requires that the farming be conducted in accordance with a system of crop rotation. A scientific crop rotation is dependent upon the number and size of the fields in the farm to which it applies. The permanent subdivision of the farm into fields, where windbreaks are essential, is determined by the forest planting, hence the inauguration of any scientific system of crop rotation on a prairie farm should be preceded by a planting plan definitely locating the forest plantations.

UTILITY OF FOREST.

Forests are useful to man in two distinct ways, namely, the direct and the indirect. The direct usefulness of a forest is dependent upon the production of useful articles, such as lumber, poles, ties, fuel, tan-bark, nuts, turpentine, resin, etc. The direct effect of forest growth is the one usually seen and appreciated first by man. The indirect value of forests depends upon their power to modify climate, conserve the soil moisture, protect from disagreeable and destructive winds, prevent soil erosion, and to beautify the land, making it more desirable as a home for the human race. The people who settled in the great prairies of the Middle West were the first citizens of our country to discover that forest trees may have an indirect value that far outweighs their direct value. It took the conditions of treeless Nebraska to bring about the observance of Arbor Day. The drouths in Southern California are rapidly teaching the people of that region the value of forest as sources of water supply for irrigation.

PLANTING STILL NEEDED.

Even in the States of Kansas and Nebraska where forest planting has been extremely popular, the planted area in comparison with the total area of the country is but an insignificant fraction, being but a little over one-third of one per cent, or one acre in two hundred and seventy-five.

The origin of all hot winds in the prairie States is local, and they can be controlled by local devices if all the people of a region will co-operate for this purpose. The remedy is tree planting in sufficient quantity that the green leaves will keep the air cool. No one ever experienced a hot wind blowing from the green foliage of a forest.

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The destructive drouth of 1901 shows the need of more trees in the Middle West. In 1901 the hot winds began to blow early in June in the prairies of Texas, having originated on the stubble fields of the early harvested grain crops. As they increased in intensity they killed the corn and dried up the prairie grasses, thus forming conditions for increasing the radiation and consequently increasing the heat of the air. The belt of country devastated gradually extended northeastward, the hot winds following in the wake of the wheat harvest, until the first of August, when the wind was so hot in the James River valley in central South Dakota that the green corn was dried up in 48 hours so that it would burn like dead prairie grass. Of course the precipitation during this period was light, but after the conditions of dead vegetation were once established it would have taken a soaking rain every two or three days to have prevented hot winds. While the corn was drying up, the leaves of the few trees which the region contains were still green. As one neared the forests of the Ozark Mountains and the fringes of timber along the streams in eastern Kansas, eastern Nebraska, Iowa and Missouri, the destruction to crops was much less than in the prairies farther west although the drouth in parts of Missouri that season was even more intense than in the plains of Texas and Kansas.

VAST DIRECT VALUE OF PLANTED FORESTS.

Not only is forest planting at the basis of farm management in the prairie States because of the indirect effects of forest trees, but the importance of forest products to this treeless region is so great that planting for the growth of timber is highly practicable. The fence problem has been only temporarily solved by the use of the make-shift barbed wire fence. In Kansas there is no doubt but that barbed wire fences have killed and injured enough stock during the past 25 years to pay for replacing of the barbed wire with smooth woven wire. The difficulty with a woven wire fence, however, is that to be a permanent effective fence it must be supported by two or three times as many posts as is necessary with barbed wire. The scarcity of timber in the region has prevented farmers from replacing their old barbarous barbed wire by more modern woven wire. Catalpa fence posts may be profitably grown by planting on good land in many parts of the Middle West.

The production of a cheap grade of lumber from planted trees is also practicable. The cottonwood on sandy river botton land will grow large enough for a saw log in 20 years. Cases are on record where planted cottonwood trees have been lumbered when 15 years old. While the cottonwood does not make good finishing lumber, it does make excellent dimension stuff and is well adapted for the structural timbers of barns, elevators, grist mills, etc. The Carolina poplar, a horticultural variety of the common cottonwood, promises to be a much more valuable timber tree than the wild form. The rapid depletion of our native forests will soon make general planting for timber supplies necessary.

FOREST PLANTING MEANS BETTER FARMING.

Forest planting on the farms in the prairie States will determine in a large measure whether the farm is to be managed intensively or extensively.

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Intensive management is only possible where the production of a wide range of crops is possible. This diversification of agriculture is accomplished most successfully where forest protection modifies climatic extremes. Intensive farm management requires that the land be divided into fields of comparatively small dimensions. There is no better border for a field in the prairie States than three or four rows of planted trees. As the farm management becomes more and more intensive the land will be subdivided into smaller and smaller fields from time to time. Increase of forest belts should go hand in hand with this process.

FOREST PLANTING AND THE FARMSTEAD.

The portion of a farm containing the buildings, orchards, barn-yard and garden is called a farmstead. Forest planting is of great benefit to a farmstead, particularly in a treeless country. Throughout the Middle Western States, successful fruit culture demands that windbreaks be planted on the south and west sides of the orchard. The comfort of the rural home demands also that a windbreak be planted on the north side of the farmstead to protect it from winter storms. It is thus evident that the farmstead should be protected by forest belts on three sides, namely, the north, the west and the south.

WHAT TO PLANT.

In the discussion of the subject of forest planting, one of the first topics that interests the prospective planter is what to plant. The unreserved recommendation of any one species is liable to cause harm, because local conditions of soil, moisture supply and climate may make the planting of a species very valuable for one locality, a very hazardous undertaking in another locality. Whenever we meet a man who professes to have a tree that is good in all situations, we may put it down at once that that man is a fraud. In the region to which this discussion applies we hear a great deal said in favor of the hardy catalpa. This species is an excellent tree to plant in river valleys at moderate altitudes where an abundant moisture supply is within reach of its roots. It is absolutely worthless except with irrigation throughout the semi-arid plains. It will not endure the winters of Minnesota and the two Dakotas. Its optimum region for planting may be said to embrace the river valleys of the eastern half of Kansas, the eastern third of Nebraska, the southern half of Iowa, the northern two-thirds of Missouri, the southern half of Illinois, and the southern third of Indiana.

Another excellent tree for planting in the Middle West that may be given good soil to thrive is the black walnut. Its optimum region extends from the Appalachian Mountains to central Kansas, and from southern Minnesota to Texas. It will grow on much poorer soil than the catalpa, and is a much longer lived and hardier tree.

The tree that has been planted most widely in this region is the common cottonwood. When planted along river banks it makes the best growth of any species and if we leave out the question of the production of fence posts, it is probably the most profitable. It is peculiarly well adapted to land which overflows.

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Two other species that have been planted very extensively in the region are box elder and silver maple. These trees are both about as poor species for planting as could have been selected. They neither make fence posts nor good fuel, and as for lumber they are not worth considering. The only reason they have been planted so extensively is that they grow from seed as easily as weeds and consequently are profitable to nurserymen.

The white elm and hackberry are two species very similar in habit of growth and very hardy. They will grow throughout the Middle West although their rate of growth on very poor land will be slow. These species deserve to be planted very much more extensively in the future than they have been in the past.

The Osage orange and Russian mulberry thrive throughout the southern half of the region. They will not stand the cold of Minnesota and Dakota winters. The chief value of the Osage orange and mulberry is for hedges and windbreaks. Their timber also makes excellent fence posts.

The black locust has been planted very extensively in the southern half of the region and, if it is not attacked by borers, it is likely to prove profitable because of the great durability of its timber. The honey locust is a much hardier tree and wherever planted south of South Dakota it has proven a success.

One of the hardiest species for prairie planting from the Canada line to Texas is the green ash. It is rather slow in its growth but very persistent. In the northern half of the Middle West its timber is prized very highly by farmers for fence posts.

Farmers have paid little attention to the conifers in this region. Since the evergreens grow with very much less moisture than is required by deciduous species, it seems that the conifers ought to be especially well adapted to the semi-arid plains. In the planting that the Bureau of Forestry is undertaking on the Nebraska sand hills no other species except conifers are being tried. The western yellow pine from the Rocky Mountains and the jack pine from the Great Lake region are the chief species now being tested.

WILL IT PAY TO PLANT?

The first question that is likely to be raised when a farmer is urged to plant forest trees is, will it pay? A few instances where it has paid are the following:

At Howe, in southeastern Nebraska, is a grove of hardy catalpa 25 years old, 2.4 acres in extent, that has produced a total value in fence posts and poles of $890.60, or $371 per acre, averaging $14.84 per acre per annum, not reckoning compound interest. During nearly half the time since the grove was established the ground has been used for grazing and the thinnings from the plantation have afforded considerable wood for domestic uses on the farm. Another catalpa grove owned by Mr. C. D. Robinson of Pawnee, Nebraska, of 12 acres in area, produced when 13 years old, fence posts to the value of $190 per acre, or $14.61 worth per acre per annum.

Four years ago a gentleman near Tekamah, Nebraska, cut 30 planted cottonwood trees 31 or 32 years old from a row in his fence line which yielded

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20,000 board feet of lumber. He was offered $16 per thousand for the lumber, but refused to sell it, preferring to use it in building a residence and barn. It cost him $5.50 per thousand board feet to convert the trees into lumber, leaving a net value of $210, or $7 per tree for the cottonwoods.

Mr. Kilvert—On the point mentioned in regard to windbreaks, Mr. Clothier, you suggest single rows of trees down through the fields?

Mr. Clothier—Yes, sir.

Mr. Kilvert—In Mexico our fields are laid off into 25 acre lots, and 32 fields make a plantation, and 10 plantations make a ranch. They are planted with cottonwood, and the oldest cottonwoods are about 18 inches through, so on the timber side you can increase your figures, if you are talking about Mexico. The land which lies near the ditch will naturally be surest to produce better plants. Our rows run both east and west and north and south, so that for three months the sun is practically overhead, and a certain space is shadowed by the tree for about eight hours. Just as far as that eight hours shadow travels there is pretty near a bare place.

Mr. Clothier—I am aware of that, but if you grow alfalfa, you can grow almost as much as if the shade was not there, can you not?

Mr. Kilvert—I presume so. I just wanted to bring this point up and see if it was a local condition.

Mr. Clothier—It is a general condition.

Mr. Stewart—Such trees as the gentleman from Mexico spoke of grow much faster in our country. They will grow one-third more in the same length of time. They are an advantage to the alfalfa, and save us the trouble of keeping the weeds out of the ditch, and also in shoveling the mud out of the ditches. We used to cut all of the little cottonwood out, but now we are watching them and keeping them in the ditch to keep it from washing out.

Mr. Eberlein—In the country around Hay City the timber is honey locust. Would conditions be the same as in the country you speak of, and can these plans be carried out in Kansas?

Mr. Clothier—I know of one place, 75 miles north of Hay City, where 30 trees were cut that were from 30 to 32 years old and they produced 20,000 board feet of lumber, having a total net worth of $210, or $7 per tree. They grew in a fence line and did not take up any land, and also acted as a windbreak at the same time. The cordwood was not counted in this estimate.

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FOREST PLANTING IN THE SAN GABRIEL FOREST RESERVE.

T. P. LUKENS, U. S. Bureau of Forestry, Pasadena, Cal.

That portion of Southern California susceptible of a high state of cultivation, has a southwest frontage of over 200 miles on the Pacific Ocean. Running nearly parallel with the coast from northwest to southeast are the Sierra Madre Mountains, all but extending to the ocean at the northwest extremity, the space between mountain and ocean gradually widening towards the south.

This mountain range has been made into reserves for the conservation of water, in all close to 4,000,000 acres. There are about 1,000,000 acres more of moutainous area from which more or less water is derived. It has long been understood that the mountains and forest-covered areas are alone to be depended upon for irrigation water in arid and semi-arid regions. Many species of trees suited to arid conditions grow there.

FIRE DESTRUCTION.

From the earliest history until very recently the destruction by fire and unwise methods of lumbering and stock-grazing have seriously impaired the conserving power of our mountains, while now only 20 per cent of our mountain area is covered with trees which are growing along streams and on the medium zone above 3000 feet elevation, while 80 per cent of the area is covered with chaparral.

There are no other mountains on our coast so precipitous as ours, consequently nowhere is it of so great importance to maintain a forest growth for the conservation of water and to prevent erosion.

With our long rainless season, often eight consecutive months, all growth on the mountains becomes very dry, and fires have wrought great damage. Forests have been supplanted with chaparral, and in time over much of the area chaparral is supplanted with a light growth of herbacious plants, with little root power. As a result, many perennial streams that formerly flowed to the sea have ceased flowing entirely except in form of floods immediately after storms.

WATER SUPPLY AFFECTED BY FIRES.

Southern California has a population of 384,000 and an assessed valuation of $324,000,000. There could hardly be any limit to our growth in population and wealth if our water supply could be increased, to accomplish which would require first for temporary relief the building of storage reservoirs. But for a permanent water supply, measures must be adopted to arrest the devastation of our watersheds by fire, and to plant over the denuded areas.

Once Persia was the most fertile land of Asia, well watered and richly wooded. Once the Sahara was the granary of Africa and of Europe. To-day they are barren sands, brought about by the irrational use of the forests. The fearful famines in India are traceable to a large extent directly to forest

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destruction, and many other parts of the world, once rich in growing crops, have become desolate, barren regions from the destruction of the forests.

A few years ago the United States Geological Survey selected a watershed in the State of Washington, and one in Arizona, each covering an area of 142 square miles, their purpose being to ascertain comparative value of forested and non-forested areas in the regulating of stream flow. The area in Washington, Cedar Creek, was completely forested, and the annual precipitation was from 93 to 150 inches. The maximum run-off from Cedar Creek was 6321 cubic feet per second, while the maximum run-off from Queen Creek in Arizona, with a precipitation of but 15 inches annually, was 9000 cubic feet per second.

ENCOURAGING RESULTS OF EXPERIMENT.

In a careful study of the behavior of the stream-flow on several small catchment areas in the San Bernardino Mountains it has been found that the effect of the forest in decreasing surface flow on small catchment basins is enormous, as shown in the following tables, where three well-timbered areas are compared with a non-timbered one:

Precipitation and run-off during December 1899.

Area of catchment basin.	Condition as to cover.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Per cent.*
0.70	Forested	19+	36—	3
1.05	Forested	19+	73+	6
1.47	Forested	19+	70—	6
.53	Non-forested	13—	312+	40

At the beginning of the rainy season, in early December, the soil on all four of these basins was very dry as a result of the long dry season. The accumulation of litter, duff, humus and soil on the forest-covered catchment areas absorbed 95 per cent of the unusually large precipitation. On the non-forested area only 60 per cent of the precipitation was absorbed, although the rainfall was much less.

Rainfall and run-off during January, February and March, 1900.

Area of catchment basin.	Condition as to cover.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Per cent.*
0.70	Forested	24	452+	35
1.05	Forested	24	428+	33
1.47	Forested	24	557+	43
.53	Non-forested	16	828+	95

The most striking feature of this table as compared with the previous one is the uniformly large run-off as compared with the rainfall. This clearly

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shows the enormous amount of water taken up by a dry soil, either forested or non-forested, as compared with one already nearly filled to saturation. During the three months here noted, on the forested basins about three-eighths of the rainfall appeared in the run-off, while on the non-forested area nineteen-twentieths appeared in the run-off.

Rapidity of decrease in run-off after the close of the rainy season.

Area of catchment basin.	Condition as to cover.	Precipitation.	April run-off per square mile.	May run-off per square mile.	June run-off per square mile.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.70	Forested	1.6	153—	66—	25—
1.05	Forested	1.6	146—	70+	30—
1.47	Forested	1.6	166+	74+	30+
.53	Non-forested	1	56+	2—	0

The above tables clearly show the importance of forests in sustaining the flow of mountain streams. The three forested catchment areas, which during December experienced a run-off of but 5 per cent of the heavy precipitation for that month, and which during January, February and March of the following year had a run-off of approximately 37 per cent of the total precipitation, experienced a well-sustained stream flow three months after the close of the rainy season. The non-forested catchment area, which during December experienced a run-off of 40 per cent of the rainfall, and which during the three following months had a run-off of 95 per cent of the precipitation, experienced a run-off in April (per square mile) of less than one-third of that from the forested catchment areas, and in June the flow from the non-forested area had ceased altogether.

EFFORTS TO REFOREST THE MOUNTAINS.

With all these facts clearly established, showing the incalculable benefit of trees on our mountains, a determined effort is being made to re-clothe them, and for several years experiments have been carried on to determine the most economical and practical plan to pursue. As a preliminary to planting is the preparation of the areas so as to exclude fires, or at least to reduce the danger to the minimum. That can be done by clearing the ridges of brush, so as to confine the fire to narrow limits.

The experiments carried on thus far have been under the most unfavorable climatic conditions. Southern California has just passed through a series of very dry years, during which time natural reproduction has been precluded, not only of trees in the forested areas, but of chaparral as well.

Seeds were planted in the open ground, some without preparation, but in most cases beds were prepared by digging a space a foot or more across and a foot deep, on which a number of seeds were planted. The plan promised well, but the long season—ten months—without rain, left but few trees. Our experiments with transplanting trees promised to be the better plan. We are growing in nursery and at two years old will plant on the mountains with confidence of success.

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KINDS OF TREES TO PLANT.

To determine on the species of trees to plant has necessitated a careful study of nature's plan, with which we keep in as close touch as possible. Coniferous trees form the base, of which by far the greater number will be used, planting them in their indigenous zones, and as far as possible in soil and conditions of their choosing. Along water courses we are succeeding in growing ash and walnut trees. Seeds of indigenous conifers "and of a few species of exotics in an experimental way" are grown under lath houses, and at the end of the first year's growth transplanted in the open ground to harden, and at two or three years old are to be planted on the mountains.

Our nursery is located in the mountains at a medium altitude that the propagation may be more certain and the trees having been grown in the same character of soil they are to be finally planted in are more certain to succeed. Where the tree is to be planted a small space is loosened with a mattock, in which the tree is planted and mulched. The planting must be done during the rainy season, which is between November and April, that the trees may become anchored before dry weather sets in.

HOW WILL IT PAY?

As I have said before, the assessed valuation of property in Southern California is $324,000,000. If we were to say it would cost $22,000,000 to completely restore tree growth on our mountains and properly care for them and prevent fires for fifty years, it would without consideration be declared impossible on account of expense, but when it is looked at from a business standpoint it is clearly a good investment; an annual levy of 13 cents on $100, or a total of less than 7 per cent of present assessed valuation of property in Southern California over a period of fifty years.

The British government is carrying on tree planting on the watersheds in India to prevent erosion, filling their reservoirs with silt. There, labor is 10 cents per day, while here it is $2.00.

The same applies to Japan, where dirt is carried in baskets in which to plant the tree, on areas where once was a luxuriant growth of trees, but now barren rocky slopes, brought about by sheep, goats and fire.

It is the natural and proper thing for the U. S. government to take the lead in this work, to make the investigations along scientific lines, establish working plans and supervise the work, which they are doing well, but where so much is needed as in Southern California, the people directly benefited, yes, whose very existence depends upon the work, must raise money to carry it on if it is to be accomplished.

For equitable climate, richness of soil, and scenic beauty Southern California is unsurpassed. The only thing that can limit the growth in wealth and population is the supply of water, without which but little can be accomplished.

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THE RELATION OF FOREST COVER TO STREAM FLOW.

J. B. LIPPINCOTT, Supervising Engineer U. S. Geological Survey.

The relation of rainfall to run-off is very uncertain, depending upon the nature of the storms, whether gentle showers or violent rains, the steepness of the drainage basin and its covering, and whether the precipitation is snow or rain. It has been found that in the districts where the forest cover is small the output of the basin occurs in violent floods of short duration. Because these floods are violent, and of large volume, and owing to the fact that the soil of the drainage basins is not held together by a network of roots extensive erosions occur in these barren basins and the stream carries much silt in suspension. Where the basin is covered by forest, the mat of twigs and leaves which covers the ground is an absorbent sponge, retaining in itself large quantities of water and preventing evaporation from the underlying soil. This permits of a holding back of the floods and the gradual draining off of the water, thus largely accomplishing the purpose of regulating reservoirs.

A striking example of the output of a barren, treeless drainage basin is shown in the following table of discharge for the year 1896 for Queen Creek, taken from the Eighteenth Annual Report of the Geological Survey, Part IV—Hydrography. It represents a typical year's output:

Estimated monthly discharge of Queen Creek at Whitlow's, Arizona. Drainage area, 143 square miles.

Month, 1896.	Discharge in Second-feet.		
	Max.	Min.	Mean.
January	2	2.0	2.0
February	2	2.0	2.0
March	2	2.0	2.0
April	2	1.0	1.5
May	1	1.0	1.0
June	1	1.0	1.0
July	9,000	0.0	121.6
August	1,433	0.6	13.1
September	3,428	0.5	17.1
October	1,188	0.5	13.3
November	80	0.6	1.3
December	207	0.6	2.0
	9,000	.0	15

In contrast with Queen Creek in Arizona a table is given showing the discharge of Cedar Creek, Washington, for the year 1897.

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Estimated monthly discharge of Cedar Creek near Seattle, Washington. Drainage area, 143 square miles.

Month, 1897.	Discharge in Second-feet.		
	Max.	Min.	Mean.
January	2,812	815	1,430
February	2,415	823	1,303
March	1,366	723	901
April	2,752	790	1,599
May	2,143	939	1,562
June	1,410	780	1,060
July	2,284	572	1,135
August	561	342	427
September	418	311	350
October	433	294	339
November	3,155	323	1,318
December	3,601	674	1,639
Total	3,601	294	1,089

The amount of solid matter carried by a stream is a very serious problem in connection with the construction of storage reservoirs thereon. The most astonishing stories are told of volumes of sediment carried by the rivers of Southern Arizona from their barren drainage basins. It is said that when these floods first appear, discharge off of ranges that have been traveled by the large herds of cattle in quest of grass, the soil which has been exposed to the direct action of the sun, being exceedingly light and dry, is washed off in quantities that are enormous. In order to determine the amount of silt in the Gila River at The Buttes, which stream has a similar basin and regimen to that of Queen Creek, the Geological Survey has made observations by taking samples of the water daily, and permitting the mud to settle, measuring it wet and then determining its dry weight. The average amount of silt for the twelve months' observation was 10 per cent by volume wet, and the amount of solids 2 per cent. No other stream in the United States is known to carry such a high per cent of sediment. This is in striking contrast with the clear streams of our northern forested basins. The water supply used for domestic purposes from Cedar Creek, Washington, does not require filtering or settlement.

The serious nature of this silt problem can readily be appreciated by those who have studied the storage of water for irrigation. It is probably the gravest of all the engineering problems related thereto. Forestry should assist greatly in removing difficulties of this nature.

Mr. James W. Toumey, Collaborator Bureau of Forestry in the Agricultural Department, has selected certain small and adjoining drainage basins in the San Bernardino Mountains in a portion of the catchment area proposed to be utilized by the Arrow Head Reservoir Company. Throughout this area this corporation for a term of years has been making exhaustive hydrographic studies of the available water supply. It is proposed to divert the water flowing from a number of these small mountain basins which are situ-

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ated on the northerly slope of the San Bernardino range by means of gravity canals and tunnels to the southern side of the range and into the San Bernardino Valley. This Arrow Head Reservoir Company has placed its hydrographic data at the disposal of the Bureau of Forestry, which organization made a forest study in connection therewith. The data that is presented by Mr. Toumey is perhaps the most precise and definite information on the subject of related stream flow to forest cover that we have so far been favored with in the West. His conclusions, while they were to be expected, are gratifying in their definiteness. We can do no better than to quote from Mr. Toumy in extenso:

"Because rainfall is most abundant where forests grow, many believe that forests exert an important influence on the amount of precipitation. A more reasonable inference, however, is that *rainfall is the great factor in controlling the distribution and density of forests.*

"Precipitation occurs whenever the air is suddenly cooled below the dew-point. The most effective cause of this is the expansion of air on ascending. This upward movement is caused very largely by cyclonic storms. Whether forests have any appreciable effect in cooling the air to below the dew-point is uncertain. From the known effect of forests on the temperature and relative humidity of the air, it is reasonable to infer that they may have some effect, at least to a small degree, and consequently that they have some influence in increasing precipitation. The present evidence, however, derived from many series of observations conducted in Europe and elsewhere, is so conflicting that a definite answer to this question, having the stamp of scientific accuracy, is not possible.

"In a careful study of the behavior of the stream flow on several small catchment areas in the San Bernardino Mountains it has been found that the effect of the forest in decreasing surface flow on small catchment basins is enormous, as shown in the following tables, where three well-timbered areas are compared with a non-timbered one:

Precipitation and run-off during December, 1899.

Area of catchment basin.	Condition as to cover.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Per cent.*
0.70	Forested	19+	36—	3
1.05	Forested	19+	73+	6
1.47	Forested	19+	70—	6
.53	Non-forested	13—	312+	40

"This is the stream discharge during a month of unusually heavy precipitation.

"At the beginning of the rainy season, in early December, the soil on all four of these basins was very dry as a result of the long dry season. The accumulation of litter, duff, humus and soil on the forest-covered catchment areas absorbed 95 per cent of the unusually large precipitation. On the non-

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forested area only 60 per cent of the precipitation was absorbed, although the rainfall was much less.

Rainfall and run-off during January, February and March, 1900.

Area of catchment basin.	Condition as to cover.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Per cent.*
0.70	Forested	24	452+	35
1.05	Forested	24	428+	33
1.47	Forested	24	557+	43
.53	Non-forested	16	828+	95

"The most striking feature of this table as compared with the previous one is the uniformly large run-off as compared with the rainfall. This clearly shows the enormous amount of water taken up by a dry soil, either forested or non-forested, as compared with one already nearly filled to saturation. During the three months here noted on the forested basins about three-eighths of the rainfall appeared in the run-off.

Rapidity of Decrease in run-off after the close of the rainy season.

Area of catchment basin.	Condition as to cover.	Precipitation.	April run-off per square mile.	May run-off per square mile.	June run-off per square mile.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*
0.70	Forested	1.6	153—	66—	25—
1.05	Forested	1.6	146—	70+	30—
1.47	Forested	1.6	166+	74+	30+
.53	Non-forested	1	56+	2—	0

"The above table clearly shows the importance of forests in sustaining the flow of mountain streams. The three forested catchment areas, which during December experienced a run-off of but 5 per cent of the heavy precipitation for that month and which during January, February and March of the following year had a run-off of approximately 37 per cent of the total precipitation, experienced a well-sustained stream flow three months after the close of the rainy season. The non-forested catchment area, which during December experienced a run-off of 40 per cent of the rainfall, and which during the three following months had a run-off of 95 per cent of the precipitation, experienced a run-off in April (per square mile) of less than one-third of that from the forested catchment areas, and in June the flow from the non-forested area had ceased altogether.

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Annual rainfall and run-off on forested and non-forested catchment areas in the San Bernardino Mountains, California.

Area of catchment basin.	Condition as to cover.	Precipitation.	Run-off per square mile.	Run-off in percentage of precipitation.
Sq. Miles.		*Inches.*	*Acre-feet.*	*Per cent.*
0.70	Forested	46	731	28
1.05	Forested	46	756	30
1.47	Forested	46	904	36
.53	Non-forested	33	1,192	69

"In conclusion, it may be said that although the forest may have, on the whole, but little appreciable effect in increasing the rainfall and the annual run-off, its economic importance in regulating the flow of streams is beyond computation. The great indirect value of the forest is the effect which it has in preventing wind and water erosion, thus allowing the soil on hills and mountains to remain where it is formed, and in other ways providing an adequate absorbing medium at the sources of the water courses of the country. It is the amount of water that passes into the soil, not the amount of rainfall, that makes a region garden or desert."

It will be observed in the table last above that the total annual run-off of a treeless basin is 38 per cent greater than from an afforested one. The deduction, therefore, would appear that provided storage reservoirs were used to conserve the floods that this would permit of the greatest economy in the water supply. It must be remembered, however, that flood water so held is subject to evaporation from broad water surfaces. It would be impossible to make an exact general statement as to the extent of this loss, but it seldom is lower than 20 per cent of the total amount stored and often reaches 40 and 50 per cent, depending on numerous local conditions. Therefore, provided the floods from a treeless basin are retained in storage reservoirs and from the water so impounded is deducted probable evaporation losses, we will have a net annual result from such a condition which would more closely resemble the total annual output from the timbered basin. It must be remembered that even in forested basins floods occur, and while the tree is a regulator of the stream, it does not necessarily obviate the uses of the storage reservoir. On the other hand it may be said that the forest is the protecting friend of the storage reservoir, each supplementing the benefits of the other.

SACRAMENTO FLOODS.

The drainage basin of the Sacramento River includes the greater part of Northern California. It has been occupied by Anglo-Saxon settlers for the last fifty years. During the first portion of the American occupation of this State, sea-going vessels are reported to have proceeded up stream as far as the present city of Sacramento. The tidal range of the river was observed also at this point. Placer mining was the first industry. This work consisted in washing the oriferous gravels found along the western foothills of

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the Sierra Nevadas. The resulting debris was discharged into the streams and has, to a very material extent, filled their channels, so that to-day the head of tidal water is many miles below Sacramento, near the upper end of Grand Island, and only flat bottom river steamboats are able to ascend the Sacramento River as far as the city of that name. This stream condition has been still further aggravated by the destruction of extensive areas of forest, both by fire, lumbering and sheep grazing. Yet the lumber industry is but in its infancy in this section, and plans are being perfected to cut down great areas of virgin forest. Extensive forest reserves have been provisionally set aside, covering most of the remaining timbered portions of the basin. These contemplated reserves have been greeted with a storm of public protest from central and northern California that has been hard to allay. In February, 1904, northern California was visited by heavy rain storms. While the precipitation was great, it was by no means the heaviest rain which has occurred in this section, and it was one that could reasonably be expected to be exceeded in violence in the future. However, with the combined conditions of reduced forest cover and filled river channels, a flood condition was produced in the Sacramento Valley last February which has no known equal in the previous history of the State. Eight hundred thousand acres of valley lands were submerged and the damages are estimated to have reached into the millions. All this is in spite of the fact that over twenty million dollars had been expended in the construction of levees to prevent these overflow conditions. A great State convention was called in San Francisco to consider the disaster that threatened the commonwealth. Eminent engineers have been brought to California from the lower Mississippi basin and elswhere in the East to study this great overflow problem. Organizations have been perfected to urge, if not demand, both from the State and from the Nation, relief from impending disaster. It is contemplated that a comprehensive levee system must be constructed the entire length of the valley at enormous expense.

It may be stated that while there is no definite scientific information that forests increase rainfall, yet we have certain striking instances presented where the rainfall is greater on adjacent forested areas than on those that are denuded. At least in the arid regions it may be stated that the total annual output from a deforested drainage basin is greater than from a timbered area, but that the regimen of the stream is distinctly to the disadvantage of all who are interested in the use of the watered resources of the country, whether he be navigator, irrigator or water power investor. From the denuded area the floods are greater and the drouth is more intense. To remedy this condition one naturally turns to the storage reservoir for relief, yet even in this extremity one is confronted with adverse conditions. The violent flood from the bare basin rushing through the mountains carries with it eroded sediment, which it deposits in the first pool of still water that it encounters. The result is the reduction of the storage capacity of the reservoir along its course. Forests are the natural and greatest storage reservoirs and regulators of water supply. On few streams do we find reservoir capacities even approximating the total annual output of the drainage basins above them. Accepting the facts as outlined above, the great importance of preserving the forests, particularly in

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the seim-arid regions of our country, is most manifest. In Southern California, Arizona, and New Mexico particularly, we are so closely bordering on a condition of desert that when the forest is once destroyed the difficulty of reproducing it renders the task well nigh hopeless. We should therefore all join with the Bureau of Forestry in its effort to save the forests and store the flood.

Question—Have you any figures in this connection bearing on the evaporation of storage reservoirs which reduces this difference?

Mr. Lippincott—This is dependent on a deep or shallow river, but it is a very ordinary occurrence for 25 or 50 per cent of the water in the storage to be slowed off, and I think as a general statement you might say you should consider a loss of 20 per cent. That is dependent on the time of year and water. Now, in Colorado the storage water is all held from February, but in Arizona it is held from the two different seasons of rain; but generally speaking you lose about 20 per cent of storage water by evaporation.

Mr. Kilvert—Your article will be a great deal of use to me in Mexico, and I wish you would put in a paragraph covering what you have just said.

Mr. Hurd—Would not the loss in storage depend on the size of the reservoir. If you had a reservoir say covering an area of 100 feet, the loss would not be so great as a smaller one?

Mr. Lippincott—No, sir; it would not.

Mr. Clothier—Is it not possible that storage water running down into the ground, and which is not taken up by the usual wells, would increase the per cent of loss?

Mr. Lippincott—We have been studying the question a good deal, and the volume of water passing through we find to be practically small in every instance. I do not believe it would figure into a very great volume.

Gen. Snyman—Don't you think the different climates and soils have a good deal to do with this water?

Mr. Lippincott—Yes, sir.

Gen. Snyman—I know it was always a great question in our country to look for black ground, which is called in this country "alkali," which is more water tight. I have known places where water has been stored where there has not been rain for eighteen months. Now I am only speaking of reservoirs catching rain waters where you have no rivers.

W. T. Swingle—Do you not think the winds, their course and temperature, effect the evaporation?

Mr. Lippincott—Yes, sir. The Weather Bureau has some valuable information on this point.

Mr. Sterling—I should like to ask if any silt masurements are being made?

Mr. Lippincott—No, sir.

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grazing does have an effect upon the stream flow appears to be a well-established fact, because wherever the undergrowth, forage plants and grasses have been destroyed by excessive grazing, the result has been a change in the flow of the streams to a more rapid and torrential run-off, while on watersheds where grazing has been judiciously managed, and the natural forest and forage conditions preserved, the stream flow has continued regular and normal.

The injury from grazing is mostly due to tramping and the destruction of vegetation which would check the flow of water, keep the ground in a more pervious condition and prevent its erosion. Where the watershed is in a natural condition, the rain and melting snow is rapidly absorbed, and by underground seepage keeps up the steady flow of springs and streams.

Investigation of the ranges has shown that damage caused by live stock is usually due either to overstocking, grazing too early in the season, or the manner in which stock has been handled.

Under the free range system of the West there was at first very little restriction as to the number of stock any one had the privilege of pasturing, and owing to the opportunity offered to engage in the business of stock raising, and to the alluring chance of money-making which it apparently offered, the ranges of many sections became overcrowded and soon commenced to decline in their pasturing capacity.

CAUSES OF DAMAGE BY GRAZING.

Serious controversy arose over the use of the range between cattle and sheep owners, and also between different owners of the same class of stock. No one thought of reducing the number of his stock, but each stockman exerted himself to keep the other fellow off of what he claimed as his range. In this struggle for supremacy little consideration was given to the future utility of the range itself.

This was about the condition which existed on some of the summer ranges which were included within the forest reserves. They had been overcrowded with live stock, in some sections with sheep and goats and others with cattle and horses, until the excessive use of the range had resulted in injury to the young growing forests and destruction of the forage plants and grasses to a greater or less degree, and also in tramping the earth in a way which greatly increased its erosion and reduced the capacity of the watersheds in absorbing and storing the rain and snow which fell upon them.

The damage by sheep grazing was found to be largely due to the manner in which they were handled. In places where the sheep had been camped on the same bed ground for a long time, perhaps a month or more in the same place, the grass and forage would be completely eaten out for a mile or so around and many of the young trees nibbled by the hungry stock. Damage by this system of handling is usually entirely unnecessary, and is detrimental to the best use of the forage as well as injurious to the forest. The forest reserve regulations require that sheep must not be bedded in the same place for more than six nights in succession.

One of the greatest evils in the destruction of forage is that of putting stock on the range too early in the season while the feed is yet immature.

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Lack of range control is usually responsible for this condition. If the number of stock to be driven to the mountains for summer pasture is in excess of the number there is sufficient pasture for, there is often some particular section of the range which one stockman desires to secure ahead of his competitors, and in the struggle to get there first the stock are driven along as fast as possible, and destroy as much feed by tramping as they consume in feeding. In some sections this competition for range continues during the entire season, and of course results in great destruction of forage as well as damage to the forest and water supply.

IMPROVEMENT UNDER GOVERNMENT CONTROL.

Immediately upon a range coming under government control in a forest reserve, the damage from this cause is checked and a better use of the forage results. The total number of each class of stock to be allowed permits to graze upon the reserve is decided upon, the dates on which the stock will be allowed to enter and on which the grazing season will close are designated; the ranges are divided in the manner which appears most practicable, and for the best interests of all, either into individual ranges, districts to be used jointly by the owners of a certain number of cattle and sheep, or districts to be used exclusively by the owners of either class of stock. Sometimes it happens that the conditions are such that it is necessary to exclude all stock from limited areas for a period, but usually all that is necessary is a reasonable restriction on the enforcement of proper regulations.

Under this system of management each stockman who is granted a permit, knows just what portion of the range he will be allowed to use, how many stock he can pasture and when he can drive them in, and furthermore, he knows that on arriving there he will not find the range already occupied by someone else, consequently there is no need for any haste in driving and the stock are grazed along in a way that little damage is done.

PRACTICAL RESULTS OF REGULATION.

It has been found in some cases that ranges which apparently were greatly overstocked have shown a marked improvement in condition by the application of the grazing regulations without any reduction in the number of stock, showing clearly that the damage has been caused largely by the manner in which the stock was handled.

Cattle prefer to graze in the meadows and parks rather than in the timber, and consequently when a summer range is heavily stocked with cattle the greatest damage usually appears to be in tramping out the grass in the meadows and on the neighboring slopes. Every effort should be made to prevent the concentration of the cattle. As many watering places as possible should be provided. Where the springs and seeps are liable to be injured by traveling, they should be fenced and the water piped out into troughs. In salting stock the salt should be placed in many different localities, and a short distance away from the water.

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GRAZING REGULATIONS NOT UNPOPULAR.

Since the regulations regarding grazing have been modified and a more liberal policy towards the livestock interest adopted, much of the opposition to forest reserves has been removed. In many of the reserves grazing has been under control for a sufficient length of time to practically demonstrate the advantages of this system of range management, both in the improvement of the forage and the regulation of the flow of streams, and stockmen who had first opposed the reserves, realizing the benefits to be derived from control of the ranges, are among the most earnest supporters of the reserves.

The stockman has learned from experience that forest reserve protection of the summer range means an improvement in the condition of his stock and an increase in the profits of his business. During the past season when stock in many range sections suffered severely on account of lack of feed and water, those who were fortunate enough to have pasturing privileges in the forest reserves were able to get their stock fat while many of the outside stock remained thin in flesh, the result being that the stock pastured on the forest reserve were in better demand and sold for more money than those from the outside ranges.

As the policy of the government becomes better understood and the benefits to be derived from judicious management of the grazing land is shown by practical demonstration, the opposition of the stockmen to the creation of forest reserves will be entirely removed and they will co-operate with the government in the proper regulation of grazing and the permanent improvement of the ranges.

Question—I would like to ask you now, if the grazing of cattle and sheep would not assist in extinguishing fires in the mountains and ranges, and would it not add to the advantages of the forest that stock be taken in there in the prevention of fires? Fires start from various causes—the burning of brush, and sometimes from lightning striking the grass. There is a great deal of trouble about that, but I think if the range was allowed to be grazed off to a certain extent it would be an advantage in keeping down fires.

Mr. Potter—Yes, sir.

Question—There is another point—the permit to use the range by the government. Do you not think it would be better if there was a rental charge for it, a lease for a limited number of years—don't you think it would be an advantage to both the range and stock owners?

Mr. Potter—I think along that line where arrangements are pretty well settled, the greatest advantage would be to extend the term of five years' lease, and in that way the stockmen would feel encouraged in trying to improve its condition. But the government tries to manage the stock reserve just the same where the stockmen do not pay, and a great many of them feel that there ought to be a government charge and they try to devise the best regulations possible. I think one of the things which is needed most along that line, where the question of range right is pretty well settled, is to make a lease term of five years.

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Question—Well, to give a five or ten years' lease, don't you think it would be fair to the government and stockholder for the stockholder to pay a rental; would it not make him take more interest in it?

Mr. Potter—Yes, sir; it might.

Mr. Stewart—In speaking about the driving of cattle and sheep from one range to another, I want to state to you how we are situated. The sheep graze in the summer time on the Monkhill Mountains and in the winter time down on the desert; there is a travel of 100 miles between the two ranges. Now, our idea is that they scatter in going from one range to the other, and in some cases they scatter all over the country near Salt River, where we are building a dam. This country is practically bare. Now, if they were passing about five miles in a trail, they would simply ruin that strip. The cattle are not as much of a damage as the sheep are.

Mr. Potter—I think you are right in that particular section, but generally speaking it is better to let the sheep scatter out. Now if the forest reserve was to be extended over that section of the country, the trail would be extended.

Mr. Stewart—There have been trails, such as you speak of, through the Black Mesa surveys made by sheep, and some of them are transient sheep, coming through some of them from a very great distance, and they have already established a trail. If this were extended, that system of trail would be extended down there and sheep would be confined to a different trail. I would say that under our government administration they would not allow a general travel by sheep or cattle. They started in allowing 300,000 in a reserve, but they cut them down, and I think the number mentioned would be allowed in case this was extended—they might allow a certain number to commence on.

Mr. Potter—Can the government have any control over these sheep after they pass off of the reserve?

Mr. Stewart—No, sir. I am in favor of the lease law—I have been in the cattle business about fifteen years and had a good deal of experience, and I should think that the term of lease years should not be less than ten.

Mr. Potter—I think that would be fair.

Mr. Stewart—Now, the cattlemen are an advantage to the lease land, because every time a fire breaks out they all go out and help fight it with all their men. I think they are an advantage. The cattlemen will be of great help to keep fires down, and they do not hurt the pines at all, as the pine burs seem more liable to catch on the side of the hill where the cattle tramp. I knew that this work was being done, but did not know that it had gone on so far, and if there is anything I can do, or the cattlemen can do, we would be glad to help you in any way we can.

Mr. Pinchot's two resolutions were next offered and, upon motion duly seconded, adopted by the Section.

Adjourned until 2:00 p. m., November 16, 1904.

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THE RELATION OF FOREST RESERVES TO THE MINING INDUSTRY.

MAJ. F. A. FENN, Forest Superintendent Forest Reserves in Idaho, Lewiston, Idaho.

Ever since mining first became an important industry in the United States the government has dealt with it in the most liberal manner. The steadfast policy has been to stimulate the prospecting of the country and encourage the development of its mineral resources. Whatever tends to retard the progress of the miners' work contravenes that policy, anything calculated to advance his interests accords with it.

Congress in the enactment of the law authorizing the setting apart of portions of the public domain as forest reserves consistently adhered to its course respecting mining when it provided in that Act as follows:

"It is not the purpose or intent of these provisions, or of the act providing for such reservations, to authorize the inclusion therein of lands more valuable for the mineral therein * * * than for forest purposes."

And further, "Nor shall anything herein prohibit any person from entering upon such forest reservations for all proper and lawful purposes, including that of prospecting, locating and developing the mineral resources thereof. *Provided,* that such persons comply with the rules and regulations covering such forest reservations."

And further still, "And any mineral lands in any forest reservation which have been or which may be shown to be such, and subject to entry under the existing mining laws of the United States and the rules and regulations applying thereto, shall continue to be subject to such location and entry, notwithstanding any provisions herein contained."

While the Act contains the above quoted provisions, it also outlines a plan for the preservation of the forests within the reserves and gives to the Secretary of the Interior power to elaborate the system and make it effective, by authorizing him to "make such rules and regulations and establish such service as will insure the objects of such reservations, namely, to regulate their occupancy and use and to preserve the forests thereon from destruction."

Realizing the vital importance of the mining industry to the national prosperity and at the same time appreciating the necessity of protecting the forests for the benefit of the people, the lawmakers devised a scheme of forest protection that enables forest reserves to be maintained and the mining industry to be carried on simultaneously in the same territory, not only without conflict or friction but in such manner that scientific forestry may be applied in fullest measure while the best interests of the miner are subserved and promoted.

Strange as it may seem, after knowing the provisions of the law cited above, the establishment of a forest reserve in a mining region often excites grave apprehension in the minds of the residents of the locality. Fearing dire results from the presence of the reserve, with the administration of which they are unfamiliar, and the effects of which they have not studied, mine owners are frequently aroused to strenuous opposition and seek in every way

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to escape from imaginary ills. What they would avoid they find in the end to be a boon. An apt illustration is found in the history of the Black Hills forest reserve, one of the earliest to be set aside. The great Homestake mine is within the limits of that reservation, and when the reserve was created the Homestake people were panicstricken. They thought the innovation would at once close their mine, and they believed its continuance would result in the practical destruction of their property. They sought to have the reserve abolished. The government was firm, however, and insisted on conferring its benefits. The experience of years has shown the Homestake owners their error. Now they appreciate the reserve system and are working hand in hand with forest officers in all that concerns the reserve. Not only so, they have adopted reserve methods in the management of their own extensive timber holdings. Now they regret that the reserve was not created before their mine was discovered.

The forest reserve system contemplates the accomplishment of a two-fold object in the preservation of the forests; first, to keep them in the state of highest continued production for the benefit of the people locally dependent upon them for a supply of timber products; and, second, to conserve the water supply and maintain an equable flow in the streams. These two chief purposes are admirably suited to meet the needs of the two great branches of the mining industry, lode mining and placer mining. The principal natural products required by the lode miner is timber, while the placer miner is powerless to carry on his operations without water.

Man is ever extravagant with whatever nature bestows, and miners in the use of timber, if unrestrained, demonstrate the rule. Their business makes them creatures of the present. They rarely consider the ultimate good of the community when they are cutting timber; they regard only the satisfaction of their own immediate needs in their quest for wealth. Commonly in the mountainous mineral districts there is naturally a goodly supply of timber, but the discovery of mines leads quickly to the reckless destruction of this and to the heedless impairment of the forest growth. No thought is given to the future. Wasteful, careless methods of cutting prevail and vast accumulations of tops, limbs and other refuse soon encumber the cut over tracts. Fires now get in and what may have escaped the chopper fall a prey to the flames. Were the fire confined to the areas cut over, the damage would not be so great, but, unopposed, it does great damage. Thus are destroyed quantities of timber compared with which the amount consumed is insignificant. The fire is the great and real destroyer, but man is responsible for the conditions which make the destruction possible.

Worse yet is the damage done by the incendiary, who in order to clear a brushy hillside or remove thick timber in a canyon sets fire to the country to facilitate prospecting work. Thousands of acres of most valuable timber have been burned in this way to the inestimable damage of the mining industry. The anxious seeker for a mine lets selfishness blind him to the best interests of the community. He destroys the supply of timber upon which, very likely, hinges the question whether or not his mine may be profitably worked.

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In the vicinity of almost every mining camp the naked hillsides testify to the destruction wrought in the early days. Where formerly the mountains were covered with forests they are now denuded. Favored spots may be seen whereon a limited number of seedlings and saplings proves nature's effort to restore normal conditions, but many years must elapse ere her object can be attained even with all the care and assistance forest reserve methods may render. In the meantime the mines nearby must, at great cost, draw upon distant sources of supply for such timber as is necessary to their continued operation.

Everyone familiar with placer work in any long established camp has heard the general complaint. "The climate must be changing, for water gets scarcer and scarcer every year." Streams which formerly furnished ample water for the working of extensive properties during the full open season a few years ago are now without a sufficient flow for more than a few weeks' run in the claims. The true reason for the changed situation is not far to seek. The mountain slopes once forested tell the tale of repeated fires and the consequent reduced water-storing capacity.

These deplorable conditions prove the importance of preserving the forests if mining is to continue to hold its place among our industrial pursuits.

Whenever it is the purpose to run a tunnel or sink a shaft for development, or to extend the workings of a property in extracting ore, it is known beforehand that timber will be needed for such underground work; if the construction of a mill is contemplated, the first thing to look for is suitable material; if a steam power plant is to be operated, above all fuel must be provided. This timber question in all such matters is fundamental and should, it would seem, receive primary consideration. The prudent manager of a mine in a forest reserve would, therefore, make provision for timber at the very beginning of his preparations for any such proposed undertaking, by submitting proper application for the amount which he estimates will be required to serve his ends.

Miners are more prone to be careless in the use of timber than most other people and consequently from them come the bitterest criticisms when they are first brought in contact with the regulations. The explanation is simple. For fifty years the miners of the West have followed the suggestions of their will; they have cut and slashed the forests unrestrained. Unfamiliar with the new order of things, they look upon the country as their own by right of discovery and exploration. When once he appreciates what the innovation is intended to accomplish he promptly adapts his affairs to the new regime.

The honest miner who in good faith is developing or working his property encounters no real difficulty when he confronts the forest reserve law and regulations; but it is the stake locator and the person who seeks fraudulently to secure a body of timber under a pretended mining location that meet with obstacles. What mine owner when looking for timber in the vicinity of his claim has not found the best and most accessible supply covered by invalid locations made by some unscrupulous person for no other purpose than to "hold up" the legitimate miner and compel him to purchase a worthless claim in order to secure timber to which he thinks he is entitled?

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While reserve officers are protecting the forests from damage by fire and from spoliation they are at the same time vigilant to guard the government against fraud and in the illegitimate location, occupancy and use of pretended claims by persons who from selfish motives attempt to evade the law relative to the acquisition of title to mineral land. The prospector or miner receives every assistance and encouragement from forest officers; they facilitate his operations.

Where a forest reserve is established in a mining locality, so soon as the reserve law and regulations are fairly understood, opposition on the part of the law-abiding element of the population ceases.

The prospector and miner have nothing to fear from a forest reserve. It is established for the advancement of their interests together with the promotion of the general welfare. Examined comprehensively the relation of forest reserves to the mining industry appears so intimate, the success of the one so directly interwoven with the continued prosperity of the other, that the possibility of real antagonism between them cannot be entertained. The forest reserve system has come as a public benefactor of the mining industry and there is every incentive for miners to give it their loyal support. Forest officers in the administration of reserves will labor for the common good and reciprocally miners, as active and efficient friends, may co-operate in the achievement of the objects alike beneficial to themselves and conducive to the public weal.

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INFLUENCE OF TREE PLANTING UPON THE DUTY OF WATER IN IRRIGATION.

F. H. King, University of Wisconsin.

In the effort to discover and establish underlying principles of agricultural science and to direct agricultural practice along lines which shall be in harmony with them, thus leading more directly and certainly to higher economic returns, we stand generally in need of an increasing body of accurately determined fundamental facts; and it is very much to be hoped that it will be more and more recognized that the development of these fields falls properly within the purposes of Government aid and work. An adequate discussion of the broad problem of how to secure the maximum duty of water in agriculture is not at present possible on account of lack of a sufficient body of well established facts; and this is especially true of that phase of the problem relating to the influence of tree planting upon the duty of water. The body of accurately determined facts regarding the influence of windbreaks of any type upon the wind movement close to the surface and especially upon the rate of evaporation from foliage, soil, and water surfaces, is extremely small and yet such knowledge is necessary to a proper treatment on the subject. Some general facts and tendencies have been ascertained which are helpful for a preliminary consideration of this subject.

INFLUENCE OF WINDBREAKS UPON VEGETATION.

There is no doubt but that under certain critical conditions windbreaks do exert a very measurable influence upon vegetation. In the spring of 1894,* during May and June, an opportunity was afforded to make a somewhat critical study of this subject under field conditions. There is in Wisconsin an area of some 10,000 square miles of light sandy soil or sandy loam and, upon the lighter and more sandy portions of these soils, crops are occasionally very seriously damaged by the drying effect of the wind; and the fertility of the soil is much reduced by the drifting which occurs at such times. At the time in question there had been a heavy fall of rain on the 5th and 6th of May, but on the 7th it was clear and cold with a strong wind blowing from the northwest. During this and the following day, notwithstanding the rain, the soils on many fields about Plainfield and Almond, Wis., had been badly drifted. On the morning of the 8th the drifting had gone so far, on many fields, that at both places, the loose sand with which oats had been covered, whether with seeder or with drill, had been driven from the fields to such an extent as to leave the kernels entirely exposed and the plants lying flat upon the ground, hanging by the roots and whipping in the wind. On the fields where the whipping had not been so severe and where oats stood three inches high, the oats had been cured like hay close to the ground and even the leaves of dock sorrel were blackened and so dry as to crumble in the hand. Very many of the blades of oats, through wilting, had broken over close to the ground, presenting an appearance which suggested to the farmers that they

*Bulletin 42, Wisconsin Agricultural Experiment Station.

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had been cut by the sand. It was at once evident, to the most casual observer of the fields at this time, that wherever a field lay to the leeward of any sort of shelter the destructive effects of the wind were either not apparent or else they had not been nearly so severe.

About three weeks after the first serious injuries had occurred a careful study was made of many fields and the results are recorded in detail in the bulletin to which reference has been made. Some of the observations made at this time are cited here in illustration of the decisive evidence regarding the influence of windbreaks upon vegetation. A north and south road two rods wide fenced with wire along which were scattering trees 10 to 18 feet high, together with a scanty growth of hazel, had a field of oats lying to the east which was greatly damaged, but a strip two rods wide, next to the road, appeared wholly uninjured. A field of oats lying to the east of a field of timothy in which there was a strong growth of dock sorrel, had a strip of oats 200 feet wide next to the grass where the stand was good while on the eastern half, 30 rods wide, the plants were entirely destroyed. Another oat field having grass on the north and west sides, and bordered by a rail fence, showed a strip of uninjured grain 100 feet wide next to the two fences and fully 200 feet wide in the northwest corner of the field in the lee of the two fences. In another oat field fully five-eighths of it had been so thoroughly destroyed by the wind that it was harrowed and fitted for potatoes, but a strip along a rail fence on the south side, 150 feet wide, had been allowed to remain on account of the better stand, and on this area, as was usual generally, the number of plants increased as the fence was approached. To the west of this same field there was another of timothy and adjacent to this there was a strip of oats 200 feet wide where the stand of plants was markedly better than farther away; and the same fact was observed in an adjacent field lying to the east of a closely fed pasture free from trees and shrubs. In another field 120 rods long from north to south and 80 rods wide, seeded to oats and clover, the effect of the surroundings upon the crops is indicated in figure 1 where it will be seen that at a certain distance from the conditions which have influenced the temperature, humidity and velocity of the wind the oats had been very much injured and the clover had been entirely killed out.

In figure 2 the southeastern field is 80 rods long and 30 rods wide. Here it will be seen the oats were good along the road in the lee of the two fences 40 per cent gone further away and entirely destroyed on the eastern half. Further north the field of oats adjacent to the field of grass and with woods to the north and in the distance to the west, had a good stand of plants, being seriously injured only at the south end where the wind came through between the two pieces of woods along the course indicated by the arrow. Similarly, in figure 3, the influence of shelters are clearly and sharply brought out by the condition of the crops observed and there recorded. The southern field in this figure was 60 rods from east to west and 30 rods wide. It will be seen that the half of the field stretching out into the path of the free wind coming through the gap between the two pieces of woods, as indicated by the arrow, had lost all of the crop while the stand increased toward the woods on the west and was good at a distance of 10 to 20 rods from them.

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The piece of oats lying on the south side of the scantily wooded pasture was in excellent condition and although only 15 rods wide a very appreciable difference could be seen in the stand of clover, to which the field had been seeded, on the margin most distant from the pasture. Even fields of corn stubble having fields of oats to their leeward were observed, in three instances, to have exerted very marked effects upon the stand of grain and in one of these fields, on one portion of the protecting corn stubble, there was a strong growth of dock sorrel. To the leeward of this part of the field the oats had been much less injured, suggesting that the effect of the humidity of the air passing across this may have been enough altered to render the wind current appreciably less destructive. Observations like these appear to place beyond doubt that, under certain conditions, at least, windbreaks do exert a very measurable effect upon the vegetation of cultivated fields.

On three other oat fields which had been seeded to clover and which were bordered on the west with fields of grass, the number of clover plants upon unit areas which had survived the effect of the wind was determined at different distances from and to the leeward of the fields of grass. The counts were made in series along east and west lines at right angles to the margins of the grass fields and the results are given in the following table.

Table showing the decrease in the number of young clover plants per unit area with increase of distance to the leeward of the margin of grass land.

Distance from Margin of Grass, Feet.	No. of Plants, Series 1.	No. of Plants, Series 2.	No. of Plants, Series 3.	No. of Plants, Total.
		Field No. 1.		
50	187	209	187	574
200	120	139	131	390
400	88	75	68	231
		Field No. 2.		
100	77	73	99	249
200	55	109	113	277
400	43	78	72	193
600	67	66	56	189
800	54	54	30	138
1000	27	11	10	48
		Field No. 3.		
50	377	382	371	1130
400	166	209	225	600
700	203	180	160	543

These three sets of data appear to leave little room to doubt that in some manner, the grass fields to the windward of the fields seeded to clover did exert an influence which materially affected the stand of clover on them. In what manner this effect may have resulted will be referred to later.

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INFLUENCE OF WOODS UPON THE RATE OF EVAPORATION TO THE LEEWARD.

At the time of the observations just described others were made to measure the rate of evaporation at different distances to the leeward of woods, using a form of Piche evaporometer rendered more sensitive by increasing the diameter of the evaporating surface to 5.9 inches, thus giving an effective area of 27.06 square inches, deducting the area of the water reservoir, the latter being graduated to .1 c. c. The instrument as placed in the field is represented in figure 4.

With a series of six of these instruments set up in a line at right angles to the margin of a black oak grove having a mean height of 12 to 15 feet, the rate of evaporation which occurred simultaneously between 11:30 a. m. and 12:30 p. m. was measured, with the results given in the next table.

Evaporation at one foot above the surface at different distances to the leeward of a grove of black oak in a field of sandy soil recently planted to corn.

Distance from Woods, Feet.	Evaporation in One Hour, C. C.
20	11.0
40	11.1
60	11.3
80	11.2
100	11.9
120	12.9

These results show that until a distance greater than 100 feet is reached but little difference in the rate of evaporation was found. At 120 feet the evaporation was 17 per cent greater at 20 feet. Three of the instruments were next set up at 20, 40, 60 and at 280, 300 and 320 feet from the same grove and in the same field. During one hour the amounts of evaporation were as given in the next table.

Evaporation at one foot above the surface at 20, 40, 60, and at 280, 300 and 320 feet to the leeward of a black oak grove in a field of sandy soil recently planted to corn.

Distance from Woods, Feet.	Evaporation in One Hour, C. C.	Distance from Woods, Feet.	Evaporation in One Hour, C. C.
20	11.5	280	14.5
40	11.6	300	14.2
60	11.9	320	14.7
Average. .40	11.66	300	14.4

From this table it is seen that the rate of evaporation was 23.4 per cent. greater at 300 feet than at 40 feet, basing the computation upon the averages.

In another locality the evaporometers were set up at distances ranging from 20 to 500 feet to the leeward of a piece of black oak woods where they had an average height ranging between 15 and 25 feet and were thicker on the

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ground. The results secured during an hour of sunshine in the middle of the day are given in the table which follows:

Evaporation one foot above the surface of ground in a field of oats at different distances to the leeward of a black oak grove of trees 15 to 25 feet high.

Distance from Woods, Feet.	Evaporation in One Hour, C. C.
20	11.1
100	14.3
200	15.7
300	18.5
500	18.3

In this series the evaporation appears to have become constant at about 300 feet from the woods and was some 66 per cent greater than at 20 feet distant.

The effect of a scanty hedgerow was also measured. This was composed of a strip of bluegrass 16 feet wide in which there were scattering black and burr oak from 6 to 8 and occasionally 12 feet high. The hedge had open gaps in it and the nearest evaporometer was set up in the lee of a clump of six trees spanning a length of 40 feet, there being a gap of nearly equal length on either side. To the windward of this hedge there was a naked field of 80 rods wide recently plowed and being planted to potatoes, and the instruments hung above the field of oats where the plants were about 4 inches high. The next table gives the results obtained.

Evaporation one foot above the surface of a field of oats at different distances to the leeward of a scanty hedgerow.

Distance from Hedgerow, Feet.	Evaporation in One Hour, C. C.
20	10.3
150	12.5
300	13.4

In this case the evaporation at 300 feet from the hedgerow was 30 per cent. greater than at 20 feet and 7.2 per cent. greater than at 150 feet, and the results make it clear that even scanty hedgerows exert a measureable influence upon the rate of evaporation at considerable distances to the leeward.

INFLUENCE OF A CLOVER FIELD UPON THE RATE OF EVAPORATION TO THE LEEWARD.

Adjacent to the naked field behind the hedgerow just considered, there was a field of clover 360 feet wide along the margin of the oats and extending 780 feet back from it, across which the wind passed in its course from the north. At the same time the last observations were made a similar series was taken to the leeward of the clover, the results being these given in the following table:

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Evaporation one foot above the surface of an oat field at different distances to the leeward of a field of clover.

Distance from Clover Field, Feet.	Evaporation in One Hour, C. C.
20	9.3
150	12.1
300	13.0

These results indicate that at 300 feet to the leeward of the clover the rate of evaporation exceeded that at 20 feet 39 per cent and that at 150 feet 7.4 per cent. Comparing the evaporation from the two adjacent areas where, as stated, the evaporometers were similarly and simultaneously exposed, it is seen that the air coming across the long stretch of naked ground and then passing through the hedgerow, caused measurably more evaporation than did the current which had traversed the field of clover; and these results appear to be in complete accord with the observations cited regarding the stands of grain and clover to the leeward of woods, hedgerows, grass fields and shelters of other kinds.

INFLUENCE OF WOODS AND GRASS FIELDS UPON THE HUMIDITY OF THE AIR TO THE LEEWARD OF THEM.

At the same time that the several sets of observations were taken and at the same places, others were also made with wet and dry bulb thermometers of the Henry J. Green make, reading to tenth of a degree C. The results obtained are given in the following table, each value being a mean of 10 readings, which were made in regular rotation, passing from station to station of each series during the interval of exposure of the evaporometers:

Relative humidity of air three feet above the surface at different distances to the leeward of woods, hedgerow, clover field and naked soil.

Distance to the Leeward, Feet.	Mean Dry Bulb Readings, Degrees F.	Mean Wet Bulb Readings, Degrees F.	Mean Relative Humidity, Per Cent.
Grove No. 1.			
30	65.32	49.46	27.0
300	63.80	47.35	24.0
Grove No. 2.			
20	75.04	58.35	34.6
100	73.13	56.39	33.0
200	72.03	55.83	34.2
300	71.47	55.13	32.8
400	73.63	55.63	29.6
500	73.31	55.94	30.8
On leeward margin of clover field.			
0	52.48	43.97	48.0
On leeward margin of naked field.			
0	53.24	43.57	44.0

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The four series of observations, although too limited to serve as the basis of general conclusions, are, in a general way, quite in accord with the records of evaporation which have been cited and also in harmony with the very pronounced observed protection afforded to oats and clover to the leeward of the various shelter conditions which have been cited. To my own mind, however, the surprise lies in finding such profound differences in crop conditions associated with the observed differences in meteorological and surface conditions. It should be borne in mind, however, in considering these relations, that the meteorological observations were not made at the time the destructive work was going on, hence what differences then existed are not known. The relations which have been observed and pointed out are clearly vital to the reclamation problems of the arid and semi-arid West and merit full investigation, especially from the standpoint of field conditions.

The very marked influence which has been observed upon the stand of both oats and clover under the conditions cited is undoubtedly, in large measure, due to the character of the soil and to the stage of growth of the crops, the wind coming at a time when the root system of the plants was yet scantily developed and very close to the surface; but the measurable differences in the stand of clover, at such long distances from the conditions which have evidently produced them, leaves little reason to doubt that crops are sensitive to such differences of temperature, humidity and velocity of the air near the surface as must result from the conditions whose types have been here considered. There can be no doubt that rows of trees along canals and about reservoirs must very materially reduce the loss of water through evaporation from their surfaces, and such observations as have been cited make it hopeful that their influence upon the loss of moisture from adjacent fields and their effects upon crops themselves may be of much greater importance, especially in plains regions, but only fuller investigations can make certain the true relations.

WIDTH OF THE ZONE INFLUENCED BY WINDBREAKS.

Newell,* in speaking of the influence of windbreaks on plains, states that: "It is estimated that every foot of height of compact trees protects a rod of ground; hence a Lombardy poplar windbreak of an average height of 60 feet, properly set out, has a beneficial influence extending practically 1000 feet to the leeward." In the cases which have been cited the rate of evaporation and the humidity of the air were measurably affected at distances having the same or perhaps a little higher order of value; but when the effect upon the crops themselves is taken as an index the influence clearly has a wider range, there being in the case of the fields seeded to clover so strong a contrast as 183 to 48 between the distances of 800 and 1000 feet to the leeward of a grass field, where it appears that the influence must have been exerted in some manner other than by directly modifying either the wind velocity or the humidity of the air. It appears possible that broad, continuous naked fields of dry soil or sand on clear days may have a peculiar effect upon air currents sweeping across them. The dry soil or sand itself

* Irrigation by F. H. Newell, page 370.

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under such conditions, becomes heated and tends to expand the air lying in contact with it, making it relatively lighter than the much cooler and more rapidly moving currents above, and it may be that when these conditions are established the warm air is displaced by the heavier, cooler and more rapidly moving air from above. Such a current from above, aside from its higher velocity, would be likely to exert a peculiarly parching influence as its temperature rises after coming in contact with the soil. Grass covered surfaces and damp soil could not be expected to have this effect in so marked a degree and the result may be that during windy times the air moves across damp surfaces and fields of grass in a less turbulent manner and, as a consequence, maintains a higher humidity which reduces the parching effect. If, however, the turbulency of the air currents at the surface of the ground increases their parching effect it may be asked whether windbreaks on plains may not augment the turbulency of the currents and thus while exerting a protecting influence over a certain distance to the leeward of them, they might not lower the duty of water in the district as a whole and have a prejudicial effect upon average crop yields. Indeed it appears quite possible that if the windbreaks were placed too far apart such an effect might be the result, but hardly otherwise. But even if windbreaks do exert in general a beneficial effect and tend to increase the duty of water, exact observations are yet too limited to indicate whether the magnitude of such influence would be sufficiently great to make their establishment an economic investment, much less to permit an estimate to be made of what returns might be expected from such an investment; but the problem is capable and worthy of solution.

RATE OF EVAPORATION FROM WATER SURFACES.

There is already a considerable body of data accumulated in this country which indicate the magnitude of the rate of evaporation from water surfaces. A portion of this data has been obtained by measuring the loss of water from tanks floating in reservoirs or canals, but most of them show the loss from tanks 3 feet square or in diameter and 3 feet deep set in the ground so that the rim is within twelve inches or less of the general surface. The mean evaporation during the growing season, April 1st to October 31st, as indicated by the records of nineteen stations located within the rectangle 103 and 121° of longitude and 32 and 43° of latitude, is .21 inches per day; 21.149 inches per 100 days and 47.358 inches for the 214 days in the period under consideration. The minimum evaporation at any station indicated in the records was .14795 per day; 14.795 inches per 100 days, 31.66 inches for the seven months; while the maximum—not including two at Wheatland, Wyoming, which appear to be exceptional—was .273 inches; 27.295 inches per 100 days and 58.41 inches or close to 5 feet for the seven months, at Logan, Utah. East of the Mississippi we have access to records from but five stations in the rectangle 71 to 90° longitude and 39° 30′ and 44° 30′ latitude, and the mean evaporation has been .145 inches per day; 14.533 per 100 days and 31.1 inches for the seven months. The records obtained at Boston, Mass., and Rochester, N. Y., are from floating tanks and the mean evaporation was at the rate of 12.09 and 11.448 inches per 100 days respectively.

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In the absence of fuller data it is perhaps permissible to assume that the ratio of evaporation at 20 feet and 300 feet from the woods, as observed with the Piche evaporometers, is the same as would have been found from water surfaces had they been similarly placed. The mean of the three sets of observations with the evaporometers indicate that the evaporation at 300 feet was 40.73 per cent greater than at 20 feet. If we consider the probable saving of water by windbreaks, it appears likely that, except in the cases where the trees exclude the sun from canals or reservoirs, the 40 per cent represents the maximum saving which could be expected from windbreaks. With an evaporation of 47.358 inches, given as the mean above, the maximum probable saving would be 18.94 inches of water from a canal or reservoir.

EVAPORATION OF WATER FROM CONTINUOUSLY MOIST SOIL.

During the summer of 1903 a soil evaporometer having an evaporating surface of 11.7 square feet was maintained at each of four stations, Goldsboro, N. C., Upper Marlboro, Md., Lancaster, Pa., and Janesville, Wis. The soil surface was kept continuously capillarily saturated by maintaining a water level in the soil at about 12 inches below the surface from which an autographic record was secured in each case. The mean evaporation, per 100 days, at the several stations, was found to be 21.2, 19.2, 15.3, and 18.0 inches at the four stations respectively, given in the order above, or an average of 18.43 inches per 100 days and of 39.43 inches for April 1st to October 31st. If the mean evaporation from similarly moist soil surfaces in the arid regions holds the same relation to that in the humid region as is indicated by the relative rates of evaporation from water surfaces in the arid and humid regions the total evaporation from a constantly moist soil would average 60.04 inches instead of 39.43, the mean found at the four stations east of the Mississippi during the growing season, computed to 214 days. If five feet is the mean rate of evaporation from continuously moist soil in the West the maximum saving through windbreaks would be, according to the observations cited, some 40 per cent of the total, or 24 inches. It is, of course, never true that the surfaces of fields are maintained continuously as moist as was the case under which the rate of evaporation has been determined. It is true, however, that during the time water is being applied in irrigation and for some considerable time thereafter, the rate of evaporation will exceed that which has been recorded from the surfaces kept capillarily saturated from a water level one foot below; and irrigators recognize the fact of rapid evaporation during the hot portion of the day through the notably less distance water will travel under a given head, before sinking into the ground, than is the case at night and when it is cool.

COMBINED EVAPORATION FROM SOIL AND CROP.

At each of the places where the soil evaporometers were maintained and at the same time, an entirely similar one filled with the same soil matured 10 stalks of maize. The water level in these evaporometers, however, was maintained at 3 to 3.5 feet below the surface instead of at 1 foot and an auto-

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graphic record of the evaporation was obtained. The time between planting and harvesting averaged 120 days and, during this time, the mean total evaporation amounted to 24.15 inches, or a rate of 20.13 inches per 100 days and a total of 43.08 computed to 214 days. On these evaporometers the mean yield of dry matter per acre was 13,881 pounds, 10,000 being a large field yield. This observed mean rate of evaporation is, therefore, likely to be some higher than for ordinary field yields under the same climatic conditions, and the indications are that the evaporations from the field surface under crop may not be quite as large as has been found from the continuously wet soil surface. It may appear impossible that such a relation as this can exist, but the probability of it being true is made clearer when it is understood how great is the reduction in the rate of evaporation from soil surfaces when a thin layer at the top is allowed to become dry and especially if it is loose and in the condition of an earth mulch. The surface of the soil in the plant evaporometers was maintained in the condition of a good earth mulch three inches deep, and the effectiveness of earth mulches is clearly brought out by the results given in the following table where the mean amount of evaporation from firm and mulched surfaces of six soil types are given:

Evaporation from six soil types during 28 days with surfaces firm and under three-inch earth mulches, computed to 214 days—seven months.

Soil Types.	Surface Firm, Inches.	Surface a 3-inch Mulch, Inches.	Difference, Inches.
Sandhill	14.37	1.57	12.80
Selma silt loam	22.13	5.92	16.21
Pocoson	25.64	7.11	18.53
Norfolk Sandy Soil	31.87	5.89	25.98
Goldsboro compact sandy loam	40.85	6.73	34.12
Norfolk fine sandy loam	49.79	8.70	41.09

These observation were made at Goldsboro, N. C., in June and July and they show that there is a very great protection against evaporation afforded by 3-inch earth mulches; also, that there is a large variation in the loss of water from different soil types under like conditions through surface evaporation. As the data of this table were obtained during a comparatively dry period, and when the temperature was high, the rates and differences are perhaps as large as are likely to occur, on the average, in the irrigated districts of the West, under such conditions.

In another series of observations made under what must have been conditions closely similar to those of arid climates, columns of capillarily saturated soil 10 feet long were maintained under a continuous draught and without moistening the surfaces, during 314 days where the temperature ranged between 60 and 90 degrees F. The loss of water which occurred was only determined percentagely, but from the weights of the soils per cubic foot the total evaporation, computed to 214 days, must have been very close to the amounts given in the next table:

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Evaporation from ten feet in depth of two soil types under arid conditions continuously during 314 days—amounts computed to 214 days.

Soil Types.	Surface Firm, Inches.	Surface under 3-inch Mulch, Inches.	Difference, Inches.
Sandy loam	2.85	2.49	.36
Heavy clay loam	6.55	4.65	1.90

From these observations, and those given in the last table, it is clear that whenever the surface of a field is protected by a layer of dry soil, whether this is firm or loose, the evaporation will be relatively small but less from the loose than from the firm surface.

It is probable that the losses of water by evaporation from fields in the irrigated districts of the western United States ranges all the way between 1.57 inches and 50 inches from April 1st to October 31st. If this is the case the maximum conservation of soil moisture, through windbreaks, is likely to be found to lie somewhere between 40 per cent of 1.57 inches and of 50 inches or between .63 inches and 20 inches for the period April 1st to October 31st.

The windbreaks themselves, of course, transpire not inconsiderable amounts of water, but when they are planted about reservoirs and along canals, laterals and head ditches, they may draw largely upon water that would otherwise be lost through percolation or seepage; moreover, the land which such windbreaks would occupy is often, in part at least, necessarily waste land unless used in this manner. But if it shall be found practicable to make the windbreaks by using fruit and nut-bearing trees so that an annual income will be realized from them even though it must be small, the promise of a good investment along this line becomes much better.

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RELATION OF FORESTRY TO IRRIGATION.

FREDERICK H. NEWELL, Chief Engineer Reclamation Service, U. S. Geological Survey.

Mr. Chairman and Gentlemen of the Committee:

I want to express to you gentlemen the fact that we, from an irrigation standpoint, appreciate heartily the work which you are doing, and want to keep together, as this is a great movement for the natural resources of the country. The principal thing now for us to do is to convince the public and thinking men that in forestry lies a large portion of the wealth of the country. We are getting beyond the time of mere enthusiasm, or, "Woodman, spare the tree" idea—we are getting down to where the tree is looked upon as a useful thing both as lumber and as wood. Yet we have to come and convince them that we want the trees—we want them to grow, we want them to use. We want the forests on the mountains, not because they are pretty, but because they are useful, and year by year we can see the demand for them growing.

I wish to say I appreciate the opportunity of coming to meet you and to say a word, and that we are heartily in sympathy with this move, and want to be as useful to you as you are to us.

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HOMESTEAD LEASEHOLDS AND GRAZING RANGE ADMINISTRATION IN THE WEST.

R. H. Forbes, Director Agricultural Experiment Station, Tucson, Arizona.

The problem confronting the range interests of the West at the present time is, on the basis of adequate knowledge of the public range, to devise land laws which shall enable a maximum population to support itself in a pastoral country; and to make these laws so flexible as to apply to all grades, both best and poorest, of grazing lands, harmonize all kinds of stock interests thereon, and provide for the often unexpected development, through irrigation, of agricultural lands within formerly purely grazing districts.

UNSATISFACTORY REMEDIES PROPOSED.

Practically the only proposals thus far made to remedy existing conditions are to lease the public lands in blocks at stated rents, or to issue permits to individuals to run stated numbers of animals upon specified portions of the public range.

The unsatisfactory nature of these proposals is attested, in part, by their repeated rejection by one or another faction of those concerned, and for reasons quite evident when the merits of the measures are considered. Lease or fence laws permitting the control of large bodies of land on the basis of competitive bids are usually favored by the wealthier stock raisers who would be at an advantage under such laws, and are earnestly opposed by the small men who would be exterminated through their operation. Horizontal lease laws have been proposed providing for the leasing of all grazing lands at the same rate per acre of rental. When it is considered that different grazing districts may easily require all the way from 3 to 60 acres to support a single cow, the unjust discrimination against the more desert ranges of a horizontal rate-per-acre lease law is too evident to require discussion.

The leasing idea, nevertheless, has a good foundation in the fact that it recognizes that in order to place the grazing industries on a stable basis, *stockmen, like farmers, must have control of the land upon which they operate.*

The permit system has many advocates—possibly largely for the reason that this method has been put into practice on forest and Indian reserves and its results are known to those who would expect to take advantage of it. The permit system, however, is practically no better than free range with a tax added to the stockman's expenses and a more or less unsuccessful attempt on the part of the government to regulate the number of animals in a specified district.

AUSTRALIAN EXPERIENCE AND RESULTS.

Australia, which is and always has been, more a pastoral than an agricultural region, for the last 75 years has been making and remodeling her laws relating to the disposal of Crown lands to settlers. As they now stand the land laws of various of the Australian states present the following sensible features: First, grazing lands are divided according to their capacity to

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carry stock into as many as four classes and settlers are permitted to occupy smaller or greater allotments of territory according to its quality. Second, these lands are occupied under long tenure leases, with renewal privileges, which give practically permanent control to the stockmen. In addition to the motive thus created to improve their leaseholds, they are also usually required by law to fence and otherwise improve their holdings. Third, the classification of lands and their allotment to settlers is done by a Board of Commissioners acting for the government with a view to correct judgment and equitable division of the public lands.

The operation of these laws with reference to the development of pastoral industry is stated to be highly satisfactory. Vast areas of semi-desert lands, divided into comparatively small holdings, are legally occupied for long terms by stockmen who, prompted both by law and their own best interests, improve their holdings. Thus it is that in Australia an immense pastoral country has been fenced, substantial improvements are installed, provision is made gainst famine in dry years, animal pests are exterminated, poisonous plants are eradicated and an era of improvement has apparently been inaugurated *directly due to the recognition of the fact that the Anglo-Saxon must have proprietary interest in land if he is to be expected to improve its condition.*

In unhappy contrast to the upbuilding of pastoral Australia is the reverse process everywhere evident in our own Western States. The spoliation which has resulted, inevitably, from the lack of laws having for their object a saving administration of the range country, has resulted in a gradual but sure decline of its carrying capacity. In some districts, especially where, under stress of overgrazing, the soil is easily eroded by rainfall, this damage can never be repaired; in others, restriction of grazing, reseeding, and other remedial measures may effect a large measure of restoration.

PRINCIPLES ON WHICH SOUND GRAZING LAND LAWS MUST REST.

Successful grazing range laws must of necessity rest upon two kinds of knowledge—knowledge of the range itself—the forages that it bears, their habits of growth and reproduction, their food value for animals, the classification of grazing country into different grades, and the carrying capacity and endurance of these different kinds of range.

The second sort of knowledge required is that derived from legislative experience in dealing with purely grazing lands elsewhere.

Australian experience, considered together with the traditions of our own land laws points to the practicability in the United States of the stockman's homestead or long term leasehold in pastoral districts. The homestead idea, long-tried and well approved in this country, is, briefly, that a settler shall be granted enough territory to afford him a living—enough and no more.

THE MEANING OF THE HOMESTEAD.

As applied to the Mississippi Valley a homestead meant 160 acres of land, this area being found in the average instance sufficient for a farming family.

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But when the tide of immigration pushed west of the 100th meridian into the semi-arid regions it was found either that 160 acres with water was worth a great deal more, or that 160 acres without water was worth vastly less than that same area back in the Mississippi Valley.

Why should we not apportion grazing ranges so as to grant a sufficient acreage for a sufficient time to afford the small stockman the necessary territory to support the herd whose increase shall give him a living income, and protecting him in his tenure for a sufficient length of time to create an incentive for the maintenance and improvement of his range?

In Australia, from 1,280 to 40,000 acres of grazing lands, according to quality are thus leased, at rates proportionate to value, for terms of from fourteen to forty-two years. Many benefits are experienced under these provisions. Sheep and cattle wars are rendered impossible since each interest is confined to its own territory. Co-operative arrangements are entered into extensively where co-operation permits of more economical management of large adjoining leaseholds. Grazing leaseholds are operated in connection with cultivated farms; and humane methods of handling stock are rendered possible.

OBJECTIONS TO BE ANSWERED.

It is objected by some that long tenure leases will close those public lands now thought to be purely grazing lands to future agricultural development; that such development is now occurring in sections formerly thought to be unreclaimable, and likely to continue indefinitely and to an unexpected extent. There is no more reason why the grazing leasehold should stand in the way of the agricultural homesteader than that it should stand in the way of the prospecting miner. The right-of-way and the opportunity to make good are, apparently, just as possible to farmers, as to miners in a parallel situation under the well-tried mining laws of our western country. With suitable provision, as in Australia, for allowing the pastoral leaseholder preferential homestead rights on his leasehold, no hardship is implied, but the way is parallel for an easy transition from grazing to agricultural pursuits in regions capable of higher development.

Again, recurring to the subject of permits, it is thought by some that the solution of the range question lies in the extension of the permit system—that all public lands should be apportioned to grazing interests by permit, until taken up by homestead. This idea, with all deference to those who are working on that basis, may be questioned, both in practice and its adoption to Anglo-Saxon human nature. In the first place, to carry it out on the enormous grazing domains of the West implies the creation of a numerous official body over whose work it would be impossible, in the nature of the case to exercise close control. The abuse of the permit system by stockmen who can easily take advantage of their official overseers is stated to be frequent. The permit system, giving stockmen tenure of their range from year to year only, puts the industry on a less permanent basis even than under the free range regime, and, in addition, adds a tax to the already severe conditions under which, in this day of decline, stockmen are laboring.

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Yet again; the stockman, no more than the farmer, wishes to be officially regulated in the technical management of his business. Give him his territory, define his rights, make scientific knowledge and advice available to him—*but* give him the *management* of his own business.

Still again; to those who imagine that the interests of the farmer are jeopardized by those of the grazing leaseholder, let attention be called to opposing facts. The irrigation farmer is virtually interested in the condition of his watershed. An improved condition of grassy watersheds confers a great and direct benefit upon irrigation farmers; and this improvement will be brought about by the proper protection of the stockman upon his grazing range.

As to the feasibility of range improvement it is only necessary to point to the results already obtained on the experimental grazing range reserve south of Tucson, Arizona.

This reserve, containing 49 square miles of diversified lands, was selected and fenced under the co-operative arrangement between the United States Department of Agriculture and the Arizona Experiment Station. Practically a desert when it was fenced two years ago, protection from the ravages of stock for that time has resulted in a remarkable restoration of forage grasses.

There can be little doubt that the scientific and economic basis on which range administration must rest is capable of adequate development. It only remains to devise and put into operation a suitable system of tenure whereby the natural wealth of our grazing regions may be developed and utilized by our people.

Mr. Potter—Have you sowed grass seed extensively in that reserve?

Prof. Forbes—No, sir; however, nature seems to be grassing that point rapidly.

Mr. Potter—It comes up without being seeded?

Prof. Forbes—Yes, sir. If it is just given a chance it will produce a fair crop. There are patches of grass coming in all over that reserve, so I do not doubt that in the course of ten years it will be grassed, even in its most baren portions.

Mr. Walter T. Swingle—I would like to ask Mr. Forbes if this fenced range would not keep it from spreading with good grasses?

Prof. Forbes—They tell me that the Black Droma is slowly dropping out. Dr. Griffith, I think it was, said that the grasses were spreading out most rapidly, and washes and waters have probably carried seed. On the other hand it is a fact that worthless weeds have obtained a hold in that country and have come to stay.

That country has a soil particularly subject to rain, and when once a valley is cut down into a deep gulley, the whole is forever to be changed.

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FIRE PROTECTION IN THE SANTA BARBARA FOREST RESERVE.

COL. WILLIS M. SLOSSON, Forest Supervisor Eastern Division Santa Barbara Forest Reserve, Nordhoff, California.

The Santa Barbara Forest Reserve contains approximately 1,800,000 acres, in Santa Barbara, Ventura and Los Angeles counties, State of California, and is divided into two divisions, the eastern and western. As forest supervisor I have charge of the eastern division, which contains about 1,100,000 acres, lying in Ventura and Los Angeles counties.

There is considerable pine, cedar and fur timber in the mountains along the north side of this reserve, but the reserve is mainly covered with brush. Nearly the entire eastern division is the watershed of the Santa Clara River, which flows from east to west and empties into the Pacific Ocean a few miles southeast of Ventura.

The purport of this paper is to give the present plan of fire protection, and what is needed to improve it.

The Santa Barbara Forest Reserve is mainly a brush-covered reserve and most people think brush is a useless cover, but the settlers of Ventura and Los Angeles counties know the value of it on this reserve, the eastern division of which is the watershed of the Santa Clara and Ventura Rivers. In the Santa Clara River valley $1,000,000.00 worth of lima beans were raised this year, and the farmers who irrigated their land raised on an average double the number of sacks per acre in comparison with those who did not irrigate. At one place where the bean-fields of two different ranches joined the farmer who irrigated raised twenty sacks per acre, while the farmer who did not irrigate got only eight sacks per acre, and as the beans are worth at least $3.00 per sack the irrigation was worth twelve sacks or $36.00 per acre to the man who irrigated his land. The same can be said of the sugar-beet industry of that valley, one of the largest beet-sugar factories in the country being located at Oxnard, near the center of the valley. The refined sugar turned out of this factory this year is 400,000 sacks of 100 pounds each. One orchard of English walnuts contains four hundred acres, and the English walnuts raised in the valley are valued at $350,000.00 this year. The Lemonaria ranch, near Santa Paula, is the largest lemon orchard in the country. But if this valley is to continue in its prosperity and produce good crops it must be irrigated and the cause which makes the splendid crops grow must be protected. As the watershed is the Santa Barbara Forest Reserve, then the cover that best conserves the water-flow is the cover to be protected. On this reserve it is brush and the denser the brush, the better the water is conserved.

VALUE OF BRUSH COVER.

A good test of the value of brush as a cover for conserving water has been shown in the Ojai Valley the past year. In October, 1903, the canyon in that valley, where the San Antonio Water Company obtained the water for their water for irrigation, was burned over and they did not get one-half the flow

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of water this season that they did during the season of 1903, though the rainfall each season was about equal.

The government in its management of forest reserves allows sixteen rangers for the eastern division of this reserve in the summer or dry season, and eight for the winter or wet season. In the summer season each ranger is assigned a certain district to patrol, and is instructed to be courteous to all, but firm in the enforcement of the rules and regulations. He notifies the hunters and campers to be careful with their camp-fires, and keeps fire-warning notices posted at all the camping places. He is also instructed to ascertain the cause of every smoke that he sees in his district or adjoining districts. If the ranger cannot handle the fire alone he is allowed to get outside help, for which twenty cents per hour is paid. The second class ranger in whose district the fire is located takes charge of the work, provided the supervisor does not get there.

MUSCULAR AND NERVY RANGERS WANTED.

The main feature of our plan of protection is to have rangers who have good judgment, muscle and nerve. The ranger should keep "level-headed" and have judgment to know how and when to take every advantage of a fire. He should have nerve and muscle to face the fiercest fire when called upon and jump in and fight it, even though it singes his hair. Men who can and will do that kind of work often win the fight.

In fighting brush fires in the mountains we have found that an attack on both flanks is necessary. Therefore we are cutting trails or fire-breaks along the tops of the main ridges between canyons and along the different ranges. these trails or fire-breaks allow the rangers and men fighting fires to confine the fire usually to one canyon, as they have an open pathway on each side of the fire where they can keep along with it until the top of the range is reached; or until night comes and the draught is down the canyon, when they may be able to close in and head off the fire in the canyon. In the low places along the ridge, at the heads of some little canyons are the places that usually try the ranger's nerve. The brush is usually thicker and the fire comes up pretty lively, and if it crosses the trail it will burn along the side of the next canyon and slowly down into it. Therefore at these places hard work is called for, and the fire-break is cut wider. A patrol is established around the burned district and kept up until all danger is past.

ORGANIZED FIRE FIGHTERS.

Shovels and axes are the principal tools used and each ranger has to carry them, so that he will be ready when fire is discovered. At times it seems impossible to make any headway against a brush fire, and starting back-fires is resorted to, but this kind of work is a kind of double-acting proposition and is usually dangerous. Therefore we rely principally upon the flank work along the ridges, and are cutting trails and fire-breaks as fast as possible to perfect that plan of work.

We have two cabins where tools and supplies can be stored and rangers camp. This saves packing the tools and supplies at time of fire. Drinking

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water is very necessary for men working, but in some places it is hard to get, therefore each man is supplied with lemons as a substitute.

Some may think twenty cents per hour for extra men too much, as we pay at that rate from the time they start until the fire is out or under control so the rangers can handle it. But when they replace the clothes and shoes that get burned, torn and destroyed, the balance is not an extra compensation for forty-eight, sixty or eighty hours' work. I do not believe in hiring too many extra men, but get good workers if possible, and men that will go ahead and not have to be told every move to make. Neither am I in favor of depending upon a volunteer force, unless the volunteer is personally interested, for the reason that too many bosses show up in a volunteer force.

What is needed to improve the plan is: rangers enough to complete the trails and fire-breaks as now planned, and more cabins where tools and supplies can be stored, thereby saving time in packing them long distances at time of fire. Arrangements should be made so that the extra men hired to work at fires do not have to wait from thirty to sixty days to get their pay. It would be a great benefit if a telephone line could be built to several places overlooking the reserve. But the greatest benefit would be to have the State enact a law governing the careless burning of brush by owners and settlers in and along the borders of forest reserves or other places useful as watersheds. A majority of the fires and those doing the most damage to watersheds start from the careless burning of brush, weeds and stubble on private holdings.

There may be other and better plans of handling brush fires, but during the past six years we have been more successful where we had trails, fire-breaks or an open pathway along the adjoining ridges, where we could work on the flanks of the fire. With the thermometer registering from 100 to 110 degrees in the shade, but little can be done to stop the headway of a fire until night; then possibly success may come in an effort to head it off.

More cabins should be built and located in places where the surrounding territory is accessible. At the cabins rangers can camp, an extra supply of tools should be kept stored in these cabins by the government. Many other improvements might be made that would be pleasant, but whatever else is done, trails and fire-breaks must be made, so that rangers can get around a brush-covered reserve, if it is to be protected as a watershed.

Mr. Walter T. Swingle—I would like to ask if you could get any assistance from stockmen renting range, in putting out fires?

Col. Slosson—I will say that in forest reserves permits have to be granted to stockmen, and in the application it provides that they shall aid in their locality. There are more cattle grazed in the Santa Barbara reserve than all the rest of the reserves in Southern California. One reason why I ask that stock enough be allowed is so that each year the grass that grows in the canyons may be fed off, because it dries up in dry seasons, and if there is a body of that scattered over the ground the fire gets a quicker and better start. We are not always in a position to get the wet sacks and it gets a headway so we can not stop it. Therefore, I believe it is better to get enough

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stock, but not overstock it. I think they are making more money and grazing districts are kept in better condition if not overstocked.

Question—Would it not be well to leave it to a supervisor to name the amount of stock necessary to eat off this grass?

Col. Slosson—That would depend a great deal on the honesty of the supervisor. The supervisor is allowed to issue a permit to settlers. He is the man on the ground and understands the position, and if he is honest there will be no damage. I think the stockmen should be compelled to fence springs around the mountains and put in troughs and pipe the water out to the stock.

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CONDITION AND ADMINISTRATION OF THE GILA RIVER FOREST RESERVE, NEW MEXICO.

R. C. McClure, Forest Supervisor Gila River Forest Reserve,
Silver City, N. M.

This national forest reserve was created March 2, 1899, and comprises an area of 2,327,040 acres, is located in the southwestern portion of the Territory, in the counties of Grant, Sierra and Socorro. It was formerly divided into eastern and western divisions, and under the management of two Forest Supervisors, but is now one reserve and under the management of one supervisor, assisted by a number of forest rangers, with headquarters fixed at Silver City, the most accessible point of location for the accommodation of citizens having business relations with his office, accessible to daily mail and affording telegraphic communication with the central office at Washington, D. C.

Included within its area are five distinct mountain ranges, the Black, Diablo, Mogollon, Tulerosa and San Francisco, all spurs of the Rockies, and in these mountain ranges the Mimbres, the Gila and San Francisco Rivers and their tributaries have their source, and in the continuous flow of these rivers a large per cent of the population of both Arizona and New Mexico are interested. I have it from a forest inspector familiar with the various reserves of the United States, that the Gila is one of the best timbered reserves in the Middle West, has upon its areas sufficient timber to comfortably house and home twice the population of the Territory in which it is located and leave young timber and seed-bearing trees sufficient upon its area as to reproduce itself in the next fifty years.

This reserve has a resident population of about 1500, due to the fact that prior to its creation agricultural lands lying in the narrow valleys of the rivers and their tributaries heretofore mentioned had been entered and most of them passed to patent before the date of the creation of the reserve. Citizens of the reserve are generally satisfied with conditions, and, in fact, most of them would protest against any proposed elimination.

In the foothills of the Mogollon mountain range, to the west, is located a large group of valuable mining claims, properties pregnant with richest ores, and representing millions of capital, located in the west center of the reserve and about ninety miles north of Silver City, their nearest railroad shipping point. This important industry, perhaps the leading industry in the Territories of Arizona and New Mexico, it is the province of the national government to foster.

PREHISTORIC RUINS.

The Gila River Forest Reserve abounds in ruined pueblos, prehistoric mounds and cliff dwellings. The best known cliff dwelling is located on the west fork of the Gila River. The main cliff is about 600 feet in length, has a perpendicular face averaging 150 feet in height, showing various phases of aboriginal engineering and architectural skill of numberless "human martins" that carried on their backs up steep cliffs every stone and every bit of mortar used

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in building cozy little rooms in this ponderous edifice, and the skill here displayed stamps them as a most extraordinary little people. We judge of their size by the presence of tiny little doorways leading from one compartment to another, and from the size of the rooms in which they lived. These ruins, what is left of them, it is made a part of the duty of forest officers to protect from further vandalism, that they may be left undisturbed and together, so that the scientist ambitious for the solution of the interesting and mystifying problems of American ethnology and archæology may have the benefit of any knowledge to be gained by a study of these relics, and this exhibition of engineering and architectural skill of this little people which ages ago so proudly held their own in isolation and solitude.

In the southwest corner of this reserve are about two hundred thousand acres of lands that have practically no timber upon them. They are neither forest lands, mineral lands or agricultural lands. The only classification that may be given is that they are high mesa grazing lands, not susceptible of irrigation and possibly never will be.

GAME LAWS ENFORCED BY FOREST OFFICERS.

The headwaters of the streams heretofore mentioned are full of fish and in the deeper recesses of the forest may be found bear, mountain lion, wild turkey and deer, the latter of which are increasing in number, due to enforcement of Territorial game laws by forest officers. The reserve abounds in numerous hot springs, waters from some of which issue from the ground at boiling point, best known of which is called Gila River hot springs, by some called Hill's hot springs, best known for the reason that these springs are located upon patented lands, have been improved for the use of the public by putting in of bath tubs and the building of a kind of way-side inn, where the people who frequent these may get hotel accommodations, and bathe in these waters, which are said to contain medicinal properties.

Administration is a most important question, not only in the Gila reserve, but in every other forest reserve of the United States. The service is being improved with each passing year and the standard of proficiency is being raised and men already in the service are acquiring larger experience and a better understanding of what is expected and what is contemplated. We have commenced the doing of permanent work, such as the building of permanent trails, construction of rangers' cabins centrally located, cutting of fire-breaks, etc. The efficiency of the men is being brought to a higher standard, and promises for the future greater protection and more satisfactory administration.

Stock grazing in New Mexico is one of the leading industries and the national government in its efforts to foster it has provided for limited grazing in its forest reserves, and this year admitted to graze in the Gila River Forest Reserve 150,000 head of sheep and 55,000 head of cattle and horses.

STOCK GRAZING IN RESERVE.

For the accommodation of this number of stock the reserve has been divided into nineteen grazing districts, this division into grazing districts

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made necessary for the more equitable and systematic apportionment of grazing areas and distribution of the maximum number of stock allowed to graze according to the grazing capacity of the several districts and to better enable forest officers to prevent over-grazing. This division of the reserve also enables us more equitably to divide the range between cattle and sheep, which, it is claimed, do not thrive well on the same area. For this reason sheep are assigned to certain districts and cattle to others. When patented ranches of cattle owners fall within sheep allotted districts we assign to such cattle owner home range in the vicinity of his ranch or farm, from which sheep are excluded. Sheep were admitted to graze from April 1st to August 1st, and cattle, as a rule, the year round.

I believe that all grazing in forest reserves is, more or less, detrimental, yet danger from forest fires would be very much augmented by a failure to permit sufficint grazing to consume the grass that would otherwise grow up and become a tangled mass. Once on fire in this arid region during the summer months great loss would result, so that the risk in this particular outweighs the little damage that is done the reserve by restricted grazing. This distribution of sheep and cattle has not given entire satisfaction to either the cattlemen or the sheepmen, but it is the most equitable of which the supervisor is capable and its abandonment will work injury to one or the other of these industries and ultimately result in exclusion of either sheep or cattle.

The taking down of unlawful enclosure was perhaps the most delicate task yet assigned forest officers. But fences down, the stockmen have found that it is possible, by leasing a school section here and there, to get along fairly well without these vast areas of unlawful enclosures, and they never questioned the justice of the order.

Forest rangers, in addition to wearing a badge of authority, have voluntarily adopted a uniform of gray color with green stripes, and the good effect makes it commendable and bespeaks a personal pride on the part of the field force.

The justice and the wisdom of setting apart this vast expanse of well-timbered areas is no longer questioned by thinking people, who concede that the right of the individual ceases where the right of the public begins. A healthy public sentiment favorable to national forest reserves, wisely administered, now exists among the people.

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FOREST PLANTING A REQUISITE TO SUCCESSFUL IRRIGATION IN NORTHERN MEXICO.

MAXWELL ALEXANDER KILVERT, General Manager Tihualito Agricultural Company, 28 Ortega, Mexico City.

What makes up Northern Mexico politically comprises three sections of distinct physiographic character. There is the coastal plain on the east, which includes the State of Tamaulipas and part of Nuevo Leon. The climatic conditions existing there resemble those of the Texas littoral, modified by the high ranges of the Eastern Sierra Madre. On the west are the ranges of the Western Sierra Madre, and the much narrower Pacific coast plains. It is the central table land which presents the serious problems indicated by the title. This district forms an irregular quadrangle, of which the south side nearly coincides with the Tropic of Cancer, from the 100th to the 104th meridian west of Greenwich, and the north side lies along the frontier from 29 to 32 degrees north, and between the 101st and 106th meridian.

This district is an elevated plateau, with a height of some 6000 feet above the sea along its southern border, falling off toward the north, and more especially towards its northwestern corner, where it is only slightly over 700 feet. There is a pronounced depression in the western edge about one-third of the distance from its southern to northern limits, in the neighborhood of Torreon, and just where the most extensive irrigation operations in Mexico are being carried on. The altitude here is about 3500 feet, and from this point the plateau falls off, in fan shape, toward the north and east to its low point at Eagle Pass, rising, however, along its western side to about 4600 feet at Chihuahua, and dropping about 900 again from there to El Paso.

This table land is very much broken by clumps and ranges of hills and low mountains, rising from 200 to 300 to perhaps 1500 feet above the surrounding plain. These ranges run in a general northerly and southerly direction, and some of them are unbroken for many miles by passes feasible for wagon roads.

The prevailing formation is limestone. These elevations are totally bare of forest. Short of forested hills, they show every stage of chaparral covering, of mesquite and other large shrubs of spaise grass covering, of rocky, cactus and ixtle-like covered areas down to the bare soil-stripped rock. The plain itself presents many phases. In the northwest part are large areas of fair to poor grass-covered range, and from the south to the northeast every condition, from good chaparral to the apparently hopeless stony desert stretches, with nothing except various forms of the cactus making a struggle for existence. Vast areas, however, are composed of the most fertile alluvial deposit, the result of thousands of years of disintegration, washing down, blowing off, and settling. These plain areas need only the stimulating touch of water to equal in fertility the most bountiful districts of the world. The depth of the alluvial deposit in many places is very great. Experiments made recently in well-digging in the principal irrigated districts have shown over 200 feet of alluvial deposit, of strata of humus, sand, light clay and some gravelly strata.

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AN ARID SECTION.

The amount of rainfall throughout this district is still largely a matter of conjecture. It is, however, quite safe to say that by far the greater part of the area falls within the limits of the distinctly arid belt, only the part referred to as the range country reaching the semi-arid class. Observations taken at a point near Torreon, between the 22d of March and the 22d of October, of the year 1904, a period which includes more than the so-called "rainy" months, show a rainfall of 5.02 inches, and this is undoubtedly a relatively wet season.

The only hope for the reclamation and productiveness of this territory lies in irrigation, and for the most part, in works on an extensive scale.

The water which is available for this purpose to-day is the run-off from rains in the mountains. It is that precipitated on the more considerable ranges that must be dealt with. Except in the northwestern and extreme northern part of the area, the water courses are quite dry during most of the winter and early spring months. In summer and autumn they fill from the hill rains, and when not otherwise diverted, carry the water down through the plain, most of them forming small ponds and lakes. There are very few of these which receive enough water to prevent drying up during the dry season.

Of the few of this class, the principal one no longer exists, all the water of the stream which fed it being now utilized for irrigation. This stream is the Nazas, and the land which its waters now irrigate are known as the Laguna district, and comprise the area formerly covered by the lakes formed by its flood waters, and much more in addition. What has been done by the Laguna represents the most extensive and systematic attempt yet made in Mexico in the line of irrigation. There are probably some 300,000 acres under ditch, and the service requires close to 3000 miles of main and distributing ditches and perhaps more. The holdings are very large, half a dozen or so owners probably holding a large fraction of the cultivated area, and with one exception having few or no lessees. Cotton is the main commercial crop. If the water supply were regular and permanent, conditions would be ideal, the dryness, sunshine and heat of the climate being insurance against serious insect depredations, except in abnormal years. But the flow of the Nazas River, like that of all the others, depends on the rains in the nearer mountains and the eastern ranges. The beginning of the summer flow ranges anywhere from the first of July to the middle or last of August. This irregularity of flow renders a crop, which would otherwise be much more dependable than most, almost as uncertain as under "sky farming."

TO CONSTRUCT IMPOUNDING RESERVOIRS.

Anything which would so regulate the flow of this stream that the big floods were checked, and if possible, to such an extent that the run-off was carried entirely through the year instead of ending at any time from January to April, as now, would be worth a very large expenditure. The government is proposing to achieve this end by the construction of impounding

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reservoirs, and now have engineers investigating the feasibility of a project for damming a canyon not far above the upper canal intake dams. If the manifold difficulties of handling flood waters which are exceedingly heavily charged with silt, are overcome, the regulation of the flow by a reservoir system would doubtless be an improvement on dependence upon the unbridled vagaries of the present stream. But the hills of by far the greater part of its catchment basin have been stripped clean of trees, and as the foothills immediately surrounding the plain are reached, they are bare of everything but ixtle, cactus and the hardier shrubs. There is still much more rainfall on them, however, than on the immediately adjacent plain, as judged by inspection, for no measurements have been taken in the hills. It may be impossible to reforest the scattered hills in the plain, but further back into the range a foothold can be secured and the mountains reforested, and miles by miles the desert can be driven back, and the excessive flood waters checked. It is quite certain that this area was once forested.

The Nazas has been used as an illustration because its use has been so fully developed. The total volume of water discharged from 1st of July, 1902, to the 30th of June, 1903, according to the government expert, was in round figures 787,000,000 c. m., or say approximately 650,000 acre-feet, of the total amount for any year, probably nearly two-thirds would be delivered in about four months. This proportion applies in a still more marked degree to most of the other water courses emptying into the district under discussion. The great fluctuations of the rivers, both those emptying into the temporary lakes of the plain, and those running into the Rio Grande or its tributaries, all present the same difficulties in handling as does the Nazas, and from the same cause.

THE FORESTRY IDEA UNDEVELOPED.

As yet practically nothing has been done in Mexico in the way of preserving the existing forests, to say nothing of reforesting. The only law of general application on the subject is one forbidding the cutting of wood or timber within ten miles of the bank of a stream. This is intended to preserve the banks from erosion and caving, but it is not generally enforced. New lumbering companies are constantly forming, and rapid inroads are being made on the standing timber. The main ranges of the Sierras, hitherto immune for lack of transportation facilities, are now being attacked. Within five or ten years damage will have been done which it will take more than a generation to repair. The government is turning its attention to the subject, but the lumbermen are moving much faster than the government. All the work that could be handled in reforestration, and in the expenses of maintenance for considerable forest reserves, would not require more than a fraction of the amount lost in this year alone by the Central Railway and the Laguna planters on account of the irregular flow of two streams only.

For successful irrigation in Northern Mexico, for the uninterrupted maintenance of its means of communication, for the preservation of its climate, and for the conservation of the timber necessary for its industries, a comprehensive system of forest preservation and extension by tree planting is necessary in Mexico, and necessary to-day.

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TREE AND PLAIN.

Discussion of the Problem of Aforesting the Great Plains.

WM. T. LITTLE, Editor "Oklahoma," Perry, Okla.

There are forests where there are rains, not rains where there are forests, yet, being to a certain extent correlative, one must perceptibly induce the other. There, maximum altitude suggests minimum moisture. Great land expanse remote from large water surface induces hot air of low moisture content. The 30 degree parallels are high pressure areas, so from there air is forced down and out, establishing them as dry belts, one of rainfall's prerequisites being an ascending current. Intervening with north and south wind, the Rockies mitigate this ill, yet their removal 100 miles westward would make forests of the prairies, prairies of the plains and plains of the almost desert.

The less of annual precipitation the greater per cent of crop season rainfall. The 20-inch rain belt has, approximately, four-fifths of its supply during crop season, while one-half in summer and one-half in winter is common ratio for the more humid States. Four-fifths of 20 is 16, and one-half of 36, very common for portions of Wisconsin, Michigan, Illinois, Indiana, Ohio and New York, is 18, giving a growing period advantage of but two inches.

Increased evaporation and decreased air humidity partially offset this advantage. This first is susceptible of relief by frequent cultivation. In this way is evaporation limited to foliage, and the humidity of air equalized and supplemented, the loose soil receiving more water. And here lies the secret of growing trees on plains. As east and west determine precipitation, so north and south determine evaporation. At its minimum point, the 20-inch rain belt of Texas has two and one-half times the evaporation of that same belt in Minnesota. In addition to heat, this is partially accounted for by greater prevalence of wind. It would be reasonably fair to say the average annual evaporation of the total country considered would be something like 45 inches, or two and one-fourth times its entire precipitation. Mr. Kellogg gives its middle district, a part of Kansas, as 54 inches of evaporation and 20 inches of rain.

THE FABLE OF INCREASED RAINFALL.

Honest ignorance has led agents to publish tables of the plain's increased rainfall, which but retards remedy. Sun radiation is excessive on sand surface and barren soil. A tree's north will remain moist with dew much longer than the south and sprout more twigs. Corn to the north of prairie ponds will the longer survive hot winds. In malaria countries you will find Indian camps between wind and creek. Black clothes take up many degrees more of heat than do white ones. The government's experiments as to effect of wind velocity on evaporation, from water surface, also establishes the principle as applying proportionately to soil surface. In this connection it should be well to know that fourteen miles per hour is an average wind velocity for portions of the plains, increasing that by 50 per cent for weeks at a time and occasionally doubling even that. From the former surface a 25-mile per hour wind takes up from six to nine times as much water as would evaporate dur-

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ing perfect calm. The average western Kansas wind increases the calm's evaporation by five fold. So four-fifths of that soil's water is lost, and much of the precipitation becomes flood water. These things both emphasize our necessities and suggest possibilities. At Lawrence, where artificial timber has been planting for half a century, Prof. Snow records the period of from 1888 to 1893 as having eight per cent less wind velocity per hour than the period of from 1873 to 1888.

On heat's control and wind's defeat,
  So many things are pending.
That what we hold within our power,
  Appears to have no ending.

There is suggestion that reforestration has perceptibly re-established normal precipitation and surface wind velocity in certain Old World districts. Some few official recordings support the old settler conviction of Pennsylvania's denuded areas being subject to increased wind velocity and constancy. Generation yet extant recalls "the wind-swept prairies of Illinois," an expression so gradually thrown into disuse by silviculture as to make unnoticeable its departure

The 20-inch rain belt, meaning semi-aridity, crosses the extreme southern point of Texas and the northwestern corner of Minnesota, three times bending to the West in obedience to east and west streams approaching with co-operative effect, the Wichita mountains possibly once aiding results. Upon entering the zone of earth rotation winds, water courses lost effect, however, possibly because of their north and south direction.

Artificial timber diverts cloudburst flood water into earth percolation that later evaporates through foliage, equitably supplementing atmospheric moisture. Increasing topographical sameness, by giving air more freedom of motion, accentuates disadvantages of a constantly increasing altitude. This can be neutralized by trees that would, in effect, create hills of wind-reducing capacity. Besides being reduced in amount, precipitation concentrates for fewer and more violent efforts. Possibly incapable of serious increase, ravine dams would prevent much of its return to the ocean, and trees so delay progress as to establish perennial springs, replenish water courses and possibly so evaporate as to tempt overhanging rain clouds. The plain's misfortune arises less from absence of moisture in her higher atmospheres than from the absence of vertical moist currents.

Tropic trade winds come up from southeast of Florida and, turned north by land banks of New Mexico, pass up the Mississippi valley. Once in that more northern zone, where elevated winds incline toward the earth's rotation, they mingle with a colder current and condense for an eastern journey that brings rain immediately upon coming in contact with an upward current of sufficient moisture and particle content. The dryer and more level is surface, the less likely is a vertical current, as there are fewer temperatures to induce mingling of strata.

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TREES WOULD KILL THE WINDS.

Were the country in question one compact forest, these wind-swept plains were perfect calm, and just so near as the first condition is approached, to that degree will the second be attained. King's test showed that during a light wind, evaporation from water surface 200 feet from an oak grove windbreak was 41 per cent greater than at its base, 300 feet being about the limit of benefit. The higher the protection and the more intense the velocity, the greater the ratio of protection. In a general way it is said these distances and heights are as sixteen to one, so a 30-foot east and west board windbreak, every 480 feet from Gulf to British domain, could not but be a solving. Dr. Saunders once found this 16 feet extended to 80. Replaced by trees, some wind would escape through foliage, and their rounded tops would make applicable that rule of spheres effecting but one-half the resistance presented by square flat surfaces whose square equalized the sphere's diameter squared. Dovetailing into the vital questions of precipitation, surface evaporation, soil water, pond construction and artificial tree windbreak becomes the alpha and omega of both sub-humid and semi-arid farming, absolute aridity being left to irrigation.

The eventual feasibility of this tree-planting, pond-building enterprise must be argued from observation and experience, yet there is much of daily discovered scientific knowledge possibly more potent. From the plain's early Spanish visitors come no sign or token as to how far east buffalo grass extended or how far west the tree had taken up abode, for largely by these things are we to determine how far up the Rocky Mountain slope non-irrigated agriculture may hope to climb, unless a system of dust mulch agriculture be adopted. No plain-crossing gold seeker has left satisfactory data on these subjects. Through activity of science, Central Asia, Steppes of Russia and south Mediterranean Sea deserts will eventually produce and sustain, but our plains are enough better to warrant effort for such climatic changes as constant occupancy and agriculture can sustain.

GRADUAL ENCROACHMENTS OF THE TREES.

Answering my recent inquiry, Col. Van Horn, editor of Kansas City's only paper in 1856, writes: "In 1856 land to the immediate southwest of Kansas City looked like a green ocean to me. Now it looks like a succession of parks." An equally recent letter from Timothy Hersey, in whose log cabin Bayard Taylor ate that now famous last house meal upon crossing the plains, says Dickinson County, Kansas, upland and bottom, was then buffalo grass. From Mr. Hersey's letter and my travels in all but one of Kansas' counties, every county in Oklahoma and each reservation of the Indian Territory, conclusion is that, had the millions of buffalo continued their tireless tramp of soil compacting, buffalo grass would to-day extend east of the 30-inch rain belt. Mr. Hersey insists upon such radical change of climate during the past half century as to warrant us in expecting final and full treeing of both sub-humid and semi-arid belts.

There were even then large trees, but so limited to extremely favorable environment that the country was termed "destitute of timber." Yet the lone

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tree's presence indicated possibilities. Those natural tree conditions can, at least to small degree, be made general. Of course, work, looking to the establishing of universal forest conditions on the plains is not to be thought of, knowing one foot of forest humus has been said to require 5000 years of leaf deposits; but I desire to be distinctly understood as holding this question of artificial windbreak and dams for the increasing of atmospheric humidity, to be a part of the nation's obligations to the sub-humid and semi-arid belts, the same as our flood neighbors of the humid and arid belts have been accorded, in proportion as they have demanded and proven themselves worthy. Growing trees are annually giving proof of plains' forestration being practical, and the fact of forest litter reducing soil evaporation 87.5 per cent is enough to insure large result from small effort. And it is well to know that, on equal space, trees evaporate less than field crops.

TREE GROWTH IN A GENERATION.

Raised at the head of old Chisolm trail, I have seen Texas droves mill in the Smoky Hill, where banks were destitue of all save the solitary cottonwood. I have lived to see those self-same banks densely forested back just so far as the plowman's avarice will permit. On the old-type mustang I have driven the old-type long-horn, and they fought, when at bay, across bottom lands so rent into drouth-cracks as to frequently admit a hoof, a certain horse once going in with both front legs. These identical lands are now alfalfa meadows and cornfields. Do not tell me climate is immutable as time, though rainfall may not increase.

A professor of the Nebraska University returned to his boyhood home in Brown County, Kansas, finding the brush of neighboring ravines had climbed an intervening hill to, at the apex, intertwine the branches of wide spreading trees. Near Overbrook, while appraising Indian Territory upland, where eight years before the roots of succulent grasses dominated, I have occasionally found it impossible to even lead a saddle horse through post-oak thickets grown since stockmen quit the country and ceased fires eight years before.

NOT POLITICAL PLUMS.

Colonel Glazier, who brought the first passenger train into Oklahoma, says sand hills to the immediate north of Guthrie's Cimarron bridge were then, practically, barrens, both as to trees and grasses. To-day wild plum bushes cluster among those hills, while 20-foot elm trees are noticeably common.

This government is proving Nebraska's semi-arid sand hills capable of pine production. Upon reading a paper before the American Forestry Association, during the Omaha Exposition, I had the pleasure of some hours with J. Sterling Morton, father of Arbor Day. He spoke of saw log walnut from seed of his own planting. There was present Tree Planter Stephens, who, as contractor with filers under the old timber culture act, has probably planted more trees on the plains than any ten men. A friend quoted him as saying a catalpa survived an eight-inch annual precipitation on upland 4000 feet above the sea, without any kind of attention. At any rate he enthuses on treeing Nebraska, in some soils, well up to the Wyoming line.

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GOVERNMENT INVESTIGATIONS OF THE TREELESS PLAINS.

Royal S. Kellogg's recent report on western Kansas tree growing, from the Bureau of Forestry, is a wealth of condensed experience and lifetime of observation. In almost any country land should be from 10 to 25 per cent timber, immense stretches of level inland prospering best with far larger percentage. Besides a wood lot for stock shelter beds, common to more eastern farms, there should be field crop windbreaks of from 15 to 30 acres.

If not caring to familiarize yourself with the scalding of seed and freezing of nuts, buy transplanted seedlings, making it possible to reset when conditions warrant, and evading the drying out of roots during shipment.

Unless certain of a wet winter plant just prior to spring growth, full leaf being preferable to during its forming. This same applies largely to pruning, and the wound should be annually coated with white paint. Plains induce low heading, and heavy branches should alternate with tall growers calculated for early use. The less there is to be of cultivation and trimming, the thicker should be the planting, even on uplands, 2x8 feet being preferable to 4x4, each allowing 2732 trees per acre. If selfish enough to crop tree ground, grow a very short-lived crop.

DISTURB NOT THE ROOTS.

Trees should be constantly cultivated, never plowed. At 4200 feet above the sea, in Colorado's Cheyenne Wells Rainbelt Experiment Station, with water 260 feet below surface and annual precipitation of 13 inches, a semi-monthly treatment of dagger-toothed harrow, or five-toothed cultivator, has kept an unirrigated apple orchard thriving and bearing, green ash and black locust doing as well.

The best time to remove trees is during a rain. The French now replant choice individuals between 10:00 p. m. and 2:00 a. m., for several days bathing the limbs.

Conifers transpire from one-tenth to one-sixth as much as many deciduous trees, requiring the same planting dates, and demanding shade while very young. It has been claimed that seedlings have died from three minutes of root exposure to dry air.

Red cedar, the hardiest of all, and growing about eight inches annually, thrives scarce better on bottom than upland, but it harbors fruit enemies. It is the longest lived of all and is affected the least by cultivation or soil constituent.

Pine is not so hardy as cedar, but its growth is about double. Scotch and Austrian pine, under some degree of care, have proven satisfactory even on dry western upland. In new Mexico, within 75 miles of Kansas, bull pine is habitat, one solitary specimen appearing near 12 miles southeast of Oklahoma's northwest corner.

DROUTH RESISTERS.

Honey locust, Russian mulberry and Osage orange defy drouth, the last two sometimes freezing back. In Colorado, at 4200 feet, and under 13 inches of annual precipitation, the first, on compact upland, grows 16 feet in

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ten years. In Kansas, at 2500 feet, and under about 18 inches, it grew 15 feet in an upland grove and 17 feet in a row on bottom. Largely immune from borers and root sprouting, selection of thornless individuals and such trimming as will thicken foliage can not but make of the honey locust a model western street shade. Osage is the slowest grower of all, but grass can not kill it. Russian mulberry will make a post in ten years, it, like Osage, demanding excessive pruning, unless planted thick. Osage orange grew 40 per cent less on upland than bottom.

Green ash grew 11 feet on upland in 16 years at Cheyenne Wells, Colorado, and 16 feet on bottom at Leoti, Kansas. It is hardy as against dry and cold weather, also being less subject to borers than is black locust.

Within 18 miles of Colorado, a nine-year old Kansas grove of black locust is thriving right among upland buffalo grass. In 1900 at Bryan, Oklahoma, Mr. Updegrove planted eight acres to two-foot black locust trees, every four feet in rows six feet apart. Two cultivations the first year, one the second and one the fourth brought three years of actual growth to 18 feet.

Slow of growth, immune from insects, smaller and hardier than the elm, hackberry has proven an acceptable street tree at Columbus, Neb.

Long of life, the heavy soil loving white elm requires time to establish, even then not being so hardy as honey locust, although without a street or park superior. On Kinsley, Kansas, upland, in rows, it grew 15 feet in 12 years, and 25 feet in 14 years on bottom.

IMMUNE FROM THE BOLL WEEVIL.

Unless within reach of some sort of constant moisture, cotton wood should not be planted. Slips from staminate trees will produce non-cotton raising trees. The box-elder, a northern tree, makes the same first requirement.

Like silver maple, the walnut is scarce practical off watered valley, or conditions similar.

If determined upon black locust, the fastest post maker, read up on borers and cultivate so shallow as to not cut roots and induce sprouting.

In soil qualified for walnut, catalpa speciosa is a plantation tree beyond compare.

An ultra Presbyterian father taught the efficacy of prayer, and I recall a childhood supplication that God would grow trees on scorced plains and give me a spotted pony to drive cattle. At times, sand hills made the barefoot boy an impossibility, and Easterners have been seen protecting faces with silk handkerchiefs.

Personally, my first tree experience came after winning a homestead in the Cherokee Strip horse race, planting on upland section line a double row of walnut seed. I have picked nuts from those trees, and my neighbor, Mr. J. H. Nelson, had on exhibit at the Omaha Exposition four walnuts on a tree that I personally know to have been less than 27 months from seed.

CITY FORESTRY.

My home town's business surrounded a dust driven courthouse square of three bottom acres. Within two years after I had planted 8600 American white elm seedlings, under the county board's contract to pay whatever bills I might

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make, a neighboring town offered, for the surplus above park needs, $172 in excess of total cost. Some of those trees, at nine years of age, are now 30 feet in height, one shading a circumference of 90 feet, and another having grown an 11-foot branch in 120 days.

A few years later the school board gave me charge of one of their two surplus upland blocks for five years. I planted 12,000 elm, maple and black locust seedlings. Two years brought the first to six, the second to eight and the third to twelve feet, selling one-twentieth of the locust for one-half the cost of the whole.

I then induced the city council to order, under my purchase and planting care, 5000 seedling pine for rocky soil planting in the cemetery.

This season a new school board authorized me to make whatever I considered necessary expense in parking a second block, from the first's surplus, and a new city council did the same for a block given it by the government some eleven years ago.

Some few years ago a governor vetoed my measure, introduced upon my city council's unanimous request, authorizing councils in cities of the first class to let seven-year street parking contracts, binding their successors and duly insuring tax levies.

Each contract has stipulated that I receive no remuneration, directly or indirectly. *At last, suspicion has been disarmed and the people lend an ear.* I come to this Congress courting co-operation from those sanguine characters who are gathered to build a yet greater new West, to this end, that the general government financially recognize artificial tree windbreaks on subhumid prairies and semi-arid plains, as has the paternalism of internal improvement fostered levees and irrigation structures.

This contemplates subsidiary endeavor by state, county, township and individual; but those regions' self effort in this regard has, *through a half century,* been establishing the case as here submitted.

Mr. Little—I will say that I am worried to death with letters from all parts of the Territory, wanting to know how to plant trees. I have to let a great many letters go unanswered.

Mr. Lippincott—I am figuring on inducing the planting of more trees by a tax exemption, that is, that we have a tax exemption to a certain extent. I have talked to several men here, and twenty men are willing to put out trees with a tax exemption.

Gen. Snyman, of Mexico—In Africa the government supplied the land and seed and gave the man the benefit of whatever he might raise for nine years. After ten years the lease expired. This paid the government, and the same system is carried on there now.

Mr. Pinchot—What happened to the land at the end of ten years?

Gen. Snyman—It became forest reserve; and people jumped at it. It was this that gave the people an idea of the necessity of planting on their property. Places like you have in Colorado are now covered with trees.

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Section Production by Irrigation.

DIVISION A.

CHAIRMAN: E. BENJAMIN ANDREWS, LL. D.

Wednesday, November 16, 1904.

This Section was divided among four Chairmen; Prof. Andrews, Prof. Shaw, Mr. O'Donnell and Mr. Myrick. Mr. O'Donnell and Mr. Myrick were unable to attend.

THE IRRIGATION OF THE PUBLIC LANDS IN TEXAS.

DR. WM. B. PHILLIPS, University of Texas, Austin, Texas.

The State of Texas has its own General Land Office and through it administers its own public lands. These lands belong now to the Public School Fund and include also the University and Asylum lands. The National Government owns but little land in this State, some small areas here and there are military posts, wharfage, etc., comprising its holdings. In speaking of the irrigation of the public lands in Texas it must, therefore, be understood that reference is made only to the lands owned and administered by the State.

The Land Office of the Republic of Texas was opened for the transaction of business on the 4th day of January, 1838, within four years after the Declaration of Independence. John P. Borden was the first Commissioner of the General Land Office, having been appointed to this position by President Sam Houston, in 1837. It was not until 1849, however, eleven years after the opening of the General Land Office that any systematic attempt was made to estimate the extent of the public domain. At this early date in its history the boundaries of the State were somewhat uncertain. They included a large part of what is now New Mexico and extended, in a narrow strip, through the southwestern part of Kansas and the central part of Colorado into Wyoming.

In the year 1849, and under the Governorship of George T. Wood, a report was made by Robert Creuzbar to George W. Smyth, Land Commissioner, that the area of Texas was 379,054 square miles. At that time there were outstanding claims amounting to 94,732 square miles. In 1851 Commissioner Smyth reported that Texas had ceded to the United States Government 110,-937 square miles of territory and that claims, liquidated and unliquidated, amounted to 99,661 square miles. Most of these claims were subsequently decided in favor of Texas so that the present area is held to be 265,780 square miles.

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We need not trace the sale of the public lands in Texas through the last fifty years. Suffice it to say that they comprised about thirty millions of acres in 1882, about twenty-two millions of acres in 1902 and about the same amount in 1904. More than one-half of the acreage belonging to the Public School Fund lies now west of the Pecos River in that portion of the State known as trans-Pecos Texas. The following table gives this acreage:

Acreage belonging to the Public School Fund west of the Pecos River, August 31, 1904.

County.	Acreage.
Brewster	2,064,542
El Paso	4,094,674
Jeff Davis	770,792
Pecos	2,273,033
Presidio	1,513,265
Reeves	1,027,284
Total	11,743,590

The following table gives the number of square miles of area within each one of these counties, together with the total acreage, taking 640 acres as one square mile:

County.	Sq. miles of area.	Acres.
Brewster	5,006	3,203,840
El Paso	9,353	5,985,920
Jeff Davis	1,922	1,050,080
Pecos	8.312	5,319,680
Presidio	3,970	2,540,800
Reeves	2,610	1,670,400
Total	31,173	19,770,720

The following table gives the percentage of acreage held by the Public School Fund in these counties:

County.	Percentage.
Brewster	64.40
El Paso	68.40
Jeff Davis	73.40
Pecos	42.70
Presidio	59.50
Reeves	61.50

That is, of the entire amount of land in Brewster County the Public School Fund owns 64.40 per cent; in El Paso County 68.40 per cent; in Jeff Davis 73.40 per cent; in Pecos 42.70 per cent; in Presidio 59.50 per cent, and in Reeves 61.50 per cent.

The valuation placed on these lands varies according to their character, whether they are fit for agricultural purposes, dry grazing, wet grazing or mining. The Land Commissioner may not dispose of the public school lands for less than a certain minimum price, but the valuation affixed above this

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minimum is within his discretion. The minimum price may be as low as one dollar per acre, the maximum price for certain oil lands in East Texas has been as high as $1500 per acre.

IRRIGATION OF PUBLIC SCHOOL LANDS.

The irrigation of the public school lands in Texas is a subject far too great to be considered within the limits of this paper. One is compelled to discuss it in a very general way or to select a part of the State in which the necessity for improving the land is more imperative. We shall have to disregard, for the present, about one-half of the total acreage held by the public school fund and confine our attention to that part of the State in which this fund owns large blocks of undivided land.

A slight digression becomes necessary here in order that those who are not familiar with the system in vogue in Texas may be apprised of certain vital considerations.

Under the terms of the law granting lands to railroad companies a large portion of the public domain was divided into blocks and sections, the State reserving one section (640 acres) and giving the other to some railroad company. The State then came to own each alternate section. An ordinary checkerboard will illustrate this if we remember that the black squares belong to the State and the white squares to some railroad company. Under this plan neither the State nor the railroad company could own or in fact did own large undivided blocks. To the north, south, east and west of any State section there were railroad sections, and in the same directions from any railroad section there were State sections. Under this plan, furthermore, the railroad companies made a great many of the surveys and the boundaries were not permanently marked by monuments at the corners of the sections. The failure to do this has given rise in some portions of the State to considerable uncertainty as to the location of the section lines.

While the alternate section system maintains over a great part of the region west of the Pecos River, to which we confine these remarks, there are important exceptions and these are of special force in the present discussion. There are large undivided tracts of land in trans-Pecos Texas, in the Panhandle and in the Llano Estacado, but it is to the first named that attention is now directed.

The successful application of the principles of irrigation does not necessarily imply sole ownership of the land, yet, in practice, such sole ownership gives a distinct advantage and in dealing with the improvement of public lands it is almost an indispensable condition. If our checker-board lay wholly within the control of the State there would be no other party of interest and the question of dealing with it would be comparatively simple. But if one-half of it is beyond the State's control, in respect of material improvement its betterment would yield no revenue to the State except that due from increased value, a somewhat uncertain and evasive source of revenue in this part of the world.

It has been stated that in trans-Pecos Texas the Public School Fund now owns 11,743,590 acres of land. Of this amount there are in El Paso County

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alone 4,094,674 acres, or more than one-third (34.8 per cent) of the entire amount. This land does not lie in a solid body, but something more than one-half of it does. In other words, more than one-half of the public school land in El Paso County lies in undivided blocks over which the State has absolute jurisdiction. The State may do as it will with this land and consider plans for its betterment in whole or in part. It may select sites for storage reservoirs, lay out and construct canals and ditches, fix water rates, determine how much land may be allotted to any person or association of persons, and collect, with certainty and regularity, revenues arising from its use or occupancy. Most of this land is in blocks of large size, ranging from 15,000 to 30,000 acres. In this county the university owns 499,000 acres in sixteen blocks, one block (M) containing 57,600 acres.

THE IRRIGATION SUPPLY.

There is not much of the public land in trans-Pecos Texas that can be irrigated from running streams. There are two rivers in this region, the Pecos and the Rio Grande, the one being the eastern boundary and the other the south boundary. There are a few streams which supply more or less water of varying quality at intervals during the year. Comanche and Independence creeks in Pecos; Toyah creek in Reeves; Limpia creek in Jeff Davis; Tornillo, Maravillas and Terlingua creeks in Brewster; Alamito, Cibolo and Capote creeks in Presidio may be given as streams which will supply more or less running water during the year. Of these, Comanche creek, at Fort Stockton, Pecos County, and Limpia Creek, at Fort Davis, Jeff Davis County, are the most important, affording large volumes of good water at all seasons. There are excellent farms near Fort Stockton and Fort Davis. The irrigated area around Barstow, Ward County, is not considered at present, and for the reason that the area under cultivation is on the east side of the Pecos. The same observation applies to the irrigated farms around Grand Falls, Ward County.

It is, perhaps, possible to irrigate portions of the Toyah basin with water taken from the Pecos River near Riverton, but serious demands are already made upon the natural flow of this stream above Riverton. Allowing that this river would supply enough water of fair quality for this purpose, the amount of land that could be so improved is only a small fraction of the public school holdings west of the Pecos. The great strip of land that begins on the Texas-New Mexico border, thirty miles northeast of El Paso, and continues for fifty miles in a southeasterly direction, with a width varying from six to forty miles can not be irrigated by water from any running stream. If improved at all it must be by means of underground water pumped to the surface, or by rain water held in storage reservoirs, or by a combination of these two methods. There is in this part of El Paso County now a body of land of more than 400,000 acres. In places it is well grassed and for the most part would make a good cattle range. But it can not be leased because there is no water on it and but little probability of securing it except from deep wells. Its reclamation is to be hoped for only through the agency of storage reservoirs for rain water.

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If the public lands in trans-Pecos Texas generally and in El Paso County particularly are to be improved at all it must be for the most part through the agency of storage reservoirs conserving the rainfall.

The average annual rainfall at El Paso is 9.33 inches. At Kent, in the eastern part of the county, it is 12.72 inches. At Fort Davis, Jeff Davis County, it is 14.03 inches. Taking El Paso County as a whole it is not likely that the average annual rainfall exceeds ten inches, and more than one-half of this falls during the months of June, July and August. There will be, normally, six inches of rain during these three months and four inches during the remaining nine months. At El Paso the annual rainfall, during the last twenty-five years has varied from 2.22 inches in 1891 to 18.30 inches in 1884. During this period there have been sixteen years in which the average rainfall was below ten inches, seven years of which it was between ten and fifteen inches and two years in which it was between fifteen and nineteen inches.

A rainfall of one inch means that on each square mile, or section, we would have 17,612,000 gallons of water, and this is equivalent to about 27,520 gallons per acre.

SURVEYS FOR STORAGE RESERVOIRS.

Mention may here be made of two surveys by R. W. Goode several years ago, for they bear on the subject of irrigation of the trans-Pecos lands by means of storage reservoirs. One of these surveys was of a reservoir site nine miles south of Marfa, Presidio County. The approximate area of the catchment basin, which comprised the upper part of the valley of Alamito creek, was 440 square miles. It extends twenty-two miles north of Marfa, eleven miles east, four and a half miles west and ten and a half miles south. The proposed dam was ten and a half miles a little west of south from Marfa. The surface area of the reservoir was 1.43 square miles and the height of the dam was 100 feet. It was calculated that a run-off of one and one-third inches from the entire catchment basin would fill the reservoir and give sufficient water for irrigating about 20,000 acres. The other survey was of a tract of land in Brewster County, the reservoir site being seven miles northeast of Alpine. The approximate area of the catchment basin was 203 square miles. It extended about nine miles north of Alpine, five miles east, ten and a half miles west and six miles south. The surface area of the reservoir was 1.45 square miles and the height of the dam was fifty feet. It was calculated that a run-off of one and one-fourth inches from the entire catchment basin would fill this reservoir and give sufficient water to irrigate about 7000 acres.

Neither of these proposed reservoirs would supply water for undivided public school lands, nor is it known just how much school land would be benefited.

There is a possible reservoir site in the foot-hills of the Sierra Diablo, three miles north of Allamoore, El Paso County. Here the approximate area of the catchment basin would be fifty square miles. But at this place also we came in contact with the alternate section system and we do not know how much public school land would be susceptible of irrigation.

If any definite information is to be acquired concerning the possibility of

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irrigating even a portion of the large undivided blocks of public school land it will have to be on the initiation and at the expense, in whole or in part, of the State. Up to this time but little has been done under State authority, although a start has been made under a plan of co-operation between the University Mineral Survey and the United States Geological Survey. Last year Mr. George Burr Richardson of the Government Survey was detailed to work under this plan of co-operation and he examined that portion of El Paso County which lies north of the Texas & Pacific Railway with special reference to the water problems. It is in this part of the county that the larger undivided blocks of public school land are situated. Mr. Richardson's report is now in press and may be obtained upon application to the University Mineral Survey, Austin.

In further pursuance of this plan of co-operation an additional 30-minute quadrangle is now being surveyed by a topographic corps of the United States Geological Survey, under charge of Mr. Arthur Stiles. This area of about 1000 square miles lies north of Van Horn, El Paso County, and includes the Sierra Diablo. With the completion of this work we shall have nineteen excellent topographic maps within the trans-Pecos country, to wit: El Paso, Cerro Alto, Salt Basin, Van Horn, Rio Grande, Fort Hancock, Sierra Blanca, Eagle Mountain, Chispa, Valentine, Fort Davis, San Carlos, Marfa, Alpine, Ruidosa, Shafter, Polvo, Terlingua and Chisos. These sheets cover an area of about, 14,000 square miles, or nearly one-half of the entire area west of the Pecos River.

With the exception of some large undivided blocks in Reeves County these maps embrace nearly all of the undivided school lands. They may be used for estimating the areas of catchment basins and for detailed study of the more favorable sites for reservoirs.

EXPENSE BORNE BY FEDERAL GOVERNMENT.

The National Government has done this work at its own expense, with the exception of about 1600 square miles comprised in the plan of co-operation referred to. In other words, the National Government has borne the entire expense of preparing excellent topographic maps of more than 11,000 square miles of country in West Texas in which it had no ownership interest whatever. It has done all that could reasonably be expected of it and it now remains for the State to assume further consideration of this matter.

How much of the public school lands in West Texas is susceptible of irrigation? We do not know.

What is the character of the soil and for what purposes is it best suited? We do not know.

There is an impression in some quarters that vast tracts of this domain would produce almost any kind of crops if sufficient water of good quality were brought upon them. This may or may not be the case; we have not data enough for a reliable opinion. But we do know that there are extensive tracts which, to all appearances, would not respond profitably to such attempts at betterment. There has been, it is true, little systematic study of this subject, but in the nature of things there must be radical and far-reaching diversities of soil in so large an area. What then is to be done?

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NEED FOR STATE ACTION.

The State should give authority and means to the General Land Office to inquire into these matters. The General Land Office may have the authority now but it certainly has not the means. How may the means be provided? By setting aside each year a certain proportion of the money derived from leases and interest on sales for the survey of lands that might be improved by irrigation. The money so obtained would, of course, have to be replaced from other sources, for it belongs to the general school fund, but it is sound policy to use a portion of the revenue derived from a portion of any property for the improvement of other portions. For the two years ending August 31, 1902, the interest receipts from sales of all school lands, wheresoever situated, were $1,005,152, and from leases, $869,775, a total of $1,874,927. One half of one per cent of this sum would provide an annual sum of $9,387 for irrigation surveys.

The sum of $10,000 a year for each of two years would be sufficient for irrigation surveys, especially when we consider that the active and substantial aid of the National Government could be secured. This would involve merely the extension of plans that have been carried out, with respect to topographic surveys during the last two years. In the light of what has already been done, with respect to co-operation, it may not be too much to say that the National Government, through its Geological Survey, would contribute to the study of irrigation problems in Texas an amount equal to that which the State would contribute. Furthermore, it would be possible to secure the services of trained men who have made a study of such questions and who would bring to their solution practical experience of the highest order.

THINGS TO BE DONE.

Looking at the matter in a broad way there are four things to be considered.

1. The chemical and mechanical composition of the soils.
2. The topography of the areas in hand.
3. The geological structure of catchment basins and of reservoir sites.
4. The suitability of local materials for the construction of dams.

For the elucidation of these matters specially trained men are required. It is not every chemist, or topographer, or geologist, or engineer who has had opportunity to acquaint himself with the necessities of such work. We are dealing with a region concerning which but little is known, in so far as relates to the possibilities of irrigation, and it would be idle to place its investigation in the hands of any but trained men.

For the improvement of its own lands the State must, so to speak, put its hand into its own pocket. It would not have to incur the entire expense, but it must be willing and able to pay an equal part.

It is not likely that the value of the public lands in West Texas will increase except as the demand for them as grazing and agricultural lands increases and this can hardly be effected unless some assurance be given that the water supply is to be improved.

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FORAGE CROPS FOR IRRIGATED LANDS.

W. J. SPILLMAN, Agrostologist, U. S. Department of Agriculture, Washington, D. C.

Alfalfa is beyond all question the most important forage plant on the irrigated lands of the West. It is the greatest hay plant in the world. In the State of Washington, on irrigated lands, it gives three to four cuttings of hay a year, while in Southern California near the Mexican line, eleven cuttings annually are reported. In the vicinity of Los Angeles, California, it is cut eight times. In Southern Texas, in the vicinity of Carrizo Springs, nine crops a year are obtained from the alfalfa fields. The yield of hay of course depends upon the fertility of the soil. The average yield of alfalfa hay for the whole United States according to the census of 1899 is two and one half tons per acre, while the average of the ordinary perennial grasses is one and one-tenth tons. On the irrigated lands of the West, a good farmer expects at least five tons of alfalfa hay per acre annually. A good many farmers get as much as eight tons, and a few instances are recorded of yields between eleven and twelve tons per acre.

ALFALFA AN ANCIENT CROP.

The alfalfa crop was introduced into California by the Spaniards in the early days. When gold was discovered there, prospectors from the Eastern and Middle States found this new and strange forage plant growing in the vicinity of the monasteries where it was used for food for their live stock. As irrigation developed in the West, cultivation of alfalfa spread until it is now the principal forage plant on all of the irrigated lands of the West. It took a great many years for the eastern half of the United States to become thoroughly interested in this crop, but for the past five years it has rapidly invaded the East. It has not been found successful on all types of soils but wherever there is a good rich soil, not too wet, it has succeeded, and the acreage of it at the next census will doubtless be fully twice what it was at the last.

The advantages alfalfa possesses over other hay producing crops are: first, its great yield; second, its richness in protein or nitrogenous material, thus making it, to all intents and purposes, a concentrated feeding stuff. The fact that it draws its nitrogen supply from the atmosphere instead of from the soil makes it a valuable manure and gives it an important influence as a nitrogen fertilizer. For this reason alfalfa does not exhaust the soil as do wheat, corn, oats, and other cereal crops. Another great advantage of this crop is its longevity. Under favorable conditions alfalfa fields last almost indefinitely without reseeding. The yield usually increases for three or four years after sowing and then remains large for ten to twenty years, or even longer. There is one small field of it in South Carolina sixty-nine years old still yielding fair crops. Many fields in the West are doing well at twenty-five and thirty years of age. Ordinarily, however, weeds get in and the trampling of stock pastured on the field kills out plants here and there, so that after twelve or fifteen years it usually pays to plow up the field and reseed it. Another great advantage alfalfa possesses lies in the fact that it

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can be fed alone with very good results. This is not ordinarily the best way to feed animals, but almost all kinds of stock do fairly well when fed nothing but alfalfa. In many parts of the irrigated West, dairy cows live on alfalfa the year round and give a good flow of milk. This is an exceedingly cheap way of feeding. It is true the cows would give more milk if fed a little grain with the alfalfa, but it would frequently be inadvisable to feed the grain on account of the cost. Alfalfa is also the best hog pasture in the world. On abundant alfalfa pasture hogs thrive very well without other feed, but where grain is available, the best way to handle hogs on alfalfa is to feed them about one-third of a full grain ration. If grain for this purpose can be had at a reasonable price, there is no better way for raising hogs.

A WIDELY DISTRIBUTED FORAGE CROP.

Alfalfa has also very wide adaptability as regards climatic conditions. It thrives from Montana to Mexico, and from California to New York under practically all kinds of temperature and moisture conditions, but it wants good soil. It would be strange that a plant with so many qualities in its favor should have no faults. Alfalfa has its faults, the most serious being the fact that when cows or sheep are pastured on green alfalfa they are very liable to suffer from bloat. In Central Washington farmers state that they lose about five per cent of their cattle annually from bloat, yet they insist on pasturing their cattle on the fourth crop of alfalfa, saying that it pays to do so in spite of these losses. While green alfalfa bloats cattle and sheep, dry alfalfa hay is as good feed for this class of stock as can be found.

The effect of alfalfa on soil fertility has already been mentioned. The fact that so much of the irrigated lands of the West have been devoted to this crop has prevented the possibility of drawing conclusions from the effects of farming on the fertility of irrigated lands. This subject will be referred to below.

Next to alfalfa, sorghum is the most important forage crop on irrigated lands of the West, particularly in the southern half of the irrigated section. By this I mean both the sweet sorghums and nonsaccharine sorghums, such as Kafir corn, dwarf milo, etc. On good land under irrigation, sorghum yields enormous quantities of good feed. It is mostly utilized as green feed, for which purpose it is an excellent crop, all kinds of stock eating the ordinary sweet sorghums in green state eagerly. I was very much interested in a bit of information I picked up recently in Los Angeles in this connection. Sorghum yields enormous quantities of fodder in that section, but the farmers state that they can get more milk by feeding straight alfalfa than they can by feeding part sorghum and part alfalfa. The reason for this undoubtedly lies in the fact that the sorghum is a less concentrated feed than the alfalfa; but for idle animals there is no doubt that green sorghum mixed with perhaps a little alfalfa would be an ideal ration, and it could be utilized for animals that are at moderate work.

KAFIR CORN.

Kafir corn is extensively grown on irrigated lands in New Mexico and Western Texas and would undoubtedly succeed throughout the southern half

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of the irrigated region. It is grown mostly for grain. It yields large quantities of grain which makes very good stock feed. The value of Kafir corn seed is probably about nine-tenths that of corn for feeding purposes. I was very much interested recently in a crop which was new to me but which I found growing extensively in the Panhandle Country in Texas and in part of Oklahoma. The farmers there call it "maize" or "milo maize," and sometimes "dwarf milo maize." The plant is not a maize at all but is a sorghum, and we have recently bought a hundred bushels of the seed of this plant and are distributing it under the name of dwarf milo. We do not yet know what it will do on irrigated lands in the West, but it is certainly worthy of attention. It somewhat, resembles Kafir corn but yields more grain of a better quality. It is also a greater drought resister than Kafir corn. In fact, so far as I know, it is the most drought resistant of any grain crop known in this country. We hope within another year, by means of the distribution we are now making, to ascertain what parts of the country are adapted to the cultivation of this crop. The seed is larger than that of Kafir corn and is more brittle and seems to be better relished by all classes of stock.

BERMUDA GRASS.

Bermuda grass has attracted more or less attention on the irrigated lands, particularly on the southern half of the West. This grass, on good land, in a warm country, is perhaps the best pasture grass in the world, but it is very tenacious of life and when once started in an alfalfa field, the only remedy I know is to plow up the field, as it will choke out the alfalfa. It is not difficult to control Bermuda grass if one understands its nature and habits, except in regions where it produces seed as it does in Southern California, Southern Arizona, Southern Texas, and Central and Southern Florida. In sections where it produces seed and where irrigation is practiced it spreads along the irrigating ditches and it is well nigh impossible to control this grass. For this reason great care should be used not to get it started in the sections mentioned. Where it does not produce seed, it can be killed out by growing crops that make a dense shade, such as millet or sorghum sown at the rate of two bushels of seed per acre in summer, and oats or barley in winter. It will not stand shade, and being of a low growth, it is overtopped by the taller growing crops mentioned and thus smothered out.

Johnson grass is also getting introduced on the irrigated lands of the West. This grass is, of itself, a splendid hay grass, but it is so tenacious of life and so vigorous a grower on irrigated lands that it is nearly impossible tc grow other crops where it has once been started. Whether alfalfa can be successfully grown on Johnson grass land in the irrigated section, as it can be in the nonirrigated section further east remains to be seen. Johnson grass produces a great many underground stems and soon forms so dense a sod that within two or three years it makes comparatively little growth unless cultivated. When Johnson grass land is plowed up, the roots harrowed out of the ground as much as possible and then alfalfa is sown, by cutting the alfalfa very promptly before the Johnson grass overshadows it and keeping this up for two or three years, the alfalfa usually gets ahead of the Johnson grass, and within six or eight years it practically disappears, leaving the alfalfa

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alone. This plant may not succeed on irrigated land but it is worth trying for the reason that it has succeeded further east.

FORAGE CROPS MAINTAIN SOIL FERTILITY.

One of the principal reasons for growing forage crops is to maintain soil fertility. On nonirrigated lands in the East this is a question of much importance. As intimated above, we do not know a great deal about the effect of irrigation in preventing the wearing out of cultivated lands, yet a few facts of interest are at hand. Where the irrigation water contains the surface wash from surrounding regions and is loaded with a good deal of decaying organic matter which has been washed from the surface of the soil and leaves this matter as a deposit on the irrigated fields, it would seem that there is a gradual increase of fertility up to a certain maximum which is afterwards maintained, so that lands irrigated with such water do not wear out. Where the irrigation water contains no humus making material conditions are different and the land does wear out sooner or later, not so fast, however, as nonirrigated land, for the irrigation water from ordinary streams, even when perfectly clear, contains a considerable amount of mineral plant foods in a state of solution, thus carrying to the irrigated fields a good deal of fertility and decreasing the draft upon the soil made by the growing crops. It is true that irrigation has been practiced for many ages in some parts of the world, but not in those regions where careful scientific investigations have been made or the relation between irrigation and the maintenance of fertility. Irrigation is too new in our own western country to give very positive results as yet. Studies of this kind, however, are now in progress and we hope within the next few years to be able to learn something more definite on this point.

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ROTATION AND IRRIGATION.

PROF. THOMAS SNOW, Editor *The Farmer*, St. Paul, Minn.

The producing power of Western soils is proverbial. In some instances it is so great as to exceed the claims of fabled story and to bring into the mind the thought of that golden age when the earth gave up its generous crops without any labor from man. Soils in the Red River valley in Minnesota and Dakota have produced as many as twenty-five crops of hard Fife spring wheat in an unbroken succession. Those around Walla Walla in Washington have grown good winter wheat for nearly fifty successive years, and in some of the valleys of California and others of the mountain States, it is claimed that alfalfa meadows have been grown and cut for twenty-five to thirty successive seasons, and some authorities claim for even a longer period. Such results seem almost incredible to the inhabitants of New England and many parts of the Southern States, where, if one is to get a paying crop, he must first apply some fertilizer, which in nearly all instances is more costly than the labor entailed in preparing the land. Nor can he succeed as a rule in growing the same crop two years in succession without diminution in yield, unless special attention is given to the fertilization of the land. Truly, therefore, may western farmers say that the lines have fallen to them in pleasant places and theirs is a goodly heritage.

But will they care for it as they may and as they ought to? Man is singularly constituted. The doctrine may seem strange, but it is true, that with reference to the maintenance of soil fertility, man will only do what he is compelled to do. Naturally he is a soil robber, not having the slightest regard for those who come after him or even for his own distant future, and it is to be feared that the farmers of those western irrigated lands will form no exception.

Just as sure as the sun shines, the growing of successive crops the same in kind will some time end in agricultural disaster, hence the imperative need of giving attention to the matter of the proper rotating of crops. The farmers of the Red River valley do not get crops of wheat so uniformly good as they did when their lands first came to be tilled. The farmers who grow wheat around Walla Walla and other parts of Washington are not always going to get 30 to 60 bushels of wheat per acre from their lands as at present managed, nor will those around Vernon in the same State continue to reap 100 bushels of oats per acre as regularly as the seasons come and go. The farmers of Illinois who have grown corn successively on this same land for seventy-five years have brought the yield down to twenty-five bushels per acre, whereas lands in the same vicinity farmed by a rational system of rotation still produce from 75 to 100 bushels per acre. Hence, just as sure as irrigating waters run toward the sea, disaster will overtake the operations of the farming of those wonderful mountain valleys unless sufficient attention is given to the proper rotating of crops.

CROP ROTATION NECESSARY.

The soil calls for the rotating of crops in order to maintain its fertility. Suppose the same crop is grown for successive years upon the same land and

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nothing returned, and that the crop is not a legume, it follows that the nitrogen, phosphoric acid and potash, the three most essential elements of plant growth in the soil, will be reduced by the amount removed in each crop. It cannot be otherwise, therefore, than a time must come if the process is continued long enough, when the crops grown will not be able longer to get enough of one or the other of these ingredients. The moment that any one of them is so reduced that the crop cannot get a sufficient supply, it falls below the maximum in production.

The first of these that is likely to fail is nitrogen, since it is the most soluble. When purchased in the market it is the most costly. When soils become nitrogen hungry, only one of two things can be done if maximum crops are to be produced. Nitrogen must be bought and applied at a cost of fifteen to eighteen cents a pound, or plants must be grown which have the power of supplying it from some outside source. Happily for the race, one whole family of plants has the wonderful power of drawing nitrogen from the air and depositing it in the soil to supply the crops that come after them. This is one of the most astonishing and beneficient truths in agriculture and also one of the most important. But the man who goes on growing successive crops of the small cereals on his land has no more regard to the value of this truth than the mole which burrows in the soil which he tills. These legumes include all kinds of clover and alfalfa, and all kinds of peas and beans. By growing one or the other of these in proper rotation the supply of nitrogen in the soil can be maintained and even increased.

TO SUPPLY PHOSPHORUS AND POTASH.

But how shall the supply of phosphoric acid and potash be maintained in soils, as legumes cannot increase the supply of these? On the other hand they draw upon the same while they grow. In the first place, most soils are furnished with enough of these to grow crops for a very long period. Western soils are particularly well stored with these as witnessed in the enormous fruitage in proportion to the straw, in grains, and to the size and quality of fruit produced by fruit bearing trees. In the second place, certain crops gather of these in the subsoil lower than the roots of other plants can go. If these crops are grazed or fed and the manure resulting put back upon the land, the equilibrium in the supply of these in the surface soil can be maintained. No plant grown probably is the equal of alfalfa in its ability to gather phosphoric acid and potash in the depths of the subsoil for use in the upper sections of the soil. If the amount of these elements thus brought is less than the amount utilized by the crops grown and sold from the farm or ranch, then the only resource left is to maintain the equilibrium by purchasing phosphates and potash.

In the judgment of the writer a judicious use of alfalfa in the rotation in irrigated areas would maintain a sufficiency of these elements in the soil to produce crops for an indefinite period. This, however, is on the condition that the fertilizer resulting from feeding alfalfa is put back on the land.

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WATER A MANURE.

A third source from which these fertilizers can be obtained is the waters of irrigation, a source of fertility which puts the irrigator on a far higher plane of vantage ground than the farmer who depends upon rain. In other words, irrigating waters are usually much more heavily charged with fertilizing matters than rain waters, owing to the fertilizing matters which they carry in solution and much of which is left in the land as it filters through the same. The amount of these fertilizing materials is dependent largely on the character of the soils through which they previously have filtered or flowed over in their descent toward the plain. The more vegetable matter there is in the soil which those irrigating waters are made to filter through when they are applied, the more the fertilizing matters that will be extracted from them. On the other hand it is easily possible for water passing downward through soil to carry downward and away from it elements of fertility already there. When water is applied in excess it is certain to do this, hence the tremendous importance of adjusting the water to the exact needs of the crop.

ROTATING IMPROVES MECHANICAL CONDITION OF SOIL.

But the soil also calls for rotation in order to keep it in a proper mechanical condition, that is, to so adjust the relation of the soil particles to one another that the soil will be sufficiently porous and sufficiently compact to make maximum production possible. When soils becomes too porous they become too leechy and suffer loss of moisture too readily from surface evaporation. Sandy soils are sure to suffer in this way unless supplied with enough vegetable matter to prevent such loss. There are only two ways of doing this. The first is the application of farmyard manure and burying it in the soil; the second is by growing on it some deep-rooted crop, the roots of which fill the spaces between the soil particles in their decay. When these spaces are thus filled in soils, their power to arrest and hold water for the growing crops, whether it comes from above or below, is greatly increased. The bearing of this upon the amount of irrigating waters used is most direct and far reaching. The more vegetable matter thus supplied to the soil, the less the amount of the waters of irrigation that are required. It would probably be correct to say that the amount of irrigating water absolutely needed could be reduced by one-half. This vegetable matter could be supplied by now and then sowing alfalfa or some other legume, but of these in the mountain regions none is so suitable all in all as alfalfa, for reasons that will be given later. The application of this principle to the soils of many areas in the West where irrigation is impracticable would work wonders in the producing powers of the same.

The lack of a sufficiency of humus in loam and clay soils allows them to becomes so impacted that they become cloddy, rather friable. The particles lie too closely to admit of proper aeration or filteration. The bacteria concerned in soil improvement become less active and these soils do not dry out quickly enough when water is applied to them. The remedy is the same as in the former instance, viz.: to keep them supplied with vegetable matter

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on the plan outlined above. Such matter lying between the fine particles of soil prevents them from adhering to one another. Humus thus supplied in sandy and loam soils is a two-bladed axe, both blades of which cut with equal effectiveness.

WEEDS A FACTOR IN SOIL ROTATION.

The weeds of the crops grown upon the soil call for rotation for several reasons. First, if only one crop is grown for successive years the element or elements of fertility which it draws most heavily on are very likely to fail first. As soon as they do through even partial exhaustion, maximum crops cannot longer be grown. If, on the other hand, an interchange has been made in the crops grown, by introducing varieties that drew most heavily on the different elements of fertility in the soil, the period of maximum crop production would have been longer maintained, for reasons that will be at once apparent.

Second, some crops feed ravenously on decaying vegetable matter. Where it is sufficiently present, yields will in some instances be doubled as compared with soils in which it is absent. Such are some of the small grains, Indian corn, sorghum, field roots, rape, flax, potatoes, and in fact nearly all non-leguminous crops. But the humus thus helpful cannot be maintained without occasionally putting vegetable matter in the soil and in no way can this be done so cheaply as by growing it there.

Third, where the same crop is grown on soils for an indefinite period, the difficulty in warding off disease is very greatly increased should it appear. It has been the story of disease in field crops or fruit, that it multiplies eventually with increase in the continuance of growing one crop without change. In this way the abandonment of the growth of certain crops in various countries of the world and in some of the States of the Union has been forced, as illustrated in the practical abandonment of wheat culture because of the prevalence of chinch bugs in certain areas and because of the presence of certain fungous diseases in others. Alfalfa happily is more free from disease and insect enemies than other crops, but it is by no means immune. The deadly dodder is increasing in alfalfa fields at an alarming rate in some parts of the country, and in no way can its ravages be so effectively met by a change in the rotation. Disease in the alfalfa crop to the extent of endangering its general cultivation would be the greatest agricultural calamity that could come to this western country.

The farmer who grows but one crop in irrigated areas is happily free from the hazard that the farmer incurs in regions of rainfall of having that one crop greatly damaged by rain, but he does incur the danger of having much of it waste through inability to care for and market it at the proper season. In some of the western hopyards, acres and acres of hops have gone back to earth ungathered some seasons because of inability to get help to do the work of picking, and this is one of the most highly productive hop-growing areas in all the world. What a sad story it would make if it could be told, as to the bushels and bushels of rich ripe fruit that have rotted in this western country because those who grew them were unable to gather and market them.

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LIVE STOCK GROWING CALLS FOR ROTATION.

The needs of the farmer imperatively call for rotation if he is to keep live stock on his farm or ranch. Unless he does his foods will not be in balance. He will have too much protein in the one instance or too little in the other, and he will also need to purchase foods to keep up the equilibrium. It is an axiom in agriculture that the intelligent farmer can usually grow foods more cheaply than he can buy them, hence the wisdom of rotating crops on the part of those who grow live stock.

The growing of live stock will in the end prove the safest and most profitable kind of farming to the average rancher with large holdings. Fruit may glut the market during any very productive season. Hops may again sink below the price of profitable production, but as long as the sun continues to shine in the favored area and as long as the snow rests upon its mountain peaks, just as long will there be a reasonable demand for live stock and live stock products that will amply repay the grower. Through growing live stock, the rancher is compelled to diversify and rotate, and through the same medium he secures fertilizing materials for the land and virtually without cost.

But what, it may be asked, will be the character of the rotation? That will depend largely on the leading line of production. For instance, the rotation of fruit culture will be different from that in grain farming, and in growing live stock and live stock products it will be different from both. What is imperatively insisted on in this paper is that rotation shall be practiced in all the irrigated country, as well as in that where irrigation is not required.

ALFALFA THE STAR LEADER.

As to the plant that will form the basis of the rotation, there need not be any doubt. That plant is alfalfa. This claim will seem all the more surprising when it is remembered that alfalfa is not usually regarded as a rotation plant. In the Mississippi basin and in the East, many farmers object to growing it because it is not a rotation plant, but the behavior of alfalfa in the West is very different from the same in the East. In the East it grows much more slowly and delicately. There it has in a sense to be nursed to get it safely through the first winter. Here it grows with the vigor of a weed and produces one to two cuttings the first season. Of course the clovers may also be used in soil renovation, and Canada field or cow peas, but of all soil renovating crops that can be grown on irrigated lands, alfalfa would probably be the most valuable, and because of its extended and extensive root system. It not only brings nitrogen nodules to the soil for some distance below the surface for its enrichment, but the roots of the alfalfa in their decay also bring humus to lower areas of the soil and subsoil than other plants and they open up channels which facilitate the movements of water in soils.

In orcharding no fitting of the soil for planting will compare with that which is furnished by an alfalfa sod broken up and prepared by some careful and patient plowman. The decaying roots of the alfalfa furnish food to the trees for years. The roots of the trees easily follow the minute channels

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made by the alfalfa roots as they reach down in search of food, and if alfalfa or clover is sown upon the orchard and buried in the same from time to time the feeding process goes on from year to year. Thus managed fertility in orchards should be matured without great cost.

When alfalfa or some other legume precedes a pasture crop grown for fattening animals, the results will be wonderfully helpful. Such are crops of peas grown for fattening sheep or swine while grazing on them in the mature form. Swine pastured on alfalfa with a small grain ration added and then finished on peas consumed by the swine where they grew, will make pork more cheaply than it can be made in the corn belt, and of the very high quality. So likewise peas can be utilized in fattening sheep and lambs when preparing them for market. Or immense crops of rape could be made to follow on those lands adequate to the fattening in good form of fifteen sheep or lambs per acre when grazed upon it and without the necessity of adding a pound of grain. Eight to twelve weeks of such grazing would fit the animals for any market in the United States. Good crops of rape could doubtless be grown on many soils not thus preceded by alfalfa or clover sod, but the yields of the same could in some instances be doubled by growing them on overturned alfalfa or clover roots.

TIMOTHY AFTER ALFALFA.

Timothy of all grasses grown stands king among the grasses of America in furnishing suitable hay for horses. This crop can be grown, as everyone knows, on ordinary mountain valley soils except where the summer climate is too hot, but if grown in an alfalfa or clover rotation, the yields will be immensely increased because of the abundance of the nitrogen in the soil and for other reasons. Similar results will follow from the growing of any kind of grass which it may be necessary to grow. All the grasses pure and simple require much nitrogen to produce a maximum of growth, and this need is met by the roots of the legume in their decay.

But nowhere will results more beneficent be furnished than in following an alfalfa or clover crop by one of small grain or Indian corn, or any of the saccharine or non-saccharine sorghums. With such a rotation enormous crops of wheat, coarse grains, corn and sorghum may be grown. Which of these should be given the right of way in growth depends upon the requirements of the grower and the climate. Where the grower can secure from forty to sixty bushels of barley per acre or sixty to eighty bushels of oats, why should he care whether or not corn was accessible for the fattening of live stock. With from three to four crops of alfalfa per acre and the yields of grain given above on other portions of his land, why should the ranchman of the mountain valleys fear competition in fattening cattle or sheep from any part of the United States? The fact is now known that cattle may be fattened on alfalfa hay as against fattening on corn and corn fodder by using only one-third as much grain in the fattening process. The same is true of sheep.

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PLOW UNDER THE LEGUMES AND MAKE NITROGEN.

Should the small ranchman be growing garden truck or potatoes, in no way can he so cheaply or so effectively fit his land for growing good crops of these as by burying every few seasons a crop of clover or alfalfa in the soil. In some instances the results will be as good should the alfalfa or clover crop be first reaped and the land then plowed. Such a rotation is peculiarly adapted to the needs of the potato crop.

The frequency with which the alfalfa crop should thus be grown when grown as a rotation crop will depend upon such conditions as the needs of the soil and variety in the crops wanted. The rule is a safe one that would not grow more than two or three crops of small grain between the alfalfa crops. The age at which alfalfa thus used as a rotation crop should be broken will depend upon soil conditions and the ease or difficulty found in plowing the land.

With soils of great natural richness and so easily tilled as nearly all irrigable lands are in the West, and with opportunities so complete for supplying his lands with nitrogen and humus and with good and widening markets for his crops, why should not the western ranchman be prosperous and happy? Why should he not be able to maintain fertility in his lands and increase their producing power, handing them down to his family a legacy of great value? He has the choice of doing this or of so robbing them that in time they will fail to grow paying crops. It rests with him to say which he will do.

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IRRIGATION AND ALKALI.

O. V. P. STOUT, Irrigation Engineer, Nebraska Agricultural Experiment Station, Lincoln, Nebraska.

When "Production by Irrigation" is the subject for discussion it is proper that a fair share of attention should be given to the alkali evil, for it is without doubt a product of irrigation, and its intimate relation to all other products of irrigation is one that has become painfully manifest in many localities.

The subject is not altogether a new one, even in arid America. About twenty-five years ago Dr. E. W. Hilgard, in a report to the regents of the University of California, presented the following:

"This name (alkali soils) is applied in California, almost indiscriminately, to all soils containing an unusual amount of soluble mineral salts, whose presence is frequently made apparent by the 'efflorescence,' or blooming-out on the surface, of a white powder or crust, soluble in water. This 'alkali' becomes most apparent in dry weather following upon rains or irrigation. Later in the season it usually becomes less perceptible from intermixture with dust, as well as from the failure of the soil water to rise near enough to the surface. The first rain, dissolving the salty substances, carries them partly into the water courses, but chiefly back into the soil, whence they rise again at the recurrence of dry weather.

"The immediate source of the 'alkali' is usually to be found in the soil-water, which, rising from below and evaporating at the surface, deposits there whatever of dissolved matters it may contain. Such water, when reached by digging, is by no means always perceptibly salty or alkaline, and the same is mostly true of the soil, an inch or two beneath the surface. For since the soil, acting like a wick, draws up the soil-water and allows it to evaporate at the surface, it is *there*, of course, that all the dissolved matters accumulate, until the solution becomes so strong as to injure or kill all useful vegetation. The injury will usually be found to be most severe just at, or near, the crown of the root, where the stem emerges from the soil.

"One obvious and practically important conclusion to be drawn from the above considerations is that the more water evaporates from the surface of the soil within a season, the more alkali salts will be drawn to the surface. Hence, within certain limits, a greater rainfall will bring up a larger amount of alkali; or if, instead of rain, surface irrigation is made to supply an additional amount of water, the same effect will be produced; *always provided*, that the rainfall or irrigation does not go so far as to actually wash a portion of the salts definitely beyond the reach of surface evaporation, into the lower strata, from which springs or seepage will carry them into the country drainage.

"The measure of the rainfall, or amount of irrigation water, that will accomplish one or the other of these opposite results depends in a large measure upon the nature of the soil, as well as of the underlying strata. It is more difficult to wash the soluble salts out of a clay soil than out of a sandy one; and the moisture and accompanying salts will keep rising through the

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former from greater depths, and for a greater length of time after the cessation of rains or irrigation."

Under the head of "Reclamation of Alkali Lands" he continues:

"The most obvious remedy for this evil is, of course, the leaching-out of the injurious salts by flooding, and, if possible, *under*-draining. This method is habitually resorted to in seacoast marshes, near the mouths of rivers, after the salt water has been excluded by embankments.

"The limited salty spots so frequently met with in the uplands of some regions, are promptly cured by a few underdrains, through which the winter rains wash the salts definitely beyond the reach of the soil-water. Such spots are commonly found extraordinarily fertile afterwards.

"The problem of affording relief, however, becomes much more difficult when either a stratum of saline water or an earth layer containing much saline matter lies a few feet beneath the surface in a level region, as is, unfortunately, very often the case in California. When this happens, the evil can only be mitigated, but scarcely altogether cured. According to the value of the land to be reclaimed, one or several of the following remedies may then be employed:

"1. When the 'alkali' is not very abundant or very noxious, *frequent* and *deep tillage* may afford all the relief needed. For, inasmuch as the damage is in most cases the result of an excessive accumulation *at or near the surface,* it is clear that frequent intermixture of the surface layers with the deeper portions of the soil may so dilute the injurious salts as to render them powerless for harm.

"Moreover, since a perfect tilth of the surface greatly diminishes evaporation, it tends to diminish, concurrently, the accumulation of the alkali near the surface. The same effect may be produced by mulching, or by covering the surface with sand.

"With the aid of deep tillage, it is often possible to raise on salty seashore lands, root crops, such as beets or carrots, which absorb a large amount of soluble salts, and sensibly relieve the soil so that cereal crops may be grown in the second or third year.

"2. *Underdrains* may so far lower the water table from which the saline matters are derived, and may so far favor the washing out of the salts during the rainy season that the latter will thereafter fail to reach the surface so as to accumulate to an injurious extent, with reasonably deep tillage. The roots of plants will go deeper for the requisite measure, but will not be injured by the weak saline water below.

"With the aid of underdrains, in many cases a comparatively small amount of irrigation water may, when applied at the proper time, be made to produce the leaching effect upon the surface soil that would otherwise require a long time and a much larger quantity of water in order to wash the alkali into the country drainage.

"3. When the quantity of the salt or alkali is small, but its nature such as to be nevertheless very injurious or corrosive, the evil may be greatly mitigated or sometimes completely relieved by the application to the soil of *chemical antidotes* cheaply procurable in commerce. In order that the proper

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antidote may be chosen, it is of course necessary to determine the nature and in a measure the amount of the "alkali," by chemical analysis."

This extensive verbatim quotation has been made, not only because of its truth and completeness, but because it serves to emphasize the fact that progress in respect to the reclamation of alkali lands, or the redemption of lands which have passed out of cultivation or are about to do so in various parts of the irrigated West, has been remarkably and unjustifiably slow. The statement which has been quoted was made at a time when a large part of the irrigation in this country was in its inception, and was made in a report which presumably has had an extensive circulation in the regions most directly affected and among the men who from the scientific, agricultural and practical or financial standpoints have been most interested in the subject. The additions which have since that time been made to the theory of the rise of the alkali and to the conceptions of the practical and effective methods of combating it, while they have been by no means unimportant, have been chiefly in the nature of minutiæ or details, filling in along the line that was marked out so many years ago. It is surprising, in view of the fact that every laboratory investigation or scientific study, and every practical test that has been made since the foregoing statement was published, have fully confirmed the truth of the statement and the judgment of its author, that only a very limited application has been made of the principles which were enunciated. Tracts of land here and there in the irrigated region which have become charged with alkali on the surface have been drained, with the result that the land has been restored to crop production. These instances, while comparatively few in number and of small magnitude, are fairly well distributed geographically and many of them have been well described in publications which have had extensive circulation.

HAVE REVERTED TO DESERT.

Still it is true that township after township of land all over the irrigated West, and in localities where neighboring lands suitable for irrigated agriculture or horticulture have the highest values, are lying to-day under a crust of alkali which precludes the growth of crops of any kind, and no move is on foot for their reclamation. The soil under the alkali crust is of a nature which, in the absence of the concentration of the alkali, insures the most liberal returns to cultivation. Therefor even a heavy expense, in many instances far exceeding that to which eastern farmers are accustomed when they undertake to drain their wet or overflowed lands, would be justified and would prove a good financial investment. That very little of the work has been done goes to show that the vaunted western alertness to opportunity is not all-pervading or universal.

I think that I am quoting one of Dr. Hilgard's later expressions, as well as stating a demonstrable proposition, when I say that under-draining of the affected land is the only complete remedy or certain preventive in any case. In view of this fact, and in deference to the limits of this paper, therefore, no more than incidental attention will be given to any of the other remedies or palliatives which have been mentioned.

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DRAINAGE HANDMAID OF IRRIGATION.

It has been truthfully said that drainage should be considered in connection with irrigation works at their inception in every instance. This does not mean that drainage works should be constructed in connection with every system of irrigation works, although the exceptions are remarkably few. Neither does it of necessity follow that in all cases in which it is decided that works of drainage will be needed they should be constructed at the time that the irrigation canals are built, although it will usually be found that the construction presents fewer difficulties at that time than at any later period. An advantage in postponement arises, however, from the fact that it will give opportunity to observe the tendencies in respect to the rise of the ground water and the alkali, thus furnishing a basis upon which the location and dimensions of drains may be determined accurately in accordance with the purpose which they are to serve.

It will sometimes be found that the entire area irrigated or to be irrigated has a good slope and is underlaid at a moderate depth by a bed of gravel, so that adequate natural under-drainage is assured. More frequently, however, this condition does not obtain over the whole area under ditch, and unless artificial drainage is provided the lower lands and those of least slope will become swamped or alkalied. When canals are constructed in extensive plains of little slope it may be assumed at once that artificial under-drainage of practically the entire irrigated area will sooner or later be necessary.

IRRIGATION DRAINAGE A NEW SCIENCE.

The design of a drainage system to counteract the rise of the ground water which results from irrigation involves some considerations of a decidedly different nature from those which come before the drainage engineer of the Middle West who is called upon to design a system for the removal of excess of water from the surface of the land. The permanent service which the drains in irrigated land should render is the prevention of the rise of the ground water to a height such that the capillary action of the soil can bring the water and the dissolved alkali to the surface. That is to say, practically all of the water which the drains receive, after the regimen of the system has been once established, is that which comes up to them through the soil. They must be large enough to receive this practically as fast as it comes when rising at the maximum rate. Correspondingly, in the humid region, the drain must be designed for the rate at which water will come down to it through the soil, either directly and at once, or indirectly and after a time. The designer, therefore, makes a study of rainfall records, the rate of downward movement of water in the different soils, and the length of time which it is allowable that lands may be submerged pending the removal of surface water by drains. In the West we are concerned as to the porosity of the soil in which the drain is to be laid and which surrounds it on all hands; with the degree of freedom of movement of water which this particular soil permits within it, and we must have measurements or statistics bearing upon the rate at which the ground water rises when the ditches are put in operation at the opening of a season, or whenever the rise is the most rapid. If reliable data can be had on these points, the area which a single

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drain can serve, and the capacity which the drain must have in order to serve the area completely, can be calculated.

Certain circumstances have been noted in connection with soils as constituting limitations upon the design and operation of drains. Some of these will be discussed briefly in the following paragraphs.

Soils which are permeated by small channels, such as may have been formed by rootlets, or by surfaces of separation caused by the segregation of soil particles into groups or lumps, may present difficulties in the way of the leaching process. When water is applied to the surface that which first goes down carries the alkali from the surface and also soaks up the soil below. The water which follows, carrying little or no burden of alkali, and going by way of root holes or other gravity (as distinguished from capillary) channels, is that which alone reaches the drains. It is believed that success in such cases will attend repeated light floodings rather than a less number of copious floodings.

In this connection it may be observed that if a redistribution of the surface alkali throughout the soil from which it came can be accomplished, the result may be better than if the alkali were washed down into the drains and completely out of the soil, carrying with it many of the soil ingredients which it is desirable to retain.

It is reported that in parts of Idaho where tile drains have been tried it has been found that a fine silt, having cementing qualities, enters the drains and in time interferes seriously with their operation. The writer has not encountered this condition, but it seems that the frequent and systematic cleaning of drains which is practiced in California to remove intruding growths of rootlets might prove effective to prevent this accumulation of hardened silt. The engineer who reports the circumstance considers that the difficulty may be met by using the bottomless plank drain.

A distinction which has been borne in mind in all of the foregoing, but to which no specific allusion has been made, is that which obtains between the first service and the permanent service of a drain laid in alkali land. The first service is to afford opportunity to leach out or redistribute the alkali in the zone of soil above the drain. After this has been accomplished the permanent service is to *prevent* the rise of the ground water into that zone. The drains are laid deep enough so that when the ground water is held down to this level capillary action will not draw the water thence to the surface of the land. This necessitates that the drains be laid much deeper than when their office is merely to remove excess of surface water.

A NOTABLE TEST CASE.

In order that some of the points involved in this discussion may be brought out more clearly a brief description of one of the most notable instances of the alkali evil will be given.

In parts of Fresno County, California, the statement is current that when the irrigation water was first applied to the ground it was the first time that it had been thoroughly wet since the creation. It was bone dry down to depths varying usually from thirty to sixty feet below the surface. However, the soil is one which permits the ready passage of water in any direc-

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tion in which there may be an impelling force to give it motion. Moreover, the country is a nearly perfect plane, with but a slight slope in the direction of its greatest declivity. Owing to the looseness of the soil the applied water went quickly down, and meeting with the water table standing on approximately the same slight slope as the surface of the plain, it was impossible for it to find it way out into the country drainage, in spite of the open nature of the soil, as fast as it was supplied by the application to the fields and the seepage from the ditches. Thus the water began at once to rise in the ground, until now it has reached a height so near the surface that at the time of the annual rise, following closely upon the date when the ditches first begin to run for the season, the ground water in many places over several hundred square miles of territory comes nearly or quite to the surface. In fact, a large number of low places or depressions in the plain have been converted into lakes with depths ranging up to ten feet or more. But the transformation would attract comparatively little attention if it were confined in its manifestations to these depressions. It is not so confined, but extends to the most fertile lands of the valley, some of which in earlier years reached the highest cultural development. In these places the ground water stands so high during a considerable part of the season that the alkali is dissolved out of the soil, brought by capillarity to the surface, and left there by evaporation. Lands which have been worth from $150 to $400 per acre are in their present condition worthless, and return no revenue to their owners. Vineyards which at one time were the show places of the valley are now scenes of desolation and return no revenue to their owners. Their only value is that which is based on a distinct prospect of reclamation.

Several plans have been proposed for the drainage of parts of the affected area. One of the most extensive of these, which has been worked out in detail and has been looked upon with favor, applies to about three quarters of a township consisting of lands immediately adjoining the city of Fresno, lands which when relieved from the actual and potential evil which overhangs them will reach the maximum of production and value. The plan contemplates the subdivision of the region into a number of subdistricts, each to have its own system of tile drains leading to a sump so located that the drainage water can be pumped from it into an irrigation ditch.

ALKALIED LAND DRAINAGE CAN BE USED FOR IRRIGATION.

Analyses have demonstrated that the drainage water does not carry an excess of alkali which will unfit it for use in irrigation. While this statement as to comparative freedom from injurious salts is true of the ground water of which the drainage water will chiefly consist after the regimen of the system has been established, it may not be true of the first water which reaches the drains after having been applied on the surface for leaching purposes. It may be expected, therefore, that the leaching according to this plan must be done when the ditches are not in service for the irrigation of crops.

An enumeration of some of the considerations of which account was taken in design may be of interest. It was provided that no drain should be laid at a less depth than five feet, to which depth, according to the evidence at

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hand, the capillary action did not extend from the surface. The trouble which might be encountered due to water running alongside the drains and throwing them out of line and grade is avoided by the provision that the drains shall be laid on a plank base. Each drain is made of a size sufficient to carry water at the rate of two and one-half cubic feet per second for each square mile of tributary territory. This estimate of two and one-half cubic feet per second per square mile is based on a number of considerations, including a series of observations which had been made for several years of the rise and fall of the water surface in one of the depressions which have been noted, measurements of the amount of water delivered by the few private drains which have already been constructed, and estimates of the amount of seepage from the ditches traversing the area under consideration.

ALKALI FROM CANAL AND DITCH SEEPAGE.

Incidentally it may be remarked that it is believed that the present ground water supply is kept up almost wholly from the seepage which takes place through the beds and banks of the ditches. In all probability the excess of water applied to the land had a significant effect in this respect in the early days of the irrigation system, but it has been observed that the irrigator of the present day in that locality limits his use of water to that which is plainly needed, and the contribution of excess from this source must now be a minimum. The near approach of the ground water to the surface has seemingly reached a limit in some localities, and instances can be cited of vineyards beneath which the depth to ground water is the most favorable, with the result that irrigation of those vineyards has not been necessary for a number of years, in some cases twenty years.

In laying drains in the humid region, care is taken that the line of the drain does not approach within certain limits of water-loving trees or plants, as it has been found that the rootlets will enter and clog the drains. In the fruit regions of irrigated America it is not practicable to observe this precaution. No location can be found for a drain in an orchard or a vineyard which is not close to some deep rooted growth. Consequently the limited experience which has been had with private drains has already established the fact that they must be brushed out regularly with a special form of brush and apparatus for introducing it into the drains and dragging it through them.

Taking into consideration that drains for the prevention or cure of the alkali evil must be laid deeper than drains in the humid region, that in general they should be supported on a plank or other continuous rigid base, and that in many instances the maintenance will involve frequent cleaning of the drains, it would seem that the cost in the West will be very high as compared with what it is in the East. This is undoubtedly true so far as soils of the same texture are encountered in the two localities, but it is a fortunate fact in relation to the soils of the arid region that many of them will permit a remarkably free and rapid passage of water, and for that reason the drains need not be placed as near to each other as in the more retentive soils. The Fresno plans contemplate an expenditure of from about ten to fifteen dollars per acre drained, with the probability that in some instances the individual land owner will find it necessary to build private supplementary drains.

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THE STATE OF NEVADA.

ROBT. L. FULTON, Reno, Nevada.

No other State in the Union has been so misunderstood and misrepresented as has Nevada. She took up the burdens of statehood unwillingly, at the urgent solicitation of Abraham Lincoln, who found his influence in the Senate rather weak during the last days of the Civil War; and for a generation she was supposed to be little more than an ash heap with a few streaks of silver through it. Later on the word went out that her mines were exhausted, and many intelligent people were led to paraphrase the scripture and ask, "Can any good thing come out of Nevada?"

However, no good citizen of the Republic can look with indifference upon anything that may affect the fortunes of any State. Our country is so strongly bound together, its higher interests are so closely interwoven that none can suffer decay without sooner or later affecting all the others. The different sections of the Union so happily compliment each other that the greater the activity in any part the greater the prosperity of the whole. It is one of the blessed things about our beloved land that in every corner are natural resources which can be developed without coming into competition with those of any other part, and if this Congress serves no greater purpose than to make the West better known to the East and South, make closer friends of our more distant neighbors, break down sectional prejudices, if any remain, it will well serve its day.

The fact is that nothing necessary to the upbuilding of a great State was omitted when Nevada was created. The raw materials were abundantly bestowed and only the lack of human endeavor has prevented her from taking a high place among her sister States. The worst that can be said is that she lacks population, and it must be apparent that if that is a fault it is chargeable, not to those who live there, but to those who remain away. Perhaps the greatest drawback to her reputation comes from the fact that she is constantly compared with California, which is incomparable, instead of with her neighbors to the east. If Virginia, or Massachusetts, or even Maine lay where Nevada does, and the blossoming plains of the Golden State could be reached only after traversing their territory, they would suffer in contrast far more than they do now when surrounded by States of like condition.

INEXHAUSTIBLE SOIL.

The indefinable charm which covers all "The Land of Little Rain" extends over Nevada, with its sunny skies, its vivid sunsets, its violet tinted hills and its rush of sudden storm. Within her borders lie some of the richest lands upon the globe and when they can be reached by water the crops are never-failing, the quality the finest and the yield far greater than in the rainy States. Like the island of Sicily, which has raised wheat continuously for 2000 years, her soil is largely volcanic, and its strength has not been dissipated by centuries of showers, but lies ripening in the sun, waiting for the plow which shall tickle its surface and make it laugh a harvest.

In her early years agriculture was merely an incident. The wonderful richness of her mines brought her forward as pre-eminently a mining State,

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and only the most tempting inducements were sufficient to lead men to forego the more exciting pursuit of prospecting for that of tilling the soil. The first attempts were made in favorable localities, where hay grew naturally or shallow streams made easy gardening or ranching on a small scale. It was soon found that lands which had been considered worthless desert would produce in astonishing abundance, and the uniform success attending the efforts of everyone who put seed in the ground anywhere shows that all the great stretches of sage brush, the immense valleys and smooth benches require only water and work to make them blossom as the rose. Even the beds of alkali are made by a superabundance of plant food, which can be fertilized by proper treatment. The many valuable premiums taken at the different expositions, from the Centennial down to St. Louis, furnish convincing proof of her capacity and quality. Considerable attention has been paid to stock raising, dating from quite an early day, and it certainly may be said that she has as good horses as any State in the Union. More than one world-beater has been turned out from her stock farms and Governor Sparks' Herefords have brought home many a gold medal.

The finest kind of beef comes in from the ranges and her mutton is second to none. All of the inter-mountain States are famous for wool and most of them come to Nevada for blooded bucks, Hereford and Durham bulls and for Theodore Winter's blooded horses.

VOLCANIC GRIST PLUS WATER.

No country in the world yields to intense cultivation as does one with a volcanic soil under irrigation, and the truth is that Nevada should be the seed farm for the nation. Her climate is perfectly adapted to the production of all of the cereals and the finest of the hardy fruits. The elevation is right and the seasons mild. Her wheat is perfect, with a full, rich kernel and a clean, golden straw, free from smut and rust. It has taken prizes at all of the great expositions and wins its way among experts wherever it goes. Some few years ago a bright young merchant of Elko County gathered up all the fine grain he could find, and after cleaning it thoroughly made it up into one pound packages in attractive style. He then advertised in the leading magazines, like Harper's and the Century, "Golden Wheat, One Dollar a Pound." He sold all he had and his customers came back for more. Nevada beets yield as high as twenty-three per cent of sugar; her celery grows large, white and crisp, breaking like ice in the hand. She could raise onion seed of all the finest varieties by the ton, and already furnishes alfalfa seed to the trade. Nevada potatoes are little bunches of meal done up in a clean, bright sack; her turnips have the mountain flavor, and all of her produce is of superior quality. She has the variety of soil, the different slopes of hillside, plain and valley to meet every requirement. Two farms in the Mississippi valley may be a thousand miles apart, but they will be exactly alike in all their important characteristics, both having been built up from sediment carried down by the floods of ages, but the smallest farm in Nevada may have a dozen varieties of soil lying side by side so that one would produce the finest berries, another luscious fruit, the next juicy tomatoes, and so on through a long list, each one receiving that certain food best suited to its needs and

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receiving the proper slope for sunshine and having moisture fed to it scientifically instead of at nature's caprice. Such are some of the advantages the Nevada seed grower would have over his neighbors.

The very fact that Nevada was selected for the first irrigation system under the act of June 17, 1902, is sufficient proof of the capacity of her soil, the abundance and durability of her resources. Mr. Taylor, the engineer in charge, estimates that a million acres can be added to her present area of cultivated land and the remaining sixty-five or sixty-eight million acres are rich in mines, in forage plants and in beds of salt, borax and nitre. Nothing could be more tempting to the settler than the chance to find a good mine near home, and there is not a valley in Nevada that does not lie within sight of ranges of hills containing a good percentage of the precious metals. The farmer's boy in Nevada does not need to loaf in the saloon or the postoffice, if he has energy and sense. He can open a prospect and work all winter in a good warm tunnel or a sheltered cut, and, if he finds ore, he can have it hauled to the quartz mill in the spring, just as his father hauls his wheat in the fall. Mining in Nevada has had a wonderful history, with the record of the finest camp the world has ever seen, where over six hundred million dollars were taken from one rock a mile in length, but the past is but a promise of what is to be when the State is settled and the university has taught our boys how to test the rocks and prospect the hundred thousand square miles of territory that has hardly been scratched as yet. Such is the opportunity for the honest homeseeker, when under a wise and benign statesmanship, the idle men and the idle money of the country will be made use of to carry the idle waters to the idle lands, for it is easy to see that Nevada will receive a larger, speedier and more direct benefit from the reclamation policy than any other State and that it will advance her from the bottom of the class several degrees.

A MESSAGE FROM JAPAN.

I have been an optimist in all that concerns Nevada since first I crossed her border, but I never realized the magnificent possibilities of my adopted State until I visited Japan and other countries where land hunger has become chronic, and saw what man's ingenuity could make of tiny bits of ground when his stomach was empty and there was no other way to fill it. The area of the Japanese Empire is almost exactly the same as that of the State of California, and yet upon this small space she subsists nearly fifty million of the happiest and most contented people on earth. But this is not all. The whole region is of volcanic origin and comparatively new, geologically speaking, so that only one acre in eight can be cultivated. Even this restricted area is not very productive in quality. The soil has never been ground to dust and fertilized by glacial action, as have the rolling hills and rich prairies of our own country. A narrow fringe along the shores of most of the islands is nearly enough on a level to be cultivated, while steep, high mountains fill the interior. Unlike our elevated ranges these do not produce nutritious grasses, and generally but poor timber.

In order to support so large a population upon so limited an area of land the most intense husbandry is practiced. Extensive systems of irrigation

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are necessary for rice cultivation, although some hill rice of a fine quality is produced, and far up in the mountain valleys the streams are diverted to the terraced paddy fields and the water is never released until it reaches sea level, and sometimes not then. It flows down from one to another terrace until it reaches the planic, where the *noria* or Persian water wheel is a good deal used to overcome slight differences in levels. Nowhere in all Japan did we see the native to better advantage, from an artistic standpoint, than when perched upon the graceful wheel with a long pole which reached the ground to prevent a fall, he patiently and lightly tripped along as the wheel revolved beneath his feet. He was generally naked to the waist, both ways, and his trim and airy figure was a study in the classics for any sculptor. The blades of the wheel fitted in a box, and as it revolved each blade lifted a couple of gallons of water at a time and sent it flowing off in a new direction. During the rice season the streams are polluted and the water carries contagion, making dysentery and diphtheria endemic as well as epidemic.

The finest irrigation system I have ever seen taps a lake about the size of Tahoe, Lake Biwa, a fine sheet of water 14 by 40 miles, in the hills above Kioto, carrying water under a mountain by means of a tunnel over 8000 feet in length to the valley beyond. At the outlet iron gates 36 feet high are set in stone work of massive strength, with a similar set of gates 60 feet below. Two intakes are built, each 25 feet wide, with duplicate sets of these big iron gates. The intakes are separated by a massive stone wall, but they come together a few yards below the lower gates and make a stream 25 feet wide and 25 feet deep, running four or five miles an hour. The canal is walled in with blocks or cement. Boats ply up and down at intervals and we paid three yen to make the trip, which was most interesting. Three long tunnels were shot, and it was a weird sight to see a boat push forward from nowhere, as its crew dragged it along by a wire cable fastened to the opposite wall. All along the way stone gates are set to measure out water to the farmers. The main canal divides, one branch going to the Kioto waterworks, generating electric power as it falls to the town, and the other branch goes on to irrigate more farms. It is a government work and cost a million and a half.

Nothing could be more picturesque in the way of landscape gardening than an irrigation system in Japan as seen from any of the steep hillsides above it. The honey bee makes no more economical use of space in building its comb than does the thrifty little Jap in dividing his sloping land and building his banks to form terraces for rice culture. The form of each field is determined by the natural conditions and the tiny farms are cut up in every conceivable shape. The crop averages over twenty-eight bushels to the acre as against fifteen and a half in India and thirteen in the United States. The annual crop is about two hundred million bushels a year, of which about one-eighth is exported. Cereals are absolutely grown by hand; each grain being dropped in a hole made by the finger, liquid manure is poured over it with a dipper and the earth pressed down with the hands. When the barley is receiving the last cultivation in May, beans are planted between the rows, and so three crops are made to grow on the same ground during the year. At this time the rice plant is showing green in the seed beds and

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by the middle of June it is transplanted in hills about five inches apart, with rows eight inches from each other. The sweet potato was introduced about 200 years ago and is now the chief food in many of the islands. Fish is a staple diet, and without their use it would be impossible for the Empire to sustain anything like its present population.

Compared with the Orient our own country is indeed a happy one, but the man who seeks a home in the new States might well take a few lessons from the Japanese farmer; in his cheerfulness, his industry and his sobriety, in his happy faculty of developing his resources to the uttermost, he leads the world. They drink liquor there, but we saw only one drunken man in all Japan. We have a better soil, a more healthful climate, a much more comfortable manner of living and we should have the happiest homes on earth.

Sufficient has been said to demonstrate Nevada's future. The very fact that the State, the fourth in size of the whole Union, has but forty thousand people located upon her 71,000,000 acres of land is the best evidence that unlimited opportunities can be found for the earnest and capable man. Every county in the State has undeveloped resources, open lands at two and three dollars an acre, mines to be found by effort, wages at the best rate going for farm work, sheep tending, lumbering and all sorts of trades. With a climate famous for its sunshine, an air free from malaria, with rivers rapid and deep, capable of furnishing unlimited power, with a soil rich in phosphates, and mountains seamed with veins of ore, with valleys that have attracted the attention of both the capitalist and the government as favorable fields for reclamation enterprises, the man who moves to Nevada now will find her just trembling on the rise. The long period of depression is of the past, the future is assured, and not in a thousand years will she be as poor as she is to-day. To become a part of the upbuilding of a great State appeals to the good man everywhere, and the roster of its pioneers is a roll of honor in every community for all succeeding generations.

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RECLAMATION OF ALKALI LAND.

PROF. C. W. DORSEY, Bureau of Soils, U. S. Department of Agriculture.

Certain of the work now being carried on by the Bureau of Soils of the U. S. Department of Agriculture is the practical demonstration of methods whereby alkali lands can be reclaimed and made productive. Those of us who have spent any considerable time in the West are more or less familiar with the subject of alkali. Whether it is white alkali or black alkali or a combination of both, we know it is injurious to crops, and if it is accumulated in sufficient quantities in the soil no crops at all can be grown.

We who have made a careful study of this subject state that alkali consists largely of some form of sodium salts. The black alkali is sodium carbonate. One form of white alkali is sodium chloride or common salt, while another form of white alkali is sodium sulphate or glaubers salts of commerce. We may have only one form of alkali present in the soil or we may have various combinations of all three forms I have mentioned.

Black alkali is most injurious to plant growth and sodium sulphate is the least injurious form of white alkali. The statement is also made that two-tenths of one per cent of black alkali in the soil is sufficient to prevent successful crop production. Crops will stand considerable more white alkali, but certainly not more than one per cent. We also know that certain crops are more resistant to alkali than others. We know that sugar beets will stand much more alkali than such crops as alfalfa or wheat. The date plum is an example of a tree that will stand comparatively large amounts of alkali. But alkali in excessive amounts always exerts a toxic or injurious effect on plant growth, no matter how resistant the individual plants may be to small amounts of alkali.

FOUND THROUGHOUT THE ARID WEST.

When we consider the extent of land containing alkali we find that almost every irrigated district in the arid West has suffered some loss from just this cause. Careful estimates seem to indicate that from 10 to 15 per cent of every irrigated district contains sufficient alkali to at least very materially lessen the productiveness of the soil, while 5 per cent of every district contains so much alkali that no crops can be grown at all. In order to realize what this means to the irrigation farmers it may be interesting to introduce some figures on the subject. In 1902 the Census Bureau estimated that in the arid States there were 8,470,000 acres under irrigation. Five per cent of this amounts to 425,000 acres in round numbers. That much land carrying alkali is unfit for use. This is actually more than twice the acreage of irrigated land in Washington, nearly twice the amount in Arizona and New Mexico, and nearly equals the amount of irrigated land in the State of Oregon. Estimating that this land if reclaimed would be worth $50 an acre, a conservative estimate I think, we find the West loses valuable lands to the extent of $21,000,000 through alkali. This makes us realize how serious the alkali question is at present and we all are aware how fast it is spreading almost everywhere.

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ATTEMPTS TO COMBAT THE TROUBLE.

Farmers have tried to check the spread of alkali in one way or another but with only partial success. Some have flooded their lands for a period of a few hours and have then drawn the water off. In some cases this has effected a partial remedy. Again attempts have been made by soaking the land and driving the alkali below the surface. Often this has enabled the farmer to crop the land for one or two years longer, but no permanent cure was obtained. Again the use of gypsum on black alkali land has been advocated by many, but this does not remove the alkali, but merely changes it to a less injurious form, besides this method is altogether ineffective on white alkali land.

When the Bureau of Soils took up the study of Western soil conditions several years ago a study of the origin, accumulation and spread of alkali was also made. As the various reports were issued covering these studies, specific recommendations were made looking to permanent reclamation of the soils from injurious accumulations of alkali. Especially were the good effects of heavy flooding recommended after a complete system of under-drainage had been installed. By such methods it was claimed even the worst alkali land could be economically and permanently reclaimed. Such suggestions were made from time to time in the various reports, but little or no efforts were made to reclaim any lands, even in the worst districts. Believing that by establishing a number of demonstration experiments in alkali land reclamation much good could be accomplished, certain tracts were selected and their reclamation attempted. At present we have reclamation farms located at Fresno, California, in the San Joaquin valley; at Salt Lake City, Utah, at North Yakima, Washington, Tempe, Arizona, in the Salt River valley, and at Billings, Montana, in the Yellowstone valley. In each case a tract of twenty or forty acres was selected and usually this was the very worst alkali that could be found, and in some cases the ground water was almost at the surface, so we had to fight seepage water as well as alkali. We picked bad tracts of land so there would be no question of the efficiency of the methods after the reclamation was completed.

BAD LAND SELECTED FOR TESTS.

Some of the tracts were parts of ranches that had gone bad to alkali, others had always been considered worthless and their cultivation never attempted. Complete tests of the soil were made to a depth of four feet, and on some of our tracts the soil contained upwards of three per cent of alkali.

On each of the tracts we have different soil, climatic, as well as varying alkali conditions. At Fresno, California, and North Yakima, Washington, we have been experimenting with black alkali. At Tempe, Arizona, and at Salt Lake City we have white alkali of the sodium chloride variety, while at Billings, Montana, we have sodium sulphate, another form of white alkali.

Our mode of procedure is to lay common drain tile, such as are used so extensively in Indiana and Illinois, at an average depth of four feet. By this means a complete system of under-drainage is assured. Then the tract is nicely leveled and checks thrown up so that all of the land can be flooded to a depth of several inches. The work of flooding is carried on as rapidly as

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possible, depending of course on the water supply and the time required for the water to soak through the soil. The principle of this method of reclamation is quite simple. The alkali is a soluble substance that can be dissolved by a copious supply of water and carried downward and out through the drain tile. By continuing such a process even the worst alkali land can be freed from any excess of alkali and made as fertile as fine virgin soil containing no alkali whatever.

COMPLETE SUCCESS ATTAINED.

So much for the methods of attacking the problem; now as to the results and what we have accomplished up to the present time. In California two weeks ago I visited our tract, two and one-half miles south of Fresno, and found the owners very well pleased with the manner in which the land had responded to this treatment. At one time this land was worth $250 per acre and was one of the choice tracts of land near Fresno. At the time we took it, in 1903, it had only a nominal value of a few dollars an acre on account of the large accumulations of black alkali. For crops it was practically worthless. Last year at the close of the season's flooding all but five acres were reclaimed and produced crops this year. This season we have practically completed the reclamation and a good stand of alfalfa is starting while the soil has lost all the bad characteristics of land carrying much alkali.

At Tempe, Arizona, last week I saw a very good stand of barley on land that the owner had attempted to crop for years and had failed each time. This was accomplished after a few months of heavy flooding. The indications point to the reclamation of the entire tract at an early date. At Salt Lake City we took 40 acres that had always been too salty for crops and had no value as farm land whatever. This fall, after two years of flooding, we have calculated that 8000 tons of salt have been washed out of the soil and now it is in shape for almost any crop that can be grown in the vicinity and is easily worth $100 per acre for farming purposes. At North Yakima, Washington, after a short season's flooding last year and again this year, we believe we have at least four-fifths of the twenty-two acre tract reclaimed and in such shape that alfalfa can be sown on it next spring. The whole tract was seeded to wheat the last of September, and the last reports from there were that the crop was doing nicely, indicating by a practical test that by far the greater part of the tract is reclaimed. This land formerly was a salt grass pasture, of no value for crops. So carefully has our experiment been watched and believed in by the farmers of the neighborhood, that adjoining salt grass pastures have very materially risen in value on account of the chance of reclaiming them and converting them into valuable farm lands. In the Yellowstone valley, at Billings, we can make no statement of our work, for it has only been installed and flooding will not commence until next May, when the water is in the canals. Our problem there is to wash 2300 tons of white alkali out of a stiff gumbo soil and leave it in a fertile condition, suitable for any crop grown in the valley.

DOES IT PAY?

So much for the results for the reclamation experiments; now for some questions that will naturally arise about the work. The first that may be

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asked is, I think: Is the work practical; can it be done cheaply; and, again, just what is the cost? The cost of reclaiming alkali land will depend largely on the cost of labor in digging ditches and on the cost of the tile delivered at the ranch. To put a tract of land in shape for reclaiming it, that is, installing the drainage system, leveling and throwing up the checks, costs from $15 to $40 per acre. If labor can be cheaply secured and a tile factory is near at hand, such work can be done at a very reasonable price. Unfortunately at present tile factories are not common in the West, as there are probably not over a dozen in all of the arid States and Territories, so that the question of freight enters largely into the cost. If tile could be purchased at prices at which it is sold in the Eastern States there would be no question of profitably reclaiming land that would only be worth $25 per acre after it was reclaimed. As soon as farmers become more familiar with the valuable results to be derived from the use of drain tile there will be created a large demand that will make it necessary for small factories to be located in practically every irrigated district.

TILE FOUR FEET DEEP.

Again the question is asked how deep must we lay tile for the best results? Our experience in this direction leads us to believe that the tile should be laid at an average depth of four feet. This means that with tile at such a depth we permanently lower the ground water to that depth, as well as free the soil from alkali to the same depth, with but little chance of its being again pumped to the surface by capillary power of the soil. It is also well to mention that the deeper we have our tile the greater area of land they will drain on each side, so that depth is an important factor to be considered.

Again we are asked how far apart should the drain tile be laid? This depends altogether on the character of the soil. On a heavy clay adobe or gumbo soil it may be necessary to put them 100 feet apart. On the other hand on coarse sandy soils tile 225 feet apart will answer all purposes. Some one will ask how long does it take to reclaim alkali land? This will depend on the amount of alkali originally in the soil as well as on the texture of the soil; as to whether it is a heavy clay or a light sandy loam, for this determines largely how fast the alkali can be leached out of the soil.

The presence or absence of hardpan also enters into the question. With a very large amount of alkali in the soil, say 3 per cent, it will take at least two years to reclaim all of the land. With land only beginning to show alkali, perhaps a few floodings will be sufficient to restore it to its original fertility. The length of the flooding season and the water supply available for such purposes largely influences the question of the length of time necessary for complete reclamation. Even before the final reclamation is accomplished some crops can be grown that will reduce the cost of reclamation.

There are many other question that might be brought up about the different features of the work, but I believe I have mentioned enough to convey some idea of how the work is carried on and just how far we have been successful with this method.

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THE SIZE OF AN IRRIGATED FARM.

THOS. H. MEANS, Engineer of Soils, U. S. Reclamation Service.

Farming in an irrigated district is very different in many ways from farming in the rain belt. In two important particulars the irrigation farmer has the better of his contemporary and they are that he gets the right amount of water for his plants and gets that water at the right time. This being so, he is independent of weather in a great measure, particularly so as arid regions are most generally those in which all climatic factors favor plant growth, except in the amount of moisture in the soil. Being independent of the weather, there is no loss on account of dry seasons to be expected, and he should harvest a full crop every year. How often is the crop of the rain belt farmer damaged by adverse climatic conditions? How often at harvest time does the Bureau of Statistics report our staple export crops, the money getters, as having condition 100 or better at harvest time?

Now, I am of the opinion that under many existing systems the irrigation farmer in America is also very apt to harvest a short crop from lack of water. The fault is not with the irrigation method, but is in the works he has built to control the water. He may lack storage facilities to tide over seasons of low water; he may be unfortunate in having more neighbors than the stream can adequately supply; he may be the victim of a water company who has monopolized the water of a stream and sells water rights but don't deliver water; he may be imposed upon by neighbors up stream, but this much can be said of him, that if his irrigation works are built of the proper materials with a competent knowledge of the hydrography of the stream and he is living in a State whose laws respect and protect his rights, he will harvest a profitable and full crop in all years of diligence.

SMALLER FARMS UNDER IRRIGATION.

And by virtue of this, a living can be made on a smaller area than in the rain belt, subject as it is to the vicissitudes of the clouds and sunshine. If there is one national characteristic of American agriculture it is that it is extensive. Large areas are farmed, low yields are obtained; but by reason of the large amount handled the profits per farm are great. As an instance, the average yield of wheat for the United States is thirteen bushels per acre. In consequence, wheat farming is carried on most extensively in those great areas of prairie and plains land where large farms are managed by one man. North Dakota produces on an average twelve and one half bushels of wheat per acre. A small farmer with forty or eighty acres of wheat at this rate can not make a living, but he with a thousand or ten thousand grows rich.

In irrigated lands wheat averages from twenty to forty bushels, and yields of fifty bushels per acre are not uncommon. Here the small farmer can afford to raise wheat and he who has forty or eighty acres can have his patch of wheat and make a profit in handling it.

The following figures from the census of 1900 show the average number of acres irrigated by each irrigator, the average value of products per acre and the average value of products per irrigator. This last figure is actually the gross income per irrigator:

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Size of Farms Per Irrigator, 1899.

	Acres.	Value per Irrigator.	Value per Acre Irrigated.
Arizona	46.0	$ 755	$16.40
California	45.2	1285	28.40
Colorado	73.9	860	11.60
Idaho	56.5	605	10.70
Montana	94.0	905	9.65
Nevada	169.5	1495	8.85
New Mexico	23.2	350	15.10
Oregon	62.5	660	10.60
Utah	30.0	420	13.90
Washington	33.6	675	20.00
Wyoming	107.9	775	7.20
United States	55.5	820	14.70

It is assumed that all irrigation farms are on the average supporting a family. In three States, namely, New Mexico, Utah and Washington, the average number of irrigated acres per farm is less than forty. Where will you find a more prosperous and contented agricultural people than in the irrigated valleys of Utah and Washington? New Mexico's low acreage is largely caused by the number of Spanish speaking Americans in the Territory. There are five States—Arizona, California, Colorado, Idaho and Oregon—in which the acreage per irrigator is between forty and eighty acres, and two States with between eighty and one hundred and sixty acres, namely, Montana and Wyoming, with only one State—Nevada—in which the acreage is more than one hundred and sixty acres. It is well known to all that these last three States in which the acreage per irrigator is more than eighty acres are great cattle growing States and the principal product is forage, frequently being produced by irrigating native grasses. The value of products per acre is smaller for these three States than any others, clearly showing that the maximum production of the land is not being realized. There is no apparent reason why an acre of irrigated land in Nevada should produce products of lower value than a similar acre in Oregon, yet the table shows such to be the case, the value in Oregon exceeding that of Nevada by $1.75, or nearly twenty per cent. It would seem that the products realized vary almost inversely as the area per irrigator; that is to say, in those States where the area is large the value of products is small and vice versa. By grouping the States into those averaging less than forty acres per irrigator, those with forty to eighty acres, and those with more than eighty acres, the following table is obtained:

Table showing acreage and value of products per irrigator and per acre by groups of States.

States in Group.	Acres per Irrigator.	Value of Products per Acre.	Value of Products per Irrigator.
New Mexico, Utah, Washington	28.6	$15.00	$430
Arizona, Cal., Idaho, Colo., Oregon	56.7	17.35	985
Montana, Nevada, Wyoming	108.5	8.80	955

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This table very clearly shows the relation of size of farm and the value of products per acre. Where the farms are large the products per acre are small. The second group includes California with all the tremendous fruit productions of that State, and for that reason the value per acre is higher than in the first group.

FROM 40 TO 160 ACRES UNDER NATIONAL IRRIGATION.

The Reclamation Law of June 17, 1902, Section 4, states that the Secretary of the Interior shall give public notice of the lands irrigable under such project, and the limit of area per entry, which limit shall represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question, also of the charge which shall be made per acre upon said entries. In section 3 the size of the entry is limited to tracts of "not less than 40 nor more than 160 acres." In accordance with this the Reclamation Service is at present classifying all lands which will be irrigated under the various projects. This classification is carried out with the view of determining the value of the land for agricultural purposes. Lands are classed into four grades, as follows:

First-class land includes all which is first-class in every respect. It does not take into consideration the texture of the soil, that is, whether it is heavy or light, provided it has a texture which will permit some crop to grow.

Second-class land should be so fertile as to produce profitable crops but not so well as first class land. It may contain small amounts of alkali; be rough and require leveling; be of such a texture or composition as to be restricted to only a few crops, and therefore not so valuable as other soils which can grow a larger range of crops.

Third-class land is that which may by the expenditure of money and work be brought into a fertile condition, but which in its present condition will not produce profitable crops. It may be too rough for irrigation, may be alkaline, swampy or have an injurious hard pan. In general, it is not considered practicable to attempt the reclamation of third-class land until the first-class and second-class land is exhausted.

Fourth-class land includes all which for any reason is not worthy or impossible of irrigation.

Upon this basis the land is all carefully classified and divided up into farms. The attempt is always to include in each farm sufficient land to support a family.

In some parts of the irrigated West where the land and climate permit the production of high-value products, such as fruits, the area of each farm of first-class land can well be forty acres. In other districts where alfalfa and cattle are the principal products the area may be eighty acres. In other districts where the season is short and production is limited to grain and native hay the area may be 120 to 160 acres.

In no irrigation project can the area of irrigable land be less than forty acres, because this is the smallest farm which it is in the power of the Secretary to irrigate. It seems that one of the southern-most States in the arid West has on the average less than forty acres per irrigator, and Washington, one of the Northern States has a smaller acreage than forty acres per irrigator.

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MODERN RICE IRRIGATION.

PROF. T. U. TAYLOR, University of Texas.

Rice is a native of India and Australia. It is raised in India, China, Japan, Malaysia, Brazil, the United States, Italy and Spain, and many islands of the sea. There are many varieties, but the two best known in this country are known as the Japan and the Honduras. As a rule rice is an irrigated crop, but in all countries some trust to Providence to do the irrigating.

Before taking a hasty review of the modern methods employed, it will be well to describe briefly the older practice, both in this and other countries.

JAPANESE METHODS.

The varieties of rice known as Urichi and Moghigome are grown in Japan in the flooded fields. The season is about the same as that in the southern part of the United States from the middle of May to October or November. The first work consists in planting the seed beds which must be prepared with the utmost care, spaded and raked and surrounded by a small dyke or levee. The bed is flooded from the ditch and in June the seed are sown broadcast on the surface of the water and they sink quickly into the mud. In about one month the stalks are high enough (six or seven inches) to transplant into the rice farm. In the meantime while the seed bed was sprouting the young plant the former crop of wheat or barley is reaped and the land prepared for the rice plants. The farm is flooded after being broken up and in the mud and water the stalks are planted two in a hill from eight to ten inches apart, the number of hills varying from 60,000 to 100,000 per acre, thus making 120,000 to 200,000 stalks per acre. These are set out by hand with the utmost care. The yield per acre is from twenty-eight to thirty bushels. The farms or garden patches as we would call them in this country average in size from a quarter to a third of an acre, and one man may be the owner of several of these, contiguous or detached. The sides of the hills are terraced and several farms are located on a common ditch that taps some stream at a higher surface. The water passes from an upper to a lower farm, and so on until all the farms on the ditch are served. About November the first a harvesting is done by hand with the old reap hook, the bundles are hung up on a pole or scaffold and the threshing is done with a form of iron comb or flail followed by the winnowing or separating the chaff from the grain. The rice is then placed in straw bags for the market.

There are about nine million farms in Japan with a total acreage of 7,000,000 acres with an annual yield of 200,000,000 bushels or fifty million sacks, a production about eleven times that of the United States for 1904.

By way of relish it is interesting to note that the Japs are now in Texas in the rice belts at Webster in Harris County, at Garwood in Colorado County, and at Del Rio. At both places the Japs are operating well plants and Mr. Hawhimoto at Garwood made one of the best average yields in Texas for the season just closed.

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THE CAROLINA METHOD.

Under this head is included the methods that were in vogue all along the Atlantic Coast up to a few years ago. It is said that rice was introduced into South Carolina about A. D. 1700 by the accidental wrecking of a ship from Madagascar. Whether this is true or not rice has been a factor as a foodstuff for over 200 years. Methods where any cultivation was attempted consisted in planting rows and in flooding at certain intervals in order to supply the moisture, but the weeds were kept out by the cultivator or hoe and not drowned out by the modern method of flooding. But the methods varied in the different localities. The marshes in some sections were utilized as rice lands where the moisture was in the soil by virtue of its topography or underdrain. Of necessity the reaping had to be done by hand in the old break-back way as machinery in such a situation would soon have been out of sight. Against the tidal streams the farms were dyked in and at high tide the water was deflected into the ditches or on the farm. There was a tide in the affairs of a majority of the rice farmers which, taken at flood, led to a fair rice crop, but omitted, the rest of the year was spent in vain regret for lost opportunity and for unliquidated store accounts.

In all the Atlantic States there was a trust to Providence to supply the irrigating plant and very few were the cases where Providence was assisted with steam or similar power. Notwithstanding this, South Carolina held first place as a rice producing State till seven years ago.

The rice belt of Texas extends from the Sabine to the Rio Grande, and includes at present seven well-developed sections, (1) the Sabine Valley, (2) the Neches Valley (including its water shed), (3) the Trinity, (4) the Brazos Valley, (5) the Colorado Valley, (6) the Guadalupe Valley, (7) the Rio Grande Valley, and several detached areas that are sure, with good management, to be the forerunners of extended systems in the respective localities. In the coast section the land is a flat prairie which heretofore cut very little figure as an industrial factor. It is very flat, some of which having a slope of only 1 in 5000, and in general required small levees and small lifts at the pumps. This flat section extends all along the coast from the Sabine to the Rio Grande. The 250-foot contour above sea level is from 50 to 125 miles from the Gulf, while the strip from twenty to thirty miles wide along the shore rises only a few feet above the sea level. But in addition to this costal belt the rice section has since 1897 been rapidly spreading along and back from the coast until it has reached the Rio Grande at Del Rio to the west, and at Cuero, Columbus and to Milam County on the north. In the flat sections the water is often from bayous, frequently impregnated with salt sea water to such an extent that injury to the rice occurs. Rice must have an abundant supply of fresh water and a soil that is rich enough to nourish the rice and compact enough to hold the water. It is being successfully grown in Texas where the above factors are grouped, and money and brains are grouping them with a twentieth century effectiveness. No longer is the rice belt restricted to the old bayou country, but in the water sheds of the Sabine, Neches, Trinity, the Brazos, Guadalupe, Colorado and Rio

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Grande, over 100 miles from the coast, a high grade of rice is grown. The fresh water can be obtained from a flowing stream, surface wells, artesian wells or from rain. The well method is in its infancy, but it is certain to be a decided factor in rice production in Texas. The well plants at El Campo are the pioneers of many others in Texas, where the farmer can, with a small outlay, convert his flat lands into a successful rice farm. A well twelve feet in diameter, forty feet deep, an engine to supply power, a centrifugal pump, an open box for a flume, a canal easily constructed; total first cost $1200, constitute a one man equipment. With this 75 acres of excellent rice can be irrigated.

The rice land is laid off in sections, or "cuts," so that the extreme elevation should not exceed four inches. The size of these cuts varies with the character of the topography. A cut is surrounded by levees or dykes to hold the water. It may be that a hillock or a hole will occur in a cut, but this can be ignored as rice producers till time and the plow will level the one or fill the other. The water is pumped to the land by steam, gasoline or water power, by far the greatest part of the work in Texas being done by steam. From the best evidence obtainable in Western Louisiana and East Texas, it seems to be a consensus of opinion that it requires nine gallons of water per minute for each acre of rice, or 1 second-foot of water to each thirty acres of rice, although some companies estimate seven and one-half gallons to each acre per minute. In the Beaumont section the rainfall often reduces the pumping considerably, and in 1900, a wet year, some pumps were operated only four days. But a dry season will require the pumps to furnish nine gallons for each acre per minute, and it is not good engineering to allow less than nine gallons per minute, or 12,960 gallons per 24 hours per acre.

For 100 acres and for a lift of twenty-two feet, an engine exerting fifty absolute horse power would be required. The estimated or nominal horse power will have to be tested or reduced by a substantial fraction if disappointment is not desired.

For some plants, owing to the contour of the ground, more than one lift has to be constructed, that is, more than one pumping station has to be constructed. The pumping capacity of each station is the same if there is nc acreage under the first lift, but the machinery in one may be heavier than in the others, depending on the height of the lift.

From the pumps the water is led by means of flumes to the canals and is distributed from the main canal to the laterals, from which it is distributed over the land. The main canals are usually very wide, for in most cases they are intended to be wide enough to act as partial reservoirs. The canals are constructed by the "Humper" (a single man with a wheelbarrow, pick and shovel) by the plow and scraper, or by the modern steam grader which lifts the earth by an endless belt and deposits it on the canal embankment. The motive power is generally supplied by steam.

FIRST TEXAS RICE IN 1862.

The first rice raised in Texas by irrigation was produced in 1862, in Jasper County, by the father of Dr. S. W. Sholars of Orange, Texas. The land

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was situated on a clear flowing stream. It was covered at firs by a thick underbrush which was cleared away. The land was broken by single teams and rice sowed broadcast, and when up several inches was flooded by the stream. A small dam provided with a gate deflected the water onto the land, the depth of the water being regulated by the gate. The manner of flooding was similar to that of to-day. The rice was harvested with reap hooks, was threshed by crude methods and was milled by the original method of removing the upper stone of a gristmill and substituting therefor a section of log whose under surface was sufficiently rough to remove the husk from the rough rice and produce a clean product. After the husk had been removed the section of log which had replaced the upper stone was taken off, the stone replaced, and the clean rice was then reduced to flour.

The first modern experiments with rice in Texas began in 1888. In these experiments the farmers depended upon rainfall to furnish the water, but this trusting to Providence on the matter of rice cultivation did not pay, and to insure success pump irrigation was resorted to. This had proved satisfactory, regardless of rainfall. The culture of rice by this method began about 1893. Prior to this it had been grown only in a small way in ponds and marshes for home use. The method of growing rice on a large scale by irrigation and with improved machinery is comparatively new and peculiar to the Southwest and radically different from the methods pursued in Georgia and the Carolinas.

HIGHEST TYPE OF RICE CULTURE.

In Texas and Louisiana rice is sowed on comparatively high land, with drills or broadcast, cut with self-binders, threshing from the shock, or stacked to suit the convenience of the farmer. The same kind of machinery is used in raising, harvesting and threshing rice that is used with other small grain, the only difference being that rice lands are flooded after the rice is up to the height of three to six inches, and that the "rough" rice from the thresher is milled and made "clean" in a mill. The practice in Texas is to sow the rice at any time from April 15th to June 15th, and to keep it flooded from 80 to 110 days, 90 days being the average. The water kills the grass and weeds and causes the rice to grow very rapidly. Ten days to three weeks before the rice is ripe and ready to harvest the levees on the lower side are cut and the water is drawn off by means of ditches made in throwing up the levees. This drainage for some plants requires more engineering skill in the arrangement of the levees than is required in making them fulfill all the requirements of feeding the land with water.

From 1¼ to 1¾ bushels are sown per acre. The land is plowed and harrowed and prepared as it should be for wheat. On the large canals traction engines are used to pull a gang or disc plow and the land is thus plowed by steam. One traction engine running night and day can break fifty acres in twenty-four hours. The outfit or equipment will vary with the acreage. After the rice is planted and the water is turned on eternal vigilance is necessary to keep canals and ditches in order, to prevent breaks, with a consequent waste of water and a drowning out of part of the crop.

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NOT A LAZY MAN'S CROP.

It is by no means an easy crop to manage. The work from the first day's flooding to harvesting is a muddy history of patience. Just before the crop ripens the water is drawn off to allow the ground to harden enough to bear the binder. If the rains set in at this critical moment it entails an additional amount of expense and worry in saving the crop. In this respect the rice farmers away from the coast and further west have an immense advantage. The rainfall yields a reluctant aid during the flooding period and does not jeopardize the crop during the harvesting time. While the cost of pumping will be more in the western part of the rice belt, the surety of an undamaged product will overbalance the additional cost.

In Texas at the present two kinds of rice are raised, the Japan and Honduras. The latter is longer in grain and generally commands a better price, while the former is hardier, can stand dry weather better, and is more prolific in its field. In general, 44 pounds are allowed per bushel, 162 pounds per barrel, while the sack is rather variable in quantity, but is usually estimated at 180 pounds.

TYPICAL CANAL PLANT.

The following is a description of a big canal system with a capacity of 16,000 acres, with three lifts as it was actually in operation. The first pumping plant was on the river from which the water supply was taken, and the plant consisted of two 54-inch centrifugal pumps operated by a 250-horse power engine against a lift of 33 feet. The plant at the second lift of seven feet consisted of a 250-horse power compound engine and a 45-inch centrifugal pump with an estimated capacity of 50,000 minute-gallons; and that at the third lift consisted of a 200-horse power engine and a 24-inch Van Wie pump which was worked against a head of 3½ feet. This plant had two problems to solve in that it had to cross two draws or sags and the tracks of a railroad that ran through the farm. The flume across the sags was made of plank four feet deep, twenty feet wide and two hundred and fifty feet long, and the water was taken under the tracks of the railroad in large terra cotta pipes and in woden boxes. The acreage under the first lift was 9500 acres; under the second, 5000; and under the third 1500, making a total of 16,000 acres. The engineer in making his estimates of the power and pumping capacity needed allowed ten gallons per acre per minute, which for the ninety days of usual pumping would be a supply of four feet per season.

TYPICAL WELL PLANT.

One of the best shallow well plants in Texas is located in Wharton County. An 8x10 pit ten feet deep was excavated in the surface soil to within four feet of the water-bearing sand and in the bottom of this pit a well was bored to a depth of forty feet from the surface of the ground. A 5-inch centrifugal pump was placed on frame work in the bottom of the pit, and a fourteen horse power gasoline engine was placed on the surface of the ground on stable frame foundation. The plant complete cost $970 in place and in one year on thirty-five acres of land produced 741 sacks for which

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$3.25 per sack was realized, thus paying for the complete plant exclusive of the land twice over.

Another well plant owned and operated by a Jap irrigated 110 acres during the season of 1904 on raw land and made a yield of 20 sacks per acre.

RESERVOIRS.

The multiplication of canal systems and the possibility that the decision of the Supreme Court in the 74 Texas in the case of the Mud Creek Irrigation Company vs. Vivian will apply to the rice section of Texas whereby an upper proprietor can take all the water out of a stream even though he does not leave sufficient water for the lower proprietor for the same purpose emphasizes the necessity for storing the waters during flood or freshet before the rice season opens and of husbanding them in dry times. An allowance of seven and one-half gallons per minute per acre or of one cubic foot per minute would mean a season supply of three feet to the land. That each canal system will eventually have to obtain part of its water from its own reservoir storage system (natural or artificial), seems equitable and just. It would not be fair for the upper proprietor to get all his supply from the stream during seasons of low flow and deprive the lower proprietor of sufficient water for the same purposes although the latter might have been the pioneer in the field, whose boldness, pluck and capital made the success of such plants a certainty. If an allowance of three feet per season is made and a reservoir is designed to furnish half of this supply with an effective depth of nine feet, then one-seventh part of the farm must be set aside for reservoir purposes. That this is a feasible solution is shown by its successful operation on some plants in Texas. One plant in Jefferson County was forced to construct a reservoir covering 500 acres to a depth of four feet as a protection against a short supply of fresh water. It is true that there was plenty of water on the bayou, but in dry times this became so impregnated with salt that its use on the rice was dangerous. While the bayou was fresh the reservoir was filled and the rice was flooded by the pumps from the stream supply and the reservoir was kept filled. When the salt water appeared the pumps at the bayou station were stopped and the fresh water in the reservoir was drawn.

At least three of the large plants have taken advantage of natural reservoirs in the form of lakes or creeks to insure a safe supply in dry times. One of the largest projects on foot at the present involves the construction of a dam across an arm of the coast to keep back the salt and impound the fresh water.

CANAL PLANTS.

1. Sabine Valley section—Cow Bayou Company, Orange County Company, Des Moines Company, Samuel Wilson Company, Clark Canal Company, Giles Brothers Company.

2. Neches Valley section—Beaumont Irrigation Company, McFadden-Weiss Company, Port Arthur Canal Company, Treadway Canal Company, Jefferson County Company, Taylor's Bayou Farms, Hillebrandt Bayou Farms.

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3. Trinity Valley section—Raywood Canal Company, Trinity Rice Company.

4. Brazos Valley section—Little River Plants, Washington County Plants, Texas Land and Insurance Company, Brazoria Company, Brazos Company, Fort Bend County, Masterson Plant, Munson Brothers Plant, Walker and Cain Plant.

5. Colorado Valley section—Eagle Lake Company, Donovant Company, Red Bluff Company, Lane City Company, Bay City Company, Matagorda Company, Colorado Company, Nile Valley Company, Stewart Company, Sexton Company, Moore-Cortes, Tres Palacios, Northern Company.

6. Guadalupe Valley section—Buchel Plants, Victoria Rice and Irrigation Company.

7. Rio Grand Valley section—Brownsville Land-Irrigation Company, Moore Plant at Del Rio.

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THE RATIONAL USE OF WATER IN IRRIGATION.

DR. JOHN A. WIDTSOE, Director, Utah Experiment Station.

In these times, when gigantic reservoirs and canals are being planned and constructed by our great government, we are likely to forget that the development of irrigation in this country lies not alone along engineering lines, but depends, to an equal or greater degree, upon the manner in which the farmer uses the water in the production of crops. The building of canals and reservoirs has been greatly improved during the last fifty years. All the skill of the engineer has been bent to produce irrigation structures that approach perfection. Meanwhile, the farmer has been left to develop his methods, unaided by expert advice or assistance; and in fact, the methods employed by the farmer of to-day in producing crops by irrigation are very little in advance of those that were introduced during the first few years after the Mormons entered Salt Lake Valley.

The projected storage of the waters which now run to waste in the streams and rivers of the Great West will undoubtedly increase the irrigated area many times; but to students of this subject it appears equally true that if the water which is already diverted into irrigation canals should be used in a rational manner, the irrigated area might be doubled, trebled or even quadrupled without the building of another reservoir or canal. By the *rational* use, I mean such a use as will, with a given amount of water, produce the largest yield of crops of the highest quality and with least injury to the soil. To make such rational use of water the farmer requires a knowledge of the relation which exists between the plant and the soil and the water. It is unfortunate that investigations having such knowledge in view have only been undertaken during the last few years. However, many results are already available with which the irrigator of the immediate future must familiarize himself and which he must apply to his practice of irrigation if he desires to obtain the greatest profit from the land and water at his disposal.

THE OVER-IRRIGATION EVIL.

Perhaps the most prevalent idea in the irrigated sections of this country is that plants do best and yield most heavily when they receive very abundant irrigation. In my experience I have yet failed to find one farmer who has refused to apply to his fields all the water that he could possibly obtain, though in many cases it was manifest that the large amounts of water led to injurious over-irrigation. Plants respond very rapidly in yield and quality to the water applied to the soil, but in reality they can get along with very small amounts of water and in many respects do better when the amount applied is below rather than above the best. In fact, the irrigation farmer who is able to control the amount of water applied to plants controls one of the most important factors of plant life. The air, the sunshine and the soil, the farmer must largely accept as they exist, for he is unable to modify them materially; but the fourth great factor in plant growth, water, is completely under his control; and by judicious irrigation the farmer may obtain a marvelous control over his plant kingdom. In this respect, agriculture in an

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irrigated section is greatly superior to the agriculture in districts of abundant rainfall.

With respect to this control note the following reliable results selected almost at random from a great number of experiments on the relation of crops and soils to water, conducted by the Utah Experiment Station. The expression, inches of water, is to be understood as meaning the depth to which the fields would have been covered had all the water been applied at one time.

VAST LOSS OF WATER.

One season on a typical western soil five inches of water produced 33 bushels of wheat per acre; ten inches produced 40 bushels; 15 inches produced 48 bushels, and 20 inches produced 40 bushels. Adding more than twenty inches of water to the field did not increase, appreciably, the yield of grain. In the case of the wheat plant, then, the increase of the amount of water increases the yield of grain up to about fifteen inches, but a further application tends to diminish the yield. When it is considered that the depth of water applied to the wheat, over a very large area of the irrigated section, amounts to thirty or more inches annually, it will be understood what a loss in wheat alone occurs year after year through the misuse or too large a use of water.

With oats the variation is somewhat similar. Five inches of water in one set of experiments yielded about fifty-eight bushels of oats per acre; ten inches yielded about the same amount, though the increased quantity of water increased the weight of straw. With fifteen inches, seventy bushels were obtained; with twenty inches, eighty-six bushels, and with thirty inches, eighty-two bushels. Covering the land with more than thirty inches of water diminished the yield of oats decidedly. About twenty inches is, therefore, the best amount of water for oats, yet throughout the irrigated West, thirty inches or more are generally used in the production of oats, and thus again the wasteful use of water is emphasized.

It is generally true with all the ordinary crops grown in the Western States that increasing the amount of water increases the yield up to a certain point, after which an increase of water causes a decrease in the yield. Not all crops are alike in this respect, however. Some crops, because of their nature —leaf surface, root system, etc.—find ten inches of water about right for the season's growth. Other plants, because of their different natures, find fifteen inches or twenty or twenty-five or thirty inches the best.

FARMER SHOULD STUDY THE WATER PROBLEM.

Now, the farmer in an irrigated section should know the water requirements of the different plants that he grows as thoroughly as he knows the soil of his farm, his water right or other matters upon which his success as a farmer depends. Not all plants decrease in yield after certain amount of water has been applied. Potatoes appear to be a crop the yield of which increases continually if water is applied, up to the limit of the practicable application of water. To illustrate: In one set of experiments 7½ inches of water produced 160 bushels of potatoes; 15 inches, 233 bushels; 30 inches,

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274 bushels, and 71 inches, 315 bushels. In this series the increase is constant with the increase in irrigation water. This illustrates the necessity on the part of the farmer of knowing thoroughly the natures of the plants with which he deals.

It may be noted in reviewing the yields of wheat, oats and potatoes just considered, that the value of the first few inches of water applied is much greater than that of the later applications. For instance, 5 inches of water produced about 33 bushels of wheat, or about 6.6 bushels per inch; 15 inches of water produced about 48 bushels of wheat, or about 3.2 bushels per inch of water, while 20 inches of water produced 40 bushels of wheat, or only 2 bushels per inch. The value of the first five inches of water applied to wheat, therefore, is more than three times as much as the value of the last five inches, in a total depth of twenty inches. Similar results may be observed in the case of oats. Five inches of water produecd 58 bushels of oats, or 12 bushels per inch, while 20 inches of water produced 86 bushels of oats, which is less than five bushels per inch of water. The difference is certainly very striking. Even in the case of potatoes, the yield of which increased steadily with the increase in irrigation water, the same fact holds. Seven and one-half inches of water produced 160 bushels of potatoes, or about 22 bushels per inch, while 30 inches of water produced 274 bushels of potatoes, which is only about nine bushels per inch. Corn, alfalfa, the various grasses, sugar beets, vegetables and all other crops show similar results; namely, that the value of water is highest when it is used sparingly and carefully; that the value of water is lowest when it is applied liberally and carelessly.

With this generalization in mind note how these results may be viewed in their relation to the increase of the irrigated area.

According to the investigations of the Department of Agriculture, under the direction of Dr. Mead and his associates, thirty inches of water or more are used in the majority of places in the irrigated section for the production of crops. Let us apply the varying value of water as just explained to the economical or rational use of water. If the thirty-acre inches be spread over six acres of wheat so that the whole area of six acres will be covered with water to a depth of five inches, each acre will yield 32½ bushels of grain, or a total of 195 bushels. If the same amount of water be spread over four acres, that is to a depth of 7½ inches, the total yield of grain will be 165 bushels. Spread over three acres to a depth of ten inches the same amount of water will yield 118 bushels. Spread over two acres to a depth of fifteen inches the total yield will be ninety-five bushels, and spread over one acre to depth of thirty inches, the yield will be 42 bushels. It may thus be seen that in the case of wheat the total amount of grain produced by thirty-acre inches of water may be increased from 42 bushels to 195 bushels by spreading the water over more or less ground.

WOULD INCREASE IRRIGABLE AREA.

Certainly the nearly five-fold increase of grain thus made possible will more than pay the farmer for the labor of handling six acres of land instead of one, and of higher importance by using the water rationally the irrigated

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wheat area may profitable be increased four or five times without building another reservoir or canal.

Similar investigations of the oat yields would result in a similar conclusion. Thirty-acre inches of water applied to three acres of oats yielded 57 bushels per acre, or 171 bushels for the three acres. Applied over two acres the same amount of water yielded a total of 140 bushels, while if the same amount of water were applied to only one acre it yielded only 79 bushels. Here again the farmer has it within his power to increase his oat yield from 79 bushels to 171 or more by distributing the same amount of water over different acres of land, and here again, also, the possibility is shown of increasing the irrigated area without the building of new reservoirs or ditches. The data referring to potatoes are similar in the conclusions that may be drawn. Thirty-acre inches applied over four acres of potatoes yielded 644 bushels; over two acres, 466 bushels, and over one acre 274 bushels. These great differences in yield unquestionably would more than compensate the farmer for the handling of the extra acres of land.

It is to be remembered in this connection that land without water throughout the West sells at from fifty cents to four or five dollars per acre, while the water right to an acre of land, at least in Utah, seldom falls below forty or fifty dollars, and in many cases it is as high as $400 or $500. With land, therefore, of little value, and water of very high value, the energies of the farmer should be directed towards getting the greatest possible returns from the water at his disposal. A large acreage means little in an irrigated district; the water right means nearly everything.

WHEN TO IRRIGATE.

Without dwelling longer on this most important phase of irrigation improvement in the farmer's domain, let me suggest that even the same amount of water applied to the same area of land may be made to yield more or less of a crop according to the will of the farmer, providing, of course, the farmer is in possession of the requisite knowledge. The time in the life of a crop at which water should be applied, whether the heaviest irrigations should come early or late, the method of irrigation, whether by flooding or by furrowing, are questions of prime importance to the irrigation farmer. The answers to these questions obtained from one crop will seldom apply directly to another crop; and each crop must therefore be studied independently with respect to its water requirements. That the time and manner of application of water has a high influence on the yield can be illustrated by numerous examples of which the following is an example:

During the season 15-acre inches of water were applied to an acre of oats in two irrigations of 7½ inches each. The same amount of water was applied to another acre of oats in three irrigations of 5 inches each. The field receiving the water in two irrigations yielded 65 bushels of oats, while that receiving the water in three irrigations yielded 74 bushels, which shows a difference of nine bushels of oats to pay for the labor of the extra irrigation. In all probability the farmer would find nine bushels of oats very good pay for irrigating one acre.

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THE QUALITY OF THE CROP.

In these days of enlightenment and keen competition the yield of a crop is not the only thing to be considered; the quality of the crop must also be given full attention. We have recently learned that the quality of crops may largely be controlled by controlling the application of water. Plants receiving much water usually become richer in fat than those receiving smaller amounts of water. The sugar in beets appears to increase as the water increases up to a certain limit, when the per cent begins to decrease. The quality of fruits and vegetables may be strongly influenced, and in many cases improved by the judicious use of water. In almost all crops the so-called protein or flesh-forming substances are highest in crops that have been grown with the least amount of water. For instance, wheat grown with a small amount of water will yield a better and more nutritious flour than will wheat grown with a larger amount of water. Oats grown with a small or moderate amount of water would form a better horse feed than oats grown with more water, and so on in general with all the grains.

When this rather subtle subject shall have been investigated properly it will probably put the means into the hands of the farmer whereby he can at will produce crops that will excel the crops grown in humid climates in quality, flavor and general desirability, and as a consequence the products of the irrigated section will be superior in value to the products of the humid sections. The great lesson that seems to be enforced by recent investigations similar to those quoted is that in general the more moderate the amount of water used in the production of the crop the better is the quality of the crop.

UNDREAMED-OF POSSIBILITIES.

This paper would be entirely too long if an attempt were made to go fully into the possibilities of the production of crops by irrigation if irrigation were practiced in a thoroughly systematic manner. The above discussion indicates the important results that may be obtained by rational irrigation practices. It must not be omitted, however, to call attention to the fact that not only does the practice of irrigation bear an imporant relation to the production of crops but it is also of prime importance in conserving and maintaining the fertility of soils. Investigations carried on at the Experiment Station with which I am connected show that irrigation water a few hours after its application makes its influence felt to a depth of a great many feet below the surface. The water tends to wash the nitrates and other soluble and valuable plant foods into the lower layers of the soil. If excessive irrigation be practiced for any length of time, much of the fertility in the soil will undoubtedly be washed down into the ground water or out of the reach of the roots of plants, and this soil will cause a corresponding decrease in the yield and quality of the crop. If a district persists in over-irrigation, and I regret to say that I have observed very few localities in which over-irrigation is not practiced, the soluble materials of the soils will finally be washed out of the soil, the ground-water will be raised, there will be a seepage downward into the lower lying lands, and an accumulation there of water heavily charged with the

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soluble materials of which the higher lying lands have been robbed. Evaporation will then begin. The soluble materials in the water will be deposited near the surface of the soil as alkali, and streaks of fertile lands will begin to form the alkali barrens of the West. At the same time, from the diminution of plant food, the yield and quality of the crops on the higher lying lands will be diminished. From this point of view, also, the moderate use of water is advisable.

WOULD DOUBLE AMERICA'S IRRIGABLE AREA.

I am of the opinion that as our knowledge grows we shall find that the rational use of water consists in the use of about fifteen inches of water distributed throughout the season according to the needs of the different crops on the farm. Should this view be correct, it will mean at least the doubling of the irrigated area without the expenditure of another dollar for the construction of new reservoirs and canals. The time will come when the Reclamation Service of the United States shall have finished its first great reservoir and dug its first great canal. It will then find itself ready to allot the water to the farmers. A question that will immediately arise will be, how much water shall be considered the right amount for the production of ordinary farm crops? Not only in general, but on different kinds of soil, on the sandy, clayey, loamy, calcareous and alkali soils characteristic of the arid region, which all differ materially in their water requirements. It will hardly do for one of the experts of the Reclamation Service to allot the water according to his private opinion. The allotment must be done in a manner based on rational experience and experiments. By the time that the Reclamation Service shall have finished its first great undertaking there will be considerable data of the kind at its disposal, for a number of western experiment stations are undertaking elaborate investigations having in view the water requirements of various soils and crops.

The chief difficulty in making the farmer's work with irrigation rational lies in the fact that the farmer himself will probably feel that the necessity of knowing how much water shall be used under different conditions, and applying that knowledge, places another burden upon him. However, when he may be so richly compensated for this extra work as has been shown in this paper, that difficulty should easily be overcome. It is necessary, however, that a campaign be instituted at the earliest possible moment for the purpose of impressing upon the farmer the necessity of measuring the amount of water which he receives upon his farm and which he applies to different fields. It may be more correct, perhaps, to say that the canal companies should be impressed with the necessity of knowing how much water is taken into their respective canals and how much they deliver to their various customers or stockholders. If this work were undertaken by the canal companies it would soon follow that the farmer himself would give more thought to the actual amount of water which he received and the best disposition that he could make of it. There can be little real progress in the farmer's work in irrigation until the old haphazzard method of guessing at the amount of water received and used is changed. The greatest advance in the farmer's work in irrigation will be progress in the application of known amounts of water to

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fields and the controlling of the amount of water applied so that the farmer may be able to reap the largest possible profits from the water which enters his farm.

ROOM FOR EXHAUSTIVE STUDY.

This discussion is far from exhaustive; it is intended to be suggestive. I believe that the subject which it touches is worthy of the attention of all those who are interested in irrigation improvement and advancement. We have left the farmer's side of the work alone long enough. His problems are just as important as those now being solved by engineers, and with the present development in modern science and the increased interest in irrigation, the time seems to demand the undertaking and carrying to completion of such investigations as will develop for the farmer a *science* of *irrigation*.

In conclusion I can only repeat what I said in my paper read before this body last year, that it will be many years before the Government Reclamation Service can increase the irrigated area and the value of irrigated crops as much by the construction of new reservoirs and canals as may be done by the farmers, at the present time and with the present diverted water supply, by the adoption of rational, scientific methods in the application of water to crops.

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Irrigation in the Humid Region.

DIVISION C,
SECTION PRODUCTION BY IRRIGATION.

CHAIRMAN: PROF. THOMAS SHAW.

Thursday, November 17, 1904.

PRACTICAL SUCCESS WITH IRRIGATION AT THE EAST.

HERBERT MYRICK, Editor American Agriculturist, New York and Chicago.

In a small way irrigation is quite universal in the Eastern States. The water is applied by means of hose to lawns, flower gardens and kitchen gardens. A constantly increasing number of market gardeners and truck gardeners also employ irrigation.

Until within a few years the so-called average farmer in the Middle and Eastern States has considered irrigation quite impracticable. About one year in three he has suffered great losses from drouth, and nearly every other year dried up pastures and reduced yields of hay, forage and grain testify to the Eastern farmer's necessity for the right quantity of water at the right time. But of late years even this class of Eastern farmers has begun to wake up to the fact that irrigation is a practical necessity, either by drawing water from streams or reservoirs, through gravity ditches or pipes and hose, or by pumping water by hydraulic ram, windmill or engine. The recent improvements in engines run by gasoline or kerosene have made it possible to pump water wherever wanted for irrigation purposes, at the East and South as well as in the West, and at a cost that makes such irrigation profitable in the dry time.

The Eastern farmer rightly regards water as a fertilizer. It comprises from one-quarter to nine-tenths of the various crops. The farmer may plow and harrow his soil ever so carefully, he may cultivate with the utmost thoroughness, he may apply plant food in the form of stable manure or fertilizer, or both, to the extent of $100 per acre or even more, yet if his land is not blessed with sufficient moisture, all his effort and investment are of no avail. A drouth, even of short duration, may occur at such a time as to reduce his produce to an unprofitable degree. Sometimes only a little artificial watering will make all the difference between profit and loss.

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Of course, there is too much wet some of the time in almost every season at the East, yet drouths are inevitable and frequent. The Eastern farmer is being educated to regard any reasonable outlay for assurance against drouth as likely to be a much better investment, and certainly as essential, as insurance against fire or death. And that that has been done to the Eastern farmer's profit is shown by the following compilation of the actual experience of practical farmers in the Eastern States, who have used irrigation methods for several years, as well as by the other statements of experience made by the speakers or essayists from the humid sections before this Congress.

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IRRIGATION IN THE EAST.

GEORGE A. MITCHELL, New Jersey.

During a long drouth all farmers realize what an advantage it would be for them individually to have plenty of water at their disposal so that they could double or treble their crops when the general yield is short and prices consequently high. The value of water during short dry times is not so generally known and recognized. There was a very severe drouth in south Jersey last spring, but plenty of rain during most of the growing season after August 1st. In seasons like this the common opinion would be that many crops gathered in the fall would turn out well. I supposed sweet potatoes would recuperate from the early drouth and give a full yield. I was, therefore, surprised at the extent to which irrigation paid on several crops on my farm the past season.

Hardly a year passes but some crops on every farm are damaged by dry weather. Two years ago sweet potatoes about Vineland looked well the latter part of August and a large yield was promised. September was hot and dry and as a result there was perhaps half a crop. One or two irrigations during that month would have doubled the yield and the irrigation of fifteen acres of sweet potatoes would have meant a profit of from $600 to $1000, or enough to have paid twice over for an entire irrigation plant similar to my own. Water can be secured from various sources. By far the best source, where it can be had, is

FROM A STREAM OR POND

above the level of the land to be irrigated. This is a common source of irrigation water in the Western States. A canal runs past the seed farm of D. Landreth's Sons, near Bristol, Pa., the water in which is higher than the farm. If the canal company were willing to sell this water the whole of the seed farm could probably be irrigated. The water in this canal must come from some river and demonstrates what could be done if large irrigation canals were in use. Near Wayne, Pa., a brook running between two hills has been used for irrigation purposes for several years. A small dam is made and the water let out to one side along the sidehill. The land between the ditch and brook is seeded to grass which is irrigated by causing the water to overflow the banks of the ditch.

When the land is hilly or uneven over which the water is to flow when led from a creek to a field to be irrigated, some other device than a ditch is necessary. The source of water for the irrigation works of J. H. and G. H. Hale of Connecticut is from a small brook a mile distant, and the fields to be irrigated are one hundred feet lower down. The water is conducted in an iron pipe.

Another source of supply is from flowing artesian wells, but it is very rare that one of these can be secured, and when one is found it is liable to be on low ground where irrigation is not greatly needed. There are, however, a few

*The author was expected to deliver an address; but did not attend, and sent this article, previously written for "American Agriculturist."

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favored localities where flowing artesian wells can be used for irrigation purposes. There are a dozen or more flowing wells near Atlantic City, N. J., which flow from twenty to fifty gollons per minute. It would appear therefore that some of the land near the New Jersey coast could be successfully irrigated in this manner.

The third source of water is by pumping from streams or wells. This is practiced largely in the West and elsewhere, and the pumping is done by water, wind or horse power, gasoline or steam engines. Windmills are successfully used in Kansas and Nebraska, where there are steady winds. In the East it is difficult to find

A WINDMILL PUMPING PLANT

that has pumped enough water to thoroughly irrigate one acre of garden crops during the entire summer without the use of a reservoir larger than the tank on the mill. Since water power, like a windmill, involves no cost for fuel, it is to be used where practicable in preference to power requiring a constant outlay for fuel. In hilly countries where a brook runs with considerable fall through a farm it may be made to furnish a continuous power. Where a dam can be made a very convenient power can often be secured. If power is wanted solely to pump water a hydraulic ram can be used. With a gasoline engine and pump a large quantity of water can be pumped with small expense and with very little attention to the machinery. Steam engines, especially those of small power, cost more to operate and require the almost constant attention of an engineer. I have used a 2½-horse power gasoline engine and centrifugal pump which pumps enough water in three hours to cover an acre one inch deep.

Irrigation from wells in the East is as yet more or less an untried method. Some cities and towns are supplied with water from wells, and wells that will give enough for this purpose would answer for irrigating a large acreage. The water for the Vineland water works is pumped by steam power from fourteen driven wells two and one-half inches in diameter. The average daily amount of water pumped is 250,000 gallons. An irrigation plant recently installed for Johnson & Stokes at their New Jersey seed farm obtains a satisfactory water supply from three two-inch driven wells.

Two brooks run nearly parallel through the farm of P. S. Lorillard of Jobstown, New Jersey, who has irrigated one-fifth of his 1500-acre farm at intervals during the past twenty years. When irrigation was first thought of it was a question whether to build a small dam where the brooks entered the place and pipe the water to the other end of the farm where a considerable acreage could be irrigated by natural flowing, or whether to use for sub-irrigation purposes the seventy miles of drain tile that had been and were being laid to drain all the low land adjacent to the brooks. Irrigation by drain tile was the method adopted.

Substantial dams were constructed along the brooks at every four-foot fall. When it is desired to irrigate, the gates of the first two dams are closed, and a head of water is secured by leaving them closed for several days. After a head is secured the gates of the second dams are closed and the water let in, and so on to the last two dams. Two or three weeks are required to

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perform one thorough irrigation. When the brooks are dammed as described the water is forced back into the tile and between the tile into the soil. About 300 acres can be sub-irrigated in this way. Large quantities of potatoes were formerly grown on this sub-irrigated land, but the cost of hired labor was so great that potato raising was abandoned. Mr. Lorillard now uses all his land for pasturing.

The natural facilities afforded by a very small stream flowing along one side of the farm were taken advantage of by W. J. Baldwin of Walpole, Mass. From ten to fifteen gallons per minute of cold spring water flows in the stream. A small dam was put across the stream, which turned the water into a trough. The water was taken by this trough to a patch of potatoes of about seven-eighths of an acre. Two hundred bushels were harvested from the piece and sold for fifty-five cents per bushel, whereas without irrigation Mr. Baldwin believes that not over sixty bushels would have been secured. Another advantage of the irrigation was in

HOLDING THE WHITE GRUB IN CHECK.

The ground was badly infested with them and they would have practically ruined the crop if the ground had not been irrigated. The potato crop was followed by turnips, sown July 18th. The usual time for sowing in this neighborhood is June 25th. Without water to hurry the growth, no crop of turnips could have been secured, as was proved by the failure of the neighbors' crops.

A large strawberry grower of Glassboro, New Jersey, who has irrigated since 1884 uses a steam pump and boiler, and pumps water from an artificial pond at the rate of 800 to 1000 barrels in ten hours. The first cost of the plant was $600. The expense of operating is about $3.50 per day, including two men, fuel and wear of the plant. Strawberries were irrigated during eight years from 1884 to 1895. His smallest gross sales for any season in which irrigation was practiced were $300 per acre, while the average gross sales for twelve years were $250 per acre. Since the plants were allowed to produce only one crop this would mean $500 per acre for the bearing year. In addition to this was the profit from irrigated celery or lettuce that was grown after the strawberries were plowed under.

Thomas R. Hunt irrigates his farm at Lambertville, New Jersey, using a gasoline engine and pump, and pumps water from an artificial pond at the rate of 2500 gallons per hour. This plant was installed in 1892 at a cost of $260 for engine and $100 for iron pipe. Old fire hose and homemade hose are used for distributing the water where there is no pressure. The water is applied to the surface usually in furrows between the rows. Growing plants such as cabbage and celery are sprinkled. The first year in which the plant was in operation the irrigation of one acre of celery more than paid for the entire cost of the plant. Mr. Hunt estimates that the value of the water, merely for the purpose of wetting the plants before and at the time of setting, pays annually more than the initial cost of the plant.

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IRRIGATION IN NEW JERSEY.

PROF. E. B. VOORHEES, Director New Jersey Agricultural Experiment Station.

Little importance has thus far been attached to the matter of irrigation in the Eastern States. This is due in large part to the fact that the rainfall is usually sufficient to meet the needs of vegetation and because serious or long protracted droughts are the exception rather than the rule. Owing, however, to the changes which have taken place in recent years in the character of the farming, attention has been aroused to the importance of controlling the moisture of soils rather than accepting the conditions as they exist, and a deficiency of rainfall for even a short period is now found to be more disastrous than the long periods of drought under old conditions of farm practice, though, even under extensive systems of farming, the losses from drought are often very serious. For example, in the season of 1899 it was so dry in May and early June that the yield of hay, an important crop in the East, was very light in New Jersey. The shortage in this crop amounted to more than one-half, which at a low estimate averaged fifty dollars per farm, or a loss of more than $1,500,000 for the State. In the dairy regions the deficiency of rainfall also materially reduced the yield of the pasture and early forage crops, thus affecting the returns from this branch of farming. So seriously does a deficiency of rainfall affect the dairy interests that many progressive farmers now regularly plant a supplementary crop to provide sufficient forage in case of drouth. It pays better to have an excess of forage, which may be wasted in part, in a good season, than to have a shortage. The deficiency of rainfall in 1899 also resulted in very serious injury to early crops, particularly asparagus, strawberries and other berries; early beets and many other important early crops were also affected.

It is estimated that the loss to the hay crop of New Jersey from the drouth in May and early June, 1899, was $1,500,000, while small fruits and vegetables were even more seriously affected than the grasses. The records kept at the New Jersey Station show that in 1897 and 1898, years of abundant rainfall in April and May, the yield of hay averaged 2.65 tons per acre. In 1899 it was but a fraction over one ton, owing to the deficiency of rainfall in April and May, at the low price of $10 a ton, a loss for the twenty-five acres of over $400. The yield of crimson clover forage for 1897 and 1898 was 8.5 tons per acre; in 1899 the yield was but five tons, or in a good year the yield was seventy per cent greater. The deficiency in the rainfall at the critical period was alone responsible for this difference in yield. Oat and pea forage in 1897 and the early seeding of 1898 averaged six tons per acre; in 1899 the yield was but 3.3 tons per acre.

To show the frequency of such drouths as that of 1899, the rainfall records of Philadelphia, from 1825 to 1895, show that in 88 per cent of these years there was a deficiency of over one inch for one month, or that in 62 years out of the 70 there was one month in the growing season from April to August in which such a marked deficiency occurred as to cause a serious shortage of crop, and

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that for the same period there were 39 years in which the deficiency extended throughout two months, while in twenty-one years it extended throughout three months.

Experiments conducted by the New Jersey Station were for the purpose of determining whether irrigation during these short periods of drouth would result in sufficient increase of yield to pay for the works necessary to obtain the supply of water. The tests were made on small fruit. Careful records were kept of the yield of plats which received identical treatment, except that some were irrigated and others were not. The yields of the irrigated plats over and above those not irrigated were as follows:

Blackberries 1038 quarts per acre, worth $93.42.
Raspberries, 329 quarts per acre, worth $32.90.
Currants, 852 quarts per acre, worth $85.20.

The increase in yield would not be so marked every year as in 1899 as the drouth of that year was exceptional.

Conditions in parts of New Jersey are favorable to a low cost of irrigation by means of canals and ditches, and it is estimated that 75,000 acres can be watered without the use of storage reservoirs at a cost of about $8 per acre, not including the annual cost of application. Even if one-fifth of this, 15,000 acres, or even a much smaller area, were brought under irrigation in this way, it would enable the gathering of data which would help to determine whether the more expensive storage plants would be likely to prove a financial success. This irrigable area may also be largely increased without storage, by pumping from wells. The areas thus available for irrigation are now mostly under cultivation, and it is estimated that 175,000 acres could be irrigated in this way. Wells capable of providing 25,000 gallons per day, or sufficient water for an area of ten acres are found in many parts of Southern New Jersey, yet, aside from this, it has been shown that there is enough water wasted annually to irrigate the entire State during the driest year, and, neglecting what may be watered by wells, fully 325,000 acres may be brought under water.

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PUMPING FOR IRRIGATION IN NEW MEXICO.

J. J. VERNON, Professor of Agriculture, New Mexico Agricultural College, Mesilla Park.

In localities where there are no natural streams from which to draw irrigation waters, other means must be resorted to in order to secure water. The means usually employed for this purpose is that of pumping from the underflow. Irrigation by gravity systems has been practiced for ages, and pumping for irrigation has been employed for a great many years. Irrigators generally are not informed as to the extent to which pumping has already been carried on in the reclamation of lands throughout the arid sections, and the idea is quite prevalent that pumping for irrigation will not pay under existing conditions. If facts and figures regarding what has been accomplished by pumping were disseminated among the rural population, this misconception, in most cases at least, would be corrected. What has already been accomplished in the way of pumping for irrigation is indicative of what may be accomplished in the future. Statistics show that in British India alone there are 12,895,000 acres of land irrigated with water which is raised from wells by mechanical means at a total lift of from twenty to forty feet.

Pumping is employed for the irrigation of very large areas in different sections of this country. California, perhaps, leads in the total area of land watered by this method, and if the writer is correctly informed, the water is lifted from comparatively great depths—in places from a depth as great as three hundred feet—and yet it is a paying proposition. Pumping is spreading very rapidly in Colorado, and very considerable areas in the rice-growing sections of the South are being supplied with water in this manner. In the latter the lands usually lie slightly above the gravity systems and the water has to be pumped only a few feet. It is evident from the vast area of land that is already irrigated by pumping that this method of supplying reclaimed lands with water is of considerable importance, and will eventually have much to do with the reclamation and development of certain portions of the arid West.

THREE CONDITIONS UNDER WHICH PUMPING MAY BE ADVANTAGEOUSLY EMPLOYED.

First—Where there are no surface streams from which to secure water for irrigation, and at the same time an underflow is to be found sufficiently near the surface of the ground.

Second—Where the streams have eroded their channels so deeply that the expense prohibits the construction and maintenance of irrigation ditches through which to lead the water by gravity upon the lands.

Third—Where there is a surplus of water in the irrigation canals, which surplus may be employed by pumping it upon lands lying slightly above the gravity systems.

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VARIOUS SYSTEMS OF PUMPING PLANTS.

Pumping plants in general may be conveniently divided into the following groups:

1. A power and pumping plant located at the head of the ditch system.

2. Power and pumping plants distributed at intervals along the ditch system.

3. A central electrical power plant to supply power to pumping plants distributed at intervals along the ditch system.

These three systems just mentioned have the following disadvantages: Difficulty and great cost of developing water in sufficient quantities at one place; opportunities for misappropriation of water; loss of water by seepage and evaporation; and difficulty of making an equitable division of the water.

4. Individual power and pumping plants situated upon each farm. The objections to this system are: a relatively large initial cost of installation and a comparatively low rate of efficiency and economy of operation.

5. A central electrical power plant to supply power to individual pumping plants upon each farm, serving the land of a whole community or of a whole valley. This system combines practically all of the advantages of the other systems. Sufficient water can be developed in one place without difficulty to supply one farm; misappropriation of water is impossible for the reason that the water is developed upon the farm where it is used, and, therefore, at all times is within the control of its owner; loss by seepage and evaporation is minimized; there is no division of the water, and, therefore, injustice from an unequal division of the water is eliminated; there are no long ditches to maintain a great expense; the initial cost would be within the means of every farmer; and the efficiency and economy would be high and the cost of pumping comparatively low.

FACTORS THAT WILL CONTROL SUCCESS.

The same principles that are applied by rural economists to the agricultural industry in the rain belts may be applied in an irrigated district. The price of land, the character of its surface, the productive capacity of the soil, climatic conditions, markets, transportation facilities, machinery, systems of culture, personale, and numerous other lesser though essential factors, are all so inter-related that, in a discussion which involves the economics of agriculture, these factors must necessarily engage the attention. To these must be added in an irrigated section the cost of the water and the methods of applying it. These are the factors that will determine the success of any system of irrigation, whether the water is supplied by gravity systems, by means of pumping from the underflow, or by any combination of the two.

Wherever the land is cheap and the irrigation water is inexpensive an extensive system of agriculture may be adopted, i. e., a system that involves a minimum amount of labor and expense in growing crops. With cheap water profits may be realized from the most common crops grown upon fair or even poor soil, and when the surface of the ground is uneven or otherwise in bad condition for irrigation. Under such a system the net returns per acre will usually be comparatively small but the total net profit, if the property holdings are large, may be enormous.

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On the other hand, when the irrigation water is expensive, such a system if followed would bring disaster. With expensive water an intensive system of agriculture must be employed—a system that requires a very large amount of labor and expense applied to a comparatively small area. To warrant such great outlay in labor and money the land must have a very high productive capacity and it must be put in the very best condition for the application of the irrigation water. Improved machinery must be employed, approved methods of irrigation adopted and a most judicious selection of crops made. The products must be of excellent quality and of fine appearance; well harvested and properly prepared for market. Furthermore, these markets must be ample and the transportation facilities good. The manager must understand the practical, scientific and economic problems involved in growing and marketing a high class product.

If time would permit a complete detailed discussion of each of these factors would be highly profitable. The writer firmly believes that it is only through a thorough study and a complete understanding of the practical and economic problems involved that success in pumping for irrigation will come.

DIFFICULTIES TO BE MET.

In connection with pumping for irrigation a number of difficulties have presented themselves and some of the pumping plants that have been installed during the last two years have not given satisfaction. These difficulties for the most part, may be grouped under the following heads:

First—Those involving the development of water. In some cases the water-bearing stratum has been so poor that the one well sunk would not supply the quantity of water desired. Misunderstanding of the cause of this failure has led to discrediting engines, to discarding pumps, and to a series of petty blunders causing annoyance and delay.

Second—Too little power with which to do the work required. This trouble has been of frequent occurrence and next to that of the development of a water supply, has created more dissatisfaction than any other feature of the work.

Third—Poor installation. The installation of the machinery should receive the closest attention. The engine should be placed upon a good foundation; the well-pipe, pump and shaftings securely anchored and braced, and a perfect alignment made. If these things are not done it will be only a matter of time until vibrations, slippage of belts and friction due to the shifting and displacement of parts will cause a large loss of energy and waste of fuel.

And fourth—Improper adjustment of the machinery. In order to secure the highest efficiency and the greatest economy in fuel consumption, the adjustment of the machinery must be perfect.

One of the most important features in this connection is that of the proper correlation of the speed of the engine and pump. If the speed of the pump is relatively high, the speed of the engine may be dragged below normal, under which condition it cannot possibly develop its full horse power and may refuse to run altogether. This difficulty is most likely to occur when the power is insufficient. Two instances of this character recently came under

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the writer's notice. In one the speed of the pump was so high, when based upon a normal speed of the engine, that the speed of the engine dropped to about 30 R. P. M. below normal. This caused a loss of something like four horse power, which could have been utilized in pumping water if a proper correlation of the speed of the pump and engine had been secured. The other case was similar to the one given except that the engine was smaller and the speed of the pump based upon a normal speed of the engine was still higher. The water never reached the surface of the ground, as might have been expected. Without readjustment and further trial the pump was discarded for one of another make, thus throwing the blame upon the pump. These points illustrate how many of the difficulties come about.

Most of these difficulties are explainable, and have been the result of installing the pumping plant without due information regarding the points involved. In every case before any of the pumping machinery is ordered a thorough test should be made of the water-bearing strata before the wells are sunk, and then of the capacity of those wells. Delay and expense would be avoided by following such a rule. Many of the most reliable firms refuse to guarantee results without some such information upon which to base their estimates. By so doing the good name of the firm is not endangered and at the same time the patron's interests are protected. Such an attitude on the part of the dealer or contractor seems entirely commendable, and in the end, if adhered to persistently, will be the means of preventing many unsuccessful attempts and much litigation. The failure of a single pumping plant, no matter how trivial the cause may be or how easily it might have been avoided may have the effect of delaying the development of a whole section of the country.

Thoroughly competent men to undertake the installation of pumping plants are urgently needed in all sections where pumping must be resorted to in providing water for irrigation.

SOME RESULTS IN NEW MEXICO.

The New Mexico Agricultural Experiment Station has been investigating problems in pumping for irrigation for upwards of two years. The investigations are made in the following order: the gathering of information in regard to the progress of pumping for irrigation in New Mexico and adjoining States and Territories; the development of water in quantities for irrigation purposes; a test of pumps; and a preliminary test of fuels for use in a steam boiler. The results almost uniformly indicated that pumping could be made successful. I need not give these results here—they may be found in Bulletin No. 45 of the New Mexico Agricultural Experiment Station.

The work, as continued after the publication of this Bulletin, included a test of the use of Beaumont, Texas, crude oil in an internal combustion engine with an attachment for utilizing crude oil and kerosene, and a comparison of the fuel value of crude oil, kerosene and gasoline. Crude oil proved to be the cheapest fuel yet tested. The results in detail will appear in Bulletin No. 52, now in press.

At the same time investigations were begun to determine the relative

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cost of growing various crops by means of water supplied by pumping and by means of river water.

The cost of alfalfa hay in the stack on the farm was $1.70 per ton when river water was used, and $5.04 per ton when water was supplied by pumping. The cost per ton baled f. o. b. the car about one mile from the farm was $2.57 for river water and $5.91 for pumped water. During the season two cuttings were grown by means of river water and four cuttings by means of well water. The net profit, the alfalfa selling at $10.00 per ton, was $11.32 per acre for the river water and $12.68 per acre for the pumped water, a balance of $1.36 per acre in favor of pumping. Labor, water tax and land tax are included in the cost. The pumping was done with a 20-horse power steam engine and a 6-inch centrifugal pump, with coal at $6.00 per ton delivered.

The results are brought together in the following table:

	River Water.	Well Water.
Yield per acre, tons	1.76	3.10
Cost in the stack	$1.75	$5.04
Cost baled, f. o. b. car	$2.57	$5.91
Net profit per acre *	$11.32	$12.68

The Experiment Station Horticulturist, Mr. Garcia, grew without fertilizers 31,250 pounds of onions per acre by means of well water pumped from the underflow. The water cost $15.00 per acre. The gross returns, the onions selling at 2¼ cents per pound, was $703.12½ per acre. The net profit, after paying for the water, labor and all other expense incurred in growing, harvesting and marketing the crop was $500 per acre.

The following table shows the number of irrigations, the quantity of water and the cost of the irrigation water pumped from the underflow when used in growing alfalfa, wheat, corn and sweet potatoes:

Kind of Crops.	Number of Irrigations.	Quantity of Water. Acre Inches.	Cost of Irrigation Water per Acre.	Yield per acre Pounds.
Alfalfa	11	33	$12.75	21,080
Wheat†	4	24	8.30	2,826
Corn	4	12	4.15	.....
Sweet Potatoes	4	14	4.85	10,000

From the facts that have been brought forward it is evident that we have before us a subject of the highest importance. Pumping for irrigation has been employed in the past in the reclamation of vast areas of arid land and it will no doubt form an equally important factor in the future development of arid America.

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*Alfalfa hay selling at $10 per ton.
†Turkish red winter wheat.

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RICE IRRIGATION.

THE WORLD'S GREATEST IRRIGATED CROP.

W. A. WARD, Beaumont, Texas.

Texas has 225,000 acres under irrigation in rice. Rice is the principal food of more than half of the inhabitants of earth, and in the yearbook of 1902 the statement appears by authority of the Department of Agriculture that there are probably more acres of land irrigated to rice in the world than to all other crops combined. Certain it is that rice is one of the most nutritious and easily digested cereals, and its culture in this country has a great future.

Approximately 600,000 acres of rice lands are now under irrigation in the United States, yielding about five million bags or 17,500,000 bushels of rough rice, worth to the rice farmers about $12,500,000 and to the consumers over $30,000,000 annually.

HALF A MILLION ACRES OF RICE LANDS IN LOUISIANA AND TEXAS.

Twenty years ago the cultivation of rice was confined to the Atlantic Coast region and the lower Mississippi Valley. The lands of the Carolinas are irrigated by tides and those of the Mississippi by gravity, but these lands now form but a small part of the rice lands cultivated in the United States. Of the 600,000 acres now in cultivation the coastal plains of Louisiana and Texas furnish over 500,000. The center of the rice industry is now but little east of the boundary line between Louisiana and Texas, and at the rate this industry is moving westward the center will soon be within the State of Texas.

Rice is now cultivated as far west as the Rio Grande. On the coastal plains of Texas and Louisiana irrigation is by lifting the water from the numerous rivers and bayous by means of powerful centrifugal pumps into surface canals.

GREAT PUMPING PLANTS.

The most economical unit is a pump having a capacity of about 35,000 gallons per minute, and the lift varies from fifteen feet to seventy feet, the average lift being about twenty-five feet.

A small part is irrigated from wells. These lands are fairly well drained. The water is applied after the rice is well up—three or four inches—and is held on the land to flood it continuously during the growing season—60 to 90 days—and is drawn off as the rice begins to mature. The crop is cut with twine binder machines and threshed like wheat and oats. The same kind of implements are used in preparing and seeding the land as in wheat farming. These methods of irrigation and culture have revolutionized the rice industry.

It follows that a retentive clay subsoil is necessary in order to hold the water and to sustain the weight of the latest improved farm machinery.

What is herein designated the coastal plain of Texas and Louisiana, a strip of prairie land with an average width of about 40 miles extending from a little west of New Orleans to the Rio Grande, is nearly all of this

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character and level enough for rice culture. With her water supply properly conserved Texas has more land well adapted to rice culture than all the lands now cultivated to rice in the United States. The large pumping plants are located near the head of tide water in the numerous streams flowing into the Gulf. These streams are uniformly deep and affected by tides about fifty miles back from the Gulf.

DANGER FROM SALINE BACK-FLOW.

The location near the head of tide water is necessary in order to secure an ample supply of fresh water. Numerous mistakes have been made in locating too near salt water, and by over-appropriating, thereby causing a back-flow, and in dry seasons pumping salt water which is worse than no water because it not only destroys the crop but injures the land.

The natural flow of these streams has not been diverted except by pumping. The eastern part of this rice belt of Texas has an average annual rainfall of about sixty inches, while the western part has but little. It requires about thirty inches of water on retentive soil during the growing season to supply soil absorption, evaporation and proper irrigation for rice.

IRRIGATION NECESSARY.

The rainfall is almost sufficient in some places in some seasons, but in no part of the rice belt of the United States or in other countries is it safe to rely upon the rainfall to grow rice.

The most important effort being made at present to conserve the rainfall and natural flow of the streams in the rice belt is incidental to the construction by the general government of the ship canal from the mouths of the Sabine and Neches Rivers along the west shore of Sabine Lake to the mouth of Taylor's Bayou where it will connect with the Port Arthur Ship Canal already constructed to the head of Sabine Pass.

RIVER AND HARBOR WORK INCIDENTALLY CREATES IRRIGATION.

While the prime object is to open these deep streams to navigation, it is believed the combining of the flow of these two rivers in a narrow canal instead of allowing their waters to mingle with the salt waters of Sabine Lake will extend and increase the available fresh water supply of these rivers to irrigate bout 75,000 acres of additional rice lands. These rivers are the source of supply for about 75,000 acres at present. The Sabine and Neches and Trinity Rivers and their tributaries drain all of the vast forests of East Texas, south of Red River, and a part of the timber lands of Western Louisiana.

FOREST PROTECTION IMPORTANT.

The protection of these forests and the storing of water along the upper parts of these streams is of very great importance to the rice and other agricultural interests of Texas and Western Louisiana.

Allow me to call attention to the difficulties which will probably be encountered and which have already been experienced in drafting and passing

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a law that will apply alike to the arid regions of Texas and to the rice belt. The available water supply under present conditions of the streams flowing into the Gulf have been mostly appropriated by private individuals and private corporations. Some of these companies own large bodies of land and are irrigating for themselves and others as much as 30,000 acres each.

The proposed Irrigation Code, while it appears in general to be admirably adapted to the arid part of Texas and other States, would disturb very important industrial conditions existing in the rice irrigation district. I have been kindly furnished a copy of this proposed Code by its author, Mr. Bien, and it will be given careful consideration by the best legal talent of the rice district in order, if possible, that it may be so drafted that we shall not be compelled by the first law of nature, which is so generally recognized in all the States, including Texas, to fight its adoption by this State.

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Section Rural Settlement.

CHAIRMAN: WILLIAM E. SMYTHE,
Author of "The Conquest of Arid America," San Diego, Cal.

Opening address by the Chairman.

THE FOOTSTEPS OF THE PIONEERS.

Utah is the classic land of American Irrigation and the systems which began there have spread to others of the Mountain States. We have some of the actors in the Utah drama here to-day, and wish to hear from their lips some of the peculiar features of their colonization work.

One of the early colonies was in Northern Colorado—Greeley. I think the same plan was followed in other instances throughout that portion of the State, and it has become powerful in consequence. Greeley had some peculiar features; the people were moved in a body. A Greeley colony was formed in New York City before the people had seen the land or the land had been selected. It was formed of the devoted followers of Horace Greeley, the great editor of the New York Tribune, and was organized under the agricultural editor of that paper. It came as a sort of far echo of the colonies of the forties. They decided that co-ownership and partnership was not a success, but they wanted to employ as much co-operation as could be made feasible. They co-operated in the first place in the purchase of the land, and in that way effected a great saving. Another thing they did which I think worthy of imitation is this: They had a town site owned by the Colony Company, so that the values created went into a company fund, which was available for the benefit of the colony instead of becoming a real estate speculation for the benefit of a few. The town grew and prospered and finally became wealthy for the benefit of all. I think that is perhaps the best lesson we can learn from Greeley. Greeley was also wonderful in its social life. The first thing they did at Greeley was to put up a colony hall, and that became the center of their social life, which was delightful from the beginning. They did not realize any far-reaching plans of co-operation. It became a struggle of each man for himself, but they teach us something in the fact that the colony was organized before leaving the East; they purchased the property with a common fund, and they started at the beginning a delightful social life.

CALIFORNIA COLONIES.

A third group of colonies, notably in the territory of the Arid West, is in Southern California, beginning with Anaheim. It was formed by a party of German mechanics and tradesmen from San Francisco. They purchased their land in common, sending out a party first to discover the place; then another

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party to dig the ditches and divide the land into twenty-acre farms and plant them principally to wine grapes. Finally when the place reached a self-sustaining stage the main body of colonists went to Anaheim and this has been a very prosperous community. It has the great distinction of being the mother colony. The development of Southern California, of which we know to-day, began, we may say with Riverside, which was contemporaneous with Greeley, and which was formed somewhat on the Greeley model. It gathered its settlers from all parts of the United States and came to a land which was then regarded as worthless.

After Riverside came Ontario; it was different in this respect; it was not a co-operative company in any way, but was started by two brothers, and they put in the works of irrigation, made the streets and avenues, divided the land into small farms and perhaps did a good deal of planting. That was done prior to the seeking of colonists.

Now, I am going to ask Apostle Penrose, of Utah, to tell us about the peculiar features of colonization in that State. As I remarked in the convention hall last night, the Utah people have made an historic success in colonization in this country. Their methods are quite different from those of the ordinary colonization movements, first, because they always move their people in bodies; second, different in their manner of settlement because they employ the central village instead of scattered farm homes; third, in the high development of co-operation which they have had. So I am going to ask Apostle Penrose to tell us how their people have been successful in settling their colonies upon land and making them happy and content. A few years ago I went to the Mormon authorities at Salt Lake and asked them if it were possible to compile a statement showing how much money the Mormon people have taken from the soil of Utah.

"We see" I said "that you have reclaimed these valleys and created these towns and cities; we know that you had almost nothing to start with, and that practically all you have must have come from the arid soil of this desert, irrigated by the sweat of industrious men. Now if it is possible to get the figures I believe we will have a most convincing argument to present to the American people in favor of the reclamation of these desert lands."

Through their perfect organization they sent out circulars, and at the end of six months presented me with an impressive and valuable array of figures which I published at the time in one of the large magazines. They accounted for having taken from the desert of Utah and expended nearly five hundred million dollars. They found that divided annually among the farmers of Utah about $1482.00 per family, and allowing for a very generous living it left a net income of about $500 for each family. Now that net income of the Mormon farmer exceeded the average gross income of the highest paid skilled wage earners of Massachusetts.

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UTAH COLONIZATION METHODS.

CHARLES W. PENROSE, Salt Lake, Utah.

The people who first inhabited Utah were a band of outcasts, really, from the United States, on account of religious persecution. They had to flee from their settlements in Illinois and they congregated on the banks of the Missouri River, where what is now called the city of Council Bluffs is situated. In 1847 Brigham Young selected a band of pioneers consisting of one hundred and forty-three men, two women and three children; they started on the journey across the plains, then an unknown wilderness. There had been some parties who had crossed the plains at different times, but the country was then unknown to the people of the United States. I will not take the time to tell you anything about the perils, hardships and trials of their journey; suffice to say that on the 24th day of July, 1847, this little band emerged and obtained their first view of the Great Salt Lake; they selected the spot under the direction of the late pioneer, Brigham Young, on which to found their city. They erected a fort for protection against the Indians and congregated together and selected tracts of land nearby for farming purposes. In the fall of the year Brigham Young returned to the United States and collected people together to bring them out in companies, so that they might reinforce the small band that had settled at first at the place now called Salt Lake City.

WAS MEXICAN TERRITORY.

This plan introduced in the beginning has to some extent been followed out since. At that time this land was not on the market. At first it was Mexican territory, but the Stars and Stripes were flung to the breeze, and as five hundred of the best men of our people were then in Mexico fighting the battles of the United States, the pioneers took possession of the country in the name of the United States, and after a number of people had been gathered together there a provisional government was organized under the name of the State of Deseret. We selected our Senators and Representatives and sent them to Washington and asked admission into the Union. That petition was denied, but afterwards a territorial form of government was accorded to Utah. Thus this land was formally made a part of the United States, a territorial form of government was established, and Brigham Young was appointed governor of Utah by the President of the United States. The people who first settled the soil of Utah went there under religious influences. There was to some extent what might be called a union of Church and State; however, the two were always kept distinctly separate. Our State or Territory officers were separate and distinct from the church organization and officers. It is true, as in the case of Brigham Young, the Governor of the Territory was also the President of the church, and the leading men in the church were usually made the leading men in our civil affairs; at the same time the machinery of the Territory and that of the church were kept entirely separate and distinct. The principle that animated the people was the religious principle; they fled from the confines of the United States because of religious

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persecution. When they settled on the soil of Utah they were under the immediate direction of the church.

It will perhaps be interesting to some of you if I give you a very brief sketch of the church organization. The Church of Jesus Christ's Latter Day Saints—commonly called the Mormon Church—is presided over by three men, the President of the church and two counselors. The next body in the government of the church is the council of twelve apostles; these twelve when taken as a body, form a council equal in authority to the council of three; that is to say, if the President of the church dies, then its remaining twelve apostles is the next presiding body. Next to them come the councils of seventy elders, organized into bodies and presided over by seven of their number. At the present time there are about one hundred and forty-four of these councils of seventy elders, the whole presided over by seven men and all the first council of seventy; these with the presiding bishop and his two counselors, and the presiding patriarch, form the general authorities of the church. The different departments of the church are called States of Zion; the people composing the church are called Zion—pure in heart. These different departments of the church throughout the various settlements in Utah and regions round about are called States of Zion; each one forms a State of Zion. Now that state is presided over by a presidency of three. There is a high council composed of twelve men, corresponding somewhat to the general authorities, called the council of twelve authorities. Every little settlement is called a ward and over the ward the bishop and his two counselors preside; these are assisted by men called teachers, who are to assist in the management of affairs, and particularly to visit the people in their homes and teach them how to live, both temporally and spiritually. There are other councils in the church that I need not speak about; there is a union of the temporal and spiritual in the Mormon church and system.

ESTABLISHING A NEW COLONY.

Coming down to the conditions at present, I will take up the subject of the establishment of a colony. The plan on which we proceed in Utah is this; if some new locality is discovered, considered suitable for a settlement, some valley not before having been inhabited, a man is selected who is supposed to be a good counselor, a man acquainted also with human affairs, is selected to act in the capacity of bishop. He selects two counselors; these three form the presiding authority in the new locality. An invitation is extended to the members of the church to volunteer to go out and settle the newly discovered valley or tract of arid land. When a sufficient number of persons have volunteered to go they are organized into this bishopric. They take their wagons, teams, tools, farming implements, etc., and go out on the soil, all under the direction of the bishop and his counselors. When they arrive at the locality they select enough of the best portion for a town site, and it is usually laid out along the plans of Salt Lake City—streets crossing each other at right angles. Each family receives a city lot, generally ten by twenty rods in size; sometimes it varies a little according to the lay of the land and the extent of the settlement; then land is selected as nearly contiguous to the town lots as practicable, but before anything can be done on

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the soil water is to be obtained. In the first place the settlement is located because of its proximity to some natural source of water supply—usually some little mountain stream. A canal is then dug on this principle: Each individual has the opportunity of working upon this original ditch or canal as much as he chooses, and according to the amount of work he performs he has the right to use so much water; the more work performed the more water he has the right to use. The amount of water he is entitled to all depends upon the amount of work he performs on this canal; that is the plan we generally use.

SMALL FARMS THE RULE.

The farms are generally divided into small sections—about forty acres usually. In later years since the land has come into the market and the homestead law has been in operation, larger tracts of land are often taken up. Usually farms are divided into small sections or portions, and the right to the use of the water (there is no property right, really, in water), the right to the use of the water is determined by the amount of labor that each person performs on this original canal. A water system is organized; they have a head water master who has supervision over the entire ditch, and then there are block water masters, or water masters for different sections all under his direction; these water masters are elected; in the old times they were generally appointed by the people, who got together in mass meeting and appointed men to act as water masters. By this means people obtain possession of a sufficient tract of land for a farm and also a city lot. They live on the city lot and the farming district lies outside. This is for the purpose of religious worship and for educational and for social purposes, and in the early times for protection against the Indians. The principle is still carried out in all our new colonies of having city lots for the farmers to live upon, and a piece or tract of land outside for his farm.

SOCIAL ADVANTAGES.

The first public building erected was always what we call the school house; it was used as a school house for the education of our children and for holding religious meetings and sometimes for amusements; sometimes they would fix up a stage and have a theatrical performance, so that the original school house was the place for holding the schools and for other public meetings and for the general purposes of the people in the town site. The people also have their dances according to their own arrangements and desires, and these dances are held under the direction of the church authorities. The dances are usually opened by prayer, and they endeavor to conduct them in an orderly and moral manner; no liquor is allowed, and in fact in a great many places no liquor is permitted in the settlements. These dances are usually conducted under the direction of an amusement committee, and if there is dramatic talent in a settlement they sometimes have theatrical entertainments. Also musical talent is cultivated, both instrumental and vocal; generally we have a very good choir which attends to the music, and if there are a sufficient number of musicians in a settlement for that purpose they generally organize a brass band.

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I attribute the influence that prevails chiefly to the religious element; at the same time I think the plans that we adopt for the entertainment of the people so that they become associated closely would be adapted to colonization at other points and among other people.

CO-OPERATIVE OWNERSHIP.

Another plan usually adopted in these little settlements was to have a mercantile establishment in which every person had an opportunity of taking shares; generally put down to about $5.00 a share, and in the early times when there was no currency it would be paid in some kind of produce. Each person had an opportunity of putting in so many shares. A general mercantile store was established and the people were invited to take shares in the capital stock of the company, and after a great Zion co-operative mercantile establishment was built up they generally did their trading with the parent institution at Salt Lake City. This kept a great deal of the money within our own borders instead of sending it out. Of course a great deal of merchandise was brought in from distant parts of the country, but the plan in view was to have our own mercantile and manufacturing institutions, with branches all over the Territory or State. We had men of all trades and kinds come in, and we always endeavored to get them into the particular line of their calling; a tailor was encouraged to start a tailoring business, a shoemaker in his line of business, and a tanner in his line of business.

Question—Do you schedule your water and live literally up to the schedule in its distribution?

Answer—Not entirely. We now have a very excellent irrigation law; a State law. I could not sketch it out this morning very clearly. The State divides the water and we have a State Engineer. We are also establishing water rights through the medium of the courts.

Question—Have you any paupers among you?

Answer—No, we have no paupers at all. It is the duty of the counselors and teachers to see that nobody suffers, whether he is a Mormon, Jew or Gentile. We have a society called a relief society, composed of women, who particularly assist the bishop in looking after the sick and afflicted, so that there is no need for anybody to suffer.

Question—Is your system of co-operation a cure for the pauperism that always follows the old system?

Answer—It is to a very large extent; there are some people who will not work, and there will always be the poor and dependent. People are encouraged to work and become independent through their own exertions, but there are persons dependent upon the public; we look after them ourselves in the church. We have a system called tithing, by which it is the duty of each member of the church to contribute for the purpose of looking after the poor and indigent, building school houses, churches, etc.; each man contributes one-tenth of his income annually; this is a voluntary contribution and not a tax.

Question—Do you have tramps; do you have jails?

Answer—We have tramps and jails; that is we have tramps going through the country; we do not have tramps of our own; only transient persons pass-

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ing through the State. We have to have jails because sometimes some people will go wrong and commit crime, etc. We honor the law and turn the transgressors over to the State law and officers when it is necessary, so that we have to have jails. We do not have Mormon tramps, and we have very few Mormons who occupy the jails of the State and country.

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A MORMON COLONY IN MEXICO.

A. W. IRVINS, in charge Mexican Colony.

It is somewhat unexpected on my part—to say a word; I came here because I appreciate to a very great degree the labors of our friends in the question of irrigation and colonization, and I came for the purpose of gaining information rather than with the intention of imparting it.

My impression is that the principal thing we want to know this morning, more than any other thing, is which of all the plans that may be proposed can be the most successfully adopted in the establishment of rural settlements. Now, I am going to give you as clearly and briefly as possible, in about five minutes, the results of my experience during the last few years in colonizing our people in Mexico.

In the first place, to successfully establish a colony in this arid region, two elements are necessary—we must have land and we must also have water. Once having decided upon a location or place suitable for the establishment of a colony, we immediately determine, by an investigation by competent engineers, the most convenient and suitable point upon that tract of land for the establishment of the town, taking into consideration, of course, the elevation. We find that drainage is a very important and necessary factor, and therefore we usually select the highest spot or position on the ground or tract of land on which we decide to locate, which is susceptible of irrigation, for the establishment of the town. My opinion is that the most successful plan to adopt in laying out a small rural settlement is to make the blocks about one hundred meters square; divide each of these blocks into four town lots, thus furnishing each colonist with a corner lot. There should be at least two main streets running through the town at right angles; these streets may be made six rods wide, and the lateral streets may be made four rods wide. Of course if you are planning for a city you must plan upon a larger scale.

FORTY-ACRE FARMS THE MAXIMUM.

Now we have calculated the area of this tract of land and have determined about what the population may be which shall occupy it, allotting each person say not to exceed forty acres of land. Many people who go into a new colony will not require as much land as this; for instance, mechanics will require smaller tracts, but we have demonstrated that forty acres of good land that can be irrigated is amply sufficient to maintain a family of six persons; therefore you can very closely calculate the number of town lots that it will be necessary to lay out in order to colonize there a number of people sufficient to occupy the entire tract which shall be used for agricultural purposes.

Immediately around this town site—after having laid it out in lots and blocks—we have adopted the policy of sub-dividing the land adjacent to it, into very small tracts; say lots or blocks containing about two and a half acres each. The land which is nearest to the town is always the most valuable; it is the land most convenient to the people, and consequently it is advisable that it be divided into small tracts, in order that each colonist may

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avail himself of the advantage of having a small piece of agricultural land near his home. The land lying immediately adjacent to these smaller tracts or blocks, we have been sub-dividing again into tracts of say about ten acres, making a series of such blocks or tracts running around the entire tract of land. Then still further out from the center, or the spot which will be the center of population, and immediately adjoining the last mentioned tracts or blocks we have sub-divided the balance of the land again into tracts of say about forty acres each, taking in all the land suitable for cultivation and to which water can be supplied.

AS A BUSINESS INVESTMENT.

There is another very important question which always enters into this subject—that is the financial part. There is no promoter of a colonization scheme but that expects at least that he will get back the money which he invests in it, and usually a little more in the way of profit; the latter is what is expected and prompts men to promote enterprises of this kind. The plan we have adopted usually is this: we have an incorporated company which acquires the land; this company purchases a large body of land at the lowest possible price, which is sub-divided in the manner I have just described; in disposing of these town lots and the agricultural tracts or blocks to colonists, we place the price to those who first occupy them just as low as it is possible to place it—just as near cost as we possibly can; that induces people to buy the land and occupy it. Of course lands can never become valuable without occupancy. But in disposing of this land to the first colonists we reserve one lot in each block of the town plat, and also one-fourth of all the tracts or blocks of land designed for agricultural purposes. These town lots and the blocks of agricultural land scattered throughout the entire large tract are not sold at first to any one, but are held in reserve until such a time when, either the colonists who have already established themselves on the land, or some incoming colonists, can afford to buy them at considerably advanced prices. The benefits derived from this policy are obvious; the colonists who are first established on the land are usually poor; in the course of time they accumulate means; then they usually desire to become the owners of the unsold and vacant land adjacent to their own, which vacant land has been greatly enhanced in value by reason of the surrounding improvements; when this time arrives and they have accumulated sufficient funds, they will readily pay a much higher price for the adjacent vacant land than that paid for their original holdings, and this reserve land is disposed of at a sufficiently advanced figure so that the company is reimbursed and receives proper compensation for its original outlay of money—a profit on the investment. For example, we are now selling for three hundred dollars lots similar to those sold to the first colonists in the same settlement a few years ago at five dollars.

CONSTRUCTING THE IRRIGATION WORKS.

One of the first things that is necessary is the contruction of the main canal which is to conduct the water onto the land. This is usually constructed by the people who have become the owners of the land; they either acquire interests in this canal by labor on it, or by employing labor on it to pay for

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their interests, or may acquire their interests by purchase from those who have acquired it by labor and whose lands are insufficient to use the entire amount of water they are entitled to. Each colonist acquires a water right for the land he owns in proportion to his interest, either by purchase or by labor upon the canal. However, we make the necessary water rights to all lands appertain to the lands as far as possible, and establish rules by which it is made impossible for a person to transfer the necessary water right from the land; neither one must be transferred separate from the other. The water is taken from this main canal in laterals or sub-canals to the water users in each district. In the first place a man is appointed to take charge of the entire water system; in each sub-division there is what we call a sub-watermaster appointed; this sub-watermaster arranges a schedule at the beginning of each month, in which he indicates the hour or hours during which each water user shall take water and the hour at which his time expires, each water user being governed, of course, by the share he has acquired in the irrigation system. That schedule is made out for an entire month, and each water user is furnished with a printed copy, so that each person knows the hour or hours during which he can have the use of the water and the hour when his time expires. He must use it then or not at all; if he omits to use it he loses his opportunity for that time. This schedule is so arranged that each water user has a specified period during which he uses the water each week, and it is arranged so that the water comes upon the entire district at least once a week, thus giving each water user a certain period of the time during each week in which he may use the water on his land and in any manner he may prefer.

In obtaining the original large body of land we always calculate that there should be, adjacent to this farming or agricultural district, lands suitable for grazing purposes, because colonists must have cattle and horses in order to become successfully established, and if there are grazing lands adjacent you see how much greater the convenience is to them.

THE SYSTEM GENERALLY ADAPTABLE.

I see no reason why this system cannot be adopted by any one who desires to promote a colonization enterprise; the results obtained by it have been very satisfactory to us in Mexico. We have colonized a large number of poor people there; the land has been distributed in very small tracts, and it is a great source of pleasure to be able to say that while our operations there are only in their infancy, yet their earnings last year amounted to about five hundred thousand dollars, and if you would look at the hundreds of miles of fences and roads, and the bridges they have built, you would agree with me that this system has been eminently successful, and I see no reason whatever why it cannot be applied to any other people.

Mr. Smythe—You are not teaching those people that the dollar is the chief end of life?

Mr. Irvins—No sir; they would be very much disappointed if they expected to get rich quick in Mexico. We do not expect to get rich there.

Mr. Smythe—The main end you have in view is a good living?

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Mr. Irvins—Yes, a good, comfortable living; plenty of houses, plenty of clothing, good food, etc., and an independent life. We tan our own leather; we make our own shoes; we have our own wood-working machinery, and we encourage the people to invest their savings as far as possible in these local institutions. These companies are incorporated and conducted upon the same business principles as any other companies, with the exception that our people almost universally become stockholders in them and thus are interested in their maintenance and upbuilding.

Chairman Smythe—We have now given fifty minutes to the consideration of the Mormon colonization and industrial system; it is a very short time to give to a very great subject, but even in that short time I feel that the two speakers have thrown a great deal of light upon the subject. Many people have claimed for years that the success of the Mormon settlements has been due entirely to the church; that the church sustained the industrial system. I have always believed that the reverse was true; I believe so now, though I have no doubt the wonderful organization of the church has been a powerful factor in their success. The main thing for us to learn is that they have worked out a fairly scientific method of colonization which is adapted to our general situation. The next address on the program is by Mr. Guy E. Mitchell on the subject, "Small Farms for the West."

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SMALL FARMS FOR THE WEST.

THEY CONSTITUTE THE COMMUNITIES OF GREATEST PROSPERITY AND HIGHEST SOCIAL SUCCESS.

GUY ELLIOTT MITCHELL, Secretary The National Irrigation Association
Washington, D. C.

We have before us the great problem of telling the people of the United States the splendid prosperity which results from the small irrigated farm, of showing the country, which has sanctioned this national irrigation work, that the carefully irrigated sections of the West constitute the best communities in the world.

The irrigation of desert lands is a work which appeals to more classes of men than does any other kind of agricultural development—all the way from the intensely practical money-maker to the high idealist.

The practical land dealer or real estate man appreciates the great increase in value which comes to the agricultural lands when supplied with water; the merchant who sells manufactured articles of all kinds discerns in the dense settlement which follows irrigation a splendid market for his wares; the intending settler looks forward with deep satisfaction to owning a farm where he can control the moisture supply and be assured of maximum crops; the banker considers irrigated land gilt-edged security; the citizen, with his State's welfare at heart, welcomes irrigation development as the highest blessing which can be conferred upon his community; the scientist derives keen joy from the creation of a system of reservoirs and canals which transform the desert into a land of production—the making of something splendid out of nothing; the sociologist becomes enthusiastic at the social conditions arising from irrigation, where land becomes intensively farmed, where the inevitable tendency is to break up large tracts into small and highly productive farms, where the communities become the most substantial and prosperous of any under any form of agriculture, where a greater percentage of men own their lands and homes than under any other social system, where good roads, churches, schools, good transportation, telephones and other urban improvements invade country communities as nowhere else and where an opportunity is presented to find homes on the land for the inhabitants of overcrowded centers. Lastly, the idealist sees in the reclamation of waste places, in the conquest and the subjugation of the desert, in the development of a country's latent resources, in the production of not two blades of glass where one grew before, but of a luxurious vegetation where nothing could previously live, the fruition of a dream of Arcadia, the accomplishment of the seemingly impossible, the absolute creation of wealth, strength, power.

IRRIGATION COMPELS SUBDIVISION OF LANDS.

The irrigation movement which is sweeping over the country is pregnant with vast possibilities for good in the United States. Irrigation begets small farms, and no country is so prosperous, so stable, as that which has for its basis a multitude of small farms.

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Starting with the greatest bonanza farms in the world, where the plowman followed a single furrow throughout the day, the West will become, in the next generation, a section of small farms. The irrigated unit has already been established in a general way by the National Irrigation Act, at 160 acres; that unit will be in the coming years subdivided into 80, 40 and in some favored sections into 20 and 10 acres upon which a man will live with his family in plenty.

Not under the most exact system of farming can large tracts of irrigated land be worked with as great profit per acre as can the small tract where the farmer gives it his individual attention. Eighty acres can be better farmed than can 160.

As the great benefits of irrigation become more widely known throughout the country the practice will spread to the eastward, even to the Atlantic Coast, until in time every water supply from ocean to ocean will be utilized for increasing and insuring crop production. With this will come a subdivision of the Eastern farm units, for men will find in the East as in the West, that smaller tracts irrigated and well tilled will bring them greater returns than large tracts carelessly farmed and subject to the moods of the elements.

LANDS FOR OUR OWN CHILDREN.

America has stood for a century with her arms open to the world; the oppressed of all nations might find a welcome under the Stars and Stripes, nay, more, they might find an individual home on the land which was theirs for the taking. We are of late years becoming a little more discriminating and are taking into our ample fold only those whom we believe to be the desirable ones. Our immigration laws, many believe, might be made even more stringent without harm to ourselves. There is no great necessity for haste in building up our population to the two-hundred-million mark. The United States fears no nation to-day. Will we be the better or the worse for the next fifty million people who come into the country if they are brought in to largely swell the great centers of population now already overcrowded? Rather would it not be better to assimilate those people we already have in our midst, to take the vast floating population of Chicago, of New York and other great cities, and place them on the land and train them to get a living from it so that they might become a strength rather than a menace to the nation?

FRENCH STATISTICS FURNISH FOOD FOR THOUGHT.

We are inclined to condole with France upon her vital statistics, the fact that her birth rate does not exceed her deaths. Her population is not increasing, but her peasantry is a contented population; it is established upon innumerable small farms and it is not overcrowded and overcrowding. French statesmen are not confronted with the problem with which their German neighbors across the way are struggling—how to provide in an already crowded country for a rapidly increasing land-hungry population.

In the United States we have not reached the situation where we could not take care of a million new people a year if they were taken past the cities and put upon our lands, and there is no immediate fear of our lands becom-

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ing overcrowded, nevertheless we should recognize two facts—that the welfare of the country demands a solution of the overcrowding of our cities and that even our land resources are not entirely inexhaustible.

AMERICA'S PRESENT LAND POLICY.

And this bring us to the question of the administration of our public lands. The Eastern half of the United States has been largely given to the people and considerable of the western portion has been taken up under our various land laws.

Of this great acreage it is estimated that nearly a hundred million acres can be irrigated, while a very large additional area is capable of producing crops without irrigation. Now, the question is, are our public land laws to be so administered that this great Empire of rich farming territory, capable of supporting the most dense and prosperous agricultural population in the world, shall be as fast as possible converted into actual homes, in 160-acre or less tracts, or is the present loose system to obtain, so that speculators and land grabbers, so termed, can continue to amass into single ownership immense tracts without settlement or improvement?

LOOSE LAND ADMINISTRATION.

All of our land acquiring laws are to-day fearfully abused—the Desert Land Law, the Timber and Stone Law, the commutation clause of the Homestead Law, and even the old 5-year Homestead Law, itself. Our policy has been heretofore that pioneering should be rewarded and that every inducement should be held out to encourage the "settlement and development of the West." The most liberal construction has been placed upon the laws, and there has been no strict enforcement in letter or spirit of the principle which is assumed to pervade the laws under which the government gives away its public domain on the condition of actual settlement and home-building in as small tracts as men can make comfortable livings from for themselves and families. The practice has been to get the title out of the Government into private hands as easily and expeditiously as possible, with an almost entire disregard as to what the Government is to receive in return. The sentiment in the Western States themselves has largely supported this policy. Men urge that if stockmen and land dealers are willing to acquire large areas and place them upon a tax-paying basis, it is better for the State that they should so pass into private hands, even though they may lie idle in tracts of thousands of acres or be used as grazing properties in tracts of tens of thousands of acres, apparently overlooking that this policy prevents their settlement in 160-acre tracts which would support each a family of from three to ten people and add one hundred times to the productive capacity of the land and the wealth of State and Nation.

SINNING, BUT SINNED AGAINST.

Much criticism has been made of the stockmen as a class of land grabbers. It is true that the cattle men and sheep men have acquired ownership and control of the vastest of tracts of territory in the arid West by employment of fraud, thus preventing its settlement. But they are in reality the victims

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of a condition which, while they may have been advocates of the cause, has not proven an unmixed blessing to them. In many of the stock-growing sections they have acquired so much land and it has increased so in value, with increased taxation, that their profit has been largely reduced from the days when they ran their herds on the free range. Many of them will state that they have not desired to acquire these large tracts of land under the desert or other land laws, but the very existence of this law has forced them to become large land owners in order to prevent other men from acquiring the land and driving them out of business.

RETARDED DEVELOPMENT.

Vast areas of the land of the West which have passed from the Government into private ownership, by a transfer, the spirit of which contemplated its settlement and cultivation is to-day lying idle, is farmed in the most indifferent and shiftless manner because the owner has more than he can attend to, or is irrigated and utilized merely to produce a meager crop of wild hay to winter over stock, whereas were it open to settlement it could be taken up in 160-acre blocks and made to produce an abundance for one if not for two families desiring homes.

It is needless to go to any extent into the question of the productivity of irrigated desert lands or to quote yields per acre. Government and State statistics and even the most casual and random inquiries as to the yield and fertility of Western irrigated lands disclose the generally accepted fact that irrigated lands, tilled with understanding, skill and industry, will produce from two to three times the average of Eastern lands. The result is greater farm value per acre, a higher land value and consequent reduction of the acreage for each farm as the highest degree of development is attained

WHAT FOR THE FUTURE.

Now the question is, not of the past, nor of what has been done in the way of public land administration and public land policies, but of the future. What is the policy to pursue in disposing of our remaining Government lands? Have we yet reached the point where we should conserve our homesteads for families who are looking westward and part with title to each and every 160 acres only upon the strict condition that it shall be made into a genuine home, or can we still say that there is land enough to continue a policy of national squandering for yet a decade or two?

Population is what is needed for the West. Population will come with settlement. The only land law which fosters permanent settlement in any degree is the original Homestead Law, requiring five full years of residence, and that law carefully and strictly administered. The Desert Land Law, the Timber and Stone Law and the commutation clause of the Homestead Law have all, broadly speaking, been an actual and vast detriment to the West; they have shut the door of opportunity to hundreds of thousands of people in the East; they have fostered land speculation, land grabbing, land monopoly; perjury and falsehood run riot, and now they stand as a menace to that grand and most magnificent Western development and growth upon whose threshold we pause to-day, the working principle of which is laid down

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in the National Irrigation Act, which provides for 40 or 80 or 120 or 160-acre irrigated homes.

To-day the West is looking through the vista into a glorious future. With one of the wisest measures for internal improvement ever enacted by any nation being pushed forward rapidly and skillfully by engineers of the highest intelligence and honesty, upon a basis of merit and for the general good of the country, it remains only that the United States shall return to the real spirit of the old Homestead Law of Galusha A. Grow and provide that settlement and home-building shall follow the disposal of our magnificent public domains and our splendid water resources.

Chairman Smythe—We will now hear from a gentleman who has grown white in extending the frontiers of our Western civilization, who has been identified with our growth in many different departments—Mr. W. H. Holabird.

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THE LITTLE COLONY OF ONTARIO, CALIFORNIA.

W. H. HOLABIRD, Los Angeles, California.

Failure in colonization work is not an unusual result; this is unquestionably due to the lack of thorough preparation by the founder or founders of the colony. Ontario has been selected as an illustration chiefly because of the thorough preparation of the tract of land and the development of the water supply by the original owners. The two gentlemen who developed this colony, George J. Chaffey and his brother, civil engineers from Canada, knew nothing about irrigation unless it was the theory, but they were thorough men in everything they undertook. These two far-seeing men had a vision and saw what lay beneath that soil; they used their engineering skill and executive ability in the development of this colony. They were leaders, while most men want to be led.

When they laid out the colony of Ontario they had very little water. A great plain extends from the headwaters of the little streams that feed into the San Gabriel Valley to the Santa Ana River which supplies the remarkable orange-growing sections of Redlands and Riverside with a part of their water supply. Prior to this development by the Chaffey brothers this great scope of country, some forty miles in length and some six or eight miles in width was a dry sage brush plain; there was not a tree or brush large enough or strong enough to picket a horse to. The water obtainable by gravity flow from the mountain stream was exceedingly limited, hence the utmost importance was attached to the method of conducting and distributing this water.

HIGH CLASS CONSTRUCTION.

Concrete conduits were constructed, so that the loss by seepage was entirely eliminated and that by evaporation was slight. A broad avenue was laid out from the foothills of the Sierra Madre Mountains to the lower line of this tract of land under development. This avenue was one hundred and twenty feet wide. Two rows of shade trees were planted in the center of this avenue, giving sufficient area between them for the development of a street car line, which was afterwards installed. A drive-way thirty feet wide was made on either side of these center rows of trees, with adequate sidewalk space between the gutter and the property lines. The land was all laid off in ten-acre tracts, or squares of six hundred and sixty feet. The water in every instance was carried in open earth ditches from the concrete conduit along the upper side of each tract. Before any of this property was offered for sale the trees had commenced a vigorous growth, the sage brush had been thoroughly cleaned off and the lots and tracts accurately and intelligently outlined by stakes upon which were letters indicating the block and lot. The deeds of conveyance contained a very wise clause, and one which is worthy of serious consideration by any one attempting a colonization enterprise—that is a clause prohibiting the sale or manufacture of any intoxicating liquor; to this fact may attribute the very marked success that attended the establishment of the Ontario colony. It encouraged the settlement in the colony of people of intelligence and refinement, encouraged the establish-

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ment of schools of a superior character, where the children would grow up without the contamination of the evils that surround a community where liquor is sold without many restrictions.

ECONOMY IN USE OF WATER.

The distribution of the limited supply of water was most economical. A schedule was made giving each tract its quantity of water at certain stated intervals, as the water-right attaching to ten acres of land was of itself insufficient in its daily flow to irrigate any area of moment, but the accumulation of the water belonging to the tract (which I think in this instance was one fiftieth of a cubic foot per second flow) this water, I say, when delivered at intervals of thirty days, gave thirty fiftieths or three fifths of a cubic foot per second flow, which was all that one man could judiciously handle and economically distribute throughout his orchard. Immediately upon the termination of the time allotted to one person for the use of this flow of three fifths of a cubic foot upon his land the water was delivered to the next user, and so on throughout the entire tract, so there was not one moment's waste of the water during the twenty-four hours of the seven days of each week, and on through the entire irrigating season.

Domestic water was supplied with a small tax attached, sufficient for reasonable maintenance and absolutely unquestioned in purity.

This colony to-day has reached the acme of its development, not because of lack of land, but because of lack of water, there not being a sufficient quantity of water falling from the mountain stream which supplies the colony, plus the amount developed by pumping from deep wells, to encourage the planting of costly orchards on the still dry lands adjacent to the colony.

AN IDEAL IRRIGATION COMMUNITY.

To-day Ontario presents a picture of beauty and home-like loveliness that cannot fail to attract the most critical visitor. A trolley electric railroad now operates its line up and down this beautiful avenue for some nine miles. The orchards of orange and lemon trees are exceedingly productive, and because of the intense cultivation given them, due to the intelligence of the owners, they receive the very highest market value for their fruit.

The land at Ontario in the first instance, before the water was brought upon it, was worth about five dollars an acre; when the water was delivered upon it it was worth from one hundred dollars to two hundred dollars per acre. When the orchards were planted on it at a cost of about one hundred dollars an acre additional (some a little in excess of this amount), and had grown into bearing, they were easily worth and frequently sold at one thousand dollars per acre, exclusive of the improvements in the way of houses and other buildings.

I believe it will be appropriate for me to give an illustration of the low estimate placed upon good lands by many of the original habitants of the arid West. In the valley of the Santa Ana River, in Orange County, California, is a very fertile plain, originally given up entirely to the cultivation of barley and wheat and the grazing of sheep and cattle. An astute gentleman from the East, in the early history of the development of that region some thirty years

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ago in driving through the valley saw the unusual advantages it possessed and easily ascertained that there was sufficient water to be taken from the Santa Ana River, at an elevation where it could be distributed over a large portion of what is now one of the most thrifty and highly improved colonies in that splendid section. This man went to the owner of the land and asked him to make a price on some five hundred acres. The owner finally agreed to accept four dollars per acre. The gentleman made a small payment binding the bargain and gave the owner instructions as to whom to execute the conveyances; then the old farmer went to the nearest justice of the peace for the purpose of having him draw up a proper deed of conveyance; this gentleman, well known as the Hon. Richard Egan, tells the story as follows: that the old farmer came in and said:

"Judge, a d—n fool Easterner has dropped into my place and wants to buy that five hundred-acre patch of mine lying north of my house, and he has been idiot enough to offer me four dollars an acre for it; I want you to get a deed made just as quick as you possibly can, so I can get back with it and close the trade before the simpleton changes his mind."

He secured his deed, went back and exchanged it for the money, and the sequence of the story is that when our eastern friend had brought the water upon the land this original owner bought back a few acres at a price sufficiently high to pay for the entire tract of five hundred acres, which sold for a very large sum during the few years that succeeded its development by the Eastern gentleman; possibly $100 an acre and upwards was received for the land at that time. This illustrates that the natives in our Western country are frequently incompetent to pass upon the values in their own territory, or see beneath the surface, or in the air they breathe, attractions that people unacquainted with the arid West are the first to discover.

DON'T MAKE THE MISTAKE OF EMIGRATING TO CANADA.

Before closing I wish to say that in going through British North America I was impressed with the awful loneliness of the settlers on those great wheat farms between Winnipeg and the Rocky Mountains. I talked with some of the people who got on the train at different stations and they deplored the indescribable solitude of their lives, and I wish to urge all Americans everywhere who hear me or who may read these remarks to remember that the United States of America has a big enough territory in which to make happy and prosperous homes without going to any portion of British North America. Do not go headlong across the Canadian line for a home until your children's children are occupying the last acre capable of cultivation by irrigation in our own America.

I could dwell upon this subject of small irrigated farms and cite other beautiful illustrations, but I have already exceeded my time, and thanking you for your courteous attention, will say good-bye.

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BACK TO THE LAND.

CHARLES WOOD EBERLEIN, Portland, Oregon.

About the middle of the eighteenth century there appeared the "Deserted Village." It became at once the English classic of the homeless and expatriated and marks the decay of rural life in England. By the operation of economic laws, rural communities broke up, their population was partially absorbed in urban populations, but the greater part drifted over sea and was forever lost to their native land.

The decline of rural communities of England and Scotland in the time of Oliver Goldsmith brought a lasting change. The independence and the joyousness of lowly country life as reflected in the songs of the old dramatists, faded away and left only the toiling laborer and the hard condition of the tenant farmer.

There are lonely highland glens where to-day not even a shieling remains to mark what was once the abode of sturdy clans.

Two or three decades back there appeared signs of decay in our own rural life. The movement away from the farm set in. The youth of the farms and villages crowded the cities. This tendency was steady and showed no signs of abatement. For almost a generation the press and pulpit wrestled with the problem—its cause and its remedy—but without result. It became the theme of the essayist—the problem of the political economist. While theorists consulted precedent and built up hypotheses, a new dispensation was preparing. Farm machinery lifted the curse from the soil, the laboratory did its share, every department of physical science contributed.

When at last the cry went up "Back to the Land," the practice of agriculture had risen to the dignity of a profession. It was no longer necessary for a young man of mind and ambition to go to the learned professions.

We do not realize that perhaps the present decade is the most splendid in its triumphs for peace of the whole thirteen of our national life, and not the least of these triumphs is the significant turning of young men of American birth and training to the country.

But with this return to country life there will be no return to old conditions. The new rural community life *must*, in great measure, keep pace with the intellectual life of the cities.

American life is already beginning to feel a distinct impetus from this movement. That scientific agriculture and the irrigation movement sprang into life simultaneously, is no mere coincidence. They are two forces upon the wise management of which hangs not only the destinies of States, but the development of individuals. The problem now is how shall irrigation and scientific agriculture be made to produce the highest measure of human development and human happiness. In other words, "How shall the new rural community be builded?"

When the Aims national irrigation became the law of the land, a triumph was achieved, the full measure of which is perhaps not yet suspected. Among other things the *Great Act* strikes a blow at the evil of sectionalism. The vital principle has been evolved and must in time be generally recognized,

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that in the gain or loss of a single section of this Republic, however small or however remote, all the rest have an equal share. It is a trite saying, but if we reflect upon the work of the irrigation propaganda we must be convinced that no movement of our time *making for peace* has so stimulated mutual interest. Herein lies the opportunity for the builders of a new social order, an order that shall not have for its foundation the wreckage of an old system. The change I have in mind is not a revolution, nor yet an evolution, but a social fabric resting upon new land and upon new ideas. Many have been the experiments in the short span of our national life. Associations of individuals have turned to the soil and have attempted by artificial means to achieve the ideal life. From Brook Farm on, failure has succeeded failure—the result of oversubordination of the individual.

Now we are on the threshold of a new experiment *in living.* The National Irrigation Act establishes private ownership within reasonable bounds, and a wise, steady administration of the law as now enacted will achieve more for the common good than socialism or communism have ever done or can ever do. The settler on reclaimed lands will be assured of a competence, but dependent wholly upon his individual effort. But to get back to our rural settlements. About two years ago I visited the Roswell irrigation district, in western Idaho. The enjoyment of viewing a prosperous irrigation district is, in a greatly intensified degree, that of looking at a beautiful garden set in a glorious landscape. Roswell is a tract of several thousand acres which less than ten years ago was sage-brush desert. The transformation has been complete. The whole tract is reclaimed, and is divided into holdings, the average size of which is far below 100 acres. The houses are new and tasteful, and each stands surrounded by orchards, flowers and shrubs.

The holdings are so laid out as to border on a broad roadway. In the midst is the church, a large graded school and the town hall. The houses lie near enough so that neighbors are within call. The whole place has the air and the appearance of a beautiful suburb. In the homes is refinement and hospitality. The interior surroundings are such as might be found in residences on the outskirts of any eastern city. Roswell is an ideal that may be and should be realized in every community established under the National Irrigation Act.

Given assured independence, healthful occupation, opportunities for culture and social life, and lives that are lived from cradle to grave under the spell of sky, mountain and desert, and a new element has entered into national life.

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GETTING COLONISTS.

C. E. WANTLAND, Kansas City.

"Getting Colonists" would seem to be an easy job to handle. But why do we have to get them? Why don't they come? Because they must be shown that we have something to offer better than the "other fellow" can offer, and the "other fellow" is also after them.

In getting colonists for irrigated districts many subjects have to be considered, which colonization agents handling lands in rainfall districts do not have to wrestle with.

Irrigated districts in the United States happen to be located at long distances from the great centers of population. Railroad rates, climatic conditions, State laws, the high prices which irrigated lands command, and many other things have to be considered.

Colonization work in the West was affected when the railroad companies of the country were prohibited from continuing pooling arrangements. This prohibition forced the reorganization of traffic associations, and the officers of western railroads have ever since been so crowded with difficult problems pressing for immediate solution that colonization problems requiring great attention and a long time for adjustment have not yet been settled upon the broad basis which the importance of the work justifies.

New settlers for the new districts of the West are wanted, and the importance of the work is appreciated, but the conflicting interests in which western railroad systems have been involved have made it very difficult to separate colonization problems from the complications connected with regular passenger business, and the tourist business to the Pacific Coast and the resorts of the Rocky Mountain districts.

TO OFFSET THE CANADIAN ALLUREMENTS.

As against the difficulties we have to contend with, and the many alluring offers the people we seek have been and are receiving from the Southern districts, and from the North—from the States of this country, as well as from the vigorous work of Canadian land agents and the government of Canada, we present the *"sure crop"* argument, because we make the rain and have it come when it is needed. We present the *"great crop"* argument, because under irrigation more grain, hay, fruit, etc., are produced per acre than in the rainfall districts. We present the *"good climate"* argument, because in the irrigation districts we find also the land of sunshine.

In irrigated districts we offer great inducements to all classes of home-seekers. We offer homes under favorable conditions, in a land where long life is the rule, and where the poor man can find for himself and family the independence they seek.

We offer the inducement of great profits from land investments to the men who are not figuring alone on establishing homes, but who want profits as well.

Intelligence is generally needed among settlers in districts in which laws must be considered by all, and in which co-operation is necessary. A settler

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under an irrigation system must know something of the laws governing the distribution of water and must co-operate with his neighbors in the administration of such laws. It is true that millions of dollars were lost in connection with irrigation investments in the early history of irrigation development, where money and energy were not backed by intelligence. It is also true that marvelous profits have been constantly made, and are still being made, in irrigated lands, and we have no difficulty in proving that the investor and the farmer can make money, and the homeseeker can find what he wants in the irrigated valleys of the West. They must use their brains, and colonization agents must be reliable and must tell the truth if they expect to keep on good terms with the railroads they work with and with the people they locate.

CONFIDENCE GREW GREAT.

When Uncle Sam jumped into the irrigation ring, great confidence was given to all irrigation investments. The capitalist, the homeseeker and the investor feel that if irrigation is a good thing for Uncle Sam, it is a good thing for them, and they are coming West now with millions to invest.

Judicious advertising especially is necessary in presenting the attractions of irrigated districts. Vigorous land agency work is essential. Each State should have an immigration bureau to furnish information for homeseekers. The government of the United States should publish statements showing the resources and attractions of each district in which national irrigation works are located. As the best use of the grazing districts of the West necessarily have an effect upon the lands in the irrigated districts, the Congress of the United States should put into effect some reasonable method for the control of public grazing lands, in order that the present conflicts between the live stock interests using public ranges shall cease and that each man on the public domain shall be able to know just what he can do and how much he can be allowed to use of Uncle Sam's pasture for himself—free from any interference by his neighbor.

"Getting Colonists" is a subject which is too big to be handled in a few minutes and it will pay all who are interested in the development of the West to study well the many problems connected with the work of colonizing irrigated lands.

Intelligent work will prove to be satisfactory and profitable. The homeseeker can find health and wealth in the Irrigation Empire.

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ORGANIZATION FOR IRRIGATION IN THE NORTHWEST.

A. W. HADLEY, Special Representative of The National Irrigation Association, Spokane, Washington.

Mr. Chairman, ladies and gentlemen: It has been suggested to me to present the conditions found existing throughout the Northwestern States, where I have been operating during the past year as special representative of the National Irrigation Association. You will understand that in that section of the country the subject of federal reclamation is practically a new one, and you who are familiar with what has been going on would no doubt be greatly surprised to see how dense the ignorance along these lines really is. Prominent business men whose keen commercial foresight has established highly enviable reputations for themselves in the communities where they have labored for years are found to be most profoundly indifferent to the vital importance of the irrigation movement, and often absolutely refuse to consider the matter under any conditions.

It is in the face of these difficulties that the association has been prosecuting its campaign of education and bringing to the minds of the people the important facts regarding the movement, by means of its press bureaus and publications. Already composed of more than 2000 of the strongest commercial interests of the country, this organization has for several years been gradually extending its influence on legislation and preparing the way for the steady progress of government reclamation. No particular section of the country is in fact more interested in this movement than another. The West in a prosperous condition is of immediate benefit to the East, and vice versa. We find the factories of New England ready to extend their support because they realize that an increased population in the West means that many more people for them to furnish with clothing, hats, boots and shoes. Every factory wheel must turn that much faster and this increased activity means better markets for the cotton shippers of New Orleans, and in turn the cotton producers of the interior.

HOME MARKET FOR MANUFACTURERS.

The manufacturer of Pittsburg expects to increase his output of steel rails and farming implements, which fact in turn interests the great transit companies, the builders of lake-going freight boats and even the producers of iron ore. Go to the iron regions and you will find thousands of laboring men whose families must exist and in whose existence there thrives a host of local retailers, jobbers, manufacturers and agriculturists. Do you see how it is? Verily an endless chain. From the producer to the consumer, back and forth; a continuous round of industrial activity in which we all, individually and as a nation, must thrive and prosper.

The jobbing and manufacturing interests of St. Paul and Duluth have given every support to the national irrigation movement because of their Dakota and Montana trade fields. The grain handling and milling interests of Minneapolis are of course desirous of a greatly increased productive acreage in the Northwest and they are co-operating almost to a man. In several

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localities of the Dakotas erstwhile "faithfuls" are abandoning the deities of rain and are now bowing a more fruitful allegiance to King Irrigation. Montana is showing considerable activity of late along these lines and a number of water-users' associations are being successfully formed.

Nothing stimulates mining like the development of local agricultural resources, and this, in turn, demands increased transportation facilities for both of these great industries.

In Washington, the State which I am honored in representing at this Congress, there has recently been expressed more spontaneous, genuine enthusiasm along irrigation lines than any section in which I have ever worked. Let me give as an example the change that has come about in the so-called "Inland Empire." Not long ago so little importance was there credited to the subject that the Chamber of Commerce of a certain city absolutely refused to disseminate irrigation literature from its offices for fear their climatical reputation for humidity might be injured abroad. The National Association entered the field for an educational campaign and an interest was awakened, with the result that a few weeks ago one hundred and fifty of the most prominent business men in the city chartered a private train, and for three days toured the irrigable portion of the State, parading with a brass band the streets of twenty-six towns in the interests of an irrigation convention the week following.

DEEP DUST BROUGHT IRRIGATION ENTHUSIASM.

It was my pleasure to accompany this excursion. In some places the dust was three inches deep, but usually where it was the deepest our reception by the assembled natives was the more cordial, the band played louder and the more cider, fruit and brotherly affection we absorbed into our systems.

We have recently completed the organization of a Northwest section of the National Irrigation Association, which will eventually take in all Washington and the northern part of Idaho. Permanent headquarters have been established at Spokane, and the already lengthy membership roll is evidence of a highly successful campaign. We will have at least one thousand active members by next spring. As soon as the irrigable sections of the State are thoroughly organized we will carry the work into the coast cities, including Seattle and Tacoma.

Although little irrigation interest is manifested as yet in the western portion of the State, the jobbing and manufacturing people are bound to derive great benefits from their increased trade fields. If the government expenditure of $2,000,000 on the Palouse project brings into cultivation 100,000 acres of worthless land, thus creating 4000 new farms and an increased population of 20,000 farmers, who will expend annually $2,000,000 for manufactured necessities, what will the possible expenditure of $60,000,000 eventually amount to? These are not pipe dreams, gentlemen, but actual probabilities, and the present generation will live to see the realization of them.

ONLY A STARTER.

In carrying on this work I am constantly asked why it is necessary to create this sentiment now that the irrigation law has been passed and an avail-

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able reclamation fund is now a reality? Simply because our beginning is in its veriest infancy—the passing of the law but the birth of the movement as it were—and the present fund ($23,000,000) only the cornerstone of what must come after. It is very much as if we were passing the kitchen door and accidentally caught a whiff of the feast being prepared therein.

Why, the entire fund can be used three times over in the State of Washington alone, and even then you would not have fully utilized the available water nor exhausted the supply of irrigable land.

For another example, take Montana, where fully $200,000,000 can be spent in putting the available water upon one-third of the lands suitable for irrigation.

What are you going to do? Will the good people of your respective States accept the sums now set aside for the various projects and rest content for the next score of years, or will they arouse from their lethargy and assist in creating a sentiment which, in its demands upon Congress for increased appropriations will prove irresistible?

Congress, so often looked upon as a huge piece of unwieldy public machinery, should be viewed in a different light. Picture it rather as a gigantic mirror reflecting the hearts and minds of the people, and according to the national distribution of population, about nine-tenths of that reflection emanating from the eastern half of the United States. This, then, will be the proposition for congressional aid. One-tenth, or the West, petitioning the other nine-tenths, or the East. Do you think you will be able to get it upon the bare assertion that it is necessary to the welfare of Western development? Certainly you will not. The Eastern congressman has fish of his own to fry and his natural philanthropy is, as yet, a very uncertain quantity. Go to them, however, with a cold business proposition and you will gain attention. Whisper to the "powers behind the throne," or in other words, the great commercial interests of the East, that west of the Mississippi valley there are lying dormant and awaiting only "the man with the hoe," natural resources capable of supporting the entire population of the country to-day.

SHOULD BE AN EFFECTIVE APPEAL.

Picture to their commercial minds the millions upon millions of acres wrested from their bonds of aridity, transformed and supporting a dense and prospering agricultural population. Sound the notes of commercial conquest and you will have struck the chord of the Eastern heart. It was this appeal that finally passed the irrigation law in 1902, and it will need but a similar effort to secure the additional funds soon to be needed.

Now this is exactly what the National Irrigation Association is and has been doing. Not only are we enlisting the efforts of the East, but by bringing the facts before the people of the West a sentiment is being created toward the same end.

Allow me to say in closing that the most appalling obstacle in the whole plan is our present system of land laws. Not that these laws have not been of certain benefit to Western development, but that they have outlived their term of usefulness and are now but retarding the irrigation movement, and in fact actually threatening the life of it.

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THERE IS SENTIMENT AGAINST THEM.

The most emphatic demand that the East makes is for a reconstruction of land legislation, or in other words, the repeal of the Stone and Timber, and Desert Land Acts and the commutable portion of the Homestead Law. The East wants trade field and homes on the land. It wants this money spent for the benefit of expansion of internal trade and not to enrich speculating corporations and a few wealthy individuals whose only ambitions are to absorb vast areas of public domain.

Provided it is legal for these great tracts of land to pass into private ownership for future speculative purposes, is it just and to the welfare and prosperity of the nation when that same land might be supporting in contented independence hundreds of thousands of poverty stricken men, women and children now struggling for a miserable livelihood in our congested Eastern cities? Is it right that the scarred remnants of our great timber resources should continue to be exposed to the ravages of fire and the devastating methods of present day lumbering, when upon their preservation depends the future success of this whole irrigation movement as a means of water supply? These are some of the questions which the National Irrigation Association is endeavoring to solve in the minds of the American people to-day, and they are questions which you will be called to pass upon before this convention closes. If you, as delegates to this Congress are here for the purpose of furthering the prosperity of the localities which you represent, if you are working in the cause of humanity and the upbuilding of the nation, then take unto yourselves the true spirit of the irrigation movement, the greatest good to the greatest number, and proceed to crown the achievements of the 12th Irrigation Congress in the way you should have crowned them at Ogden, Utah, in 1903.

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Section Climatology.

CHAIRMAN: H. E. WILLIAMS,
Assistant Chief U. S. Weather Bureau, Washington, D. C.

Sessions were held on the morning and afternoon of November 16th, and on the morning of November 17th. A set of charts, consisting of twenty-six different maps, illustrating the climatology of the United States, was displayed on the walls of the room and a large number of Weather Bureau publications were distributed to the delegates and visitors.

The following papers, read before the section, are published in the Proceedings of the Congress. A number of other excellent papers were read, but owing to lack of space, they were unavoidably omitted from the published proceedings:

1. "Wet and Dry Seasons in California and Arizona." Prof. Alexander G. McAdie, U. S. Weather Bureau, San Francisco, Cal.

2. "Snowfall in the Mountain Districts in the Arid Regions and its Relations to Irrigation." Mr. F. H. Brandenburg, District Forecaster, U. S. Weather Bureau, Denver, Col.

3. "Periodic Variation of Rainfall in the Arid Regions." Mr. W. B. Stockman, Chief of Records Division, U. S. Weather Bureau, Washington, D. C.

4. "Evaporation Observations in the United States." Mr. H. H. Kimball, Librarian and Climatologist, U. S. Weather Bureau, Washington, D. C.

5. "Seasonal Precipitation in the Arid Regions as Related to Plant Life and the Growth of Crops." Mr. C. E. Linney, Section Director, U. S. Weather Bureau, Santa Fe, N. Mex.

6. "A Climatological Dictionary for the United States." Prof. A. J. Henry, U. S. Weather Bureau, Washington, D. C.

7. "Long-Range Weather Forecasts." Prof. E. B. Garriott, U. S. Weather Bureau, Washington, D. C.

8. "Distribution of Rainfall in Texas." Mr. W. H. Alexander, U. S. Weather Bureau, Galveston, Tex.

9. "Work of the Rain-makers in the Arid Regions." Mr. G. E. Franklin, Local Forecaster, U. S. Weather Bureau, Los Angeles, Cal.

10. "The Collection and Dissemination of Climatological Data and Weather Forecasts." Mr. James Berry, Chief of Climate and Crop Division, U. S. Weather Bureau Office, Washington, D. C.

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WET AND DRY SEASONS IN CALIFORNIA AND ARIZONA.

PROFESSOR ALEXANDER G. MCADIE, U. S. Weather Bureau, San Francisco, California.

The country mentioned above has been somewhat poetically called "The Land of Little Rain," but to one traveling in this section during the months of August and September of the current year the characterization given must have seemed out of keeping with the general appearance of the soil. Probably not within recorded history have such heavy and frequent rains been reported; day after day throughout the so-called arid region, especially in the mountains, thunderstorms, cloudbursts, or washouts occurred. The rain, sometimes falling at a rate of an inch an hour, washed the soft surface soil. Every mountain peak seemed to be an energetic water-vapor condenser. As there is little or no forest covering, brush or grass to hold back the flow—the run-off was both rapid and destructive. All transportation companies doing business in southeastern California, Arizona, New Mexico, Utah and Colorado, underwent an experience in repairing washed out roadbeds, weakened bridges, etc., which will long be remembered. Nothing seemed able to withstand the onslaught of the water, moving with considerable velocity and loaded with detritus. Every little water-course was a source of danger to travel.

Naturally the season has been compared with previous wet seasons, and one hears on every hand tales from memory concerning damage and high water marks of previous years.

Without further delay let us agree upon the fact that seasons differ, that there are well marked wet and dry periods and that if it were possible to forecast (upon a scientific basis of course) the general character of an impending season, the achievement would be one of immeasurable value to all who live in the Southwest. The farmer would know in advance whether to sow or not; the merchant could discount the probable volume of trade, the stockman estimate the probable feed on the ranges and stock accordingly, the engineer plan ahead for needed power; and every man in his own way turn to account this fore-knowledge of the seasonal condition.

CAUSES UNKNOWN WHICH PRODUCE VARIATIONS.

Causes there must be for these marked variations in seasons, and causes which we believe will yet be understood by man; but not yet are these known. It is easy to fancy that periodicities exist, and it is most natural to correlate seasons which seem to be similar and assume that there will be similar sequences. But to the sane and dispassionate investigator the records of years show chiefly wet seasons sometimes following wet seasons, sometimes dry seasons, seasons beginning with early rains and promising much only to prove disappointing. Dry periods will occur most unexpectedly—sometimes in the heart of a wet season—and in brief no periodic law appears to exist. Our records in California are exceedingly valuable as at several points these now cover a period of fifty-five years. The rainfall data are strictly comparable, the instruments and methods used having been reduced to present

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standards. Tables showing the rainfalls for every day for fifty-five years have been prepared; and from these in turn the wet and dry winter months have been collected, grouped and studied. Abnormal rainfalls have been compared with normal conditions; but there appears to be no apparent periodicity either in frequency or intensity.

It is well to explain that we consider the number of rainy days in a wet season, as well as the amount of rainfall. It makes a great difference in the character of the season whether the rain falls in a few heavy showers or is distributed throughout a long period. The effect upon crops, for example, is evident.

NO REGULAR SEQUENCE OF WET AND DRY SEASONS.

Considering then, both frequency and intensity, we find that there appears to be no regular sequence of wet and dry seasons, nor may we even assume that a season with marked dry or wet characteristics at its beginning will necessarily continue so to the close. We have, however, been able to detect a general relation between the permanent pressure movements and the general character of the seasons. During wet winters the Continental High is displaced well to the east of the Rocky Mountains, while the North Pacific Low extends well inland, overshadowing western Washington. An example of this is the chart for February, 1902. There were no pressure readings in early years; but so marked is the relation that we can feel reasonably sure that January, 1862, 1866, 1869, 1878; February, 1854, 1857, 1878, 1887; and December, 1852, 1866, 1867, 1871, 1880, 1889, were months of similar pressure distribution. Such a distribution is favorable for frequent southerly winds, of rather high velocity. This is a rain-bearing wind, and the angles of inclination of flow of the low air to the mountains are such as to favor slow, uplifting, cooling, and condensation. The *dry* type is shown in January, 1904. The reason why it does not rain under such a distribution is the steady, slow drift of the lower air, outward from the high; that is, from the northwest. This air can have but little vapor content and moreover passes down the western slope of the Sierra, being probably still further dried. This, then, is the type for January, 1851, 1852, 1889, 1891, 1902, 1904; February, 1851, 1852, 1856, *1864*, 1875, 1885, 1886, 1888, 1889, 1896, 1900; December, 1854, 1865 1874, *1876*, 1883, 1901, 1903.

The difference between the air movement in wet and dry seasons is shown by the series of maps herewith. We are interested chiefly in the movement of the lower air; but as it is advisable to know also the air flow at higher levels charts showing the isobars for 3500 feet and 10,000 feet are also given.

The present year serves as an excellent example of the difference between wet and dry conditions. January was dry, February wet. Why should January be dry? Chart 4 shows the isobars and isotherms at sea level and resultant surface winds for January. On such a map we expect a minimum rainfall in southern California, Nevada, Utah and Arizona. This was the case. The isobars at 3500 feet indicate a westerly drift, and at 10,000 feet, a general southwest drift. February (chart 8) shows a southerly surface

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drift, and chart 9 compared with chart 5 shows the great difference in rainfall resulting. Chart 10 compared with chart 6 shows more plainly the difference in air circulation. The contrast is brought out in a more striking way by chart 11. It is plain, then, that the swinging of the great pressure belts north and south either causes or coincides with storm movement and intensity of rainfall. But what causes the swinging of the pressure areas? And are the movements progressive? These are the great questions waiting solution; and when they are solved, then the forecasting of the seasons will be established on a proper basis. The trend of modern scientific investigation is to correlate these pressure movements. Hann's studies covering fifty years of European rainfall records indicate that the great pressure areas vary inversely. A striking illustration of this is that the winter temperature of northwestern Europe rises when the great "low" over Iceland is unusually deep and conversely there is cooler weather in Europe when the same "low" is flat.

ADVANTAGES OF A WORLD'S WEATHER SERVICE.

The meterologists of India are keenly alive to the importance of a foreknowledge of the breaking of the Southwest Monsoon in May; and we in California, although better able to undergo periods of deficient rainfall, may well study the pressure swings over the North Pacific and the seasonal conditions in Japan for January, February, March and April. And some day, let us hope, the Weather Services of the world will interchange reports, and the procession of "highs" and "lows" around the girdle of the earth be thus closely followed. The forecasters along the line will foresee conditions favoring stagnation or, on the other hand, unusual activity.

Prominence has been given in this paper to the winter rains of the Southwest. The other type of rain, that of the summer months, can be also thus investigated. The Mexican, or Sonora rains, are found to occur in excess under certain pressure anomalies. The present season showed a well marked barometric minimum stretching from the country between the Colorado and Rio Grande northeastward to the Missouri. Into this sink there was a steady indraft of southerly moisture-laden air. The mountains acted energetically to condense the vapor.

Under such conditions an individual disturbance such as developed over the Southwest on September 26, 1904, may last for several days and be accompanied by phenomenally heavy rain. The rains from September 26th to 30th of the present year will long be remembered in the Southwest, causing as they did the most extensive and destructive floods in its history. El Paso, for example, had a rainfall of 3.50 inches, or 2.39 inches above the normal; Kent, 6 inches, or 4 inches above the normal; Fort Davis, 7.86 inches, or 4.65 inches above the normal; Santa Fe, 5.37 inches, or 3.89 inches above the normal; Las Vegas, 6.07 inches, or 3.90 inches above the normal; Raton, 7.38 inches, or 6.49 inches above the normal. The normal annual rainfall over a large part of the area in question varies from 10 to 15 inches. During the one month of September from 4 to 6 inches of rain fell. It would be hard to find a more striking illustration of abnormality in seasonal rainfall.

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THE SNOWFALL IN THE MOUNTAIN DISTRICTS OF THE ARID REGION AND ITS RELATION TO IRRIGATION.

F. H. BRANDENBURG, District Forecaster, U. S. Weather Bureau, Denver Colo.

For some years the kindred subjects of forestry and irrigation have overshadowed in importance all other public questions in the so-called arid and semi-arid regions of the United States. From matters of strictly local concern, they have developed into subjects of national importance, and with national importance has come national aid. For several years the best available talent, practical and technical, has been devoted to the discovery and application of ways and means for the development of the one and the promotion of the other, until mere hopes have become theories, and these theories have in turn become practical and visible certainties; so that our attention is no longer concerned with a demonstration of the needs and desirability of irrigation and forestry, but with the location of reservoirs, canals and ditches, and the actual restoration and preservation of our forests.

As recently said by President Roosevelt, "None of our internal policies will be of more consequence to the future of the country during the next few decades than this matter of irrigation."

The value of artificial aid in the raising of crops by irrigation was early recognized, though its origin is lost in antiquity. Prof. Gipps, in a paper read in 1887 before the Royal Society of New South Wales, stated that the earliest known reservoir was constructed 2084 B. C., to regulate the inundations of the Nile. In this hemisphere, evidences of the use of irrigation canals and ditches by an earlier civilization are still visible in Colorado, New Mexico, Arizona, old Mexico and South America.

The necessity of reservoirs and the construction of such reservoirs and canals, presupposes the existence of a water supply, and this supply is naturally traced ultimately either to rain or to snowfall. Of these two sources of supply, it is the latter, in its relation to irrigation, that we intend to discuss in this paper.

In the arid region of the United States, rainfall is irregular and uncertain, while the amount thereof varies greatly even in the same section. The fall of snow in the higher altitudes, though also varying greatly, nevertheless is more certain and less variable than the rainfall. At times the rainfall is so heavy and the run-off, since the denuding of the ranges, is so rapid, as to produce floods, with consequent destruction of life and property. Except in localities where forests, the natural reservoirs of the snowfall in high altitudes, have been destroyed, the result of heavy snowfall is more beneficient, the flow therefrom more easily controlled, and, within irrigated areas, is accordingly productive of better results than the flow from heavy rainfall. No scheme of irrigation in the western part of the United States can therefore be successfully established and maintained, without an intimate knowledge and accurate understanding of the extent of the snowfall in the regions in which the rivers and smaller streams furnishing the supply have their sources. The best available records for the ascertainment of this necessary information

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are those kept by the Weather Bureau. It is from its records of 137 highest stations, many of which records cover a peroid of ten years, that the data now presented have been compiled.

IRRIGATION SOURCES FORMED AT GREAT ALTITUDES.

In the arid regions proper, the streams that afford the principal sources of supply for irrigation rise along the Continental Divide and the parallel ranges to the west, or among their spurs. The snowfall of value as a source of supply for irrigation during summer may safely be limited to areas in excess of 7000 feet in altitude. The area of territory above 7000 feet in altitude, embraced in the States and Territories of Idaho, Nevada, Utah, Arizona, New Mexico and Colorado, is 112,426 square miles. California, partly arid, has 6246 square miles.

In the study of snowfall in relation to irrigation, it would seem that the ascertainment of the seasonal snowfall should prove of greater value than data as to the snowfall for the calendar year. The averages now presented are, for that reason, the seasonal averages. In Colorado the average for the area between 6000 and 7000 feet is 54 inches; between 7000 and 8000 feet, 58 inches; for the next thousand, the amount is 121 inches, while for the next 1000 feet there is an increase, but not so marked, the value being 145 inches. In Wyoming between 6000 and 7000 feet the average is 40 inches; between 7000 and 8000 feet, 57 inches; and practically double that value, or 110 inches, between 8000 and 9000 feet. Beginning with the area between 6000 and 7000 feet and taking succeeding elevations of 1000 feet, the values for New Mexico are 19 inches, 40, 50, and 76 inches respectively, the last being for the area between 9000 and 10,000 feet. In Nevada, for the area between 6000 and 7000 feet, the records of a large number of stations give an average of 72 inches; for higher altitudes the data are insufficient, but the snowfall is doubtless greater. The same is true of the higher altitudes in Utah, though the records of many stations in that State are available for 6000 to 7000 feet and 7000 to 8000 feet, the values being 56 inches and 41 inches respectively. For Idaho, Montana and Arizona, data are available only for 6000 to 7000 feet. In Idaho the average is 103 inches, in Montana 42 inches, and in Arizona 46 inches. For the the entire area above 6000 feet in Colorado the average for the driest season is 64 inches, while for the wettest the average is 150 inches.

In Wyoming it is 55 inches for the driest as against an average of 99 inches for the wettest. In New Mexico the extremes are 26 inches and 69 inches; Nevada, 33 inches and 101 inches; Utah, 16 and 84 inches; and for 6000 to 7000 feet the extremes are: in Montana, 29 and 72 inches; Idaho, 60 and 160 inches; Arizona, 20 and 86 inches.

In view of the variations in the amounts of snowfall of different seasons, as just shown, it is manifest that irrigation interests are much concerned as to the minimum and maximum amounts that may be expected during a season. The greatest seasonal amounts of snowfall within the arid States, shown by the records, are as follows; Montana, at Butte, altitude, 5728 feet, 94 inches; New Mexico, at Chama, altitude 7862 feet, 148 inches; Utah, at Park City, altitude 6846 feet, 195 inches; Arizona, at Flagstaff, altitude 6907

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feet, 208 inches; Wyoming, at Battle, altitude 9916 feet, 246 inches; Idaho, at Atlanta, altitude 7000 feet, 318 inches; Colorado, at Ruby, altitude 10,000 feet, 644 inches; and Nevada, at Fordyce Dam, altitude 6500 feet, 1067 inches, the minimum record at this place in ten seasons being 198 inches.

During December and January the snowfall is light along the eastern slope of the Continental Divide, and it is not uncommon for almost all the snow that falls earlier in the season to melt or evaporate under the influence of the warm chinook winds that prevail during these months. April, May and June are exceedingly dry in southern New Mexico and throughout Arizona, while July is a dry month in northern Utah; in Nevada, the dry period extends throughout July, August and September.

HEAVY SNOWS ON THE CONTINENTAL DIVIDE.

On the western slope of the Continental Divide, February, March and April bring heavy snows, while in the Pacific States heavy snows on the mountain ranges are generally persistent from December to March.

Agricultural operations are most successful at altitudes below 6000 feet, with the possible exception of localities where low latitude offsets to some extent the influence of altitude. Such operations are, therefore, carried on in regions more or less remotely removed from the larger and more reliable sources of supply. The area between the agricultural districts and the higher altitude, being of a merely moderate elevation, where the snow is often melted soon after falling and almost certainly with the approach of warm weather, does not yield a large or constant supply. It is therefore manifest that the regions contributing most largely to the water supply by the melting of snow are to be found at higher altitudes, the region between 8000 and 11,000 feet being the principal source. It is true that snow falls oftener and to a greater amount above timber line, but this area is relatively very small, and being without protection from the sun and winds, a considerable proportion disappears without a corresponding increase in the water supply, while between 8000 and 11,000 feet the protection afforded by the timber not only lessens the melting as a result of the direct rays of the sun, but also partially lessens the wind movement and consequently the loss by evaporation.

Though stimulating evaporation, the beneficial effect of the high winds of winter and spring must not be underestimated. Above timber line, where there is an unobstructed wind movement, large areas are often swept bare, before the snow melts or evaporates, the winds carrying the new snow to the gulches and timber, where it is heaped up in immense drifts, or reservoirs, which release the supply gradually, as melting occurs. The packing done by strong winds is also a valuable help in prolonging the flow, and light falls of snow, which at low altitudes melt or evaporate quickly without any resultant benefit, are not lost at high altitudes, but being swept and packed into some sheltered spot contribute to the general flow with the coming of high temperatures.

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LARGE STREAMS NOT THE BEST IRRIGATORS.

The large streams, with a few exceptions, are not the main reliance of irrigation interests; this is especially true of the streams west of the Continental Divide, where the channels as a rule have been deeply eroded. Small streams on the other hand are more readily utilized, since the expense of diverting the flow is relatively small, though, as a rule, such streams drain small areas, and except at altitudes too high for successful farming, afford water for irrigation only during the first half of the crop-growing season, leaving the latter half of the season oftener than not with a scanty flow, and as a result crops suffer unless the natural flow is supplemented by flow from reservoirs or occasional rainfall.

The supply of water from melting snow is generally greatest during the middle of June, the time of the maximum flow being dependent on the temperature conditions, the absence of abnormally warm weather in the mountains during the first half of the season being a desirable factor in prolonging the flow.

Quickly following the June rise, the supply from melting snow falls off rapidly, as by that time the snow has disappeared from moderate altitudes and exposed localities at higher altitudes. Such flow as comes thereafter is from spring seepage and the gradual melting of the large and solidified snowdrifts of the early winter remaining in the gulches and in the neighborhood of the timber line. The flow from these sources is naturally small, but occasionally a large volume due to local downpours helps the situation.

NECESSITY FOR RESERVOIRS.

Statistics show that the irrigated area has doubled during the last 10 years. At the same time it is clear, in a general sense, that the limit of possible irrigation without reservoirs has been reached. It is also true that included within the area now classed as under irrigation there is considerable land for which the supply of water is neither regular nor adequate. The construction of reservoirs, therefore, would result, not merely in the extension of the irrigated area, but in making far more valuable much of the area at present classed as under irrigation.

We therefore conclude the information given demonstrates the necessity, first, and as of paramount importance, of the preservation of the forests, the restoration of denuded districts, and the prevention of the use of forests in any way calculated to lessen the natural protection to the snow afforded by them and by the vegetation throughout them; secondly, because of the irregularity in the times of melting, and in the variation of the volume of flow therefrom, the necessity for the construction of reservoirs to conserve the supply of water from melting snow in times of excess flow and its distribution as the needs of agriculture may require.

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PERIODIC VARIATION OF RAINFALL IN THE ARID REGION.

W. B. STOCKMAN, U. S. Weather Bureau, Washington, D. C.

In the preparation of this paper it was not the intention to tabulate all available precipitation data, but to compile them for a few stations in each State, and selected so as to best show the average conditions that have obtained generally over the State and region—due consideration also being given to length and continuity of record, and altitude of station.

In the compilation breaks were found in the continuity of the records from many stations, and from a number of them no record of precipitation from snowfall was obtainable.

Due to the fact that differences in altitude and local topographical features cause dissimilar conditions, or different amounts of precipitation at stations contiguous to each other, and also to the occasional occurrence of torrential rains (so-called cloudbursts), generally over a limited territory, no effort was made to pad or fill out the missing data from the records of some nearby station, but to present the data as they were recorded, except in the case of a very few stations whose contiguity and topographical features are such as to render the belief that like conditions prevailed at both stations almost a certainty. The most distant stations, whose records were thus combined, were Fort Elliott and Amarillo, Texas.

* * * * * *

In the following discussion regarding the distribution and amount of precipitation over the portions of States and Territories under consideration, it is desired to emphasize the fact that deductions are drawn only from the data that were tabulated therewith, and these stations lie between the 96th degree of longitude and the central portions of Washington, Oregon, and California.

The relatively small average annual precipitation in the Dakotas is due to their distance from the four sources of moisture of the country—the Pacific Ocean, Gulf of Mexico, Great Lakes, and Atlantic Ocean. Although the States lie in the path of practically all the storms from the Pacific Ocean that cross the Rockies, the greater portion of the moisture brought from the Pacific has been precipitated upon the various mountain chains crossed, and the other three of the sources of moisture are so far distant that the center of the disturbance has passed before much of the moisture borne in the southerly and easterly winds is released, and the winds again change to dry northerly and westerly.

RAINY PERIOD FAVORS THE DAKOTA FARMER.

For agricultural purposes the monthly distribution of precipitation is favorable, as the maximum monthly averages occur generally from May to August, inclusive, with fair amounts in April and September in North Dakota; and in South Dakota from April to August, inclusive, with fair amounts in March and in the eastern portion of the State in September. In North Dakota and eastern South Dakota the minimum averages occur in the months

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November to February, inclusive, and in western South Dakota from September to February, inclusive.

Nebraska obtains its precipitation from the same sources as the Dakotas, but on account of being nearer the Gulf of Mexico—the main source of supply—the averages, as a rule, are greater than in the Dakotas.

The distribution for crop needs is very favorable, the maximum occurring generally over the State from April to August, inclusive, and in the eastern portion over September. The minimum occurs generally from November to February, inclusive, beginning somewhat earlier in the fall, and continuing somewhat later in the spring, in the western portion. As is the case in the Dakotas the average amounts decrease from eastward to westward.

KANSAS WATERED BY GULF OF MEXICO.

Kansas, as well as Oklahoma and Texas, receives most of its precipitation from the moisture-laden winds from the Gulf of Mexico. In Kansas the maximum monthly amounts occur during the growing season, from April to September, inclusive, generally over the State, and the minimum amounts from November to March, inclusive.

The precipitation is greater in Oklahoma than in Kansas with a monthly average of more than two inches in the months from April to October, inclusive. The minimum occurs from November to February, inclusive, and is generally over one inch per month.

The season of maximum rainfall in Texas varies a good deal, and the amounts diminish from the Gulf of Mexico northward, and from the eastern portion of the State westward. In the eastern and northwestern portions it occurs generally from May to September, inclusive; occasionally stations show an earlier beginning and a later ending of the periods, when the monthly average amounts to more than two inches. At El Paso there is but one month, July, when the average amounts to two inches. In this section the rainy period may be considered to cover the months of July, August, and September. Generally over the State the months with minimum amounts are from November to March, inclusive, while in the southwestern portion the rainy period continues into April, and at El Paso into June.

The conditions in southwestern Texas differ from those in the region already discussed, and should be classed with the next tier of States to be considered—Montana southward to the Mexican border—and over which area less moisture is received from the Gulf of Mexico, consequently the average monthly and annual amounts of precipitation are less than in the region to the eastward.

In Montana there is but one station that shows a monthly average of two inches, or more, other than in May and June. Havre has an average of two inches, or more, in July also. At Ft. Shaw the greatest monthly average does not equal two inches. At the majority of the stations the monthly average is less than one inch from October to February, inclusive. In the southwestern portion the minimum monthly amounts appear to occur at various seasons from late summer to early spring.

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SMALL RAINFALL IN WYOMING.

There are few months with an average of two inches, or more, in Wyoming. In the eastern part of the State the greatest monthly amounts occur from April to July, inclusive, and in the western portion somewhat earlier. The minimum averages generally occur from October to March, inclusive, except in the extreme southwestern portion where they appear to occur in the summer and early fall.

In Colorado the months of greatest precipitation vary, being from April to August, inclusive, in the central and eastern portions; in the fall and winter season in the southwestern portion, and in the summer and early fall in the west-central portion of the State. In the central and eastern portions the least precipitation generally occurs between September and March, inclusive; in the late spring in the southwestern portion; and generally in the winter in the west-central portion, although the difference between the several seasons is very slight.

MARKED VARIATION OF RAINFALL IN NEW MEXICO.

The difference in the average amounts of precipitation in New Mexico is very marked. In the northeastern portion the months of greatest precipitation are from May to October, with a small average precipitation during the remaining months. In the western portion the greatest precipitation is during July, August and September, occasionally extending into October. In this section also the average monthly amounts are small during the remainder of the year.

The distribution of precipitation in Idaho is peculiar. Generally the maximum amounts occur from November to February, or March, inclusive, but at several stations it continues into May, and at others into June. The months of least precipitation generally are July, August, and September, in some localities beginning with June, and in others extending into October, but the lack of stations and the entire want of records from some sections render any satisfactory deductions impracticable.

In Utah the average monthly amounts also are variable, and the distribution over the several portions of the State throughout the year dissimilar. In the eastern portion the greatest amounts generally occur in the months of July, August, and September, and over the central and western portions generally from October to May, inclusive, except in the southwestern portion where the season does not appear to be so long.

YUMA IS PRETTY DRY.

Arizona appears to have two rather well defined periods of maxima and minima monthly amounts, and generally the maximum occurs during July, August, and September, and December, January, and February. In the western portion of the Territory, especially the southwestern portion, the average annual amount is very small, and is but 2.65 inches at Yuma, which is considerably less than some of the average monthly amounts at several stations in the southeastern portion of the Territory.

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In Nevada also the annual amounts differ considerably and are least in the western portion of the State.. The northern portion has somewhat larger averages than the eastern, but considerably less than the southeastern portion. The months of greatest precipitation are from December to March, inclusive, and at some stations extending into April and May.

A COUNTRY OF RAINY SEASONS.

In Washington there is a well-defined rainy season which begins in September and continues into June in the eastern portion, as it also does in sections of the west-central portion. In the northwestern section the rainy season appears to be from November to February, inclusive.

In Oregon a well-defined rainy season obtains and continues generally from November to June, inclusive, and in portions of both the eastern and western sections begins in October.

California's precipitation varies greatly in amounts, ranging from 1.87 inches at Mammoth Tank to 81.66 inches at Upper Mattole. It also has well-defined rainy and dry seasons, the beginnings and endings of which very in different portions of the State, the rainy season as a rule covering the period from January to April. The least precipitation in the State occurs in the southeastern portion.

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EVAPORATION OBSERVATIONS IN THE UNITED STATES.

H. H. KIMBALL, Librarian and Climatologist, U. S. Weather Bureau.

It is important that irrigation engineers should know not only the rainfall, but also the evaporation over any given region. Unfortunately, the measurement of evaporation presents many more difficulties than the measurement of precipitation. In fact, the rate of evaporation from land surfaces depends upon so many different elements that it can be treated only in the most general manner. Thus, it has been shown that the evaporation from saturated soil covered with growing plants is greater than from a water surface, but becomes less when the level of complete saturation falls a few inches below the soil surface, and continually diminishes as this level recedes to increasing depths. Also, the evaporation from a forest of evergreen trees is greater than from a forest of leafy trees; from the latter it is greater than from grass, from which in turn it is greater than from bare soil. The composition of the soil has its effect upon the rate of evaporation, and so also has the state of cultivation. Furthermore, the rate of evaporation from any surface has been found to vary with its temperature, with the quantity of moisture in the air, and with the wind velocity.

Even if we were able to determine the exact relation between each of these elements and evaporation, we see at once how hopeless it would be to undertake to compute accurately the evaporation over any very extensive region of land surface. It is therefore customary to deduct the run-off from the rainfall over a watershed, and to attribute the difference to evaporation. This has been done by Mr. George W. Rafter in Water Supply and Irrigation Papers No. 80, U. S. Geological Survey, for twelve drainage basins in the eastern part of the United States, as follows:

	Years of Record.	Rainfall.	Run-off.	Evaporation.
1. Muskingum River, Ohio	1888–1895	39.7	13.1	26.6
2. Genesee River, N. Y.....	1890–1898	40.3	14.2	26.1
3. Croton River, N. Y.	1877–1899	49.4	22.8	26.6
4. Lake Cochituate, Mass.....	1863–1900	47.1	20.3	26.8
5. Sudbury River, Mass.....	1875–1900	46.1	22.6	23.5
6. Mystic Lake, Mass.....	1878–1895	44.1	20.0	24.1
7. Neshaminy Creek, Pa	1884–1899	47.6	23.1	24.5
8. Perkiomen Creek, Pa.....	1884–1899	48.0	23.6	24.4
9. Tohickon Creek, Pa	1884–1898	50.1	28.4	21.7
10. Hudson River, N. Y.....	1888–1901	44.2	23.3	20.9
11. Pequannock River	1891–1899	46.8	26.8	20.0
12. Connecticut River	1872–1885	43.0	22.0	21.0

The rainfall and run-off have been computed for many other watersheds in the United States, particularly in California, where the run-off is a much smaller percentage of the rainfall than in the eastern States.

As a practical problem in irrigation, however, the evaporation from water surfaces is of more importance than the evaporation from land surfaces. The

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engineer will naturally determine his water supply, not from the annual precipitation, but from the run-off of available streams. Having determined this, the question of losses becomes important, and if storage basins are of considerable area the loss by evaporation in a dry climate becomes very serious, having been estimated to be as much as 30 to 50 per cent of the amount stored in some cases.

Fortunately, the determination of the evaporation from a water surface presents fewer difficulties than the evaporation from land surfaces. Generally speaking, the determination may be made by two quite different methods; (1) by direct measurements from properly exposed water surfaces, and (2) by computations based upon the temperature of the water surface and the value of certain meterological elements. With proper attention to exposure, direct measurements of evaporation from water surfaces should give the more reliable results. Unfortunately, proper exposure is not always practicable, and it is therefore necessary to consider the character of the exposure in connection with each series of evaporation experiments, and in some cases to apply a correction before the results will fairly represent the evaporation from a reservoir or a lake.

One of the most exhaustive series of evaporation experiments in the United States was conducted by Mr. Desmond Fitzgerald,[1] between the years 1876 and 1886, in connection with the reservoirs of the Boston water works. He not only measured the evaporation directly by means of tanks floating on the surface of reservoirs, some of them arranged to record automatically the rate of evaporation, but he also conducted elaborate experiments to determine the relation between the rate of evaporation, the temperature of the water surface, the temperature of the air, the amount of moisture in the air, and the movement of the air.

He found that the rate of evaporation depended upon three elements: The vapor pressure corresponding to the temperature of the surface of the water, the vapor pressure corresponding to the dew point of the atmosphere, and the velocity of the wind.

Representing by E the evaporation in inches per hour from a water surface, by e_s the vapor pressure in inches corresponding to the surface temperature of the water, by e_d the vapor pressure corresponding to the dew point of the atmosphere, and by $\underline{v}$ the wind velocity in miles per hour, he obtained

$$\left(E = 0.0166 \left[e_s - e_d \right] \left(1 + \frac{v}{2} \right) \right)$$

as the equation for the hourly rate of evaporation. This equation he found to hold good for an ice surface as well as for a water surface, in the shade as well as in sunshine, and by night as well as by day.

Measurements of evaporation from the water in a tank three feet cube, the top flush with the surface of the ground, have been made since 1887 at Fort Collins, Colo.,[2] under the direction of Professor L. G. Carpenter. The tem-

1)—Transactions of the American Society of Civil Engineers, Vol. 15, p. 581.
2)—See Annual Reports of the Agricultural Experiment Station, Fort Collins, Colo.

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perature of the water in the tank was found to be lower than the temperature of the water in reservoirs and lakes in the vicinity, and in consequence the evaporation was less. Fitzgerald[3] notes a like deficiency in temperature and evaporation in connection with tanks set in the ground near Croton reservoir, N. Y.; but at Lakeport, and Kingsbury Bridge, Cal., the temperature and the evaporation as measured in a tank set in the ground were found to exceed like measurements in tanks floating in lakes. Since a great many measurements of evaporation have been made from tanks set in the ground, it is important that these discrepancies in water temperature and evaporation be borne in mind.

From his investigations in 1889 Professor Carpenter found that the daily evaporation could be very accurately expressed by the equation

$$(E=0.3868\ [e_s-e_d]\ (1+0.0025W).$$

in which W represents the wind movement in 24 hours, the other symbols having the same significance as in Fitzgerald's equation. Reduced to a like period, the latter becomes

$$(E=0.3984\ [e_s-e_d]\ (1+0.0208W)$$

The agreement between the two is quite remarkable when we consider the difference in the climatic conditions at the two stations. The difference in the values of the co-efficient of W was attributed by Professor Carpenter to the fact that Fitzgerald measured the wind velocity at the surface of the water, while Carpenter's wind velocities were obtained from an anemometer on the roof of the college building.

Subsequent observations served to confirm the accuracy of his formula, and after ten years, by means of comparative readings between his standard tank and tanks floated on water surfaces, he computed the average annual evaporation from a free water surface at Fort Collins to be 59.5 inches instead of 46.3 inches as he had measured it.

In 1887 and 1888 Professor T. Russell,[4] of the U. S. Signal Service, investigated the rate of evaporation in standard thermometer shelters by means of observations with Piche evaporimeters. This instrument, as is well known, consists of a glass tube about nine inches long and 0.4 inch internal diameter, hermetically sealed at the top. Over the bottom is placed a disk of porous paper, which is held in position by a copper disk pressed against the open end of the tube by a suitable spring attachment. Capillary action keeps the paper moist. Its exposed area is known, and the amount of evaporation is determined by means of a scale etched on the side of the tube.

To determine the relation between the rate of evaporation from a Piche evaporimeter and a water surface, Russell exposed two of the Piche instruments in a closed room in which were two open tin dishes filled with water. Both the Piche evaporimeters and the dishes were weighed at frequent intervals, and it was found that the Piche instruments evaporated 1.33 times as fast as the open dishes. Eighteen Piche instruments were then exposed at various Signal Service stations from May 31 to September 30, 1888, and the

3)—See Proceedings American Society of Civil Engineers, Vol. 15, p. 617.
4)—Monthly Weather Review, 1888, p. 235.

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observed quantity of evaporation was divided by 1.33 to reduce it to the evaporation from a water surface. By the method of least squares, the relation between the rate of evaporation, the temperature of the evaporating surface, and the amount of moisture in the air, was determined from observations made during the month of June. The temperature of the evaporating surface in this case was the same as that of the wet bulb thermometer, and the monthly rate of evaporation was found to be quite accurately expressed by the equation

$$E = \frac{43.88\ [e_w - e_d] + 1.96\, e_w}{B}$$

in which e_w is the vapor pressure in inches corresponding to the temperature of the wet bulb thermometer, e_d is the vapor pressure corresponding to the dew-point of the atmosphere, and B the barometric pressure in inches. By means of this formula Russell computed the monthly evaporation at 140 Signal Service stations from July, 1887, to June, 1888, inclusive, using the monthly mean wet bulb and dew-point temperatures derived from tri-daily observations. From the data thus computed the accompanying chart showing "Lines of equal annual depth of evaporation in inches" was prepared. Russell states his belief that these figures represent approximately the evaporation that takes place from the surface of ponds, rivers, reservoirs, and lakes, in the vicinity of Signal Service stations, basing his belief principally upon the results of evaporation experiments conducted under the direction of the Central Physical Observatory at St. Petersburg, from May to October, 1875, and discussed by Ed. Stelling in Band VIII, No. 3, of Wild's Repertorium fuer Meteorologie, 1882. Stelling's equation, however, is

$$(E = A\ [e_s - e_d]\ (1 - Bv)$$

which is identical in form with Fitzgerald's, the symbols having the same significance. His constants were computed for the centigrade system, were found to vary with the seasons, and are therefore not easily comparable with Fitzgerald's.

Russell's formula, however, departs radically from those of Fitzgerald, Carpenter and Stelling, in that it substitutes the vapor pressure corresponding to the temperature of the wet bulb thermometer for the vapor pressure corresponding to the surface of the water, and adds a term depending upon this same vapor pressure, d_w, in place of the wind velocity term. This latter is dropped, and the equation represents the evaporation with a wind velocity outside the shelter of 7.1 miles per hour, which was the average at the stations where the Piche observations were being made, during June, 1887.

It is evident that this wind velocity will not apply to all parts of the United States for all seasons of the year. Neither will it do to substitute the temperature of the wet bulb thermometer for the temperature of the water surface, the former being cooler than the latter. No doubt the additive term containing d_w compensates for this substitution in a measure, but we must conclude that Russell's formula does not rest upon as sound a physical basis as does the formula of Stelling, Fitzgerald, and Carpenter. The term $\frac{1}{B}$ was

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introduced on account of the wide variations in the value of B at the different stations. It is unimportant when discussing the observations at a single station.

Upon the organization of the Irrigation Survey by the U. S. Geological Survey in 1888, arrangements were made for measuring the evaporation at several points in the arid regions of the United States. It was recognized that the rate of evaporation depended upon the dryness of the air, the temperature of the water surface, and the velocity of the wind at the water surface. An effort was therefore made to measure the evaporation from a water surface having the same temperature as the surface of lakes or reservoirs, and exposed to the same wind velocity. To accomplish this galvanized iron evaporating pans three feet square and 18 inches deep were floated on the surface of the body of water from which the evaporation was to be measured. The pans were kept nearly full, with the surface of the water in them about on a level with the water outside. The amount of evaporation was at first measured by some sort of gauge, but later was determined from the amount of water added to bring the surface to the top of a pin projecting from the center of the pan. A record of the water temperature inside and outside the pans was kept. Usually a difference was noted, the inside temperature being higher in the daytime and lower at night. The average is, however, about the same in each. It is not probable that the water in pans is exposed to quite so high a wind velocity as is the average over outside surfaces, but to offset this the water in the pan wets the sides, and this increases the evaporating surface. It is therefore assumed that in general the evaporation from a floating pan of this type when kept nearly full represents the evaporation from the outside water surface very closely.

Several of the agricultural experiment stations measure the evaporation from pans, but most of them are set in the ground, and for reasons already given their indications are not considered so accurate as those from floating pans.

For the purpose of checking Russell's computed values, the following table has been prepared. In the first two columns are the names of stations and the evaporation computed by Russell. In the following columns are the names of neighboring stations at which measurements of evaporation from water surfaces have been made, the amount of evaporation measured, and the character of the exposure. We are thus enabled to judge of the probable value of Russell's chart.

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Annual Evaporation.

Russell's Formula.			Surface Measurements.	
Stations.	Evaporation, Inches.	Stations.	Evaporation, Inches.	Exposure.
Boston	34.4	Boston	34.78	Beacon Hill Reservoir.
.....	.....	Boston	39.11	Floating pan, Chestnut Hill Reservoir.
New York	40.6	New York	39.64	Floating pan, Croton Reservoir.
Cheyenne	76.5	Laramie, Wyo	46.30	Ground.
.....	.....	Fort Collins, Colo	46.16	Ground.
.....	.....	Fort Collins, Colo	59.50	Computed for reservoir.
El Paso	82.0	Fort Bliss, Tex	82.65	Floating pan.
Salt Lake City	74.4	Fort Douglas, Utah	42.46	Floating pan.
Arizona:				
Fort Grant	101.2	Tucson	75.78	.....
Prescott	56.0	Tempe	65.00	Floating pan.
California:				
Sacramento	54.3	Lakeport	32.38	Floating pan.
.....	.....	Lakeport	33.40	Ground.
Fresno	65.8	Kingsbury Bridge	47.79	Floating pan.
.....	.....	Kingsbury Bridge	59.49	Ground.
Los Angeles	37.2	Arrowhead Reservoir	36.6	Ground, (Elevation 5,160 feet.)
San Diego	37.5	Sweetwater Reservoir	57.55	Floating pan.

The results above given are not strictly comparable since the stations are not in all cases identical, and in some cases, especially in California, the reservoirs are at a greater height than the Weather Bureau Stations, and, in consequence, the water surfaces are correspondingly colder. Generally speaking, Russell's results appear to be the higher.

Since Russell's equation was deduced from tri-daily observations, it is not applicable to the present 8:00 a. m. and 8:00 p. m. observations of the Weather Bureau. The equation of Fitzgerald and Carpenter appears to have a quite general application, provided we know the temperature of the water surface, the dew-point, and the wind velocity. It would seem, therefore, that in the absence of reliable measurements of evaporation from water surfaces an effort should be made to determine the temperature of water surfaces near Weather Bureau stations; and where the evaporation is measured from tanks sunk in the ground the relation between the temperature of this evaporating surface and the temperature of lakes or reservoirs in the vicinity should be carefully determined.

Seasonable evaporation naturally varies with geographical position. Some of its peculiarities are shown in the following table:

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Evaporation in Inches.

Month.	Boston.	Fort Collins.	Lakeport.	Fort Bliss.
January	0.90	1.50	0.85	2.35
February	1.20	2.00	0.60	2.45
March	1.80	3.50	2.00	6.25
April	3.10	5.00	2.82	7.35
May	4.61	6.50	3.85	10.85
June	5.86	8.00	4.30	11.20
July	6.28	9.50	5.90	9.60
August	5.49	8.50	4.70	9.50
September	4.09	6.50	3.72	9.20
October	2.95	4.50	2.12	6.80
November	1.63	2.50	0.65	4.15
December	1.20	1.50	0.85	2.95
Year	39.11	59.50	32.38	82.65

Several series of evaporation measurements that do not cover the winter season have not been referred to in this paper. While they are of value, the above table indicates the importance to irrigation engineers that the readings be made throughout the entire year.

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SEASONAL PRECIPITATION IN THE ARID REGION AS RELATED TO PLANT LIFE AND THE YIELD OF CROPS.

CHAS. E. LINNEY, U. S. Weather Bureau, Santa Fe, New Mexico.

Large areas of our arid West have come under the beneficent influence of the irrigation ditch and are thus no longer dependent upon nature's supply of precipitation, but much larger areas are still barren because of scant rainfall, and on still other large areas settlers are having a severe struggle in an effort to cultivate with naught save nature's gift. As there is a steadily increasing demand upon the source of supply, over much of the irrigated area, if nature can be depended upon to furnish a part of the required moisture, the draft upon the over-burdened mains and ditches will be correspondingly lightened, and indeed the number of acres irrigated may be correspondingly increased. That you may understand approximately what the seasonal precipitation is over the arid region, I beg your indulgence in quoting a few figures, for the seasonal precipitation is the life of the "dry farmer," and should be a material aid to the irrigator throughout much of the arid West, and one, too, that he should have reason to anticipate.

In the report of the Chief of the Weather Bureau for 1896-97, normal precipitation data are given for the entire country, and from these figures it appears that for the season from April 1st to September 30th, about 15 inches of rainfall may be expected along the 100th meridian, with a minimum amount of 8 inches; decreasing thence to the 105th meridian, the amount falling to 9 inches, with a minimum amount (in southeast Wyoming and in the vicinity of our convention city) of less than 4 inches, while from the middle plateau and the adjacent mountain country westward to the 115th meridian the fall rarely ever exceeds 10 inches, usually 5 to 8 inches, with minimum values of 1, 2 or 3 inches. It will thus be seen that all eastern slope irrigators may resaonably expect nature to carry a third to a half of the moisture burden, and that occasional seasons of bountiful and well distributed rainfall may be expected when the amount of irrigation water required can be reduced to a minimum. This will more clearly appear presently, after a brief study of water duty, and the minimum amount of water that is required for profitable crop production.

IN THE "WEBFOOT" COUNTRY.

Professor Henry, in this same report, summarizes the annual rainfall as follows: "There is a narrow belt of very heavy rainfall on the northwest coast, extending from Cape Flattery on the north, to midway of the Oregon coast on the south, and inland as far as the summit of the coast range, including in that designation the main and collateral ranges of mountains extending from southern Oregon to the Straits of Fuca. Eastward and southward the annual fall diminishes, reaching a minimum on the lowlands and valleys included between the coast range on the west and the Sierra Nevada and Cascade ranges on the east. The precipitation increases from

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the valleys to the mountain tops, thence fall away rapidly with descent on the eastern slope until the great plateau is reached. Here the fall ranges from 5 to 15 inches, with isolated areas where it rises to 20 inches and over. There is but little increase as the western slope of the Rocky Mountains is reached, except in central and northern Idaho. The precipitation on the mountain slopes and summits is known to be large, but a qualitative statement of the annual depth can not yet be made. The rainfall of the foothills region east of the Rocky Mountains ranges from 10 to 18 inches, and increases slowly toward the 100th meridian. Eastward of that meridian the annual precipitation varies from a little under 20 inches to about 60 inches on the Florida and Gulf coast."

In the humid portions of the United States it is shown by a number of writers that about 20 inches of precipitation are used by plants, or evaporated directly from the soil, and since the methods of cultivation in those parts were not originated for the careful conservation of soil moisture, it is probable that the amount actually transpired by plants is much less, probably not as much as ten inches, yet this region is known as the humid part of the country.

WHEAT GROWN WITH FIFTEEN INCHES RAINFALL.

The exact amount of rainfall required for the successful cultivation of crops has not been definitely fixed, nor can it be in terms of rainfall only, according to Professor Henry, who states that "on the Pacific coast and over comparatively small areas in the arid regions wheat and other cereals are grown with a seasonal rainfall considerably less than 15 inches, but it should be remembered that the climatic conditions, as regards temperature and humidity, are quite different from those which obtain in the wheat region of the Northwest. The character of the soil, especially as regards its ability to retain moisture, is a very important consideration. It is said that wheat is grown in eastern Washington where the yearly fall is generally under 18 inches, that the rainfall of winter and early spring is conserved in the soil and is supplied to the plant by capillary action during the early part of the growing season."

Plants themselves need a certain minimum supply, but a far larger quantity is required to moisten the surrounding soil to such a degree that the vitalizing processes can continue. The soil is constantly losing water by evaporation and percolation, so that the amount used by the plant is relatively small.

ENORMOUS TRANSPIRATION OF GROWING PLANTS.

Professor King, in experiments carried on at the University of Wisconsin, found that 300 to 500 pounds of water were required for each pound of dry matter produced. In other words, for each ton of hay raised upon an acre of ground 300 to 500 tons of water must be provided either by irrigation or natural rainfall. Expressed in inches of precipitation (since about 100 tons of water represents an inch of rainfall to an acre of land), 3 to 5 inches of precipitation are required for each ton of hay per acre. Five inches of water were actually required to produce a ton of barley hay.

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As our western lands have had deficient rainfall and have been under clear skies for ages, the first season of irrigation often requires an enormous quantity of water. It is said that the amount in many instances has been sufficient to cover the soil to a depth of 10 to 12 feet, and that even after several years of irrigation, 5 feet of water have been used, an amount so far beyond natural precipitation that several years of the latter would be required to approach it, clearly indicating that vastly more water is used than is required. Experienced irrigators often use far more water than is necessary, under the impression that the more water used the larger the crops, and, that having paid for it, they should use it. In the arid region, where sunshine is almost continuous and evaporation large, authorities agree that for ordinary crops at least enough water should be provided to cover the soil 4 to 6 inches a month (and in our humid States the rainfall averages 3 to 5 inches); and yet carefully tilled orchards have been maintained on much less, also, no doubt, many fine gardens.

EXAMPLE OF SUCCESSFUL ECONOMICAL USE OF IRRIGATION WATER.

Successive years of deficient rainfall in California (1897 to 1900) have served to prove that with careful cultivation, crops, orchards and vineyards can be maintained by using very small quantities of water; in some cases an amount not exceeding 6 inches in depth was applied during a year, this being conducted to the plant direct, and the ground kept carefully tilled and free from weeds. Yet for good farming in most parts of the arid region a depth of 24 to 30 inches of water during the crop season should be counted upon, while larger amounts will be required for alfalfa and the higher forage crops, which are cut several times a year. These figures are borne out by Professor King, who increased the seasonal rainfall (5.72 inches) of the dry summer of 1895 to more than 31 inches, by the addition of 26 inches of water, and thereby raised the crop yield more than 200 per cent. His experiments also show conclusively that for the central valleys maximum crop yields may be had with 25 to 30 inches of rainfall during the crop season.

WEEDS WILL USE UP THE FARMER'S WATER.

Growing plants evaporate as high as 300 times their own weight of water during the growing season, and it behooves the successful farmer to pay especial attention to careful cultivation, and to the destruction of weeds and worthless plants, for these use water rapidly and eat up the profits of an otherwise profitable field, the weeds and worthless plants often taking as much or more water than the profitable ones. Careful cultivation, to keep the soil well pulverized, is especially to be urged, for this lessens the waste of water, and by providing air spaces, breaks up capillarity and prevents the escape of water, a less amount being required accordingly. When the farmer realizes that nearly one-third of the water applied evaporates from the soil and plants during the first three days after a rain, or the application of water, he will also realize how important is early and continuous cultivation.

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REGULARITY OF IRRIGATION IMPORTANT.

Professor King has also shown that not only is the seasonal precipitation of great importance, but its regular distribution throughout the crop season is of marked importance, so that the plant will receive sufficient moisture and receive it regularly, not losing by drouth of a month or six weeks the gain made by one or two months of well distributed rainfall. He has also found that it is possible to grow fair crops with so small a seasonal rainfall as 9.72 inches, thus leading to the hope of successful cultivation of a vast area of our western land now considered without the farming belt and impossible of irrigation. To our western eye, irrigation is first and foremost the prerequisite for successful farming, at least on the intense plan which pays enormous return for the acreage under cultivation, but may it not be possible, nay is it not imperative that we devise some scheme or plan of cultivation and conservation of moisture so that the many thousand broad acres just without the irrigation area may be made to produce profitably. True it will not be on the intense plan of the irrigation farmer, but if the so-called desert can be reclaimed and made to yield even on a par with the many thousand like acres in foreign lands (alike in the lack of rainfall), then indeed shall a blessing have been conferred upon the people, quite as great as will be conferred by the conservation of our storm and flood waters by impounding reservoirs.

GREAT FUTURE FOR SUPPLEMENTAL IRRIGATION.

Along the marginal lines between our humid and arid territory it is many times not a question of reclaiming the desert, but rather a question of increasing the productiveness of lands already under cultivation, and this may also be said to be true of that vast area at the foothills of the Rocky Mountains, for something is raised every year, and in certain years bountiful yields are obtained. How to make the best use of their moderate rainfall (which fortunately largely comes during the crop season) is the question. It is undoubtedly one of soil culture, as well as the growth of those drouth-resisting plants and cereals that may from time to time be brought to the western farmer by the Department of Agriculture. Secretary Wilson says: "Experiments are under way to determine more fully the amount of soil moisture which will produce the largest yield; the proper time and manner of applying it; the effect of winter irrigation; the amount of water evaporated from soil surfaces of different kinds and under different conditions; how best to conserve moisture on the irrigated, as well as the dry farms, and farm drainage." May he speed the day when these problems are solved, that the desert may be reclaimed and homes be made for the millions.

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A CLIMATOLOGICAL DICTIONARY FOR THE UNITED STATES.

PROF. A. J. HENRY, U. S. Weather Bureau, Washington, D. C.

The trend of meteorological thought and discussion in the United States during the last fifty years has been toward the elucidation of the problems of theoretical meteorology rather than those of climatology proper. Much material has been collected and studied with a view of discovering the underlying causes of storm development and the attendant phenomena, and in the development of the utilitarian aspect of the science. Accordingly the aim has been to furnish precise information as to probable weather changes for comparatively short periods, rarely, however, for more than 48 hours in advance. In following this line of action the interests of climatology were for a time assigned to a subordinate position. In recent years much has been done towards placing climatological investigation on a firm basis. The purpose of this paper is to direct attention to the climatological work that is now being done by the U. S. Weather Bureau, especially to a reference work on climatology now in course of preparation.

There is needed in this country, at least, a reference volume that shall give the broader features of climate, if not the details, for representative stations in all parts of the globe. Verbal descriptions not accompanied by quantitative statements are not as a rule satisfactory. It is true that climatic observations have not been made in many portions of the globe, yet such observations as have been made are so widely scattered and in such form as to be practically useless to the average writer. In the United States, for example, climatological observations have been made for the greater part of a century, yet the seeker after climatic information is unable to find a comprehensive summary in any single volume.

That this state of affairs exists is not surprising when one considers the fact that climatological observations in this country have been conducted under various auspices and for widely different purposes. Some of the results of the chief series of observations are to be found in the following list of publications:

(1) U. S. Army Meteorological Register, Washington, 1855.

(2) U. S. Army Meteorological Register, Washington, 1860.

(3) Results of Meteorological Observations made under the direction of the Patent Office and the Smithsonian Institution, Washington, 1861.

(4) Smithsonian Contributions to Knowledge, No. 277. Tables Distribution and Variation in Atmospheric Temperatures in the United States, Washington, 1876.

(5) Smithsonian Contributions to Knowledge, No. 353. Tables and Results of Precipitation in the United States, Second Edition, Washington, 1881.

(6) Annual Reports and other publications of the Signal Service and the U. S. Weather Bureau.

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A CENSUS FOR THE CLIMATE.

Only a small percentage of the publications named in the above list are now available to students and investigators. For that and other obvious reasons the U. S. Weather Bureau of the Department of Agriculture has in course of preparation a census, so to speak, of the climatology of the United States. It is the intention to bring together in a single volume the available climatic statistics for each State and Territory. The State or Territory will be the geographic unit in the discussion, except that the States comprising New England will be treated as a single climatic province, and the State of Delaware will be included with that of Maryland, with which it is associated by natural as well as climatic boundaries. The ultimate geographic unit for the United States must be the county. Unfortunately, however, climatological observations have not been made in more than probably 20 per cent of the existing counties.

The plan of the volume contemplates a first chapter that will treat of the broader features of climate such as the temperature distribution, the character and amount of precipitation, the prevailing winds, etc. The remaining chapters will deal with the climate of the several States and Territories, each district or political division being treated by the local representative of the Weather Bureau stationed therein. In all, the records of about 600 stations will be used. Of this number about 130 are the so-called regular stations of the Weather Bureau where rather complete observations are made of all the principal climatic elements. The observations at the remaining stations refer mostly to temperature and precipitation, and the state of the sky.

A sample table, viz.: that for Baltimore, Md., is given below to illustrate the character of the information contained in the work:

MARYLAND.

NORTH-CENTRAL DIVISION. STATION: BALTIMORE.

OLIVER L. FASSIG, Section Director, in charge.

Established by Signal Service, January 1, 1871; latitude, 39° 18′ north; longitude 76° 37′ west; elevation (station barometer), 123 feet above mean tide.

This station is (1904) near the center of the city, in one of the buildings of the Johns Hopkins University. The open country to the west and north of the city is gently undulatory, forming the eastern edge of the Piedmont Plateau; to the east is the low, flat country of the Coastal Plain.

The thermometers are mounted in a standard Weather Bureau shelter, the floor of which is 9 feet above the roof of the station building.

The following table shows the height of the instruments in their present location:

	Above Roof.	Above Ground.
Thermometers	10 feet	69 feet
Top of rain gage	14 "	73 "
Anemometer cups	58 "	117 "
Wind vane	56 "	115 "

Location of stations and elevation of barometer above mean tide:

January 1, 1871, southwest corner of South and Water streets, 45 feet.

January 1, 1889, Neal building, southwest corner of Baltimore and Holliday streets, 76 feet.

June 1, 1891, Johns Hopkins University (Physical Laboratory), 179 feet.

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September 7, 1895, Equitable Building, southwest corner of Calvert and Fayette streets, 142 feet.

August 1, 1896, Johns Hopkins University (532 N. Howard street), 123 feet.

The mean temperatures are derived from the regular series of observations of the Weather Bureau, to which corrections have been applied to reduce to true daily mean based on 24 hourly observations.

SUMMARY.

TEMPERATURE.

Mean annual, 55°; mean maximum, 63°; mean minimum, 47°. Absolute maximum, 104°; absolute minimum, —7°. Average number of days with maximum above 90°, 17; with minimum below 32°, 69.

FROST.

Average date of first killing frost in autumn, November 5, last killing frost in spring, April 4. Number of times in thirty-three years that the first killing frost occurred one to ten days previous to the average date, 12; eleven to fifteen days previous, 2; sixteen to twenty days previous, 1. Number of times in thirty-three years that the last killing frost occurred one to ten days after the average date, 9; eleven to sixteen days after, 2; sixteen to twenty days after, 2. Date of earliest killing frost known, October 6, 1892, latest killing frost known, May 3, 1882.

PRECIPITATION.

Mean annual, 43.4 inches; spring, 10.9; summer, 12.7; autumn, 9.8; winter, 10.0.

WIND (miles per hour).

Mean hourly velocity, 5.8 (1879-1888, South and Water streets; elevation of anemometer cups, 86 feet above ground.)

Dates when the maximum velocity equaled or exceeded 40 miles per hour, and direction:

1873	Mar.	29	40 s.	1893	July	26	42 nw.
1874	Nov.	23	40 nw.	1893	Aug.	29	42 se.
1876	Feb.	2	40 nw.	1893	Oct.	13	40 se.
1878	Oct.	23	45 sw.	1894	Jan.	30	48 w.
1878	Dec.	11	40 w.	1894	Feb.	16	42 nw.
1879	Apr.	3	60 nw.	1894	June	12	40 n.
1888	Aug.	8	45 sw.	1895	Feb.	8	42 w.
1891	June	4	40 ne.	1895	Dec.	26	42 s.
1891	Nov.	17	40 nw.	1896	Feb.	6	40 w.
1891	Nov.	23	48 s.	1896	Feb.	11	40 w.
1891	Dec.	16	40 nw.	1896	Mar.	19	50 s.
1892	Mar.	10	42 nw.	1898	Dec.	4	54 e.
1892	June	27	42 sw.	1902	July	20	70 w.
1892	Nov.	15	42 ne.	1903	Jan.	30	42 w.
1892	Nov.	18	42 nw.	1903	Feb.	5	45 w.
1893	Feb.	3	42 nw.	1903	July	12	46 w.
1893	Feb.	19	45 nw.	1903	July	30	42 w.
1893	Feb.	24	40 nw.	1903	Oct.	9	42 n.
1893	Apr.	15	42 nw.	1903	Dec.	13	41 nw.
1893	May	4	40 nw.	1903	Dec.	26	40 nw.
1893	May	23	43 w.				

MISCELLANEOUS PHENOMENA.

Average number of days with fog, 12 (1891-1903); hail, 2 (1876-1903); snow, 12 (1871-1903); thunderstorms, 22 (1893-1903).

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Monthly, seasonal and annual means.

Months.	Temperature.							Precipitation.						Mean humidity.				Total sunshine.		Direction of prevailing winds.
	Mean.	Mean of the maxima.	Absolute maximum.	Mean of the minima.	Absolute minimum.	Highest monthly mean.	Lowest monthly mean.	Mean.	Number of days with .01 or more.	Total amount for the driest year.	Total amount for the wettest year.	Snow. Greatest depth in 24 hours.	Snow. Average depth.	Relative, 8 a. m.	Absolute, 8 a. m.	Relative, 8 p. m.	Absolute, 8 p. m.	Average hours.	Percentage of possible	
	°	°	°	°	°	°	°	*Ins.*		*Ins.*	*Ins.*	*Ins.*	*Ins.*	%	*Grs.*	%	*Grs.*	*Hrs.*	%	
December	37	44	73	31	— 3	45	29	3.1	11	2.1	0.6	3.3	10.6	74	1.75	68	1.87	159	50	w.
January	34	41	73	27	— 6	44	24	3.2	12	2.1	4.2	5.6	7.0	75	1.52	69	1.57	162	50	w.
February	35	43	78	28	— 7	43	26	3.7	11	4.6	2.5	7.5	15.5	73	1.48	67	1.53	179	59	w.
Winter	**35**	**43**	.....	**29**	.....	.....	.....	**10.0**	**34**	**8.8**	**7.3**	**16.4**	.....	**74**	**1.58**	**68**	**1.66**	**167**	**53**	w.
March	42	49	82	34	5	50	35	4.0	13	3.2	5.7	5.8	12.0	71	1.38	65	2.06	211	57	nw.
April	53	61	94	44	24	59	47	3.3	11	2.1	8.7	0.8	8.0	65	2.56	60	2.91	237	60	se.
May	64	73	96	55	34	71	60	3.6	12	1.0	6.8	T.	T.	68	4.04	65	4.41	239	54	se.
Spring	**53**	**61**	.....	**44**	.....	.....	.....	**10.9**	**36**	**6.3**	**21.2**	**6.6**	.....	**68**	**2.83**	**63**	**3.13**	**229**	**57**	se.
June	73	82	99	64	47	76	68	3.8	10	4.3	6.2	0.0	0.0	70	5.77	68	6.16	276	62	sw.
July	78	86	104	69	55	82	72	4.7	12	1.5	11.0	0.0	0.0	72	6.74	68	6.99	282	62	sw.
August	76	84	100	67	51	80	73	4.2	11	2.9	1.4	0.0	0.0	73	6.41	69	6.66	267	63	sw.
Summer	**76**	**84**	.....	**67**	.....	.....	.....	**12.7**	**33**	**8.7**	**18.6**	**0.0**	.....	**72**	**6.31**	**68**	**6.60**	**275**	**62**	sw.
September	68	77	101	61	39	77	64	3.8	9	4.3	4.6	0.0	0.0	76	5.15	73	5.64	243	65	se.
October	58	66	90	49	30	64	53	3.0	9	1.7	4.1	T.	T.	74	3.47	69	3.58	211	60	se.
November	46	53	79	39	15	52	42	3.0	10	1.8	6.4	0.8	4.5	75	2.38	69	2.53	165	51	w.
Autumn	**57**	**66**	.....	**50**	.....	.....	.....	**9.8**	**28**	**7.8**	**15.1**	**0.8**	.....	**75**	**2.67**	**70**	**3.92**	**206**	**59**	se.
Annual	55	63	104	47	— 7	.....	.....	43.4	131	31.6	62.2	23.8	15.5	72	3.60	68	3.83	219	58	se.

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EXTREMES OF TEMPERATURE FOR THE PERIOD JANUARY 1, 1873, TO DECEMBER 3, 1903.

Mean of minima for the coldest month, 27°; mean of maxima for the warmest month, 86°; absolute minimum, —7°, 1899; absolute maximum, 104°, 1898.

Year.	Dates when minimum temperature fell to or below 10°.	Dates when maximum temperature rose to or above 95°.
1873	Jan. 29-31; Feb. 24; Mar. 4, 5	June 20; July 3, 18.
1874		June 8, 9, 23, 29; July 10; Aug. 20, 21.
1875	Jan. 9, 10, 11; Feb. 8, 9, 10, 15, 16, 18	June 24-27; July 18.
1876	Dec. 9, 10, 17, 19	June 27; July 4, 8-13, 20.
1877	Jan. 1, 3-6; Mar. 18	June 26.
1878	Jan. 8	July 18, 19, 21.
1879	Jan. 2-5	July 3, 4, 11, 16.
1880	Dec. 29-31	June 12, 24; July 10, 13.
1881	Jan. 1-3; Feb. 2, 3	May 13; July 5, 6, 13; Aug. 13; Sept. 7.
1882	Jan. 24; Dec. 8	June 25.
1883		July 22, 23.
1884	Jan. 6, 7; Feb. 29; Dec. 19, 20	July 24.
1885	Jan. 22; Feb. 1, 17, 20, 21	June 14; July 17, 18, 20, 21, 25.
1886	Jan. 10-15; Feb. 4-6	
1887	Jan. 3, 19	July 13, 14, 16-18.
1888	Jan. 22, 28	Aug. 16.
1889	Feb. 24	
1890		July 8, 17, 31; Aug. 1.
1891		
1892		July 25-29; Aug. 9, 10.
1893	Jan. 10, 11, 13-16, 18, 21	June 20; July 26.
1894	Feb. 25; Dec. 29	June 23, 24; July 12, 13, 20, 28, 29.
1895	Jan. 13; Feb. 3, 5-9	May 30, 31; June 1-3; July 21; Aug. 10, 11; Sept. 21-23.
1896	Jan. 5, 6; Feb. 17, 18, 20	May 10; July 27; Aug. 5, 7, 9, 11, 12.
1897	Jan. 25, 26	June 30; Sept. 11.
1898	Feb. 2	June 25, 26; July 1-4; Aug. 31; Sept. 1-3.
1899	Jan. 1, 2, 11; Feb. 1, 8-15; Dec. 30-31	June 6-8; July 22; Aug. 20, 27.
1900	Jan. 31; Feb. 1, 2, 24, 25, 27	July 4, 6, 7, 15-18, 21; Aug. 6-12; Sept. 11.
1901		June 29-30; July 1-4, 6, 29, 30.
1902		July 3, 5, 6, 17, 18, 20.
1903	Feb. 18, 19	July 2, 3, 9 11, 30; Aug. 25.

The completion of the work which is expected during the summer of 1905 will only partially meet the demands of geographers. A similar work is needed for all portions of the civilized world, and the hope is expressed that the delegates to this Congress will extend their aid and influence toward the accomplishment of such a desideratum.

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LONG-RANGE WEATHER PROPHECIES.

E. B. GARRIOTT, Professor of Meteorology, U. S. Weather Bureau.

"The master of superstition is the people. And in all superstition wise men follow fools."—*Bacon.*

In submitting to this Congress a paper on prophecies, I am constrained to summons as sponsor one of the greatest philosophers the world has ever known, one who "taught men to look abroad into God's world, and by patient experiment to find their way from outward signs to knowledge of the inner workings of those laws of Nature which are fixed energies appointed by the wisdom of the Creator as sources of all that we see and use," one who expressed as his judgment "that all prophecies, including dreams and predictions of astrology, ought to be despised, and to serve but for winter talk by the fireside, that they have done much mischief and that that hath given them grace and some credit consisteth in three things: First, that men mark when they hit, and never mark when they miss; as they do also generally of dreams. Second, that probable conjectures, or obscure traditions, many times turn themselves into prophecies. The third and last (which is the great one) is, that almost all of them being infinite in number, have been impostures, and by idle and crafty brains, merely contrived and feigned, after the event passed."

The first of the things that have given prophecies credit is pronounced a very just remark as "so-called strange coincidences and wonderful dreams that are verified, when the point is considered, are really not at all marvelous. We never hear of the 999 dreams that are not verified, but the thousandth that happens to precede its fulfillment is blazoned by unthinking people as a marvel. It would be a much more wonderful thing if dreams were not occasionally verified." The second thing applies to Seneca's verse, which, translated, reads as follows: "After the lapse of years, ages will come in which Ocean shall relax his chains around the world, and a vast continent shall appear, and Tiphys shall explore new regions, and Thule shall be no longer the utmost verge of the Earth." This has been interpreted as a prophecy of the discovery of America. The third and most important thing presented affirms that practically all prophecies have been impostures. This judgment regarding human prophecies pronounced four hundred years ago, is valid and unimpeachable to-day, and in its amplification we find that prophecy without evidence is charlatanry, and that the foundation and superstructure of belief in long range weather forecasting is superstition, based upon ignorance.

SUPERSTITION A COMMON ATTRIBUTE.

Superstition is defined as "belief in omens and prognostics," "belief in what is absurd." Stated as a general proposition it is safe, although scarcely complimentary, to say that the human race is superstitious, that there is probably not an adult human being who is not, in a greater or less degree, superstitious, that there is probably not a man or woman in the most enlightened communities of the earth who is not to some extent influenced by omens, and who does not place more or less credence in prognostics of future

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happenings that are based on insufficient evidence. There are, in fact, thousands in our midst who have faith in fortune tellers, and in fakirs who prostitute for pecuniary gain the various sciences and professions. And there is no superstition nearer and dearer to many human hearts than a belief that some men, almanac makers and long range forecasters for instance, "possess a knowledge of the inner workings of the laws of nature" that is not accorded to men who by education, training, association and precedent are preeminently equipped to acquire all attainable knowledge of the physical laws that appear to dominate and influence terrestrial phenomena.

The validity of claims of superhuman wisdom receives too little consideration from the great busy public, and announcements of coming atmospheric perturbations, periods of heat or cold, drouth or flood, by men who have no standing in the field of theoretical and applied science are believed to an extent that rivals the unreserved confidence that thousands of years ago was given to interpretations of the utterances of the Delphi oracle, and arguments and facts that should conclusively prove the fallacy of announcements of this character are too often inadequate to tip the balance on the side of common sense in superstitiously inclined minds.

ASTROLOGY AND ASTRONOMY.

Superstition is an inherent human weakness on which charlatans trade, and charlatanry that is based on superstition is a relic of astrology. Before the general laws and processes of the solar system were defined, astrology was the term used in the sense of astronomy. The science of astrology was in favor when men ignorantly supposed the heavenly bodies to have a controlling influence upon terrestrial events and human destinies, a supposition that has for centuries been refuted by astronomical knowledge. Among the several branches of astrology now recognized as charlatanry, long range weather forecasting has ever held a place. In the Babylonian era, the Chaldean priests associated the rising and setting of the heavenly constellations with the character of the seasons of the year, and utilized the astronomical and meteorological parallels thus observed for purposes of astrology. They were able to predict the character of the weather that was peculiar to the seasons, and assumed that certain constellations that were associated with beneficent or malevolent atmospheric conditions could be employed to foretell human events and cast horoscopes. In Egypt the annual rise and fall of the Nile that marked the recurring seasons of drouth and flood was revealed by the appearance of certain heavenly bodies. The Greeks and Romans were also close observers of the weather, and there is evidence that many centuries B. C., changes in the weather were associated with phases of the moon, and that rotations of certain weather types were associated with a nineteen-year lunar cycle.

The astronomical wisdom that followed the solution by Copernicus of the problem of the solar system, showed that the general character of the seasons of the year was due to the influence of the sun upon the earth during the latter's annual journey around the center of our solar system, and the so-called weather predictions of the early ages were recognized as mere state-

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ments of climatic changes due to fixed astronomical causes that are peculiarly potent in producing the sharply marked seasonal weather of the tropical and subtropical countries.

So deeply seated, however, was the belief in the ancient art of divination that a disassociation of the now recognized sciences of astronomy and meteorology from the discredited practice of astrology has been exceedingly slow, and to this fact are we now indebted for numbers of fakirs and charlatans in the meteorological field. Following the passage of the astrologer, men of recognized scientific attainments became actively engaged in investigations regarding the composition, physical properties and phenomena of the earth's atmosphere, and climatic problems were systematically considered. Instrumental observations, especially those furnished by the barometer, the invention of Torricelli, and of the thermometer, credited to Galileo, aided materially in determining the character of impending weather changes, and barometric indications of the approach and passage of storms were of great value to navigators. The progress of meteorological advance during the last three centuries is presented substantially as follows, in a paper recently prepared by the writer:

DEVELOPMENT OF "OLD PROBABILITIES."

Previous to the nineteenth century, man possessed no knowledge of the laws that govern the weather nor of the mechanical processes that are employed in the production and propagation of storms and other well-marked phenomena of the atmosphere. He had noted without knowing the reason therefor, that in the northern hemisphere northerly winds are usually attended by low temperature, and southerly winds by rising temperature; that in the middle latitudes, easterly winds are generally followed by rain or snow, and westerly winds by clearing or fair weather; that certain cloud formations and movements indicate certain kinds of weather, and that manifestations of atmospheric moisture are of value in determining the character of impending weather changes. He had learned by observation to interpret the meaning of effects produced by certain atmospheric conditions on objects animate and inanimate, and had secured an intimate knowledge of astronomical facts that govern the seasons. In the early part of the nineteenth century a formal announcement of the laws of storms was made by Wm. C. Redfield, of New York, who found that the whole of the revolving mass of air that composed the storms of the Atlantic coast of the United States advanced with a progressive motion from southwest to northeast. Mr. Redfield also drew conclusions regarding storms in general that have not been materially modified by subsequent research. During the last half of the nineteenth century, regular meteorological services were established throughout the world and the sum of the achievements of this period in practical and theoretical work and investigation is represented by a rapidly increasing collection of data and facts that afford a sure foundation upon which future work may rest. Modern science does not employ obsolete methods in meteorological work, nor is it satisfied with the present generally accepted solutions of many of the problems of meteorology, and the acquirement of knowledge and the discovery

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of new laws that will justify calculations of the weather for weeks, months and seasons in advance is the aim and object of many earnest and capable workers. Moreover it is believed that present and proposed methods of meteorological services are shaping events towards the accomplishment of that much to be desired end.

The assumptions of modern so-called long range weather forecasters have led to a consideration of the merit of the systems they employ. Planetary meteorology is the term applied to the practice of the more prominent long range forecasters, and planetary meteorology is a relic of astrology. Others place upon the moon and several of the planets of the solar system the responsibility of regular and irregular forms of weather. They base their forecasts upon the moon's path with reference to the ecliptic and the earth's equator, employ a 19-year moon cycle, strengthen their statements by allusions to eclipses and occultations, fall back upon an alleged fund of mysteriously acquired superhuman wisdom, and incidently employ past records of the weather, the manipulation of the last-named element representing their only stock in trade.

Meterological literature is deficient with reference to planetary influences on the weather, and from this fact it may be assumed that long range forecasters fear to enter a field where deductions are subjected to mathematical demonstration, and where claims to superior knowledge will be confronted by established and recognized facts pertaining to the more exact science of astronomy. There are no exceptions to this assumption, and the plea for entering the field is invariably a claim of knowledge that is universally recognized as being beyond the scope of astronomy. Although popular belief in the influence of the moon on the weather will not be downed by any marshalling of facts, it is proper to say that the most exhaustive comparisons fail to show any appreciable relation between weather conditions and lunar phases, variations and oscillations. Neither is there the slightest evidence that the stars or constellations of stars have the slightest influence upon weather conditions. Interest in the meteorological possibilities of a study of solar conditions has been very active during the past few years, and the literature of this period that summarizes practically all that has been done in this direction, indicates that investigation regarding the probable association of solar variations with recurring types of weather offers a most interesting and profitable field of labor.

ANIMAL SIGNS.

Observations of the habits and conditions of animals and birds and of the appearance of plants have a recognized value in determining the character of past weather, and to a limited extent the weather for a few hours in the future. The thickness of the fur of fur-bearing animals is used as evidence of the character of future weather, when as a matter of fact the character of the fur depends absolutely upon the physical condition of the animal, and the physical condition of the animal depends upon the weather of the past and the extent to which it has affected his food supply and general health rather than upon the weather of the future. The accumulation of food by animals is known to be governed by the supply of food, and not by

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future weather. Birds of passage migrate to the south with the first breath of winter, or when their food supply is affected by inclement weather, which is peculiar to approaching cold weather, and return North when the spring sets in the South. That their flights are influenced by present rather than a knowledge of future weather conditions, is evident to all observers.

Neither animals nor plants can possibly be affected by the weather of a future month or season. Moss, bark of trees, and the thickness of nutshells and pumpkin rinds, etc., furnish another basis for long range weather speculations that also confuse and misinterpret conditions that are due to past conditions and have no bearing on future weather. Trees of great age and large growth, like the sequoias, indicate by their rings years that have been favorable and unfavorable for their growth, or in other words, wet and dry years in the region or locality in which they are located, and to this extent establish a record of the seasons that may have a possible value in future calculations.

The weather of days, months, seasons and years afford no indication of future weather further than showing present abnormal conditions that the future may adjust. An assumed, or supposed, six or seven-day period of recurring weather is indicated by the common saying, "If it rains on the first Sunday in the month it will rain every Sunday in the month." This saying possesses value in so far as the weather may conform in particular instances to a general average, and the likelihood of the weather conforming to this extent to general averages is not sufficiently great to justify the employment of the chance in actual forecast work. Sunday was doubtless selected in the saying quoted for the reason that the weather and its seasonal or unseasonal character is more closely observed and studied on certain days, notably Sundays and holidays, when men's minds are not occupied with their usual pursuits; any other day in the week will answer as well for this form of estimating the weather of the future. Long range weather forecasters for purposes of mystification, attribute the six or seven-day period to the moon's influence, and time their disturbances six or seven days apart, starting them on the Pacific coast and carrying them by regular stages across the United States, assuming in each case a conformance to general averages. Equal accuracy or inaccuracy would result if they started the disturbances in the central valleys or on the Atlantic seaboard, on corresponding dates, or introduced them on the Pacific coast on dates intermediate to those they have selected. By claiming for verification purposes a day or two on either side of the dates specified, by carefully avoiding specific forecasts of rain for specified days and districts, and by calling attention to hits that will occasionally be made under any system of chance, and never referring to misses, they successfully pursue in these enlightened times the practices of the fabulous age.

HOW THEY FAKE THE COUNTRY.

In this connection I will quote an opinion on long range weather prophets recently expressed by Professor Odenbach, director of the Ignatius College Meteorological Observatory, Cleveland, Ohio:

"How do they gain a following? Nothing easier. They cheat one-half

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the country one day and the other half the next day by the vagueness of their prophecy. Such a statement as 'There will be storms in the period of the 20th to the 27th of September,' without mentioning a special day or designating a single State, to say nothing of a county or a single city, are easily made, and any schoolboy has a formula by which he may give the percentage of possibilities for guessing correctly. It is guessing and nothing more.

"It is known that the American people wish to be humbugged. P. T. Barnum did it for years and boasted of it. But in the realm of science or in cases where the comfort and oftentimes the lives of thousands are at stake, we can not tolerate the charlatan, nor for that matter a newspaper whose financial and intellectual resources are at so low an ebb that it must look to the weather prophets to fill its paper with matter which misleads the ignorant and disgusts the intellectual reading public.

"It is unpardonable in a modern newspaper to cram its pages with lies, nonsense and productions of ignorant, eccentric or dishonest fakirs. To give them a chance is a menace to the public and a crying injustice to a set of men that are the pride of the intellectual portion of the American people, commanding the highest esteem of European scientists of all nationalities. We Americans pride ourselves on the strength of our scientific schools and intellectual advances generally. The weather prophet fad is certainly a manifestation in a contrary direction. Any man talking seriously of these quacks is set down in my mind as deplorably ignorant, at least as regards meteorological science. The same may be said for the charlatans themselves, though I would give them the alternative of being ignorant or dishonest. These expressions may seem severe, but the matter is of so serious a nature that I am justified in expressing myself as I do."

In this connection I will say that it is apparent that it is the duty of a government that is charged with the general welfare of a country to warn its citizens against fakirs who for mercenary motives ignorantly or dishonestly commit a fraud on the public; and to those men who represent the industries of the vast regions of the West that depend so largely upon rainfall distribution and rainfall storage, the warning to put no trust in men who claim either to produce rain or to foretell the character, whether wet or dry, of a month, season or year in advance is most earnestly emphasized.

GOVERNMENT FORECASTS BASED ON ACTUAL WEATHER CONDITIONS.

The Weather Bureau issues forecasts daily for periods of 36 and 48 hours in advance that are based upon actual conditions observed by the aid of telegraphic reports over an area that extends more than 3000 miles east and west, and from the northern border of South America over Canada. These are the forecasts that appear in the daily press. Its most important work, however, is found in special warnings of severe gales, cold waves, frosts, heavy snow, heavy rain and floods that are made with almost unfailing accuracy, in behalf of shipping, commercial and agricultural interests, and conservative estimates prove that benefits amounting to millions of dollars have been returned in the case of single warnings of storms on our Atlantic seaboard, and of floods

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in our great central valleys. A special rainfall and flood service is about to be inaugurated in eastern New Mexico and southeastern Colorado, whereby it is hoped that losses by destructive floods of the character recently experienced may be materially lessened.

The Bureau is extending its rainfall and flood stations as rapidly as appropriations will permit, and the forecasts of floods that will be based upon these observations, and the knowledge of seasonal conditions that have and will be obtained from a rapidly increasing amount of observational data will undoubtedly be of great value in the prosecution of irrigation operations.

In conclusion the fact is affirmed and reaffirmed that there is not at present any known basis for long range weather forecasts, that so-called forecasts of this character are made by men who are either ignorant or who knowingly commit a fraud upon the public, and that when long range forecasts can be made, if they ever can, they will be made by the Weather Bureau.

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DISTRIBUTION OF RAINFALL IN TEXAS.

W. H. ALEXANDER, U. S. Weather Bureau, Galveston, Texas.

The known intimate relation that usually exists between the topography of a country and the geographical distribution of its rainfall naturally leads one entering upon a study of this question to an early consideration of this relationship. A cursory glance at the contour any isohyetose lines of charts 1 and 2 seems sufficient to detect a relationship between the topography and the rainfall distribution of Texas, at once so intimate as to appear to be causal, but a more careful study shows this to be rather accidental.

The surface of the State rises as a rule quite gradually, though in places rather abruptly, from the coast line towards the northwest, attaining its greatest elevation in the Trans-Pecos and "Llano Estacado" regions. The annual rainfall decreases quite uniformly from the east to the west, being least in the Trans-Pecos country. But a study of the normal precipitation for each month reveals a very marked departure from this apparently fixed relationship between the elevation and rainfall, beginning, say, with the month of April and extending to and including September.

The fact is one could not reasonably expect to find a single principle or type of rainfall distribution to prevail over so vast an area as the State of Texas, an empire in itself, embracing within its limits more than ten degrees of latitude and more than thirteen degrees of longitude and an area of more than 265,000 square miles. One might just as reasonably expect to explain the rainfall of Illinois upon the principles obtaining in Alabama as to find an explanation of the normal weather conditions of the Panhandle or Trans-Pecos country in the conditions prevailing along the Texas coast. We are not surprised, therefore, to find the State divided hydrographically into a number of sections, each with its own peculiarities. With a view to bringing out these various divisions with their characteristics, a number of charts have been drawn, based upon normals obtained from records ten or more years in length. Unfortunately the Panhandle and western counties are not as thoroughly covered by these records as one might desire, but the records are sufficient to warrant some very general and practical deductions.

TEXAS RAINFALL VARIES FROM 10 TO 50 INCHES.

As regards the total annual rainfall and its geographical distribution, the fall decreases with marked regularity from a little less than 50 inches per annum in the extreme eastern and southeastern counties to less than 10 inches in the extreme west, that is, in the vicinity of El Paso. The same regular decrease is noticed along the coast as inland; there the fall decreases from about 50 inches on the east coast to about 20 inches on the west coast, in the vicinity of Brownsville. The extreme west coast and Panhandle counties have about the same annual fall. The rainfall over the eastern half of the State is ample for agricultural purposes, but over the western half it is rather insufficient and too precarious.

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"RAINY SEASONS" VARY WITH LOCALITIES.

In the greater portion of east Texas and the north Panhandle counties the greatest monthly rainfall occurs in May or June, generally in May; along the immediate coast, September has the greatest average; over that portion of the State west of the 100th meridian and as far south as, but not including Jeff Davis and Pecos counties, the rainfall is greatest in July, except in the most northern counties of the Panhandle, and along the Rio Grande valley the maximum monthly amount may occur any time from May to October inclusive. Rainfall in Texas is tropical in character in that the greater portion of it falls in heavy showers of short duration. A fall of several inches in 24 hours in not uncommon in the eastern portion of the State and along the coast highly excessive rains sometimes occur.

The question of annual rain variability is a very important one and might be discussed at some length with profit, but it can be only touched upon here. The territory is so extensive and the meteorological factors so complex that it might be safely concluded from theoretical considerations, even were it not actually established by existing records, that rain falls on an average of one day in three in some part of this vast territory during every month in the year; also that some sections of the State are not so favored and are subject to drouths of more or less severity. Such a thing as a general drouth was never known in Texas and the local drouths are not as frequent or as extended as sometimes supposed.

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THE WORK OF THE RAINMAKERS IN THE ARID REGIONS.

GEO. E. FRANKLIN, U. S. Weather Bureau, Los Angeles, Cal.

As near as can be learned, the work indicated by the caption of this paper was carried on by or under the direction of one Melbourne, either in Kansas or Nebraska, by R. G. Dyrenforth in Texas, by C. B. Jewell in Kansas and California, and also by individuals of lesser repute and shortlived "companies" organized for the purpose.

Of Melbourne's work the writer has been able to gather no certain information of any moment. It is now several years since he operated and the story of his work does not appear to have found a place in periodical literature, though it attracted considerable attention at the time. He has been dead for some time.

Perhaps the most pretentious of all efforts to produce rain artificially were those made by Gen. R. G. Dyrenforth in Texas during August, 1891, and September, 1892. These experiments were notable not only on account of the scale upon which they were conducted and the alleged results achieved, but also for their auspices and the animadversions they incurred.

Dyrenforth's operations had the sanction of the U. S. government, being authorized and made possible by a special appropriation in the Agricultural Bill.

In 1891, a ranch about 25 miles from Midland, Texas, a small station on the T. & P. R. R., was the scene of the operations. The expedition arrived there August 5, 1891, bringing a carload of materials for the manufacture of various explosives, gases, dynamite, etc.

ENORMOUS CHEMICAL EXPERIMENT.

The seriousness and magnitude of the experiments are indicated by a partial enumeration of the apparatus and material: Twenty thousand pounds of iron borings and 16,000 pounds of sulphuric acid for the generation of 50,000 feet of hydrogen gas; 2500 pounds of potassium chlorate for evolving 12,000 feet of oxygen gas, involving the use of 50 retorts and furnaces; 68 explosive balloons of 10 and 12 feet diameter, and three large balloons for ascensions. Material for 100 cloth-covered kites and ingredients for the manufacture of several thousand pounds of rack-a-rock powder and other high explosives, together with electrical and meteorological instruments.

The intention was to produce rain by violent and continued concussions, both on the earth's surface and in the air, and there were three lines of operations, each two miles in length and one-half mile apart. The first line consisted of a large number of ground batteries by which heavy charges of dynamite and rack-a-rock powder were to be discharged at frequent intervals. The second line was to be of kites flown high, with connections of electric wire, by means of which dynamite cartridges were to be carried up and exploded. The third and principal line was to be of explosive balloons, to be exploded at elevations greater than those attained by the kites, at one or two-hour intervals throughout the operations.

In the experiments the first line was operated as planned, in connection

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with the others and also independently when the others were not in operation, to keep the weather "unsettled." The second line was operated less successfully, high winds rendering kite-flying difficult, also breaking the electric wires; as a consequence, this line was not operated to the extent proposed.

THE RAIN CAME; BUT?

As to the results of the operations: rain fell for the first time after the arrival of the expedition on August 10th, but it was a questionable credit, as the preparations had not been completed and there had been only a few preliminary explosions by way of testing the dynamite on the previous evening. However, Gen. Dyrenforth telegraphed it as a definite result, claiming two inches of rain; another report says "a light shower."

On the evening of August 17th discharges were begun, followed the next day by explosions of large amounts of oxygen and hydrogen gases by means of balloons, while the ground batteries were kept in constant action for twelve hours. The morning of the 18th was fair and fair weather continued till afternoon, but at 5:00 p. m. the operators were compelled to run through a drenching rain that fell for two and one-half hours.

The final operations of the series took place on August 25th. Balloons were exploded at altitudes varying from 1000 feet to three miles, and cannonading from the ground batteries carried on till 11:00 p. m. At 3:00 a. m. on the 26th heavy thunder was heard, and at 4:00 a. m. rain began to fall "in torrents" and continued till 8:00 a. m. Prof. G. E. Curtis reports concerning this fall that it was "nothing but a sprinkle."

The second experiment by Mr. Dyrenforth was made near San Antonio in November, 1892, but with unsatisfactory results. Prof. A. Macfarlane, of the University of Texas, was present as an invited guest during these experiments, and his conclusions were adverse to the rainmakers.

For the first series of experiments $7000 were appropriated and expended, and for the second an appropriation of $10,000 was made, of which, however, only about $5000 were expended.

QUITE "IMPORTANT IF TRUE."

Gen. Dyrenforth claimed as result of his operations three heavy storms after the principal operations and nine showers of lesser importance during the sixteen days of experimenting, which was altogether extraordinary for the locality and season of the year. It may be remarked here that the latter part of July and the first half of August of the present year, 1904, show very considerable rains in the same section.

Of these results it must be said that there appears to have been almost a total lack of the scientific method in recording them. No exact measurements are given; "a drenching rain," "fell in torrents" are expressions that have little scientific value under any circumstances, and still less when contradicted by independent reports. They also admit the personal equation to a considerable degree when it is desired to establish a given result.

Of the operations of Jewell and others in Kansas and neighboring sections no detailed statement can be made. It is believed that their methods were

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"chemical" rather than mechanical as in Dyrenforth's experiments; if this was not true of all it was of some, they relying upon the liberation of some gas or gases, perhaps, also in connection with electricity, to produce rain.

Companies were even organized to go into the rainmaking business, offering to enter into contracts to produce rain in definite amounts over given areas within given times.

Mr. Jewell, aided probably by several fortunate, for him, coincidences, secured almost unqualified indorsements from one of the railroads running through Kansas, becoming known as its official rainmaker, and many business and professional men vouched for the certainty of results produced by his operations. As a result of these indorsements he was invited to conduct some experiments in Southern California, near Los Angeles, in July, 1899, after a most grievous drouth of several years which had driven agricultural interests almost to the point of despair. Of these experiments, or rather of the method, it is allowed to say only that rain was supposed to be produced by liberating hydrogen gas in connection with electricity.

A CONFIDENTIAL FORMULA.

Some of the experiments were conducted by citizens of Los Angeles according to Mr. Jewell's method, though not under his immediate supervision, and the method is still regarded as having been imparted in confidence. Six hydrogen generators were employed, though their capacity was not known, and a battery was used to generate electricity to pass off with the hydrogen. Experiments were carried on July 18 and 19, 1899, and so much alarm was felt lest the matter should be overdone that a contractor having interests that would be adversely affected by rain, procured a court injunction on the 20th, restraining the operators. This injunction was dissolved—though not by the rain—on the 25th, and operations were resumed. In the meantime Mr. Jewell had come upon the scene, and for sixty hours, on the 25th and 26th, operations were carried on. They were a complete failure as far as producing rain was concerned. There was a gathering of clouds in the distance, but no precipitation occurred.

Some hundreds of dollars had been paid to Mr. Jewell, but after the absolute failure of the experiments such representations were made to him that he returned the money in whole or large part.

During the month of April, 1904, experiments were made near El Cajon, situated in San Diego County, in Southern California, looking to the artificial production of rain. The following is quoted directly from a letter written by a participant in the experiments:

"Our outfit consisted of about twenty cannons or mortars, each weighing about 60 pounds. They were about 8 inches high and had a bore of about 3 inches. They were stationed in four groups, each group representing a corner of about one acre of ground.

"We commenced firing at about 6:30 Friday, April 22, and continued steadily until about 1:30 Sunday, April 24—making about 31 hours of actual and continuous bombardment.

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A WASTE OF GOOD POWDER.

"Each charge was about four ounces of powder, tamped in with dirt; we shot twice a minute during the entire time. We had no rain, but on Tuesday following this locality experienced a 'drizzle,' which was of no benefit as the precipitation was very light."

There is at the present time in Los Angeles, Cal., a rainmaker who claims an absolutely successful method for producing rain. Mr. C. M. Hatfield claims that out of nineteen attempts he has produced rain eighteen times. These experiments have claimed the attention of the public only during a comparatively recent period, but Mr. Hatfield says that he has been working on his method for seven years. Of course it is a secret, but Mr. Hatfield in personal conversation has expressed a willingness to reveal as much as possible concerning it. He says, "it is mainly chemical affinity with the atmosphere. I have nothing to do with bombs, dynamite or explosives of any kind whatever. My methods are original."

Mr. Hatfield uses chemicals, the combination of which is known only to himself; these are mixed in casks and allowed to remain for five days. When the operations are carried on Mr. Hatfield uses a tower of varying heights, from the top of which he liberates his gases in connection with a large number of evaporating pans from which water is evaporated by heat artificially applied.

He claims to have been operating at Bonsall, San Diego County, twelve miles east of Oceanside, in July, 1902, and in two and one-half days after he began operations the heaviest rain in 37 years fell. Again in December, 1902, in the same locality he operated with a result of 1.10 measured inches at the place where the experiments were performed. In September, 1903, February, 1904, and July, 1904, he was operating at points a few miles distant from Los Angeles, his experiments in each case being followed by rain, twice in very appreciable amounts. He says, "I have never as yet failed to produce rain in July." This is "important if true," for rain is a scarce article in Southern California in this month.

DISLIKES EASY JOBS.

Mr. Hatfield claims that he prefers to perform his experiments under manifestly unfavorable conditions in order that there may be no doubt as to his ability to substantiate his claims, and declares his purpose to operate this winter in case the drouth of former years is repeated. He says that for a cost of $100 a thorough operation can be made, and that rain will follow within five days of the beginning of the process. Upon being questioned closely as to the philosophy of his method he says that he thinks that he "attracts" a rain area even from a distance of a thousand miles.

While it is intended that this paper shall be narrative rather than controversial, it may fairly be said that in practically all cases where rainmaking experiments have not been self-confessed or proven failures, the so-called "results" have been results not of human attempts to produce rain, but of the processes of Nature working on a scale so vast as to make insignificant and trifling the artificial methods of man.

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The rainmakers have failed to show any genetic relation between their work and the precipitation that has occurred, rain having been observed in the very same localities at the same season of the year when no experiments were being carried on. In fact, to quote Prof. Curtis' words in regard to Dyrenforth's experiments: "In view of these facts it is scarcely necessary for me to state that the experiments have not afforded any scientific standing to the theory that rain storms can be produced by concussion," we may in place of the word "concussion" put "any known artificial means."

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COLLECTION AND DISSEMINATION OF CLIMATOLOGICAL DATA AND WEATHER FORECASTS.

JAMES BERRY, Chief of Climate and Crop Division U. S. Weather Bureau, Washington, D. C.

These features of the work of the Weather Bureau are embraced in its Climate and Crop Service, which is divided into forty-three sections, each section conforming to the political boundaries of the several States with a few exceptions in which some of the smaller States are combined.

In the climatological publications of the several States data from nearly 3500 stations are published in detail, the extremes of temperature and total rainfall for each day for every station being given, together with other meteorological data and a general discussion of the different elements. The value of such publications is incalculable to those pursuing investigations in which climate is concerned, and as few enterprises of moment are unaffected by climate, it will be readily seen what an important bearing the data being collected and published has upon irrigation projects, etc. While the editions of the climatological reports are small, complete files of these publications may be found at most of the larger Weather Bureau stations and in the libraries of many educational institutions. In recent years there has been no very decided increase in the number of observing stations, but the Bureau has standardized the equipment of all the observing stations, many of which until a few years ago were using instruments of various patterns, some of questionable accuracy and in instances from unavoidable circumstances were exposed in more or less faulty manner. All stations are now equipped with the standard instruments of the Weather Bureau, tested for accuracy before issue, and are given the best exposure it is possible to obtain.

WEATHER FORECASTS WIDELY DISTRIBUTED.

The daily weather forecasts and special warnings of cold waves, severe storms, etc., are sent broadcast into every part of the country where facilities for communication will permit. In recent years a most effective means of distributing weather forecasts throughout the rural districts has been made possible by the rapid extension of the Rural Free Delivery Service of the Postoffice Department and by the greatly increased number of farmers' telephone exchanges, more than 80,000 forecast bulletins being distributed by mail through the Rural Free Delivery Service, while several hundred thousand telephone subscribers, principally farmers, in the States of the central valleys, now receive the forecast each morning within a few minutes after the official forecaster has made the prediction. In this work the government bears the expense of telegraphing about 2000 messages daily to distributing points for dessemination by the various means employed therein.

Postmasters and other public spirited citizens favorably situated for reaching outlying towns cheerfully co-operate with the Bureau in distributing the forecasts. It is the custom of the Bureau to supply a simple hand printing outfit, consisting of rubber logotypes and ink pads with which the forecasts

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are quickly stamped upon franked postal cards and these mailed on early departing trains so as to reach destination in time to make the forecast of value to communities to which they are sent. This is known as the logotype system, and by it more than 200,000 bulletins are printed daily, distributed and given public display.

Some of the earlier methods of dissemination are now being abandoned for quicker and more effective means. The flag displays that once constituted one of the principal means of dissemination are no longer encouraged except where the better facilities do not exist.

SPECIAL SERVICE FOR THE FARMERS.

During the season of planting, cultivating and harvesting of crops there is issued from each Climate and Crop Service section center a weekly bulletin devoted particularly to agricultural interests. This bulletin contains information as to the progress of farm work and also a summary of the prevailing weather and its effects upon farming operations and crops. While a wide distribution of the bulletin is made, its greatest circulation is secured through reprint in daily newspapers and the agricultural press.

In the winter season there is prepared and published at each Climate and Crop center in the semi-arid regions a snow bulletin for each month from December to March, inclusive. A large number of reports from voluntary and special observers enter into the preparation of this snow bulletin, which contains the fullest information obtainable as to the amount and character of the snowfall during the month and the amount and character of that remaining on the ground at the close of each month.

SPECIFIC ADVANCE INFORMATION AS TO IRRIGATION SUPPLY.

These special bulletins contain the only authentic history extant of the winter's snowfall in the several western States covered by the published reports. From the data published in these bulletins it is possible to estimate with a reasonable degree of accuracy the probable water supply for the succeeding season. As evidence of this it may be stated that in the early months of the winter of 1903-04 there was a marked deficiency in precipitation throughout the vast mountain system where the reserve supply of moisture is stored up in gulches and ravines for the summer flow. In February, however, and afterward, a succession of winter storms gave unusual snow depths over many of the States and insured an ample water supply later in the season, but throughout middle and southern Utah and practically all of Arizona and New Mexico the deficiency in moisture continued unbroken.

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The National Irrigation Law

TO MAKE THE WEST RECLAIM ITSELF.

[Public—No. 161.]

An Act appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all moneys received from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming, beginning with the fiscal year ending June thirtieth, nineteen hundred and one, including the surplus of fees and commissions in excess of allowances to registers and receivers, and excepting the five per centum of the proceeds of the sales of public lands in the above States set aside by law for educational and other purposes, shall be, and the same are hereby, reserved, set aside, and appropriated as a special fund in the Treasury to be known as the "reclamation fund," to be used in the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semi-land lands in the said States and Territories, and for the payment of all other expenditures provided for in this Act: *Provided,* That in case the receipts from the sale and disposal of public lands other than those realized from the sale and disposal of lands referred to in this section are insufficient to meet the requirements for the support of agricultural colleges in the several States and Territories, under the Act of August thirtieth, eighteen hundred and ninety, entitled "An Act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts, established under the provisions of An Act of Congress approved July second, eighteen hundered and sixty-two," the deficiency, if any in the sum necessary for the support of the said colleges shall be provided for from any moneys in the Treasury not otherwise appropriated.

SEC. 2. That the Secretary of the Interior is hereby authorized and directed to make examinations and surveys for, and to locate and construct, as herein provided, irrigation works for the storage, diversion, and development of waters, including artesian wells, and to report to Congress at the beginning of each regular session as to the results of such examinations and surveys, giving estimates of cost of all contemplated works, the quantity and location of the lands which can be irrigated therefrom, and all facts relative to the practica-

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bility of each irrigation project; also the cost of works in process of construction as well as of those which have been completed.

SEC. 3. That the Secretary of the Interior shall, before giving the public notice provided for in section four of this Act, withdraw from public entry the lands required for any irrigation works contemplated under the provisions of this Act, and shall restore to public entry any of the lands so withdrawn when, in his judgment, such lands are not required for the purposes of this Act; and the Secretary of the Interior is hereby authorized, at or immediately prior to the time of beginning the surveys for any contemplated irrigation works, to withdraw from entry, except under the homestead laws, any public lands believed to be susceptible of irrigation from said works: *Provided,* That all lands entered and entries made under the homestead laws within areas so withdrawn during such withdrawal shall be subject to all the provisions, limitations, charges, terms, and conditions of this Act, that said surveys shall be prosecuted diligently to completion, and upon the completion thereof, and of the necessary maps, plans, and estimates of cost, the Secretary of the Interior shall determine whether or not said project is practicable and advisable, and if determined to be impracticable or unadvisable he shall thereupon restore said lands to entry; that public lands which it is proposed to irrigate by means of any contemplated works shall be subject to entry only under the provisions of the homestead laws in tracts of not less than forty nor more than one hundred and sixty acres, and shall be subject to the limitations, charges, terms, and conditions herein provided: *Provided,* That the commutation provisions of the homestead laws shall not apply to entries made under this Act.

SEC. 4. That upon the determination by the Secretary of the Interior that any irrigation project is practicable, he may cause to be let contracts for the construction of the same, in such portions or sections as it may be practicable to construct and complete as parts of the whole project, providing the necessary funds for such portions or sections are available in the reclamation fund, and thereupon he shall give public notice of the lands irrigable under such project, and limit of area per entry, which limit shall represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question; also of the charges which shall be made per acre upon the said entries, and upon lands in private ownership which may be irrigated by the waters of the said irrigation project, and the number of annual installments, not exceeding ten, in which such charges shall be paid and the time when such payments shall commence. The said charges shall be determined with a view of returning to the reclamation fund the estimated cost of construction of the project, and shall be apportioned equitably: *Provided,* That in all construction work eight hours shall constitute a day's work, and no Mongolian labor shall be employed thereon.

SEC. 5. That the entryman upon lands to be irrigated by such works shall, in addition to compliance with the homestead laws, reclaim at least one-half of the total irrigable area of his entry for agricultural purposes, and before receiving patent for the lands covered by his entry shall pay to the Government the charges apportioned against such tract, as provided in section four.

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No right to the use of water for land in private ownership shall be sold for a tract exceeding one hundred and sixty acres to any one landowner, and no such sale shall be made to any landowner unless he be an actual bona fide resident on such land, or occupant thereof residing in the neighborhood of said land, and no such right shall permanently attach until all payments therefor are made. The annual installments shall be paid to the receiver of the local land office of the district in which the land is situated, and a failure to make any two payments when due shall render the entry subject to cancellation, with the forfeiture of all rights under this Act, as well as of any moneys already paid thereon. All moneys received from the above sources shall be paid into the reclamation fund. Registers and receivers shall be allowed the usual commission on all moneys paid for lands entered under this Act.

SEC. 6. That the Secretary of the Interior is hereby authorized and directed to use the reclamation fund for the operation and maintenance of all reservoirs and irrigation works constructed under the provisions of this Act. *Provided,* That when the payments required by this Act are made for the major portion of the lands irrigated from the waters of any of the works herein provided for, then the management and operation of such irrigation works shall pass to the owners of the lands irrigated thereby, to be maintained at their expense under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior: *Provided,* That the title to and the management and operation of the reservoirs and the works necessary for their protection and operation shall remain in the Government until otherwise provided by Congress.

SEC. 7. That where in carrying out the provisions of this Act it becomes necessary to acquire any rights or property, the Secretary of the Interior is hereby authorized to acquire the same for the United States by purchase or by condemnation under judicial process, and to pay from the reclamation fund the sums which may be needed for that purpose, and it shall be the duty of the Attorney General of the United States upon every application of the Secretary of the Interior, under this Act, to cause proceedings to be commenced for condemnation within thirty days from the receipt of the application at the Department of Justice.

SEC. 8. That nothing in this Act shall be construed as affecting or intended to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use or distribution of water used in irrigation, or any vested right acquired thereunder, and the Secretary of the Interior, in carrying out the provisions of this Act, shall proceed in conformity with such laws, and nothing herein shall in any way affect any right of any State or of the Federal Government or of any landowner, appropriator, or user of water in, to, or from any interstate stream or the waters thereof: *Provided,* That the right to the use of water acquired under the provisions of this Act shall be appurtenant to the land irrigated, and beneficial use shall be the basis, the measure, and the limit of the right.

SEC. 9. That it is hereby declared to be the duty of the Secretary of the Interior, in carrying out the provisions of this Act, so far as the same may be practicable and subject to the existence of feasible irrigation projects, to

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expend the major portion of the funds arising from the sale of public lands within each State and Territory hereinbefore named for the benefit of arid and semi-arid lands within the limits of such State or Territory: *Provided,* That the Secretary may temporarily use such portion of said funds for the benefit of arid or semi-arid lands in any particular State or Territory hereinbefore named as he may deem advisable, but when so used the excess shall be restored to the fund as soon as practicable, to the end that ultimately, and in any event, within each ten-year period after the passage of this Act, the expenditures for the benefit of the said States and Territories shall be equalized according to the proportions and subject to the conditions as to practicability and feasibility aforesaid.

SEC. 10. That the Secretary of the Interior is hereby authorized to perform any and all acts and to make such rules and regulations as may be necessary and proper for the purpose of carrying the provisions of this Act into full force and effect.

Approved, June 17, 1902.

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13TH NATIONAL IRRIGATION CONGRESS

TO BE HELD AT

PORTLAND, OREGON, 1905.

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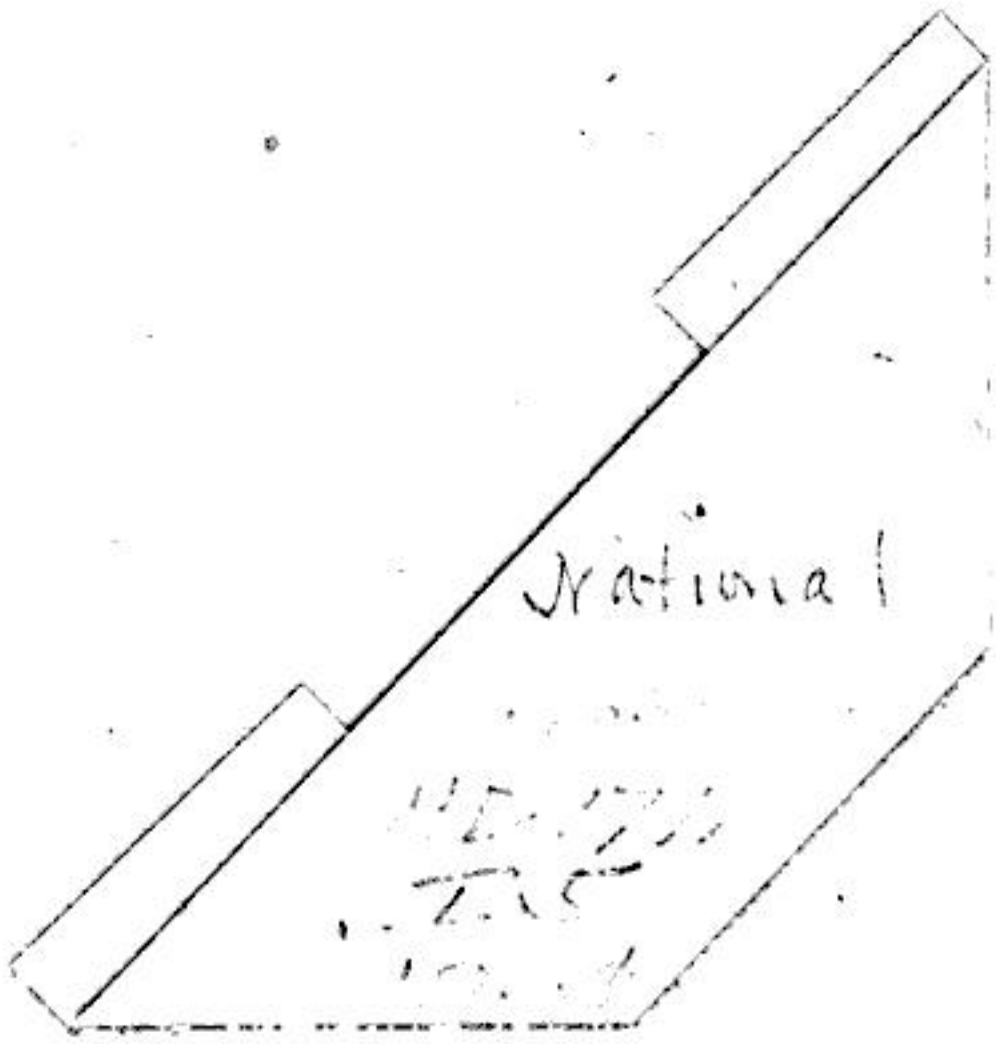

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OBSERVATIONS

ON THE

GROUND WATERS OF RIO GRANDE VALLEY

BY

CHARLES S. SLICHTER

PROPERTY OF U. S. GEOLOGICAL SURVEY.

WASHINGTON

GOVERNMENT PRINTING OFFICE

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LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
RECLAMATION SERVICE,
Washington, D. C., January 12, 1905.

SIR: I transmit herewith a manuscript by Prof. Chas. S. Slichter, entitled "Observations on the Ground Waters of Rio Grande Valley," and request that it be published as one of the series of Water-Supply and Irrigation Papers. This report contains results of recent investigations in connection with the underground-water problems of Rio Grande Valley, and it is believed that the facts made available will be of general interest and value.

Very respectfully,

F. H. NEWELL, *Chief Engineer.*

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

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OBSERVATIONS ON THE GROUND WATERS OF RIO GRANDE VALLEY.

By CHARLES S. SLICHTER.

CHAPTER I.

INVESTIGATION OF THE UNDERFLOW AT THE NARROWS OF THE RIO GRANDE NEAR EL PASO, TEX.

An investigation of the underflow of the Rio Grande was begun in the latter part of August, 1904, at the narrows of the Rio Grande, a few miles above El Paso, Tex., where the stream flows through a narrow gorge of limestone. At this place is the site of the proposed Mexican-American international dam. At the surface of the water the distance between the walls of the gorge is less than 400 feet. The dam site has been investigated by the International (Water) Boundary Commission, organized by the joint action of the American and Mexican Governments, and maps and reports concerning the proposed dam will be found in the Proceedings of the International (Water) Boundary Commission, vol. 2, page 277.

A brief reconnaissance at the site of the proposed international dam indicated that there could be no underflow of any magnitude at this point. The distance between the walls of the gorge is less than 400 feet, and the test borings made by the Mexican commission in 1897 seemed to indicate that the maximum depth to bed rock is 86 feet. A cross section of the gorge, based upon the Mexican borings, is shown in fig. 2. In this diagram the vertical and horizontal scale are the same. A cross section of less than 40,000 square feet could not transmit a large volume of ground water even if other conditions were favorable. The highest velocity ever determined for ground water is about 100 feet in twenty-four hours, and assuming this maximum velocity at the above cross section, and a porosity of one-third in the water-bearing sands and gravel, the daily discharge would be 1,333,000 cubic feet, or 15½ cubic feet per second. The gradient of the water plane at the narrows is but $3\frac{3}{10}$ feet to the mile, and all other indications point to a low rather than a high velocity.

None of the usual indications of an underflow were found at this point. If there was a true underflow a stream undoubtedly would

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flow perennially in the narrowest part of the gorge. Some miles above the site of the dam the valley broadens and is 2 to 5 miles in width, the sides gradually converging as the gorge is approached. The diminishing cross section would cause any underflow waters in the

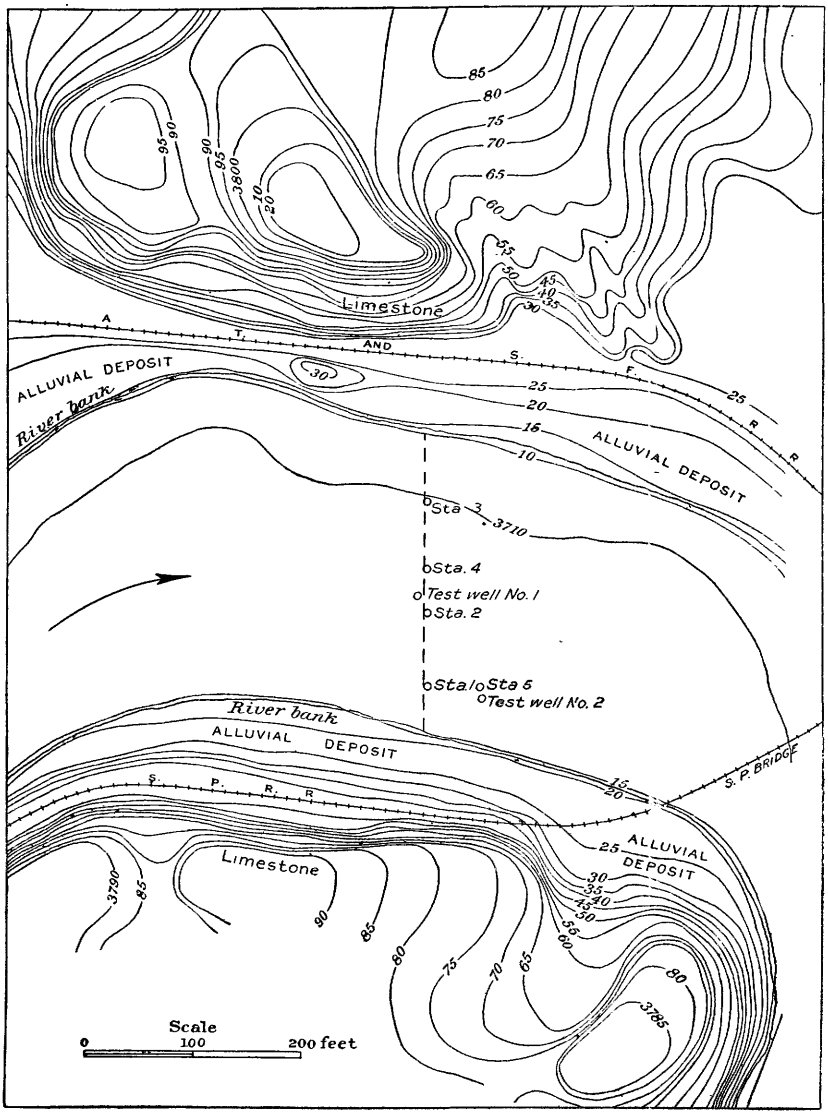

FIG. 1.—Topographic map of the gorge of the Rio Grande above El Paso Tex., where the underflow measurements were made.

valley above the narrows to seek relief at the surface in the narrow gorge and form a perennial flowing stream. Instead of this being the case the river is perfectly dry at the gorge when it ceases to flow above

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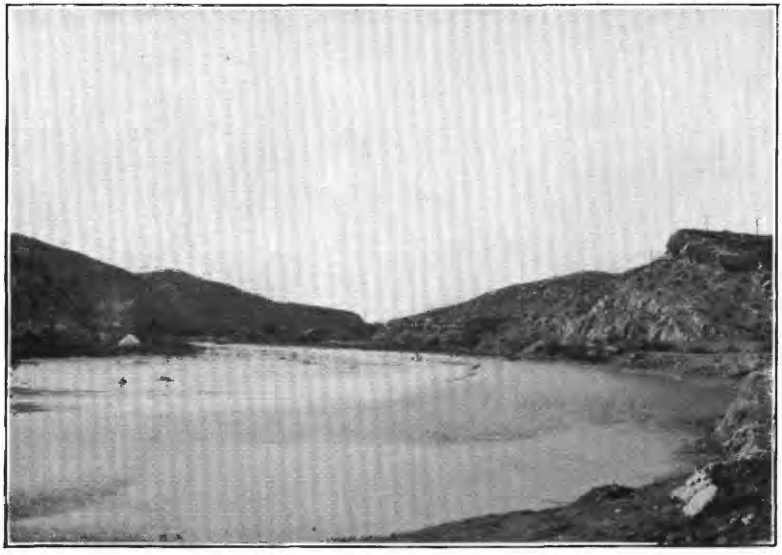
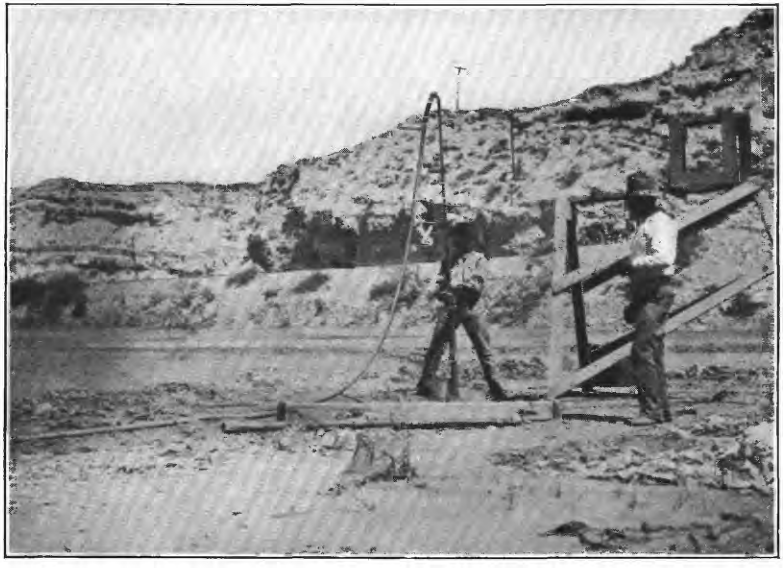


A. GORGE OF THE RIO GRANDE ABOVE EL PASO, TEX.



B. WASHING DOWN TEST PIPE AT THE GORGE OF THE RIO GRANDE.

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the pass. It was dry during several months of 1904. In addition to a perennial surface flow through the narrowest portion of and above the gorge and near its converging sides, the ground waters should have a slightly artesian character. None of these common indications of an underflow were found.

Notwithstanding the above considerations, actual determinations of the rate of underflow were begun, largely on account of a local popular belief that there is an enormous underflow at this point. The results of the investigation are in accordance with general considerations above indicated.

The material in the river bed at the site of the proposed international dam consists of sand and fine gravel with occasional layers of silt. No bowlders were encountered in sinking the test wells and the borings were made with great ease. The ground waters in the sands of the gorge were found to contain a large amount of dissolved solids.

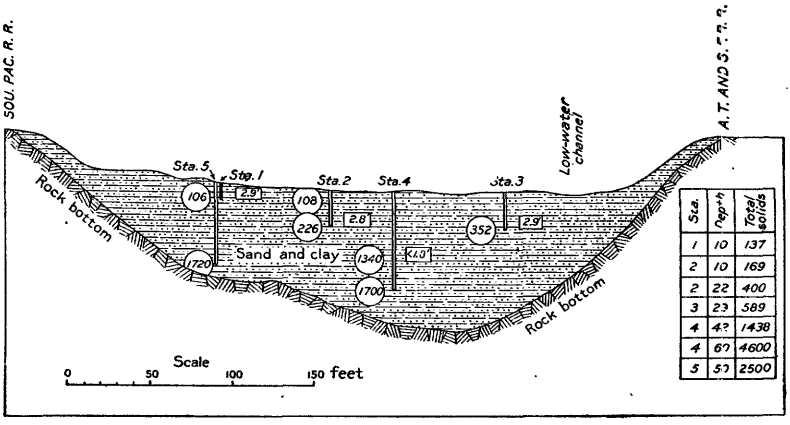

FIG. 2.—Cross section of the gorge of the Rio Grande, above El Paso, Tex., at the site of the proposed international dam.

The numbers inclosed in the rectangles give the velocity of the ground water in feet per twenty-four hours. The numbers inclosed in circles give the amount of common salt in parts per 100,000 dissolved in the ground water. The table at the right gives the depths of the test wells and the amount of total solids found in the water. The supposed rock bottom is given as determined by the Mexican borings, the vertical and horizontal scales being alike.

At a depth of 10 feet the waters contained about 100 parts per 100,000 of common salt, and the quantity became larger as distance from the surface increased. Below a depth of 32 feet so much salt was present that it was very difficult to determine the rate of motion of the ground waters. At a depth of 42 feet the common salt in solution amounted to 1,340 parts per 100,000; at 60 feet it reached 1,700 parts per 100,000; in a 50-foot test hole it amounted to 1,720 parts per 100,000. The total solids dissolved in the ground water were proportionately as large as the amount of common salt, so that at a depth of 40 feet the water was about half as strong as sea water, and at a depth of 60 feet it was

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about 30 per cent stronger than ordinary sea water. In fig. 2 the positions of the principal test wells are shown.

The velocities as found at stations 1, 2, and 3 were very uniform, being 2.9 feet per twenty-four hours at station 1, 2.8 feet per twenty-four hours at station 2, and 2.9 feet per twenty-four hours at station 3. The greatest depth at which it was practicable to make a determination of the rate of flow was 42 feet, where the common salt in solution amounted to about 1,400 parts per 100,000. In order to increase the conductivity of this water, it was necessary to make use of a stronger electrolyte than ammonium chloride. For this purpose a quantity of ammonium chloride was saturated with a gallon and a half of hydrochloric acid. This mixture was used to salt the upstream well used for determining the rate of the underflow. From the way the apparatus worked it was evident that it is possible to determine the rate of movement of ground waters as strong in salt as the water of the Rio Grande

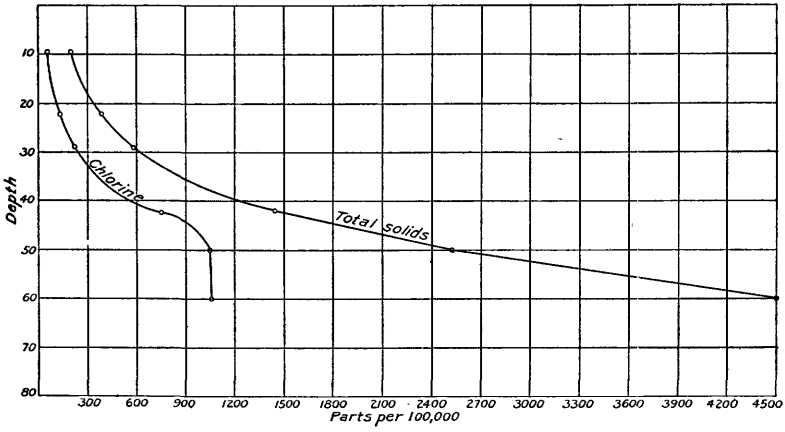

FIG. 3.—Diagram showing the variation with depth of the total solids and chlorine in the ground water at the gorge or narrows of the Rio Grande above El Paso.

The rapid rate of increase in the dissolved solids at a depth of about 40 feet indicates that the water below such depth is stagnant or without appreciable movement.

at a depth of 42 feet; as a matter of fact, however, the water at this depth is either stationary or moves much slower than at higher levels. After waiting three days none of the electrolytes had reached the downstream wells, and it was concluded that there was practically no motion of the ground water at this depth. A few of the test wells were driven to a greater depth, in order to secure samples of the water and to note the amount of contained solids, but no measurements of the rate of motion of the waters were attempted. Fig. 3 represents by curves the variation of the chlorine,[a] and total solids with the depth as determined from the various test wells. This diagram suggests that the water below the 35- or 40-foot level is not moving. The

[a] The amount of common salt is proportional to the chlorine.

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increase in total solids is not uniform, but becomes greater below the 35-foot line. The amount of chlorine shows a similar jump at about the same depth, but after increasing suddenly it seems to remain stationary. This may be due to the fact that the common salt in solution originates above the gorge, and has been slowly concentrated during a long time. The total solids, on the contrary, include the dissolved salts of lime, which can become almost indefinitely concentrated from the limestone débris in the gravels of the gorge itself.

It would be interesting to know whether the depth of the most sudden increase in the dissolved salts (say 35 feet) corresponds to the depth of the maximum scour of the river at the gorge.

The velocities of the ground water in the tests described above are undoubtedly the maximum velocities in the narrows of the gorge, since pains were taken to make the tests in the coarsest strata encountered in the borings. Layers of fine silt were frequently met with in putting down the test wells, which probably accounts for the stagnant condition of the water below the 35-foot level. These layers of silt are undoubtedly imbricated in such a way that movement of the deeper ground waters is impossible.

The total cross section in which the ground waters move is about 35 feet in depth and 325 feet in width and has an area of 11,200 square feet. If it is assumed that the porosity of the material is one-third and the maximum velocity of the ground water is 3 feet per day, the total discharge through the gorge does not exceed 11,200 cubic feet per twenty-four hours, or about 0.132 cubic foot per second, or about 50 gallons a minute. This amount of underflow is entirely insignificant. It is obvious that on account of the enormous quantity of dissolved solids the underflow would be worthless, no matter what its magnitude might be.

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CHAPTER II.

GROUND WATERS BELOW EL PASO, TEX.

The Rio Grande Valley below El Paso has been studied with reference to possibility of obtaining a ground-water supply from wells. East and north of El Paso is a very level strip of country known as the "Lanoria Mesa." This mesa lies between 4,000 and 5,000 feet above the sea level, and extends as a nearly unbroken plain between two north-south ranges of mountains. On the west the mesa is limited by the Franklin, Organ, and San Andres mountains, to the east it is bordered by the Hueco Mountains, and farther north by the Sacramento Mountains. At the southern end the east and west extent of the mesa is about 20 miles, and at the north it is almost unbroken for 100 miles. The north end of the mesa is interesting on account of several very unusual topographic features. A number of miles west and north of Alamogordo, N. Mex., are depressions which are said to be the channels of an ancient river. A great overflow of lava covers the northern portion of the mesa, and apparently hides the bank of the ancient river channel. About 18 miles north and west of Alamogordo are found the famous "white sands" of New Mexico, which consist of wind-blown hillocks of granular grains of gypsum. The white sands belt has, east to west, a width of 5 to 18 miles, a length north to south of about 40 miles, and an area of nearly 600 square miles.

In the northern portion of the Lanoria Mesa good wells are very rare, and at many places are quite unknown. The ground waters for the most part are highly alkaline and unsatisfactory for use. Running water can be noticed in many places flowing beneath the lava bed, forming a subterranean stream locally called the "Lost River."

In the southern portion of the mesa within 20 miles of the Rio Grande is a very fine-grained, water-bearing sand at a depth of about 230 feet. The water-bearing stratum is between 30 and 60 feet thick where it has been found and the contained water is of an excellent quality. The strongly alkaline waters common in the northern part of the mesa seem to be entirely absent from this portion. The water-

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bearing sand, however, is too fine grained to furnish wells of large capacity. The origin of ground water in this sand stratum is difficult

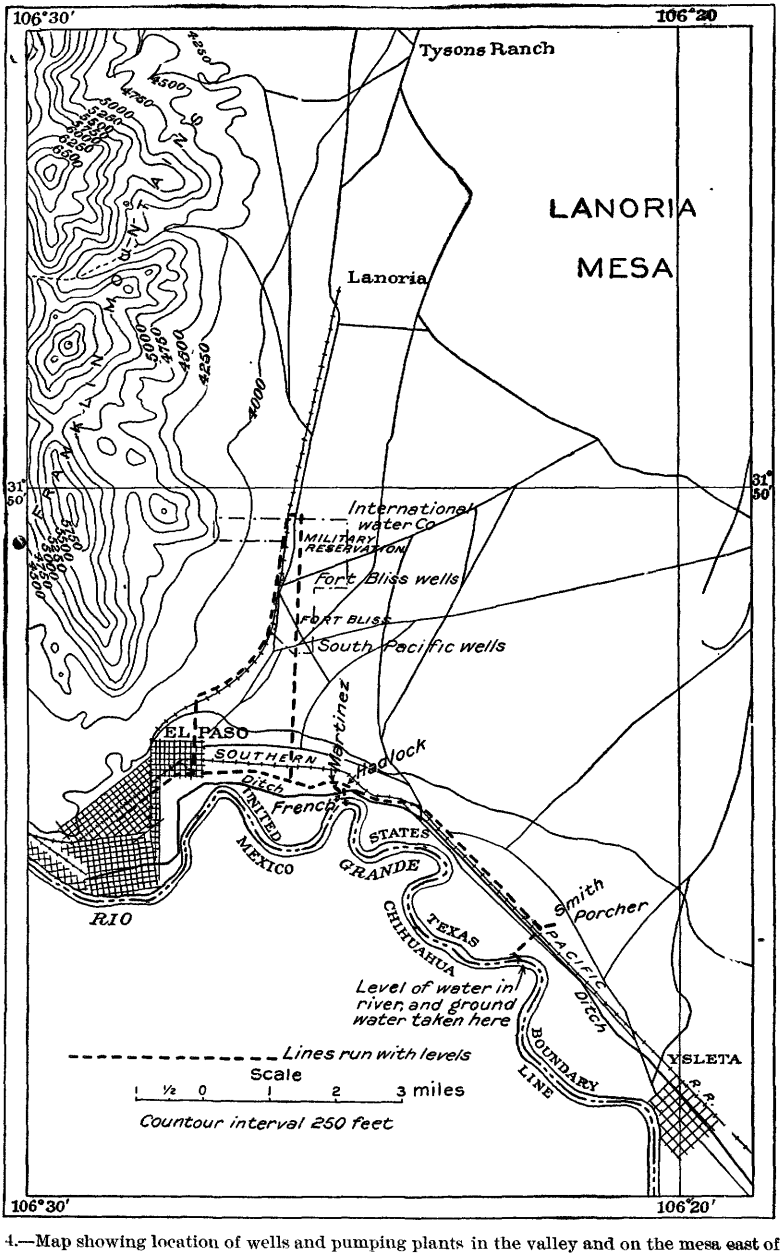

FIG. 4.—Map showing location of wells and pumping plants in the valley and on the mesa east of El Paso. The lines run with level are shown.

to trace. Nearly everywhere in the southern part of the mesa there is within a few feet of the surface from 3 to 6 feet of "caliche," a

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cemented calcareous impervious conglomerate that prevents the seepage of ground water. The deposit of "caliche" seems to be the result

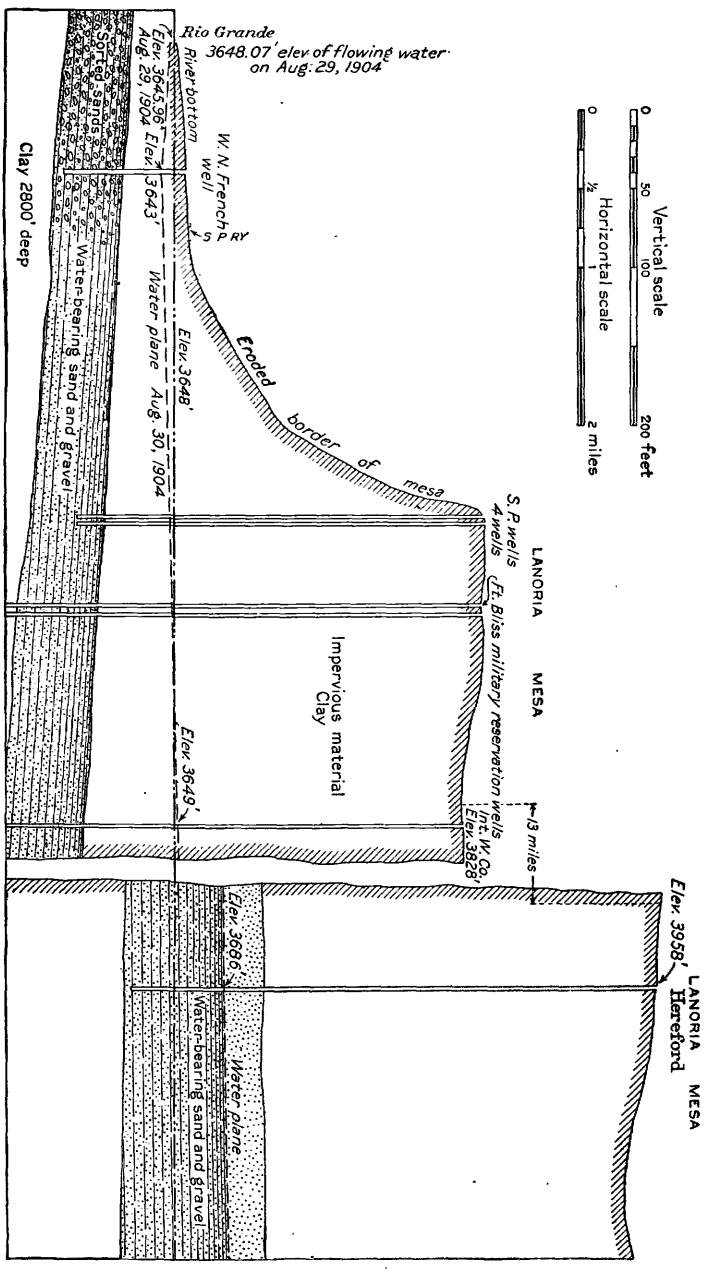

FIG. 6.—Section through Lanoria Mesa near El Paso, from Hereford to French's pumping plant, showing water-bearing sands and position of the water plane.

of the evaporation of the ground water near the surface of the mesa. Whenever this "caliche" is present the rainfall is undoubtedly unable

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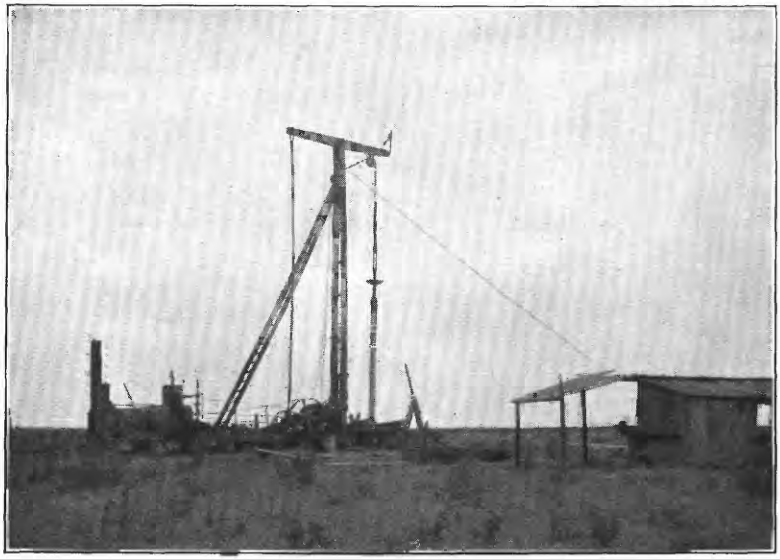
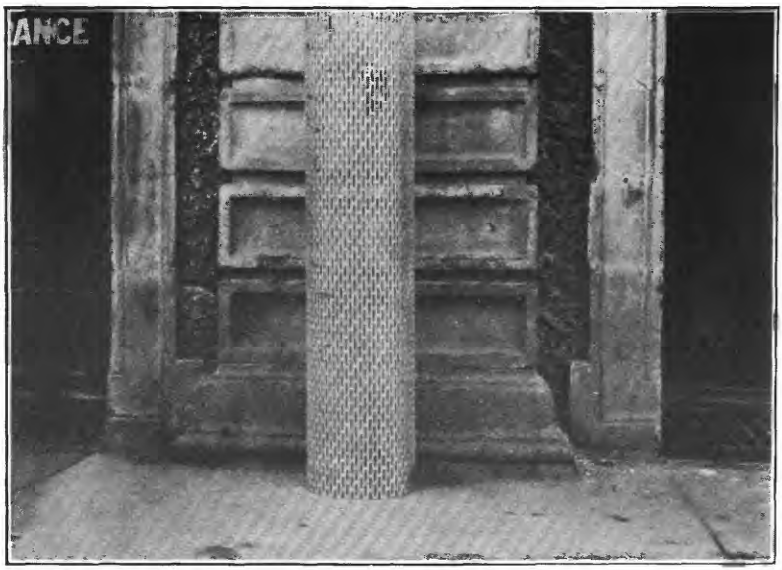


A. CALIFORNIA WELL RIG.



B. PORCHER STRAINER.

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to penetrate the ground for a distance of more than a few feet. The annual precipitation is so slight, not exceeding a total of 9 inches, that the portion that sinks into the ground must soon be evaporated by the intense heat of the sun wherever the "caliche" is present.

It is difficult to believe that the ground water in the stratum of sand referred to above is derived from the run-off from the north-south mountain ranges. These mountain ranges consist very largely of limestone; and the small canyon streams run high in calcium, but the waters found in the sand stratum are very soft and show no indication of having originated in a calcareous catchment area. The most probable source of the water of the sand stratum of the mesa is the rainfall on the mesa itself, especially on limited portions located between 12 and 25 miles north of the Rio Grande. Part of the surface material on the mesa near Hereford is very sandy and is fairly well adapted to receive and absorb a considerable part of the light rainfall. The railroad wells drilled at this point indicate that only a fractional part of the sand stratum is saturated with water, while in the lower part of the mesa in the neighborhood of Fort Bliss, near the valley of the Rio Grande, the water in the sand is found under an artesian head. These facts are brought out in fig. 5. As will be seen by inspection of this diagram, the source of the ground water found in the deep-lying sands and gravels should be sought in the neighborhood of Hereford. The ground water certainly can not have had its source near Fort Bliss, as is proved by its artesian character. North of Hereford a point is reached at which the ground waters are very strongly alkaline, and it is evident that water can not have originated so far north. The contrast between the strong waters in the north and the soft waters in the southern part of the mesa suggests that the waters of the one portion of the mesa must be cut off geologically from those of the other part.

Within a few miles of the southern edge of the mesa several deep wells have been sunk to obtain water from the above-mentioned sand and gravel. Near the southern edge of the mesa the Southern Pacific Railroad has a group of wells designed to obtain ground water for railroad purposes. The wells are 8 inches in diameter and about 270 feet deep, and each contains at the bottom a No. 6 Cook strainer, 7 inches by 20 feet in dimensions. The quality of the water is excellent, but the quantity is very limited. The four wells, each supplied with a Downey double-acting deep-well pump, are able to secure no more than 150,000 gallons in twenty-four hours. About one-half mile north of the Southern Pacific wells two wells have been sunk to obtain water for the use of Fort Bliss Military Reservation. The two wells are about 20 feet apart, the depth of the eastern well being 313 feet and that of the western 319 feet. The wells have a diameter of 8 inches, contain 6-inch suction pipes, and carry at the bottom a No. 6 Cook strainer, 5¾ inches in diameter and 8 feet long.

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They are pumped by two Cook deep-well pumps, which lift from 52,000 to 86,000 gallons in twenty-four hours. About 200 feet north of the military reservation at Fort Bliss the International Water Supply Company, of El Paso, Tex., has sunk seven 12-inch California stovepipe wells for the purpose of securing a municipal water supply for the city of El Paso. In one of these wells, which ended at the depth of 2,800 feet in a bed of dry clay, no water-bearing stratum was found below the sand referred to above. The yield of the International wells had not been determined, but it was evident from samples of material that it could not be much greater than that at the Southern Pacific or the military reservation wells. A yield of 100,000 gallons per twenty-four hours for each of the seven wells of the International Water Supply Company is probably a large estimate.

At the southern boundary of the mesa the Rio Grande is about 40 feet higher than the top of the water-bearing sand mentioned above (see fig. 5). There is every indication that at the time the river eroded the gorge above the city to the depth of 86 feet it also cut into this deposit of sand and resorted and redeposited the material, carrying away the finer portions. For this reason good wells can be had along the edge of the mesa wherever the river has done its work, except in a few places where the river has carried away all of the sand and left a local deposit of clay and mud. The water in the resorted gravels is very good, but not nearly as soft as the water of the wells on the mesa proper. In these resorted sands and gravels are located the wells used for irrigation in the bottom lands of the Rio Grande. The water found in the sands in the neighborhood of these pumping plants is probably in large part contributed by the Rio Grande. The accompanying table gives partial analyses of water taken from the mesa wells and from the wells in the bottom lands of the river. Furthermore, as shown by fig. 5, on the mesa the water plane slopes very gently toward the Rio Grande and near the irrigation pumping plants it slopes at a higher angle away from the river channel. As can be seen from fig. 5, the water planes on August 29, 1904, at the wells of W. N. French, about 3 miles east of El Paso, sloped away from the river at a gradient of 2 feet to the mile, while the slope from the mesa to French's well was two-thirds foot to the mile. On that date the water plane in the channel of the river stood about 2 feet lower than the surface of the stream. This indicates that the river probably does not furnish very much water to the sand on account of the deposits of silt in the river bed, except at times of flood, when the scour of the river extends to a considerable depth. At such times it is probable that the sands take up and store a considerable quantity of river water, which ultimately finds it way to the pumping plants.

Conditions similar to those mentioned were found about 8 miles east

of El Paso, at the pumping plants of J. A. Smith and J. S. Porcher. Fig. 7 shows the slope of the water plane between the river channel

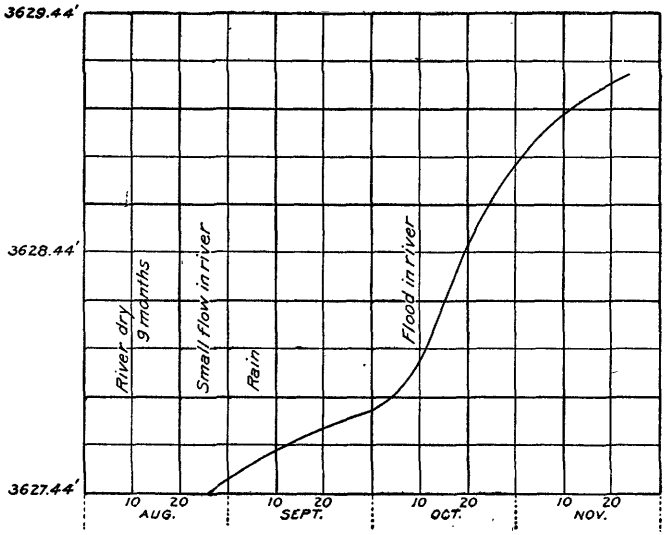

FIG. 6.—Elevation of water plane at Porcher's well No. 1.

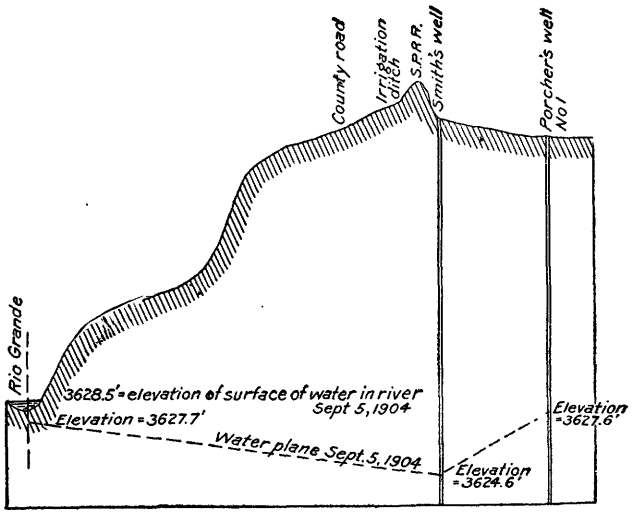

FIG. 7.—Water plane between Porcher's and Smith's pumping plants and the Rio Grande or September, 5, 1904.

and the wells of Smith and Porcher, as determined on September 5, 1904.

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Partial analyses of samples of water from the Rio Grande Valley, Texas and New Mexico.

[In parts per 100,000.]

Name of well.	Depth of well.	Total solids.	Chlorine.	Hardness as $CaCO_3$.	Alkalinity as $CaCO_3$.
Samples taken near El Paso, Tex.:	*Feet.*				
City water, El Paso, Tex	.....	127	54.0	70.4	20.0
El Paso Brewery	58	72	21.4	30.0	21.2
Felix Martinez	68	62	13.7	29.6	19.1
E. J. Hadlock	30	104	31.5	47.7	27.7
W. N. French	78	55	11.0	25.0	17.7
J. S. Porcher	60	110	22.6	73.5	25.3
J. A. Smith No. 1	62	174	55.6	67.0	23.0
J. A. Smith No. 2	60	90	18.1	40.8	20.6
Southern Pacific wells	270	42	2.13	11.1	17.5
Fort Bliss Military Reservation	315	29	1.95	10.5	16.4
El Paso and Northeastern at Fort Bliss	250 410	46	2.38	11.3	20.0
International Water Co	260	22	1.48	7.25	11.5
Samples taken near Berino, N. Mex.:					
Horaco Ranch Co. No. 2	53	126	30.9	45.8	29.6
Horaco Ranch Co. No. 1	75	170	54.2	62.8	37.0
Horaco Ranch Co. No. 3	62	203	63.9	59.5	52.5
Samples taken near Las Cruces, N. Mex.:					
G. H. Totten	62	99	19.6	59.8	29.5
T. Roualt	48	76	11.2	47.3	19.4
W. N. Hager	63	71	13.8	50.8	23.6
A. L. Hines	59	73	10.8	47.5	28.5
F. C. Barker	48	96	15.8	58.1	28.7
Mrs. E. M. Boyer	52	57	7.5	38.6	25.1
J. C. Carrera	58	83	11.2	54.2	27.3
Samples taken at the gorge near El Paso:					
River water	.....	128	9.6	55.8	11.7
Station No. 2	10	169	63	95	23.0
Do	22	400	137	100	18.6
Station No. 3	29	589	213	139	20.9
Test well No. 1	10	137	65.7	63.6	19.7
Station No. 4	42	1,438	845	245.0	31.4
Do	60	4,600	1,033	224	35.9
Station No. 5	50	2,500	1,040	224	31.4

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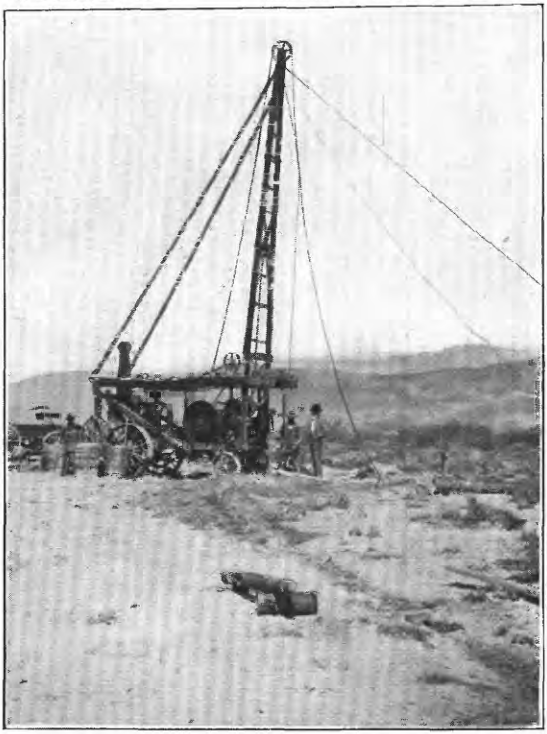

A. SMALL RIG FOR DRILLING WELLS FOR STOCK.

B. TIMBER ON SACRAMENTO MOUNTAINS.

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During nine months ending August 25, 1904, there was no water in the river channel below El Paso. During this time the water plane at the Porcher well No. 1 (an unused well 100 feet from the well of the new pumping plant) fell a total distance of 2 feet, or to an elevation of 3,627.44 above mean sea level. By September 5, 1904, after four days' rain the water in this well had risen 0.15 foot. The record of the week of rain is given in the table below. By October 2 the water plane had risen 0.37 foot (to 3,627.81 feet). On November 20, 1904, it was within 0.3 foot of the elevation before the 2-foot loss noted above, and was still rising at the rate of about one-fifth inch per 24 hours. On March 7, 1905, the water in the well had reached an elevation of 3,630.79, or a total rise of 3.35 feet in seven months. There was water in the Rio Grande during all of this period.

These observations show clearly that the principal source of the ground water near Smith's and Porcher's ranches is seepage from the Rio Grande. A heavy flood about October 9 greatly accelerated the rate of rise of the water plane, as is shown by fig. 6, where the changes in level at Porcher's well No. 1 are represented by a curve.

Rainfall, in inches, at El Paso, Tex., September 1 to 10, 1904, as reported by the United States Weather Bureau.

September 1	0.0	September 7	0.09
September 2	.09	September 8	Trace.
September 3	.53	September 9	Trace.
September 4	.62	September 10	.0
September 5	.16		
September 6	.61	Total	2.10

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CHAPTER III.

EXAMINATION OF GROUND-WATER SUPPLIES IN THE MESILLA VALLEY.

The valley of the Rio Grande begins to broaden north of the narrows in the neighborhood of El Paso, Tex. Near Las Cruces, N. Mex., the level bottom lands are about 5 miles wide, and irrigation has been extensively carried on for many years. Besides the city of Las Cruces, there are situated in this part of the valley the villages of Mesilla and Mesilla Park. Between old Fort Selden, north of Las Cruces, and the post-offices of Berino and Anthony, about 12,000 acres are under cultivation.

Owing to frequent shortage in the river supply of water, a number of pumping plants have been installed for the purpose of obtaining ground water for irrigation. One of the first wells for this purpose was drilled by the Agricultural College at Mesilla Park. At this place a coarse water-bearing gravel bed about 12 feet thick was found at a depth of 32 feet. This gravel is overlain by quicksand and adobe. The water level in the wells stood originally 16 feet below the surface of the ground. This well was used extensively for experimental purposes, and later a 12-inch well was put down to the same depth in the neighborhood of the 6-inch well. A great many tests of different kinds of pumps and engines were made at these wells, and a careful study was made of the cost of the recovery of the water, as well as of the amount of land in various kinds of crops that could be irrigated with the water recovered. A report on this work was published in 1903 by Professors Vernon and Lester and issued as a bulletin of the agricultural experiment station at Mesilla Park. As a result of the experiments and of the published reports on the wells at the agricultural station, a number of pumping plants have been installed during the present season, and many more are likely to be established in the near future. For that reason it has become important to have accurate information of the source of the ground-water supply in this part of the Rio Grande Valley and to determine the amount available for such use.

A reconnaissance near Las Cruces and Mesilla Park indicated that there is probably no underflow in this valley in the true sense in which that term is used. The rainfall upon the catchment area northeast of the valley is very slight and the run-off is correspondingly low. It

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does not seem possible that the ground waters which are used for irrigation could originate very largely in the rainfall upon the neighboring mesa and the foothills and upon the slopes of the Organ Mountains

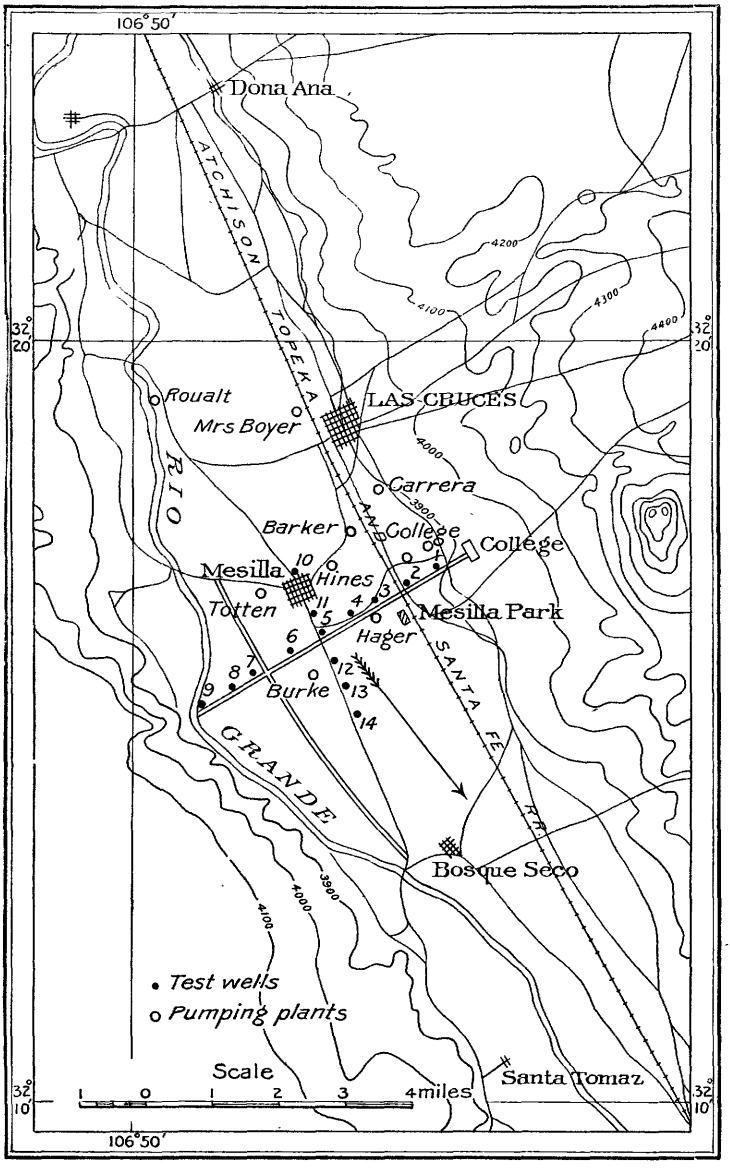

FIG. 8.—Map showing lines of test wells and location of pumping plants near Las Cruces and Mesilla Park, N. Mex.

to the northeast. These mountains are very precipitous, and furnish in all probability a very small amount of run-off to the ground waters of the valley.

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TEST WELLS.

For the purpose of determining the source of the ground waters in the Mesilla Valley two lines of test wells were sunk across the valley, one at right angles and the other parallel to the general direction of the river. These test wells were cased with 1½-inch pipe and were provided at the lower end with a common brass jacket well point. They were sunk to such a depth that the strainers would be completely covered with water at all times.

The plan of the test wells is shown in fig. 8. Across the valley are 9 wells on the average of one-half a mile apart. The wells were

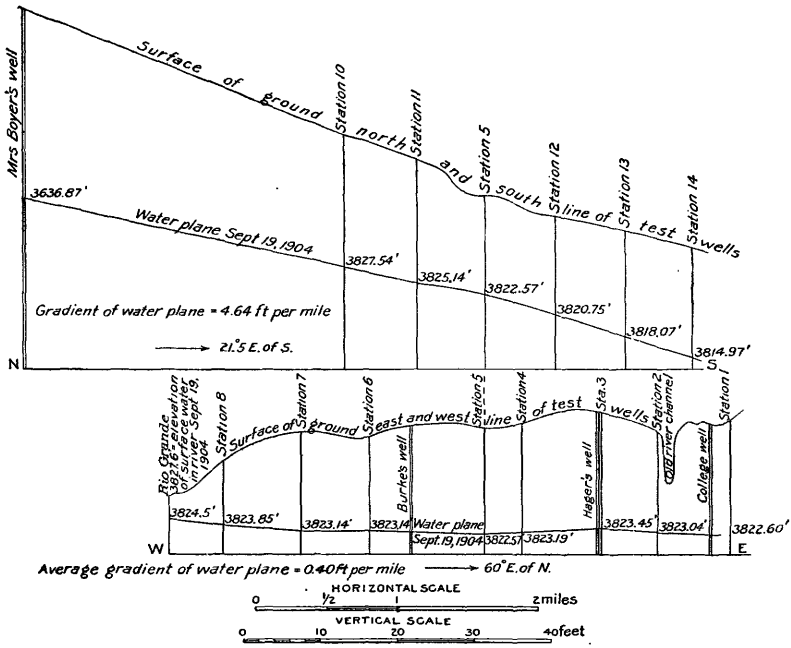

FIG. 9.—Position of the water plane September 19, 1904, in the two lines of test wells shown in fig. 8.

sunk as far as practicable along the public highways, so as to be readily accessible at all times. They were drilled primarily to determine the slope of the water plane in the valley and the changes in the position of the water plane during fluctuations in the level of the flowing water in the Rio Grande. In fig. 9 are shown the results of levels taken on both lines of test wells. In the upper part of the diagram is shown the position of the water plane September 19, 1904, in the wells of the north-south line. The Boyer well, located about 5 miles north of the northernmost 1½-inch test wells, was used as an additional test well, so as to extend the north-south line for a total distance of nearly 6 miles. As will be seen from fig. 9, the gradient of the water plane in the

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direction of the north-south line of test wells averaged 4.64 feet per mile at the time of the first observation on September 19, 1904. As shown on the lower part of fig. 9 the water plane, in an east-west direction, was nearly horizontal, but near the river it was somewhat higher than at the east end of the line of test wells, although the surface slopes gently in the opposite direction. A slight elevation in this section is seen at station 3. On an average the water plane in the east-west cross section slopes about 0.4 foot per mile toward the east end. It is evident from these cross sections that the ground water must flow in the general direction of the river valley. The direction of maximum slope of the water plane is shown in fig. 8 by the large arrow. This arrow should, therefore, indicate the direction of flow of the ground water. The gradient of the water plane of 4.64 feet per mile is very moderate, and it is probable that the real velocity of the ground water is low. The slight elevation at station 3 indicates that at this point the ground water comes to some extent from the north, and does not move from east to west. If such an east-west movement took place the motion would be uphill for the entire distance from station 1 to station 3.

SOURCE OF THE UNDERFLOW.

When the test wells were sunk it was expected that the position of the water plane in the wells would be observed every week until the time of high water in the Rio Grande, which would naturally be the spring of 1905. The test wells were sunk in cooperation with Prof. J. D. Tinsley, of the Agricultural College of New Mexico, who has made weekly observations of the height of the water plane in them. On October 5, 1904, heavy rains in the Rocky Mountains produced very disastrous floods in the Rio Grande and in nearly all the rivers heading in the Colorado Rocky Mountains. In the neighborhood of Las Cruces the maximum elevation of the river was higher than had been observed at any time in the last ten years. The period of very high water, so soon after the completion of the test wells, furnished an excellent opportunity of observing the effect of the floods in the Rio Grande upon the ground waters of the valley. Instead, therefore, of waiting for the spring floods of 1905, it became possible to determine immediately the essential facts in regard to the effect of the river upon the ground-water level. In Pl. IV the ground-water levels in the east-west line of test wells are given for each month from September 19 to March 26. The first observation taken on October 1 shows that the water had risen 0.4 foot since September 19. On October 9, however, the water at station 8 was 1.6 feet higher than on October 1. This was due to the flood of October 5. The flood raised the ground water at station 8 about 0.7 of a foot more during the next week, but from October 16 to 23 the small rise of 0.1 of a foot indicates that by October 23 the ground-water level at station 8 had tem-

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porarily reached its highest position. Therefore, as a result of the flood, the gradient of the water plane immediately adjacent to the river, between stations 8 and 7, increased from 0.7 of a foot per mile to 2.3 feet per mile. The direction of movement of the water in the gravel was therefore undoubtedly downstream, even during times of flood, for while the east-west gradient increased to 2.3 feet to the mile in the immediate neighborhood of the river, the original downstream gradient of 4.64 feet to the mile was not materially affected. The test wells in the north-south line have not shown a departure of more than 0.1 of a foot from the original levels on September 19.

The table contains the observations on both sets of test wells until March 26, 1905. The Rio Grande had water in it continuously during this time. In high stages of the river the water in the wells still further rose, as is shown by the table and fig. 8. The total rise at station 8, located 0.4 mile from the river, was substantially 5 feet. The effect of the river can be traced at least 2 miles from its east bank. The rise at stations 1 and 2 during March, 1905, took place after irrigation had begun and is largely due to that cause.

Elevation of ground water, in feet, above datum,[a] in east-west line of test wells near Mesilla Park, N. Mex.

[Feet above datum.]

Date.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
1904.								
September 19	22.60	23.03	23.45	23.19	22.57	23.14	23.85	23.85
October 1	22.61	23.10	23.43	23.15	22.85	23.19	23.16	24.25
October 9	22.74	23.21	23.50	23.15	22.85	23.19	23.38	25.85
October 16	22.77	23.23	23.48	23.13	22.86	23.14	23.59	26.18
October 23	22.77	23.23	23.46	23.13	22.83	23.12	23.73	26.22
October 30	22.77	23.21	23.42	23.13	22.86	23.07	23.81	26.28
November 6	22.74	23.18	23.36	23.08	22.84	23.03	23.94	26.36
November 13	22.77	23.20	23.36	23.09	22.86	23.10	24.05	26.38
November 20	22.76	23.16	23.32	23.06	22.83	23.10	24.13	26.34
November 27	22.77	23.18	23.34	23.03	22.83	23.11	24.18	26.42
December 18	22.69	23.08	23.27	23.00	22.84	23.22	24.41	26.59
1905.								
January 15	22.52	22.96	23.10	22.81	22.72	23.25	24.51	26.85
February 5	22.50	22.96	23.05	22.79	22.74	23.48	24.66	26.78
February 26	22.52	22.96	23.01	22.83	22.89	23.73	24.83	27.20
March 12	22.98	23.06	23.01	22.95	23.01	23.83	25.10	28.20
March 26	23.12	23.34	23.12	22.98	23.04	23.97	25.37	28.59

[a] Datum plane 3,800 feet above mean sea level.

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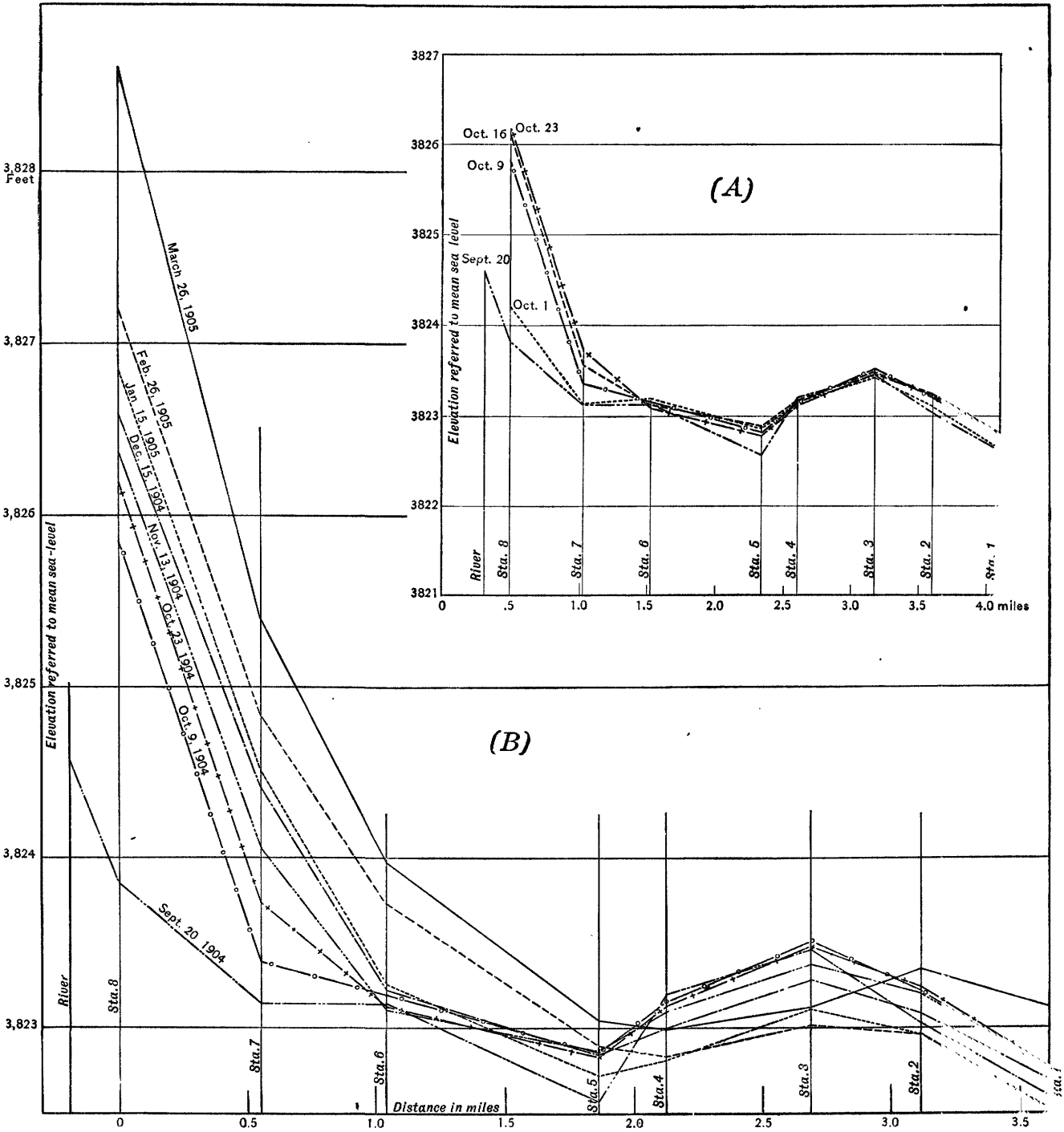

DIAGRAM SHOWING VARIATION IN ELEVATION OF GROUND WATER IN THE EAST-WEST LINE OF TEST WELLS FROM SEPTEMBER 20, 1904, TO MARCH 26, 1905.

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PROPERTY OF GEOLOGICAL SURVEY.

Elevation of ground water, in feet, above datum,[a] *in north-south line of test wells near Mesilla Park, N. Mex.*

[Feet above datum.]

Date.	No. 10.	No. 11.	No. 12.	No. 13.	No. 14.
1904.					
September 20	27.54	25.14	20.75	18.07	14.96
October 1	27.56	25.12	20.65	18.08	14.94
October 9	27.68	25.11	20.71	18.16	15.01
October 16	27.56	25.14	20.71	18.18	15.07
October 23	27.52	25.12	20.70	18.16	15.09
October 30	27.40	25.04	20.63	18.08	15.04
November 6	27.46	25.07	20.65	18.11	15.11
November 13	27.44	25.06	20.64	18.11	15.14
November 20	27.43	25.03	20.63	18.10	15.16
November 27	27.40	25.03	.....	.....	.....
December 18	27.40	25.03	20.64	18.14	15.29
1905.					
January 15	27.25	24.89	20.54	18.05	15.25
February 5	27.29	24.91	20.54	18.18	15.29
February 26	27.46	25.07	20.68	18.50	15.46
March 12	27.59	25.16	20.83	18.59	15.59
March 26	27.59	25.19	20.84	18.58	15.65

[a] Datum plane 3,800 feet above mean sea level.

The observations of the test wells show that the ground waters in the Mesilla Valley originate in the flood waters of the river. During times of low water the river bed is so thoroughly covered with mud that probably only a small amount of water escapes in the sand and gravels of the valley. During the period of flood, when the scour is deep, the contributions of the river to the underflow reach a maximum, as at that time the greatest amount of water is available for this purpose.

The observations of the ground-water level indicate also that a small portion of the underflow reaches the river valley from the mesa and foothills to the north and east of Las Cruces. The changes in the east-west line of water levels reached a maximum at the west end at station 8, with a secondary maximum at the east end at station 1. The high floods in the river were accompanied by rainfall on the mountains and mesa to the north and east of Las Cruces, and a sufficient amount of water penetrated the ground to cause the elevation of the water plane shown at the eastern end of the diagram. It will be observed that the total change in elevation at stations 1 and 2 was 0.2 of a foot. This change took place almost simultaneously with the rise at station 8.

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Nevertheless, a slight indication of a lag in the rise of stations 1 and 2 can be observed from the diagram. The table on p. 26 gives the elevation of the water in the test wells as observed by Professor Tinsley between September 19, 1904, and March 26, 1905.

INDICATIONS OF THE AMOUNT OF GROUND WATER AVAILABLE.

The following table gives the rate at which water was contributed to the underflow at Mesilla Park by the river, and also by the rainfall on the foothills and mountains northeast of the river valley. The total amount contributed by the river during the thirty-three days comprised in the period of observation was 8,900,000 cubic feet of water for each linear mile of the river valley. Of this amount 5,120,000 cubic feet, or more than half, was contributed in eight days, between October 1 and 9, which include the flood beginning October 5. In column 4 of the table is given the rate at which 1 linear mile of the river channel furnished water to the underflow, expressed as a continuous flow in cubic feet of water per second. These same facts are expressed in gallons per minute in column 5. The average rate of contribution for the 33-day period was 3.03 cubic feet per second, or 1,360 gallons a minute. If a plant which pumped continuously 1,360 gallons a minute was installed for each mile of the river valley, all the water contributed by the river would be pumped, and the level of the ground water at the end of the period would be the same as at the beginning. Any greater rate of pumping would have a tendency to lower the water plane below its initial value and make a draft upon the permanent supply stored in the gravels.

In columns 6, 7, and 8 is given the amount contributed to the underflow by the rainfall upon the mesa, northeast of the valley. The total amount contributed during the thirty-three days covered by the table was 1,517,000 cubic feet of water per mile of valley—an average flow of 0.515 cubic foot per second, or 232 gallons a minute. During the last week covered by the table the gravels near the eastern edge of the valley lost water instead of gaining, and the entries in the table for this period are negative. A well pump drawing 232 gallons of water per minute, if operated continuously during the 33-day period, would just consume the seepage from the rainfall contributed by 1 linear mile of the valley.

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Amount of water contribution to the underflow of the Rio Grande near Mesilla Park, N. Mex., between September 20 and October 23, 1904.

		Amount of ground water contributed by each mile of the river.			Amount of ground water contributed by rainfall upon mesa east of the valley per mile of river valley.		
1.	2.	3.	4.	5.	6.	7.	8.
Dates.	No. of days.	Cubic feet of water per 24 hours.	Cubic feet per second.	Gallons per minute.	Cubic feet of water per 24 hours.	Cubic feet per second.	Gallons per minute.
September 20 to October 1	11	110,500	1.28	575	40,500	0.47	211
October 1 to 9[a]	8	640,000	7.40	3,330	152,000	1.76	794
October 9 to 16	7	248,000	2.87	1,290	29,900	.35	155
October 16 to 23	7	117,200	1.36	745	— 5,950	— .069	— 31
Total	33	[b]8,900,000	.....	.....	[b]1,517,000	.....	.....
Average per day	.....	270,000	3.03	1,360	45,800	.515	232

[a] Heavy flood on October 5, 1904.
[b] Total amount contributed for each mile of the valley in thirty-three days. Converting cubic feet into acre-feet we find that the river lost 204 acre-feet of water to the gravels of the underflow in thirty-three days, and 34.8 acre-feet were contributed by the rainfall in the same period. These amounts are for each mile of the valley.

NECESSITY FOR DEEP WELLS.

The examination of the underflow of the Mesilla Valley was confined exclusively to the zone of ground waters, in which are all of the irrigation wells of the valley. These wells have a depth of from 48 to 63 feet, and contain no more than 12 linear feet of strainer at the bottom. In some cases quicksand or silt was encountered at the bottom of the water-bearing gravels, but in other cases the drill was stopped while still in good material. There are no deep wells in the valley, but there is no indication that good gravels will not be met with at greater depths than those known at present. There seems to be a reasonable expectation of increasing enormously the specific capacities of the wells, and consequently the amount of ground water available for irrigation by drilling wells to greater depths. There is great need of an experimental well several hundred feet in depth that will test satisfactorily the ultimate possibilities of ground-water supply.

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OBSERVATIONS AT BERINO, N. MEX.

Berino is situated in the Rio Grande Valley 15 miles south of Las Cruces. The ground water in this part of the valley lies for the most

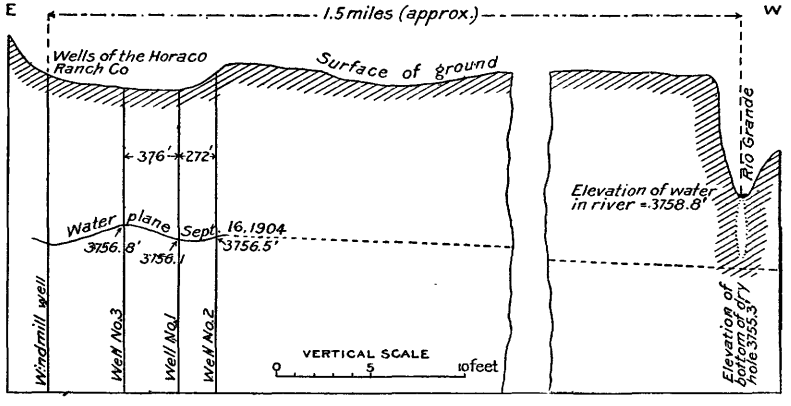

FIG. 10.—Cross section of part of Rio Grande Valley at Berino, N. Mex., showing position of the water plane on September 16, 1904. Water could not be found in a hole excavated 3½ feet below the level of running water at the edge of channel of the Rio Grande.

part within 8 or 9 feet of the surface. There is much "bosque," or lowland, which is covered with dense growth of timber, and in which the water plane is even nearer the surface.

A line of levels was run across the bottom lands of the valley at this point and the wells of the Horaco Ranch Company used to determine the position of the water plane. As shown on fig. 10, the water plane is nearly level in section A at right angles to the river valley, in which respect the situation at Mesilla Park is practically duplicated. A hole excavated to a depth of 3.47 feet below the surface of the running water in the river was dry at the bottom. The water plane is therefore some distance below the running water at low stages of the river, as at Mesilla Park and at points below El Paso. The losses of the river to the sands and gravels of its channel are undoubtedly small during low stages of water when the silt is heavily deposited. The principal contribution of the river to the underflow must take place during flood when the scour is deep.

In addition to the heavy autumn floods described above, very heavy floods came down the Rio Grande Valley during the spring of 1905. There was a good run of water during the entire winter. On this account the ground water at Berino in May, 1905, had risen about 4 feet above the level shown at the pumping plants in fig. 10.

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CHAPTER IV.

SUMMARY OF TESTS OF PUMPING PLANTS IN SOUTHERN NEW MEXICO AND TRANS-PECOS TEXAS.

The table on pp. 34–35 shows the results of tests of a number of pumping plants used for irrigation in the valley of the Rio Grande in southern New Mexico and trans-Pecos Texas. Most of the headings in the table explain themselves. Under the heading "Location" is given the post-office nearest to the ranch on which the pumping plant is located. The first three pumping plants, those of Felix Martinez, W. N. French, and E. J. Hadlock, are located about 3 miles east of El Paso, Tex. The plants of J. A. Smith and J. S. Porcher are situated in the valley of the Rio Grande about 8 miles east of El Paso, Tex. The plants of Barker, Boyer, Burke, Carrera, Hager, Hines, Roualt, Totten, and the Agricultural College are located in the valley of the Rio Grande in the neighborhood of Las Cruces, N. Mex. The pumping plants of the Horaco Ranch Company are located near the post-office of Berino, N. Mex., which is situated 24 miles north of El Paso and 17 miles south of Las Cruces.

The fuel used in most of these pumping plants is gasoline, which term as here used includes the "distillate" manufactured from Texas crude oil, which is extensively used for fuel purposes. Its calorific value is somewhat less than that of the gasoline used in the Eastern States.

DETERMINATION OF VACUUM.

In all of the plants, except the one of E. J. Hadlock, water is raised by means of centrifugal pumps, which are usually coupled directly to the top of the well casings. In order to determine the suction of the pumps it was necessary to drill a hole in the goose neck of the centrifugal pumps and insert the vacuum gage. The measurements to determine the distance the pumps were obliged to lift the water were made from this vacuum-gage tap as datum in all cases. In column 6 is given the distance the pump is required to lift the water above the vacuum-gage tap. In column 7 the vacuum reading is given in feet of water. The total lift of the pump can, therefore, be found in each case by adding the corresponding numbers in columns 6 and 7. In column 8 is given the distance that the water in the well is lowered during pumping. If the vacuum gage had been placed at the exact

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level of the undisturbed ground water, the readings in column 8 would be identical to those in column 7. The numbers in column 8 are less than those in column 7, because in all cases the vacuum gage stood some distance above the natural level of the water in the well.

The vacuum gage was carefully calibrated against a mercury column at an altitude of 3,720 feet above mean sea level, and the corrected readings are tabulated in all cases. In cases in which there were no foot valves in the suction pipe, the depth of the well and the position of the water plane could be determined by sounding through the quarter-inch hole drilled for the vacuum gage.

SPECIFIC CAPACITY.

The numbers in column 11 express the readiness with which the well furnishes water to the pump. In each case the result was obtained by dividing the numbers in column 10 by the corresponding numbers in column 8; column 11, therefore, expresses the amount of water the wells would furnish if the water level in them was lowered but one foot. These numbers constitute what is known as the "specific capacity" of the well, and are large in case of a good well and small in case of a poor well. This subject is more fully discussed in Water-Supply Paper No. 140, Chap. VII.

In column 12 are given the same magnitudes as in column 11, reduced in each case to 1 square foot of well strainer. The numbers in this column, therefore, express the amount of water in gallons per minute furnished by 1 square foot of well strainer under a head of 1 foot of water. They are a numerical expression of the degree of coarseness of the material in which the well is placed.

COST AND OPERATING EXPENSES.

In column 13 are given the costs of the plants expressed in round numbers. They are nearly equivalent in most cases to $100 per horsepower for the total cost of engine, pump, and wells. In a few special cases the cost was higher. In estimating the expense of operation, an allowance of 10 per cent has been made for the depreciation and repairs and of 8 per cent for interest. It is difficult to make an accurate estimate of the proportion of cost that should be charged up to the water recovered by an irrigation plant, on account of the presence of several unknown factors. If the plants were in operation every day in the year it would be relatively easy to make an accurate estimate of these factors in the operating expense. As it is, the plants are in operation for a longer or shorter period, depending on circumstances which vary from year to year. Most of the plants are used merely as auxiliaries to the supply of ditch water. In making the estimate of the charge for interest and depreciation it has been assumed that the plants are in operation for two thousand hours each

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season. This corresponds to a continuous use of three months of twenty-four hours daily, or two hundred days of ten hours each. It probably represents a fair average of the actual conditions.

In column 15 there is given a charge for labor and such other incidental expense—including oil and batteries—as is not properly included under the head of depreciation. The operation of the gasoline plants can be easily put in charge of unskilled labor, and for the smaller plants full time is not required of such labor.

FUEL COST.

That part of the operating expenses which is properly chargeable to fuel cost can be accurately determined. Column 16 expresses the cost for fuel per hour. Column 18 expresses the cost per acre-foot of water recovered. In column 17 are given the costs of fuel for lifting 1,000 gallons of water through a distance of 1 foot. For the purpose of comparison these results are expressed in fractional parts of a cent.

In column 5 is given the price of fuel. The price of gasoline is given in cents per gallon in barrel lots. The price of electricity is given in cents per kilowatt hour. Cost of wood at the ranch of T. Roualt is that of cottonwood per cord. The price of wood at the Agricultural College of $2.25 per cord is the rate for small Tornillo wood, which has a higher calorific value than the cottonwood used by Roualt.

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Principal data derived from tests of Rio Grande pumping plants.

Name of plant.	Location.	Horse-power.	Fuel used.	Price of fuel.	Lift above vacuum.	Vacuum in feet of water.	Amount water is lowered.	Total lift.	Yield, gallons per minute.	Specific capacity.
1	2	3	4	5	6	7	8	9	10	11
					Feet.		*Feet.*	*Feet.*		*Gals. per min.*
Felix Martinez	El Paso, Tex	10	Electricity	$0.05	16.77	25.50	22.16	38.93	378	17.50
W. N. French	do	8	Gasoline	.14	12.65	18.05	13.35	30.70	269	20.20
E. J. Hadlock	do	5½	do	.14	5.20	22.60	13.03	27.80	258	19.80
J. A. Smith No. 1	do	28	Crude oil	.03	14.00	22.70	16.24	36.70	938	57.40
J. A. Smith No. 2	do	22	Gasoline	.14	15.45	26.10	21.00	41.45	1,325	63.20
J. S. Porcher	do	15	do	.14	12.80	23.07	20.59	35.87	658	32.00
F. C. Barker	Las Cruces, N. Mex	5	do	.17	20.18	25.40	22.48	45.58	131	5.83
Mrs. E. M. Boyer	do	12	do	.17	17.60	22.70	19.76	40.30	658	33.30
F. Burke	Mesilla, N. Mex	21	do	.17	14.85	25.60	22.85	40.45	725	31.75
J. C. Carrera	Mesilla Park, N. Mex	8	do	.17	12.65	14.20	8.48	26.85	648	74.60
W. N. Hager	do	12	do	.17	17.17	17.60	15.20	34.77	325	22.30
A. L. Hines	Mesilla, N. Mex	8	do	.17	19.05	17.00	14.08	36.05	271	19.20
T. Roualt	Las Cruces, N. Mex	10	Wood	2.00	8.66	25.50	23.86	34.16	351	16.00
G. H. Totten	Mesilla, N. Mex	28	Gasoline	.17	16.95	26.40	22.50	43.35	464	20.60
Agricultural College	Mesilla Park, N. Mex	20	Wood	2.25	17.10	12.45	11.37	29.55	1,000	88.00
Horaco Ranch Company No. 1.	Berino, N. Mex	12	Gasoline	.17	9.71	14.18	13.75	23.89	837	60.80
Horaco Ranch Company No. 2.	do	12	do	.17	10.36	24.90	23.64	35.26	191	8.10
Horaco Ranch Company No. 3.	do	12	do	.17	11.56	20.80	18.55	32.36	750	40.40

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Principal data derived from tests of Rio Grande pumping plants—Continued.

Name of plant.	Location.	Horse-power.	Fuel used.	Specific capacity per square foot strainer.	Cost of plant.	Interest and depreciation.	Labor and other cost.	Fuel cost per hour.	Fuel cost 1,000 foot-gallons.	Fuel cost per acre-foot.	Total cost per acre-foot.
1	2	3	4	12	13	14	15	16	17	18	19
				Gals. per min.		*Per hour.*	*Per hour.*		*Cents.*		
Felix Martinez	El Paso, Tex	10	Electricity	1.21	$1,200	$0.108	$0.050	$0.243	$\frac{1}{27}$	$3.43	$5.75
W. N. French	do	8	Gasoline	1.37	800	.072	.120	.112	$\frac{1}{44}$	2.26	6.13
E. J. Hadlock	do	5½	do	.792	800	.072	.140	.074	$\frac{1}{58}$	1.58	6.02
J. A. Smith No. 1	do	28	Crude oil	1.01	3,000	.270	.180	.0975	$\frac{1}{171}$	.70	3.17
J. A. Smith No. 2	do	22	Gasoline	1.37	2,200	.198	.150	.35	$\frac{1}{94}$	1.43	2.79
J. S. Porcher	do	15	do	1.28	1,500	.135	.150	.21	$\frac{1}{67}$	1.73	4.10
F. C. Barker	Las Cruces, N. Mex	5	do	.337	1,200	.108	.120	.09	$\frac{1}{40}$	3.73	13.20
Mrs. E. M. Boyer	do	12	do	1.969	1,200	.108	.150	.163	$\frac{1}{98}$	1.34	3.47
F. Burke	Mesilla, N. Mex	21	do	.930	1,800	.162	.150	.34	$\frac{1}{52}$	2.52	4.87
J. C. Carrera	Mesilla Park, N. Mex	8	do	3.530	900	.081	.120	.177	$\frac{1}{59}$	1.48	3.16
W. N. Hager	do	12	do	.760	1,200	.108	.150	.31	$\frac{1}{22}$	5.14	9.57
A. L. Hines	Mesilla, N. Mex	8	do	1.790	800	.072	.120	.255	$\frac{1}{28}$	5.10	8.95
T. Roualt	Las Cruces, N. Mex	10	Wood	.62	1,200	.108	.180	.223	$\frac{1}{32}$	3.47	7.91
G. H. Totten	Mesilla, N. Mex	28	Gasoline	.760	2,000	.180	.150	.37	$\frac{1}{33}$	4.34	8.19
Agricultural College	Mesilla Park, N. Mex	20	Wood	2.32	1,600	.144	.200	.52	$\frac{1}{34}$	2.83	4.70
Horaco Ranch Company No. 1.	Berino, N. Mex	12	Gasoline	1.690	992	.090	.090	.16	$\frac{1}{75}$	1.04	2.21
Horaco Ranch Company No. 2.	do	12	do	.173	992	.090	.090	.204	$\frac{1}{20}$	5.30	10.90
Horaco Ranch Company No. 3.	do	12	do	.892	992	.090	.090	.16	$\frac{1}{89}$	1.16	2.46

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COMMENTS ON THE RIO GRANDE PUMPING PLANTS.

The pumping plants of Martinez, French, Hadlock, Smith, and Porcher are all located in the bottom lands of the Rio Grande, from 3 to 8 miles east of El Paso, Tex. Column 12 of the table shows that the specific capacity per square foot of well strainer is nearly the same at the plants of Martinez, French, Smith No. 2, and Porcher, ranging from between 1.21 gallons a minute at Martinez's well to 1.37 gallons at French's well. These numbers, it should be remembered, represent the amount of water furnished by each square foot of well strainer for 1 foot head of water, and express, therefore, the degree of coarseness of the material in which the strainer is placed, provided, of course, that the well strainers themselves offer little or no resistance to the admission of water to the well. The specific capacity per square foot of strainer at the Smith plant No. 1 and at the Hadlock plant is much smaller than at the others. In the case of the Hadlock well, the low specific capacity is no doubt due to the fact that three of the Hadlock wells obtain water from above a clay which overlies the sand and gravel from which the fourth well and the neighboring wells of Martinez and French draw their supply. Furthermore, the strainers on the three Hadlock wells consist of nothing but common pipe perforated with round holes. This poor form of strainer is sufficient in itself to cut down very materially the specific capacity of the wells.

The low specific capacity at Smith's plant No. 1 is probably due chiefly to a local deposit of fine-sized water-bearing sand. There is no covering layer of clay over the water-bearing sands and gravels at these wells. The sands contain so little coarse material that fine sand is constantly being drawn into the wells by the pumps. This draft on the sand deposit at the easternmost of the three wells at Smith's plant No. 1 is so great that several wagon loads of gravel have been placed in the pit of the east well to replace the sand removed by the pumps.

The tests of the 9 wells in Rio Grande Valley near Las Cruces, N. Mex., form an interesting study. The relative locations of these 9 wells are shown in fig. 8. The rank of these wells in order of specific capacities per square foot of well strainer is as follows:

Specific capacity, in gallons per minute, of wells near Las Cruces, N. Mex., per square foot of strainer.

	Gals. per min.
Carrera	3.530
Agricultural College	2.320
Mrs. Boyer	1.969
Hines	1.790
Burke	.930
Hager	.760
Totten	.760
Roualt	.627
Barker	.337

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The first three of these wells are located near the eastern edge of the river valley, and their high specific capacity is undoubtedly due to coarse mountain débris that has been deposited along the eroded edge of the mesa. The high specific capacity at Hines's plant seems to be an exception to the general lower average prevailing in the intermediate district between the border of the mesa and the river channel, as at the plants of Hager, Totten, Burke, and Barker. The low specific capacity of the Barker well is due in part to its small diameter, and it is to be classed, therefore, with the Burke, Totten, and Hager wells rather than with the Roualt well. This last well is close to the river channel. Its low specific capacity is an indication of the progressive fineness of the deposits as the river is approached.

The specific capacities should be considered exceptionally high in the first wells in the above list, rather than exceptionally low in the others. Even the specific capacity of the Roualt well—over one-third of a gallon a minute per square foot of well strainer—would be regarded as high in many parts of the country.

The specific capacity of the three wells on the Horaco ranch near Berino, N. Mex., present an interesting study. These plants are located but a few hundred feet apart and are identical in all respects except in the depth of the wells. Nos. 2 and 3 are 9⅝ inches in diameter, and No. 1 is 7⅝ inches in diameter. Each has 18 linear feet of well strainer at the bottom, formed by drilling 1½-inch holes in the casing and wrapping the casing with No. 9 galvanized iron wire, leaving one-eighth inch space between. The enormous difference in the specific capacities of these wells is entirely due to the fact that No. 1 is 75 feet deep, No. 2 is 53 feet deep, and No. 3 is 62 feet deep. The small expense necessary to sink well No. 2 from a depth of 53 feet to a depth of 75 feet should change the cost of the water recovered from $10.90 per acre-foot to $2.21 per acre-foot.

Most of the pumping plants near Las Cruces have been very recently constructed, and changes will undoubtedly be made in many of them as the result of the experience of the present irrigation season. The wells at the Agricultural College were the first ones sunk in this part of the valley, and an excellent report on the tests of these wells, by Professors Vernon and Lester, was issued in April, 1903. The very high specific capacity of the college wells has influenced the construction of the other plants. With a few exceptions, it may be said that at the pumping plants in Mesilla Valley the engines and pumps are entirely too large for the wells, or the wells are too small for the pumps and engines. By comparing the high lifts recorded in column nine of the table with the amount of lowering of the water in the well, which is recorded in column eight, it will be seen that the lift of many of the plants can be considerably decreased by increasing the amount of strainer surface in the wells. In most cases this will make necessary

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the sinking of additional wells, as the strainer surface can not be otherwise sufficiently increased. The necessity of keeping the lift of the pump down to a minimum is greatly emphasized in irrigation plants, and large strainer surface is the first requisite.

The efficiency of the smaller plants can also be increased by the construction of storage reservoirs or ponds for the accumulation of water before it is used for irrigation. In this way the duty of the water can be considerably increased. Barker's plant is the only one having such reservoirs. For plants that yield over a second-foot of water the reservoir is undoubtedly of little additional value.

The investigation showed that generally the speed of the centrifugal pumps had not been properly adjusted, and in nearly all cases was too high. This was undoubtedly due to the fact that the vacuum had never been determined, so that the total lift of the pumps was unknown. A table of observed and of correct speeds follows:

Sizes and speeds (in revolutions per minute) of centrifugal pumps used in the Rio Grande pumping plants.

Name of plant.	Kind of pump.	Actual speed.	Correct speed.
Martinez	Byron Jackson No. 5	1,028	565
French	Byron Jackson No. 4	938	890
Smith No. 1	Fairbanks Morse No. 6		
Smith No. 2	Byron Jackson No. 7	585	592
Porcher	Byron Jackson No. 5	712	629
Barker	Byron Jackson No. 3	1,110	1,244
Mrs. Boyer	Byron Jackson No. 5	730	665
Burke	Byron Jackson No. 6	733	585
Carrera	Byron Jackson No. 5	560	527
Hager	do	668	619
Hines	Rumsey No. 4	594	558
Roualt	Van Wie No. 3	525	
Totten	Byron Jackson No. 6	692	606
Horaco No. 1	Byron Jackson No. 5	695	513
Horaco No. 2	do	700	624
Horaco No. 3	do	692	598

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CHAPTER V.

DETAILS OF TESTS OF PUMPING PLANTS.

The following pages contain detailed accounts with diagrams of the various pumping plants discussed in general terms in the preceding chapter of this report. The location of the various plants is marked in figs. 4 and 8.

PLANTS NEAR EL PASO, TEX.

PLANT OF E. J. HADLOCK.

The plant of E. J. Hadlock is located near the main country road near El Paso, Tex., about 400 feet east of the pumping plant of Felix Martinez. Water is pumped by a 5½-horsepower horizontal Otto gasoline engine geared to a horizontal double-acting piston pump. The wells consist of four 4-inch wells, arranged as shown in figs. 11 and 12. Three of the wells, Nos. 1, 2, and 3 in fig. 10, draw surface water from

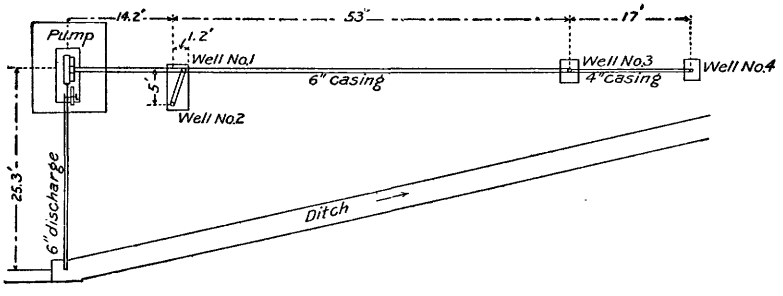

FIG. 11.—Plan showing arrangement of wells at Hadlock's pumping plant.

above a clay stratum. The fourth well, which is 54.35 feet deep and penetrates the surface water and clay, obtains very good water from a deposit of sand and gravel below the clay.

Wells Nos. 1, 2, and 3 are about 30 feet deep. Each of these has 6 feet of perforated iron pipe on the bottom, while well No. 4 has a 6-foot strainer constructed of perforated galvanized iron. During the test the engine made 210 revolutions and 81 explosions per minute. The pump made 69 strokes per minute. The vacuum gage attached to the suction pipe fluctuated very erratically, showing that the pump

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valves were badly worn. One end of the pump seemed to be working very well and showed a vacuum of 22 inches, which is equivalent, when corrected for altitude, to 20 inches of mercury or 22.6 feet of water. The lift of the pump above the vacuum gage was 5.2 feet, making a total lift of 27.8 feet. The distance from the vacuum-gage tap to the water plane was 9.75 feet. The water in the well was lowered 13.03 feet during pumping.

The discharge of the pump was determined by means of a fully contracted weir, which was placed in the main irrigating ditch. The width of the crest was 1.01 feet, height of water on the crest was 0.313 feet, and the discharge was 258 gallons per minute. The pump cylinders were 9½ by 14 inches. With the speed noted above the pump should discharge, if no allowance be made for slip, 507 gallons per minute. It is seen that the slip of the pump was 49 per cent, which shows that the valves at one end of the pump were doing practically no work at all.

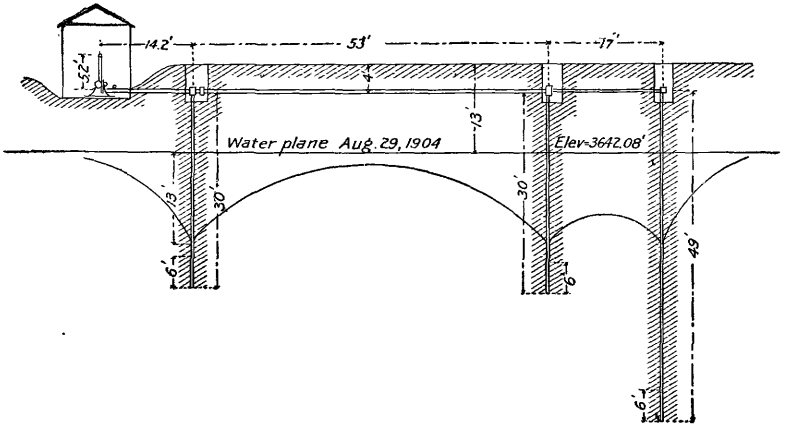

FIG. 12.—Elevation of wells at Hadlock's pumping plant near El Paso, Tex.

At well No. 4 the elevation above mean sea level of the water plane on August 29, 1904, was 3,642.08 feet, that of the top of tee on casing of this well and of the vacuum-gage tap was 3,651.652 feet, and that of the surface was 3,656 feet.

From the discharge (258 gallons per minute) and the amount that the water level in the well was lowered during pumping (13.03 feet), it is estimated that the specific capacity of the group of four wells is 19.8 gallons per minute. As the combined area of well-strainer surface in all of the wells is 25 square feet, the specific capacity per square foot of strainer is 0.792 gallons per minute.

At the time of the test, on August 16, 1904, the Hadlock pumping plant had been in continuous operation day and night for several

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months. The quantity of gasoline used was determined from the amount required to fill the tank to standard depth after one hour's run. As 2.1 quarts of gasoline were consumed per hour, the hourly cost for fuel, with gasoline at 14 cents per gallon, is $0.0735. The yield of water in one hour was 15,500 gallons, so that the fuel cost was $0.00475 per 1,000 gallons, $1.58 per acre-foot, and $0.000171, or one fifty-eighth of a cent per 1,000 foot-gallons (1,000 gallons raised one foot).

PLANT OF W. N. FRENCH.

At the pumping plant of W. N. French (see fig. 13) water is obtained from an 8-inch well, 66 feet deep, which has a 7-inch by 8-foot perforated galvanized iron strainer at the bottom. The water is raised by a No. 4 Byron Jackson horizontal-shaft centrifugal pump driven by a 10-horsepower Charter gasoline engine. The engine made 189 revolutions and 95 explosions a minute, no explosions being missed. The diameter of the driven pulley on the pump was 6 inches; that of the driving pulley on the engine was 30 inches. The speed of the pump was 938 revolutions a minute. The top of flange on the well casing is 12.65 feet below the top of the 5-inch discharge pipe, which rises from the pump at an angle of 45°. Before pumping, the water stood 4.7 feet below top of flange on the well casing. After one-half hour's pumping it was 18.05 feet below top of flange, showing that it was lowered 13.35 feet by pumping. The lift of the pump above the top flange of the well was 12.65 feet, making a total lift of 30.70 feet. The elevation of the water plane in the French well on August 29, 1904, was 3,642.969 feet; on September 8, after several days of rain, it was 3,643.07 feet. Between August 29 and September 8 it rained every day, and the neighboring pumping plant of Mr. Hadlock had not been in use. The elevation of the top of the delivery pipe at the French well was 3,658.884 feet.

The discharge was measured both by integrating with a Price acoustic current meter in a rectangular flume and by means of a fully contracted weir placed in the main ditch not far from the pumping plant. The cross section selected for the meter measurement had an average depth of 0.857 foot, an average width of 0.885 foot, and an area of 0.76 square foot. The average velocity of the water was 0.82 foot per second, giving a discharge of 0.596 second-foot, or 269 gallons, per minute.

The same discharge was also measured by a fully contracted weir. The length of the crest was 1.01 feet and the height of the water on the crest was 0.30 foot. The velocity of approach was about one-half foot per second. Using the weir formula,

$$q = c.\,\tfrac{2}{3}\sqrt{2g}\,b\,(H+1.4h)^{3/2}$$

and substituting the coefficient 0.608 for the number c in the formula (Table 23, Merriman's Hydraulics, 1903) we obtain,

$$q = 0.608 \times \tfrac{2}{3} \times 8.025 \times 1.01\ (3.06)^{3/2}$$
$$= 0.555 \text{ second-foot}$$
$$= 250 \text{ gallons per minute.}$$

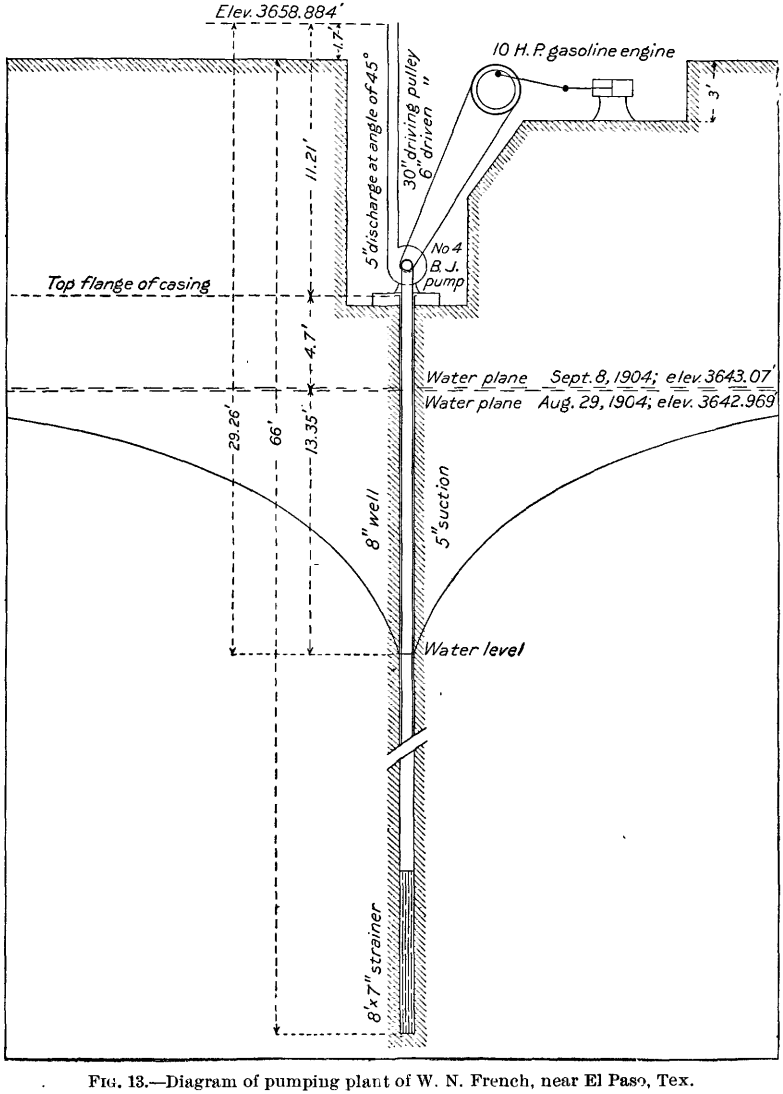

FIG. 13.—Diagram of pumping plant of W. N. French, near El Paso, Tex.

The discharge as determined by the current meter has been used in the following estimates:

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The specific capacity of the well is 20.2 gallons a minute. As the strainer has an area of 14.7 square feet, the specific capacity for each square foot of strainer is 1.375 gallons per minute.

In the French test 8 gallons of gasoline were used in ten hours. With gasoline at 14 cents per gallon the cost of fuel is 11.2 cents per hour. As 16,150 gallons of water were obtained in one hour the fuel cost per 1,000 gallons was $0.00695, or $2.26 per acre-foot. The total lift being 30.7 feet the cost per 1,000 foot-gallons was $0.000226, or one forty-fourth of a cent.

PLANT OF FELIX MARTINEZ.

The plant of Felix Martinez is located about 3 miles east of the court-house of El Paso, Tex., near the main country road (see fig. 4). It consists of a No. 5 Byron Jackson horizontal-shaft centrifugal pump run by General Electric 10-horsepower direct-current motor, type C. E., class 4. The pump is located in a pit and is connected to a 6-inch well. The well is 68 feet deep and has 10 feet of perforated or slotted galvanized iron strainer at the bottom. The gravels, which were reached at a depth of 56 feet are fairly large, but contain a great quantity of fine sand. The pump is connected with the well by a 5-inch suction pipe and discharges through a vertical and horizontal 5-inch pipe into a rectangular flume. The discharge was measured by integrating with a Price acoustic current meter in the rectangular flume. The cross section of flume where measurements were taken had an average depth of 0.475 foot, an average width of 0.992 foot, and an area of 0.470 foot. The mean velocity was 1.78 feet per second, giving a total discharge of 0.838 cubic foot per second, or 378 gallons per minute.

The vacuum gage was attached to the goose neck of the centrifugal pump. After a few minutes pumping the vacuum was 18 inches, but it gradually fell to 24½ inches at the close of the first half hour, where it remained constant during the next hour. The vacuum, when corrected for altitude, is equivalent to 22.5 inches of mercury, or 25.5 feet of water.

On August 29, 1904, the elevation above sea level of the water plane was 3,643.13 feet; that of the vacuum-gage tap was 3,646.47 feet, and that of the top of discharge pipe was 3,659.90 feet. As the water level in the well was lowered 22.15 feet by pumping, the total lift was, therefore, 38.93 feet. The specific capacity of the well is 17.5 gallons per minute. As the area of the well strainer is 14.4 square feet, the specific capacity for each square foot of well screen was 1.2[illegible] gallons per minute.

The amount of electric current used during the pumping was determined by means of a Westinghouse watt meter. The current used in one hour's test (average speed of motor 1,485 revolutions a

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minute) was 4,950 watts. Speed of the pump was 1,028 revolutions a minute. The diameters of the pulleys are as follows: Pulley on motor, 7½ inches; driven pulley on countershaft, 24 inches; driving pulley on countershaft, 14 inches; pulley on pump shaft, 6 inches.

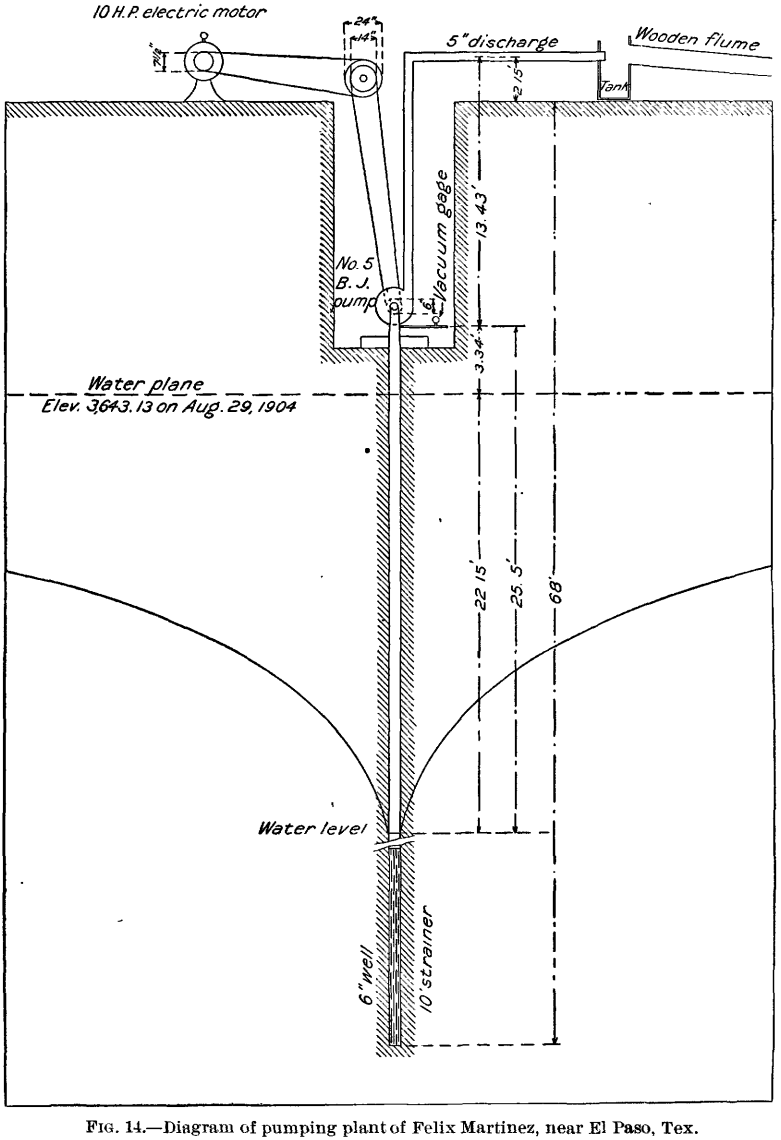

FIG. 14.—Diagram of pumping plant of Felix Martinez, near El Paso, Tex.

The power actually used at the plant is the equivalent of 4,950 watts, or 6.64 horsepower. The power represented by the discharge of 0.838 second-feet of water lifted 38.93 feet is equivalent to 2,030 foot-

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pounds per second, which is equal to 3.7 effective horsepower. If the applied horsepower, 6.64, is compared with the effective horsepower, 3.7, the total efficiency of the plant is found to be 55.5 per cent. The duty of the plant can be found by comparing 4,950 watts, the electrical energy consumed in one hour, with 655,200 foot-gallons, the work done by the pump in one hour. The resulting duty is 132,400 foot-gallons of water per kilowatt hour of electric current.

PLANTS OF J. A. SMITH.

The plants of J. A. Smith are located 8 miles east of El Paso, Tex., near the right of way of the Southern Pacific Railroad. There

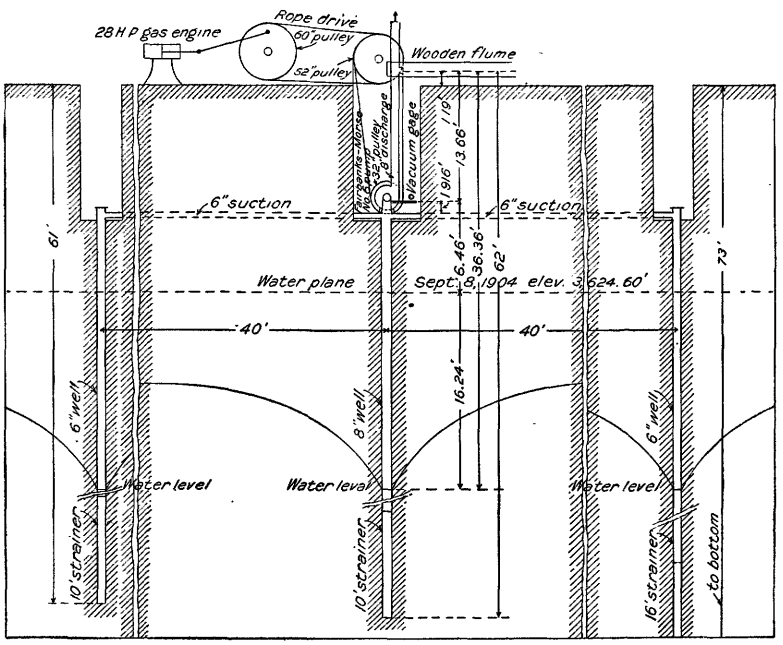

FIG. 15.—Diagram of J. A. Smith's pumping plant No. 1, near El Paso, Tex.

are two pumping plants on the same ranch. At the first or older plant there are three wells, 40 feet apart, in a row. The pump pit is over the middle well, which is 8 inches in diameter and 62 feet deep, measured from the surface. Fine sand and quicksand were passed through to a depth of 50 feet, then 12 feet of coarse gravel containing much fine material was encountered. A 10-foot slotted galvanized-iron strainer of the Porcher pattern was placed at the bottom of this well. The east well is 6 inches in diameter and 73 feet deep. The gravel at this point is 22 feet deep. A 16-foot Porcher strainer was used. The west well is 6 inches in diameter and 61 feet deep. The gravel was 11 feet deep, and a 10-foot Porcher strainer was used. All

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of the strainers have $\frac{3}{16}$ by $1\frac{1}{2}$ inch slots or perforations. The horizontal 8-inch suction pipe, which extends from the central well to the east and west wells, is 14 feet below the surface.

The water is pumped by a No. 6 Fairbanks-Morse horizontal-shaft centrifugal pump, connected with rope drive to a 28-horsepower gasoline engine, with crude-oil gas generator attached. The fact that the engine is supplied with gas generated from Texas crude petroleum renders this plant of especial interest. For the amount of water obtained the fuel cost is the lowest I have seen recorded for a small plant. The attached gas generator has been in operation several months, running continuously day and night, except when stopped for cleaning each week or two. When the generator is kept clean there is little trouble from carbon passing from the generator into the cylinder of the engine and cutting out the cylinder and packing. This plant is a decided success, as the further account to be given will show. The engine made 159 and the pump 544 revolutions per minute.

The discharge was measured by integrating with a Price acoustic current meter in a rectangular flume. The selected cross section had an average depth of 0.53 foot, an average width of 1.87 feet, and an effective area of 0.992 square foot. The average velocity was 2.085 feet per second, giving a discharge of 2.075 second-feet, or 934 gallons per minute. This measurement of discharge was made after three months of continuous pumping day and night. The elevation of the vacuum-gage tap, which was 0.917 foot above the top of horizontal suction pipe, was 3,631.06 feet; that of the water plane on September 8, 1904, was 3,624.60 feet, and that of the middle of the 8-inch opening in the tee in the side of vertical discharge pipe, from which the water enters a horizontal wooden flume, was 3,645.06 feet. The vacuum read 22 inches, which, when corrected for altitude, is equivalent to 20 inches of mercury, or 22.7 feet of water. The total lift is, therefore, 36.7 feet. The water is lowered in the wells 16.24 feet by pumping, which gives a specific capacity for the three wells of 57.4 gallons per minute. As the total area of the strainers in all of the wells is 56.7 square feet, the specific capacity for each square foot of strainer is 1.01 gallons per minute.

Several accurate tests have been made of the amount of fuel consumed at this plant. One test was made by the manufacturers of the gas generator, and consequently the consumption of crude oil appears at a minimum. This test lasted seventy-four hours and fifteen minutes. The amount of crude oil consumed was 241 gallons, or 3.24 gallons per hour. With oil at 3 cents per gallon, the cost of fuel will be $2.34 per day of twenty-four hours. The cost of water was, therefore, $1\frac{3}{4}$ mills, or ten fifty-sevenths of a cent per 1,000 gallons, or 57 cents per acre-foot. The lift being 36.7 feet, the cost of 1,000 foot-gallons was one two hundred and tenth of a cent.

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Another experimental test of the plant was made when the engine was in charge of the regular help employed on the ranch. No effort was made to save oil or make a record, everything being managed exactly as it was during several months of pumping for irrigation. The test was for forty and one-half hours, extending over four consecutive days of about ten working hours each. The amount of crude oil used was 163.5 gallons, or 97 gallons per twenty-four hours, or 4.03 gallons per hour. This represents, therefore, the actual rate at which oil was consumed during the irrigation season. The cost of fuel is $2.90 per twenty-four hours, 12 cents per hour, ten forty-sixths of a cent per 1,000 gallons, and one one hundred and seventy-first of a cent per 1,000 foot-gallons.

The cost of the water at the same plant, when pumped with gasoline, was also determined. In a test of eleven hours' run with same engine, using gasoline instead of crude oil gas, 40 gallons of gasoline were consumed, or 3.64 gallons per hour. At 14 cents per gallon, the hourly cost for gasoline was $0.51. This makes the fuel cost of water $0.0092 per 1,000 gallons and $0.000236, or one forty-second of a cent per 1,000 foot-gallons.

The above estimates do not represent, of course, the total cost of pumping, as no items have been included to cover interest, depreciation, labor, etc.

The 934 gallons per minute furnished by the above plant amounts to a little over 2 second-feet, or 4 feet per twenty-four hours. The cost of fuel per acre-foot of water was, therefore, 70 cents when using crude oil and $2.95 when using gasoline costing 14 cents a gallon.

J. A. Smith's pumping plant No. 2 is about 1,000 feet north of plant No. 1, which is on the same ranch. There are two 8-inch wells, 40 feet apart, in an east-west line. Each one is 60 feet deep and is equipped with 12 feet of Porcher slotted galvanized iron strainer. The gravel bed is 12 feet thick and is overlain by a thick deposit of clay and hardpan. A No. 7 vertical shaft Byron Jackson centrifugal pump is connected to an 8-inch horizontal suction pipe that is 12.25 feet below surface. The pump is 7 feet from the east well and 33 feet from the west well. It was driven at a speed of 585 revolutions per minute by a 22-horsepower Fairbanks-Morse gasoline engine. The engine made 195 revolutions per minute, the engine being belted to the pump shaft from 36-inch driving pulley to 12-inch driven pulley. The vacuum shown at center of the suction pipe was 25 inches, or 23 inches of mercury when corrected for altitude, corresponding to 26.1 feet of water. The vacuum-gage tap is 14.85 feet below the top of the discharge pipe, above which the discharge jet rises 0.6 foot, so that the total lift is 41.45 feet. A vertical 10-inch pipe delivers the water into a nearly horizontal rectangular flume in which the discharge was meas-

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ured by integrating with a Price acoustic current meter. The discharge was determined to be 2.945 second-feet, or 1,325 gallons, per minute. As the water in the wells was lowered 21 feet below the

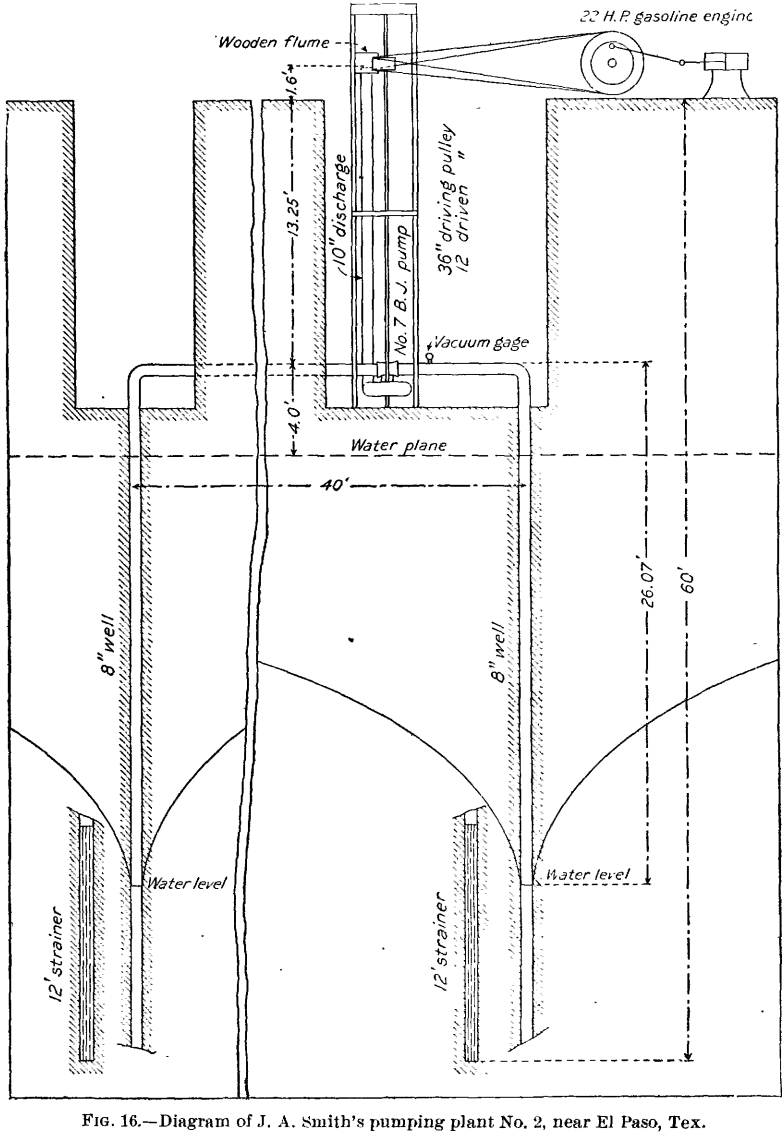

FIG. 16.—Diagram of J. A. Smith's pumping plant No. 2, near El Paso, Tex.

normal water plane by the pumps, the specific capacity of the two wells was 63.2 gallons per minute, or since the total strainer surface is 46 square feet, 1.37 gallons per minute for each square foot of strainer.

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The expense of pumping at this plant can readily be estimated as far as the cost of fuel is concerned. The engine, as run in the above test, consumed per hour 2.5 gallons of gasoline or distillate, costing 14 cents per gallon. The fuel cost is, therefore, 35 cents per hour, 0.44 cent per 1,000 gallons, $0.000106, or one ninety-fourth of a cent, per 1,000 foot-gallons, and $1.43 per acre-foot.

PLANT OF J. S. PORCHER.

This pumping plant is located on the ranch of J. S. Porcher, in the Rio Grande Valley, about 8 miles east of El Paso, Tex., and about 1,000 feet east of J. A. Smith's first wells. Water is obtained from a well 8¼ inches in diameter and 60 feet deep. The water-bearing gravel has a thickness of 12½ feet and lies below a layer of quicksand. There is a 12-foot slotted galvanized iron strainer at the bottom of the well. Mr. Porcher first used this type of strainer in the Rio Grande Valley. At the present time this form of strainer is universally used, and is known as the "Porcher" strainer (see Pl. II, *B*). Water is raised by a No. 5 Byron Jackson horizontal-shaft centrifugal pump driven by a 15-horsepower Columbus gasoline engine. The engine made 212 revolutions and 75 explosions per minute. The diameter of driving pulley was 30 inches and that of driven pulley 8 inches. The pump made 712 revolutions per minute. The water is discharged through an 8-inch vertical pipe into a rectangular wooden flume. The discharge from this rectangular flume was measured by integrating with a Price acoustic current meter. The selected cross section had an average depth of 0.1792 foot, a width of 1.92 feet, and an area of 0.344 square foot. The current meter showed that the average velocity was 4.245 feet per second, which gives a discharge of 1.46 second-feet, or 658 gallons per minute. The vacuum gage read 22.4 inches, which, when corrected for altitude, is equivalent to 20.4 inches of mercury, or 23.07 feet of water. The elevation of the ground water at the well on September 5, 1904, was 3,627.59 feet and that of the vacuum-gage tap was 3,630.07 feet, so that the water in the well was lowered 20.59 feet by pumping. As the vacuum-gage tap is 12.8 feet below the top of the discharge pipe the total lift is 35.87 feet.

Since the water level in the well was lowered 20.59 feet, the specific capacity of the well is estimated to be 32 gallons per minute, or 1.28 gallons per minute for each square foot of strainer.

The amount of gasoline used in running the engine was determined in two test runs. During the first test the consumption of gasoline from 6 a. m. to 4 p. m. was ascertained by measurements in the gasoline reservoir. In the ten hours' test there was used 14.3 gallons, or 1.43 gallons per hour. In the second test Mr. Porcher determined the time necessary to consume 5 gallons of gasoline in the engine. At 6.30 a. m. on the day of the test 5 gallons of gasoline were placed in the empty

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gasoline reservoir. All the gasoline had been used up by 10.20 a. m., so that the consumption was 5 gallons in 3.83 hours, or 1.31 gallons per hour. As the engine was run with considerable care during these

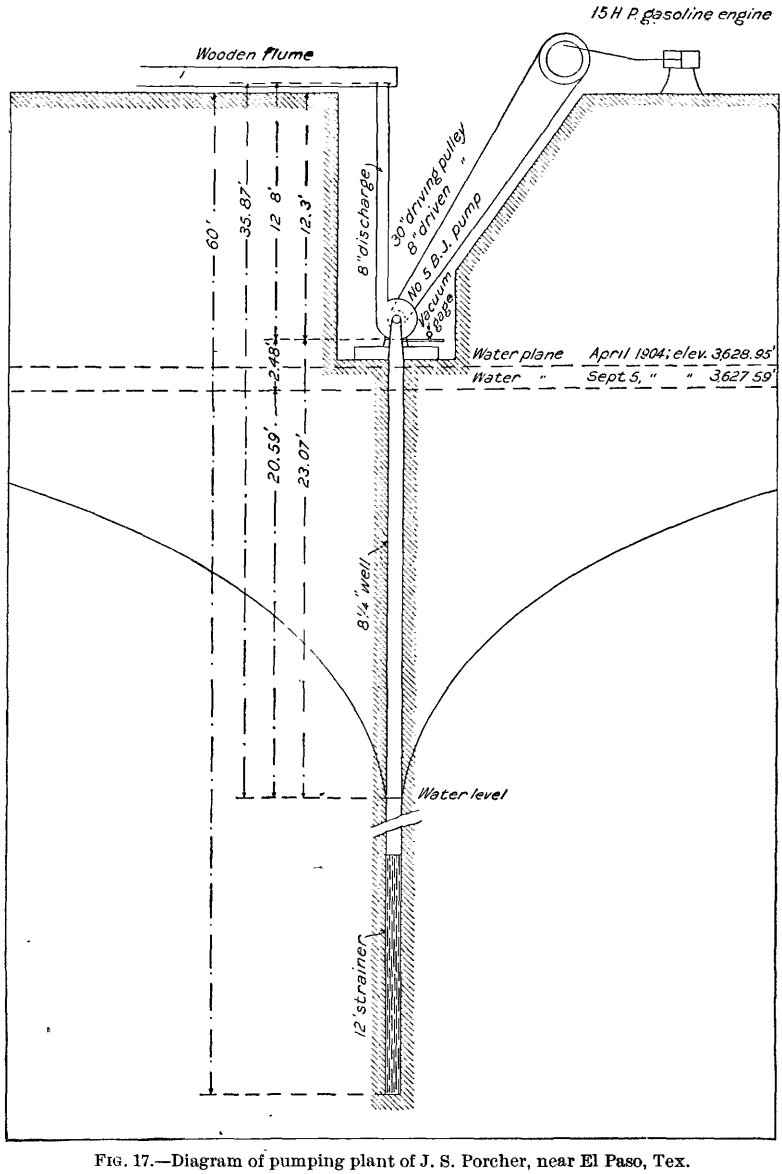

FIG. 17.—Diagram of pumping plant of J. S. Porcher, near El Paso, Tex.

tests, it is probable that the consumption of gasoline normally runs as high as 15 gallons for ten hours. The hourly cost for fuel, with gasoline at 14 cents per gallon, was 21 cents. As 39,500 gallons of water

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were obtained in one hour, the cost was $0.00531 per 1,000 gallons, $1.73 per acre-foot, and $0.0001, or one sixty-seventh of a cent, per 1,000 foot-gallons.

A 4½-acre field of alfalfa can be irrigated with the pump in from fourteen to nineteen hours. After a rain it was irrigated in fourteen hours, but sixteen hours usually are required. A number of irrigations of the same field have varied from sixteen to eighteen hours each. This field was irrigated every seven days, and the crop taken off at the end of the fourth week, so there were three irrigations to a crop.

With gasoline, or distillate, at 14 cents per gallon, or $2.36 per acre, per crop of alfalfa (three irrigations), the crop cut from the field averaged fully a ton to an acre, and at the selling price of $12 to $14 per ton, the irrigation with the pump could be carried on at a good profit. If the selling price had been as low as $7 per ton there would be no profit in the irrigation of alfalfa by pumping.

TESTS OF PUMPING PLANTS IN MESILLA VALLEY, NEW MEXICO.

PLANT OF F. C. BARKER.

This plant is located on the ranch of Mr. F. C. Barker, about 1 mile south of Las Cruces, N. Mex. The pumping plant is used to irrigate about 20 acres of garden truck. Water is obtained from a 6-inch well, 48 feet deep, containing 12 feet of slotted galvanized-iron strainer at the bottom. The water is raised by a No. 3 Byron Jackson horizontal-shaft centrifugal pump, driven by a 5-horsepower Otto gasoline engine. The engine is belted directly to the pump from a 20-inch driving pulley to a 6-inch driven pulley. The engine made 334 revolutions and from 92 to 97 explosions per minute. The speed of the pump was 1,110 revolutions per minute.

The vacuum-gage tap was 2.92 feet above the water plane in September, 1904, and 17.73 feet below the center of 3-inch horizontal discharge pipe. The lift of the pump above the vacuum-gage tap when discharging into the first of two irrigation reservoirs is 17.73 feet.

The lift above the vacuum-gage tap when discharging into the second irrigation reservoir was 20.18 feet. The vacuum gage read 24.50, which, when corrected for altitude, is equivalent to 22.50 inches of mercury, or 25.4 feet of water. This makes the total lift when filling the second reservoir 45.58 feet.

The discharge of the pump was ascertained by determining, by means of a stop watch, the time required to fill a tank holding 47.6 gallons. As the tank was filled in 21.8 seconds, the discharge of the pump is 0.291 second-foot, or 131 gallons per minute. As the water level in the well is lowered 22.48 feet during pumping, the specific capacity of the well must be 5.83 gallon per minute, or 0.337 gallons per minute for each square foot of strainer.

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This pumping plant is unusually well constructed. The machinery is well housed, and there are two concrete-lined reservoirs for storing

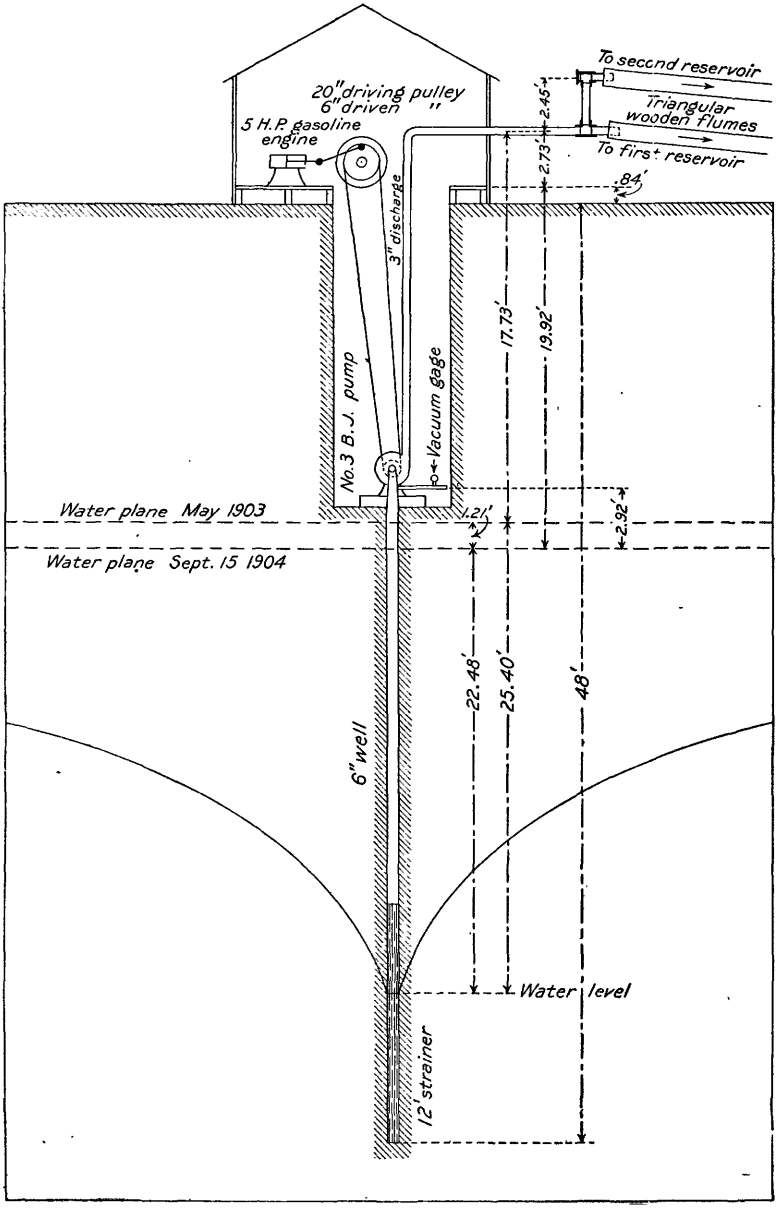

FIG. 18.—Diagram of pumping plant of F. C. Barker, near Las Cruces, N. Mex.

water for irrigation. It takes the pump eight hours to fill a reservoir, which is emptied in about an hour's irrigation. The cost of the plant complete was $1,200.

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The amount of gasoline used was not accurately determined, but it hardly exceeded one-half gallon per hour when the engine was developing about its full horsepower. With gasoline at 17 cents a gallon, the fuel cost may safely be put at 9 cents an hour. On this basis the fuel cost of water was $0.0115 per 1,000 gallons, $3.73 per acre-foot, and $0.000252, or one-fortieth of a cent per 1,000 foot-gallons.

PLANT OF J. C. CARRERA.

This plant is located on the ranch of J. C. Carrera, about half way between Las Cruces and Mesilla Park, N. Mex., near the east or upper highway between the Agricultural College and Las Cruces. The well is 6 inches in diameter and 58 feet deep, and is equipped with a slotted galvanized-iron strainer 5½ inches in diameter by 15 feet long. The water is recovered by a No. 5 Byron Jackson horizontal-shaft centrifugal pump, driven by an 8-horsepower Fairbanks-Morse gasoline engine. The engine ran at a speed of 234 revolutions a minute, missing no explosions. The pump was driven at a speed of 560 revolutions a minute by direct belting to engine from 20-inch driving pulley to 8-inch driven pulley.

The vacuum-gage tap was 12.65 feet below the center of the 5⅝-inch horizontal discharge pipe and 5.72 feet above the water, which, when the well was first dug, three years before the test, was 2.7 feet higher than at present. The vacuum gage read 14.5 inches, which gives, after correction for altitude, 12.5 inches of mercury or 14.2 feet of water. The total lift was therefore 26.85 feet. The discharge of the pump was 1.44 second-feet or 648 gallons a minute. The water in the well was lowered only 8.48 feet, so that the specific capacity of the well is 76.4 gallons per minute, or 3.53 gallons per minute for each square foot of well strainer.

Twelve gallons of gasoline were used for eleven hours' run, including the amount consumed by igniting torch. With gasoline at 17 cents per gallon, the fuel cost of water is 17¾ cents an hour, 0.456 cents per 1,000 gallons, $1.48 per acre-foot, and $0.017 or one fifty-ninth of a cent per 1,000 foot-gallons.

PLANT OF FRANK BURKE NEAR MESILLA, N. MEX.

This plant is located on the ranch of Frank Burke, about one-half of a mile south of Mesilla Park, N. Mex. Water is obtained from a 12-inch well, 52 feet deep, containing 11½ feet of slotted galvanized-iron strainer at the bottom. The well passes through 8 feet of soil and sand, 14 feet of quicksand with small pebbles, and 38 feet of sand and gravel of maximum size 3 inches. The water is recovered by a No. 6 Byron Jackson horizontal-shaft centrifugal pump, driven by a 21-horsepower Otto gasoline engine. The engine is belted to a pump

shaft from 40-inch driving pulley on engine, thence to a 20-inch driven pulley on countershaft, thence from 16-inch driving pulley on countershaft to 10-inch driven pulley on pump shaft. The speed of pump

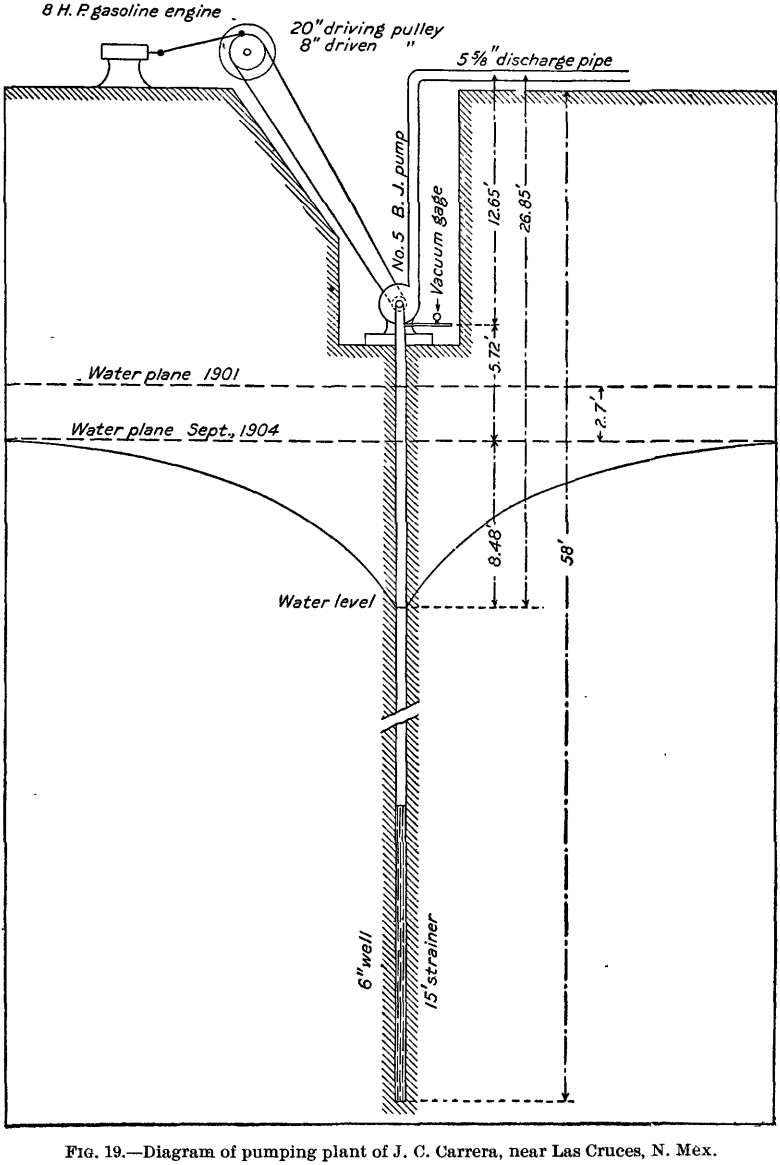

FIG. 19.—Diagram of pumping plant of J. C. Carrera, near Las Cruces, N. Mex.

during the test was 733 revolutions per minute, and of the engine 240 revolutions per minute.

The vacuum gage was placed in the goose neck of the pump, and the tap was 14.85 feet below the center of the horizontal discharge

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pipe. The vacuum gage read 25.25 inches, which, when corrected for altitude, is equivalent to 23.25 inches of mercury, or 25.6 feet of water. The total lift of the pump was, therefore, 40.45 feet.

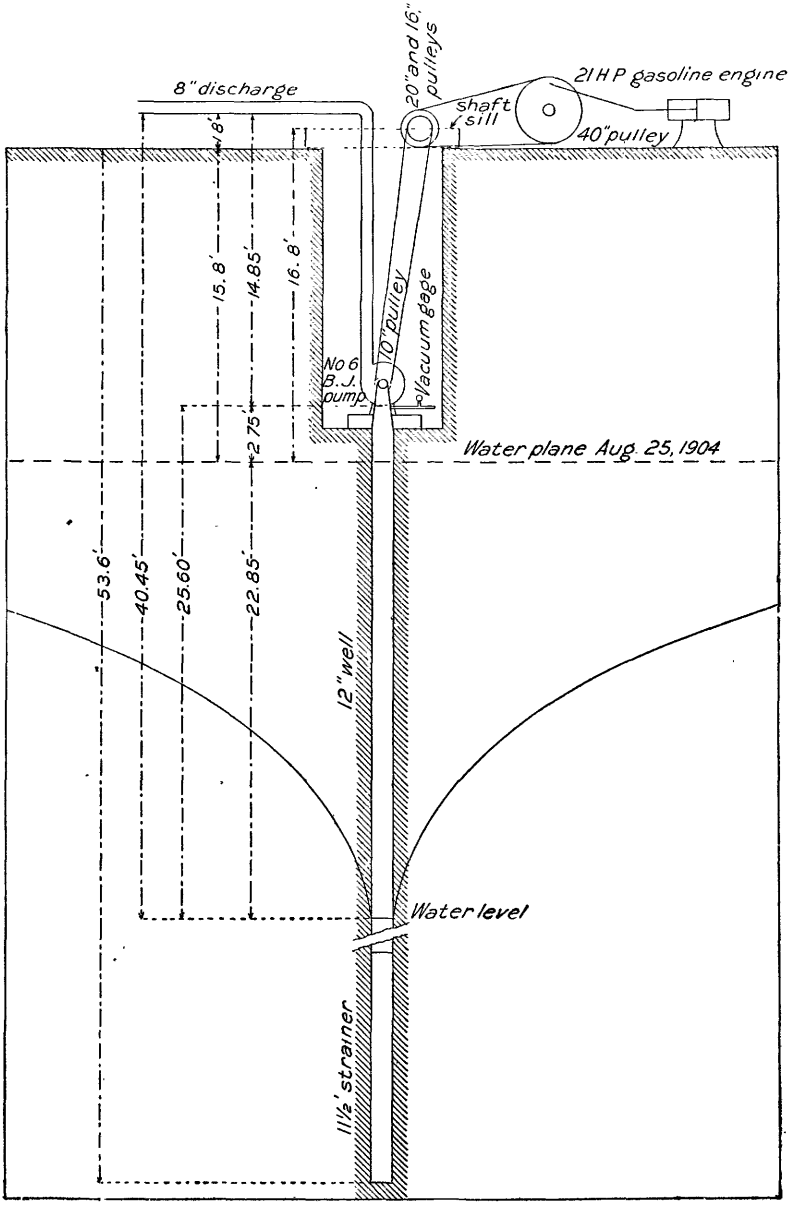

FIG. 20.—Diagram of pumping plant of Frank Burke, near Mesilla Park, N. Mex.

The discharge of the pump was determined by integrating with a Price acoustic-current meter in a rectangular flume through which the

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water was led after it had passed into the main ditch. The area of the water at the selected cross section was 0.383 square foot, and the mean velocity was 4.21 feet per second, making the discharge 1.61 second feet, or 725 gallons per minute. The level of the water in the well was lowered 22.85 feet by pumping, whence it is concluded that the specific capacity of the well is 25.4 gallons per minute, or 0.934 gallon per minute for each square foot of strainer.

This plant had been run for very short periods and no conclusive estimate of the amount of gasoline consumed can be made. During the test the engine was not run at its full capacity. The gasoline tank was so constructed that an accurate measurement could not be made. The amount of gasoline consumed, however, did not vary greatly from 2 gallons an hour. With gasoline at 17 cents per gallon, the fuel cost of water was 34 cents per hour, $0.0078 per 1,000 gallons, $2.52 per acre-foot, and $0.000193, or one fifty-second of a cent per 1,000 foot-gallons.

PLANT OF MRS. E. M. BOYER.

The plant of Mrs. E. M. Boyer is located about one-fourth of a mile north of the railroad station at Las Cruces, N. Mex. Water is obtained from a well 52 feet deep cased with 6-inch standard pipe. The well is equipped with a slotted galvanized iron Porcher strainer 5½ inches diameter and 12 feet in length. The slots are three-sixteenths by 1½ inches. The well driller reports the following log of the well: 18 inches of soil; dry sand to 20 feet; quicksand below this, changing to coarse gravel and bowlders containing sand, in which the strainer was left. The pumps threw a good heavy stream of water as soon as started, only a few bushels of sand being drawn through the strainer.

Water is recovered by means of a No. 5 Byron Jackson horizontal-shaft centrifugal pump, driven by a 12-horsepower Olds gasoline engine. The engine is directly belted to a pump from 30-inch driving pulley to 8-inch driven pulley. The engine made 208 revolutions and 93 explosions per minute. The speed of the pump was 728 revolutions per minute. The vacuum gage during pumping stood at 22 inches, which, corrected for altitude, is equivalent to 20 inches of mercury, or 22.7 feet of water. On September 19, 1904, the water plane stood 2.94 feet below the vacuum-gage tap, or 3,836.867 feet above mean sea level. The vacuum-gage tap was 14.3 feet below the surface and 17.6 feet below the center of the 6-inch horizontal discharge pipe. The discharge of the pump was 1.46 second-feet, or 658 gallons per minute. The total lift of the pump was 40.3 feet, and the water level in the well was lowered 19.76 feet during pumping. The specific capacity of the well is thus 33.3 gallons per minute, or 1.969 gallons per minute for each square foot of strainer.

A fifty-hour test of this pumping plant was run by F. H. Bascom, of

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Las Cruces, who reports that 48 gallons of gasoline were consumed during that time. With gasoline at 17 cents a gallon the fuel cost of

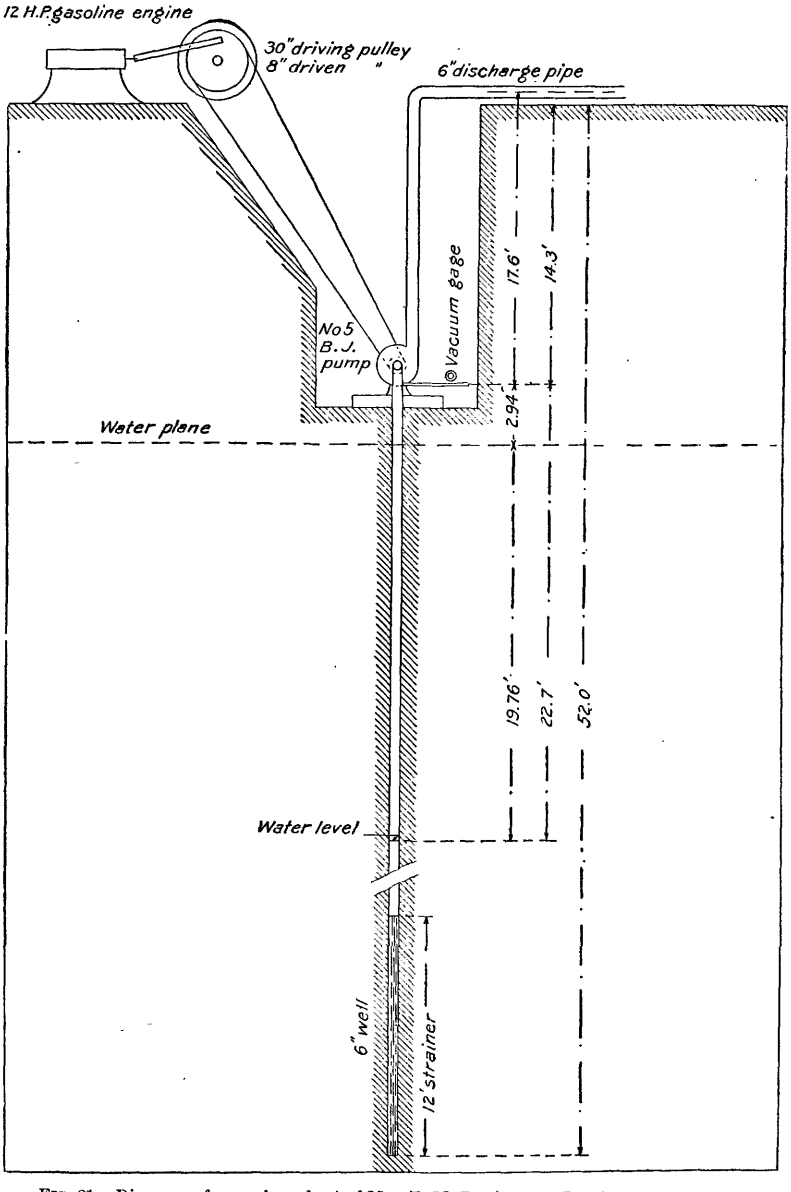

FIG. 21.—Diagram of pumping plant of Mrs. E. M. Boyer, near Las Cruces, N. Mex.

water would be 16.3 cents an hour, 0.412 cents per 1,000 gallons, $1.34 per acre-foot, and $0.000102, or one ninety-eighth of a cent per 1,000 foot-gallons.

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PLANT OF W. N. HAGER.

This pumping plant is located on the ranch of W. N. Hager, about one-half mile west of the railroad station at Mesilla Park, N. Mex.

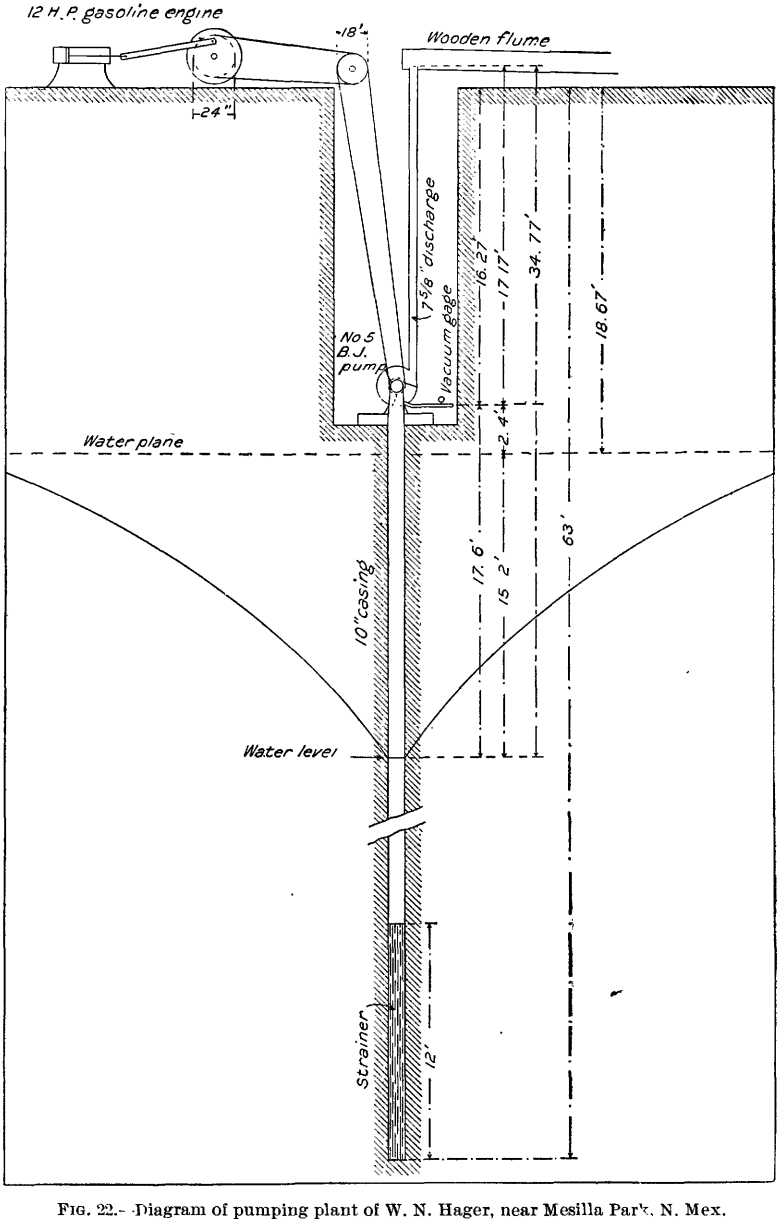

FIG. 22.—Diagram of pumping plant of W. N. Hager, near Mesilla Park, N. Mex.

Water is obtained from a 10-inch well, 63 feet deep, containing a 12-foot, slotted, galvanized-iron Porcher strainer, 9¾ inches in diam-

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eter. The pumping is done by a No. 5 Byron Jackson horizontal-shaft, centrifugal pump, directly connected to the 10-inch well casing. The pump is driven by a 12-horsepower Weber gasoline engine, power being transmitted by a belt from 24-inch driving pulley to 18-inch pulleys on countershaft, thence to 8-inch driven pulley on pump shaft.

At the time of the test the engine made 243 revolutions and 76 explosions per minute. The speed of the pump was 668 revolutions a minute. The pump discharges through a 7⅝-inch vertical discharge pipe into a rectangular wooden flume. The discharge was measured by integrating in this flume with a Price acoustic current meter. The width of flume was 1.63 feet. At the selected cross section the water had an average depth of 0.308 feet and an average velocity of 1.171 feet per second. The total discharge was therefore 0.590 second-feet, or 325 gallons a minute. An attempt was made to catch the water in a tub holding 15.9 gallons. The time required to fill the tub was determined by a stop watch, but as the water had to be diverted into the tub by closing a gate at the end of the rectangular flume, the results are not satisfactory. The average time required to fill the tub in seven trials was 4.3 seconds, indicating a discharge of only 209 gallons a minute. This result is known to be valueless, but it illustrates the impracticability of measuring such a discharge by means of a small tub, unless the tub can be placed directly under the discharging stream of water without the necessity of diverting the water to one side.

The vacuum-gage tap was 16.27 feet below the surface, and 16.84 feet below the top of the 7⅝-inch discharge pipe. The water jet is 0.33 feet above the mouth of the discharge pipe. The vacuum gage read 17.5 inches, or 15.5 inches of mercury, when corrected for altitude. This is equivalent to 17.6 feet of water, making total lift of pump 34.77 feet. The vacuum-gage tap was 2.405 feet above the water plane, so that the water in well was lowered 15.2 feet during pumping. The specific capacity of the well is therefore 22.5 gallons per minute, or 0.76 gallons per minute for each square foot of well strainer.

The amount of gasoline used was determined by measurement in a round tank 1.87 feet in diameter. In one hour a depth of 0.09 feet of gasoline was consumed, or 1.84 gallons. With gasoline at 17 cents per gallon, the fuel cost of water was 31 cents per hour, 1.6 cents per 1,000 gallons, and $5.14 per acre-foot. The lift being 34.77 feet, the cost of fuel for 1,000 foot-gallons was $0.00046, or one twenty-second of a cent.

PLANT OF A. L. HINES.

This plant is located on the ranch of Dr. A. L. Hines, about 1 mile north of east from the old village of Mesilla. Water is obtained from a well 5⅝ inches in diameter and 59 feet deep. The log of this well showed 8 feet of soil, 11 feet of dry sand, 28 feet of quicksand, and 12

feet of gravel on top of quicksand of unknown thickness. The water is recovered by a No. 4 Rumsey horizontal-shaft centrifugal pump, which is driven by an 8-horsepower vertical gasoline engine placed on

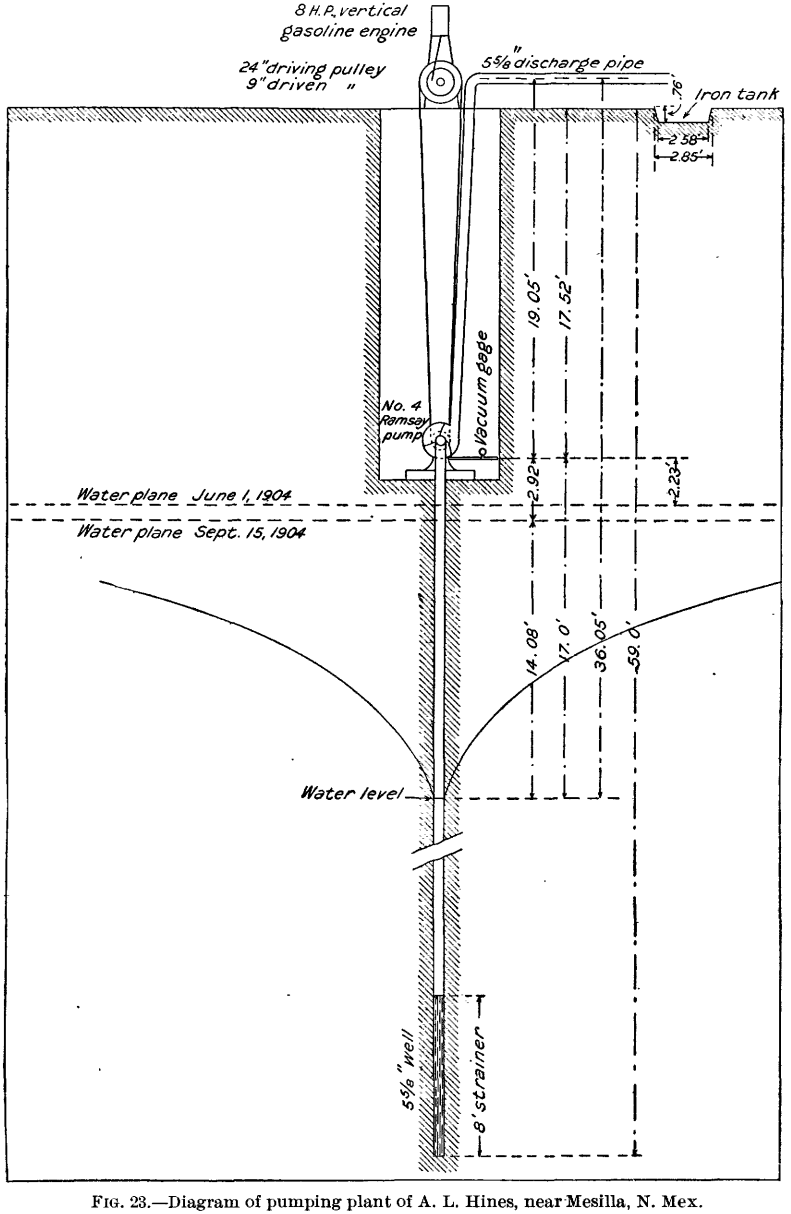

FIG. 23.—Diagram of pumping plant of A. L. Hines, near Mesilla, N. Mex.

sills extending across the top of the well pit. The engine was manufactured by the Chicago Gas Engine Company. It is directly belted to pump shaft from a 24-inch driving pulley and 9-inch driven pulley.

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The engine made 238 revolutions and 119 explosions per minute. The speed of the pump was 594 revolutions per minute.

The water plane was 2.92 feet below the vacuum-gage tap in gooseneck of pump on September 15, 1904, and 2.23 feet below on June 1, 1904; the water plane had fallen, therefore, in this interval about 8½ inches. The pumping plant had been in use only twenty days during the summer. The vacuum-gage tap was 19.05 feet below the center of the horizontal 5⅝-inch discharge pipe. The vacuum gage read 17 inches, which, corrected for altitude, is equivalent to 15 inches of mercury, or 17 feet of water. The total lift of the pump was, therefore, 36.05 feet.

The discharge was measured with great precision by determining with a stop watch the time required to fill a wrought-iron rectangular tank. The water was conducted across the tank by means of an extra piece of iron pipe until the pumping plant had been in operation for some time, when the extra pipe was suddenly pulled off. The tank held 15.08 cubic feet and was filled in 30.6 seconds. The discharge was, therefore, 0.492 second-foot, or 271 gallons per minute.

An excellent opportunity was offered for testing the accuracy of estimating the discharge from partly filled pipes by determining the mean velocity of the stream by a small current meter. Only 44.3 per cent of the cross section of the 5⅝-inch discharge pipe was filled by the water raised by the pump. The area of the cross section was 0.076 square foot, and the velocity of the water, as given by the current meter, was 8.47 feet per second. The discharge was, therefore, 0.642 second-foot, or 290 gallons per minute. The true discharge was 271 gallons per minute, showing an error of 5.3 per cent in the meter determination.

The water in the well was lowered 14.08 feet during pumping; therefore, the specific capacity of the well was 19.2 gallons per minute. As the area of the well strainer was 11.3 square feet, the specific capacity per square foot of well strainer was 1.79 gallons per minute.

At this plant 1.5 gallons of gasoline were used per hour. This is at least 50 per cent more than should have been used. With gasoline at 17 cents a gallon, the hourly cost of fuel was 25½ cents. As the yield was 16,250 gallons of water an hour, the fuel cost was $0.0157 per 1,000 gallons, $5.10 per acre-foot, and $0.000435, or one twenty-third of a cent per 1,000 foot-gallons.

PLANT OF THEODORE ROUALT.

This plant is on the ranch of Theodore Roualt, about 3 miles northwest of Las Cruces, N. Mex. Water is obtained from a 10-inch well 48 feet deep that contains 10 feet of 9¾-inch slotted galvanized-iron strainer. It is raised by a No. 3 Van Wie vertical-shaft centrifugal pump, driven by a 10-horsepower Nagle steam engine, on 18-horsepower

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horizontal wood-burning boiler. The engine is directly belted to the pump shaft from a 30-inch driving pulley to a 12-inch driven pulley.

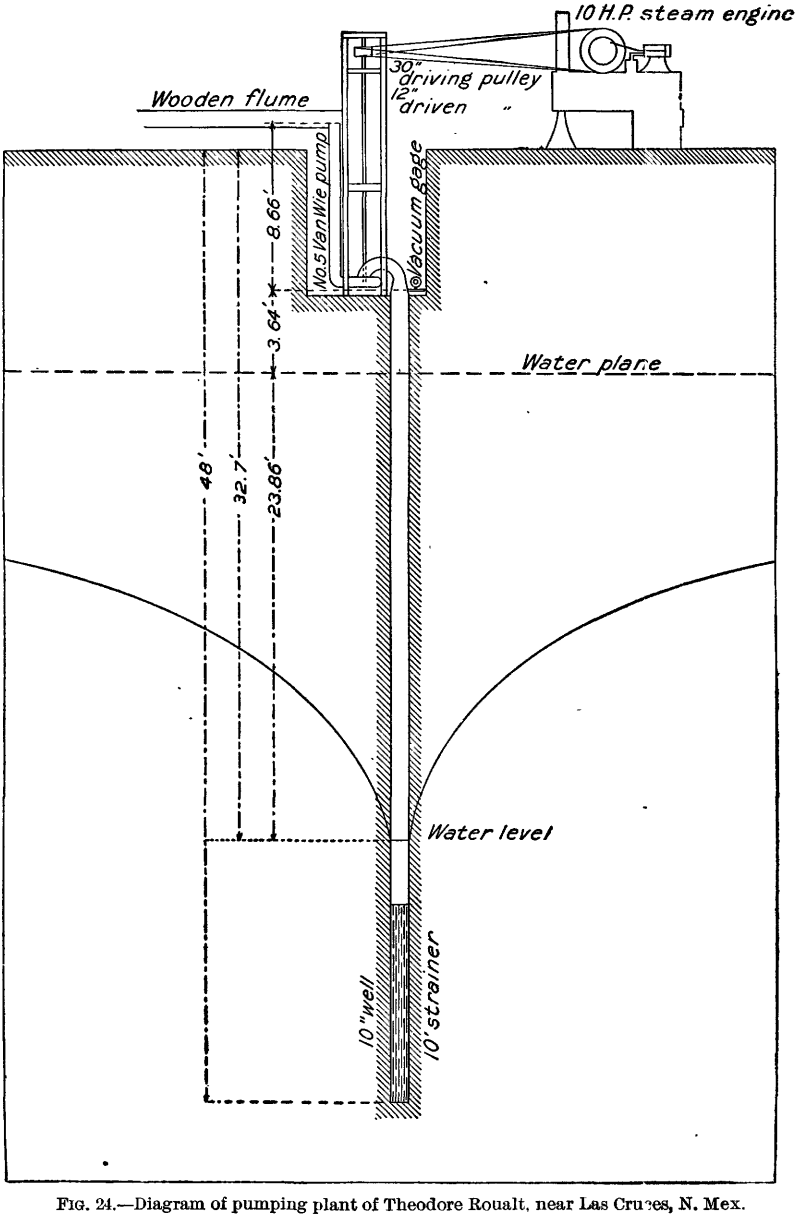

FIG. 24.—Diagram of pumping plant of Theodore Roualt, near Las Cruces, N. Mex.

The water is discharged through an 8-inch vertical pipe into a rectangular flume.

The engine made 205 and the pump 525 revolutions per minute.

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A. DISCHARGE FROM WELL NO. 1, HORACO RANCH COMPANY.

B. PUMPING PLANT OF T. ROUALT.

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The steam pressure varied between 81 and 83 pounds. The vacuum-gage tap was 3.64 feet above the water plane, 7.96 feet below the top of bottom plank of flume, and 8.66 feet below the top of water jet.

The vacuum gage read 24.25 inches, which is equivalent, when corrected for altitude, to 22.25 inches of mercury, or 25.5 feet of water, making the total lift 34.16 feet. The discharge was measured by integrating with a Price acoustic current meter in the rectangular flume. The selected cross section had a width of 1.19 feet, an average depth of 0.35 foot, and an area of 0.417 square foot. As the average velocity was 1.867 feet per second, the discharge was 0.78 second-foot or 351 gallons per minute. From this it is estimated that the specific capacity of the well is 16 gallons per minute, or 0.627 gallon per minute for each square foot of strainer.

The cost of fuel used for pumping can be readily estimated from careful tests by Mr. Roualt. For one irrigation of a 70-acre field of tomatoes the pump was run twenty-eight days of twenty-four hours, and 75 cords of cottonwood, costing $2 per cord, were consumed. During the twenty-eight days of twenty-four working hours each 14,150,000 gallons, or 43.5 acre-feet, of water were pumped. The total cost of wood being $120, the fuel cost of water was 1.06 cents per 1,000 gallons, $3.45 per acre-foot, and $0.00031, or about one thirty-second of a cent, per 1,000 foot-gallons.

PLANT OF G. H. TOTTEN.

This plant is located on the ranch of G. H. Totten, about one-half of a mile west of the old village of Mesilla, N. Mex. Water is obtained from a 10-inch well, 62 feet deep, that contains 11½ feet of 9-inch slotted galvanized-iron strainer. It is raised by a No. 6 Byron Jackson horizontal-shaft centrifugal pump, driven by a 28-horsepower Ohio gasoline engine. The engine is belted from a 36-inch driving pulley to a 16-inch pulley on countershaft; thence from a 15-inch pulley on countershaft to a 10-inch pulley on pump. The engine made 205 revolutions and an average of 78 explosions per minute. The speed of the pump was 692 revolutions a minute.

The water is delivered through an 8-inch vertical discharge pipe into a horizontal rectangular wooden flume. The vacuum-gage tap on pump was 3.9 feet above the water plane, 16.83 feet below top of discharge pipe, and 16.95 feet below top of water jet. The vacuum gage read 25.25 inches, which is equivalent, after correction for altitude, to 23.25 inches of murcury, or 26.4 feet of water. The total lift is, therefore, 43.35 feet.

The discharge was measured by integrating with a Price acoustic current meter in rectangular flume. The selected cross section had a width of 1.83 feet, an average depth of 0.38 foot, and an effective area

of 0.695 square foot. The mean velocity of the water was 1.482 feet per second, giving a total discharge of 1.03 second-feet, or 464 gallons per minute.

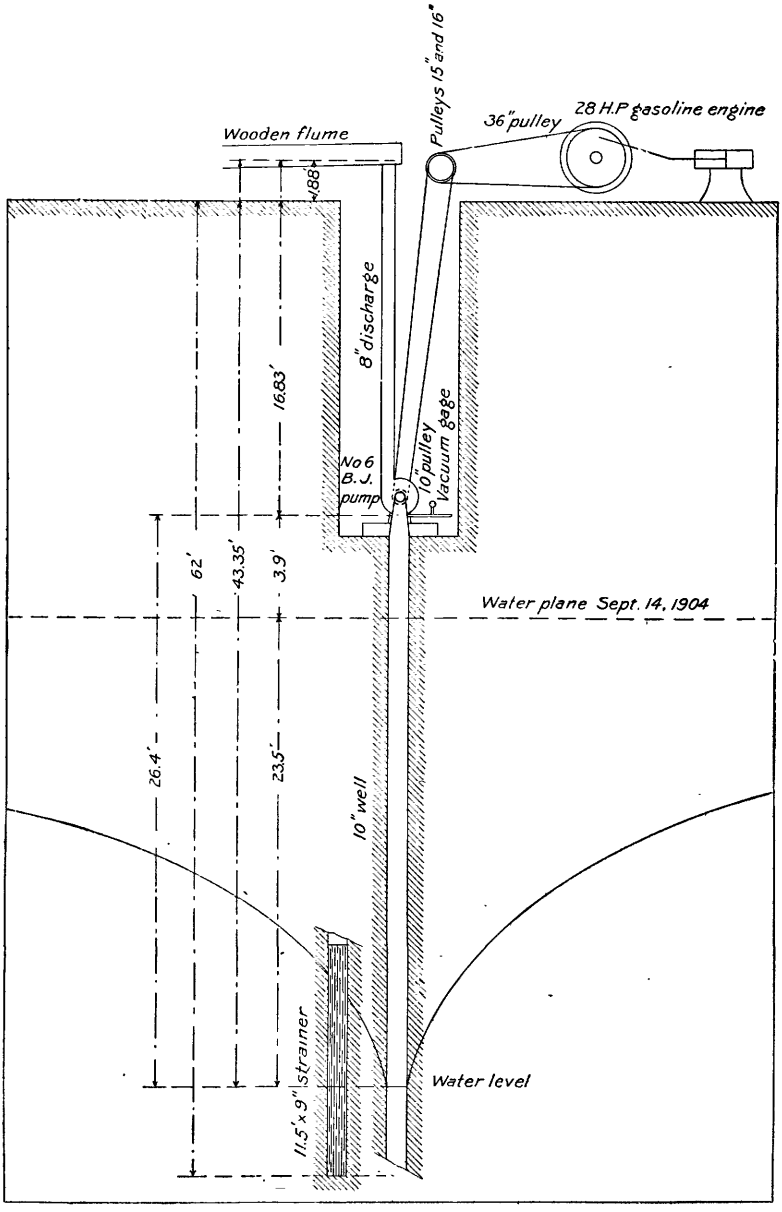

FIG. 25.—Diagram of pumping plant of G. H. Totten, near Mesilla, N. Mex.

The water in the well was lowered 22.5 feet during pumping, from which the specific capacity of the well is estimated to be 20.6 gallons a minute, or 0.76 gallon per minute for each square foot of strainer.

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The discharge was also determined from the dimensions of the parabola of flow as the water left the flume. The end of the flume was almost exactly level and the water fell freely for a sufficient distance to permit the determination of the dimensions of the parabola of the fall. This is shown in fig. 26. The water had an average depth of 0.171 foot at the end of flume, and in a total fall of 2.05 feet moved forward 1.285 feet. According to the laws of falling bodies, a body falls 2.05 feet in 0.356 second. If the water advances 1.285 feet in 0.356 second, its mean velocity per second would be 1.285 divided by 0.356, or 3.6 feet. The area of the stream is 0.171 by 1.83, or 0.313 square foot. This gives a total discharge of 1.13 second-feet, or 507 gallons per minute. These results are undoubtedly slightly too large.

The pumping plant had been used but a short time, and no experimental run had been made to determine the quantity of gasoline required. As the gasoline tank was situated so that without a consid-

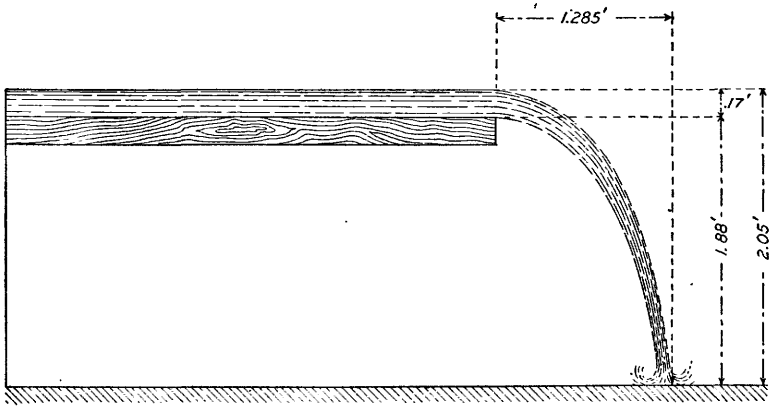

FIG. 26.—Parabola of discharge from flume at Totten's well.

erable expenditure of time it was impracticable to ascertain the amount of gasoline used, no determination was made during the test. However, it was estimated that the 28-horsepower engine gave 22 effective horsepower. It may therefore be safely assumed that about 2.2 gallons of gasoline were used per hour. If this amount were used, and gasoline costs 17 cents per gallon, the fuel cost of water would be 37 cents an hour, $0.0133 per 1,000 gallons, $4.34 per acre-foot, and $0.000307, or about one thirty-third of a cent per 1,000 foot-gallons.

PLANT AT AGRICULTURAL COLLEGE.

This plant consists of a 12-inch and a 6-inch well located on the experimental farm of the New Mexico Agricultural College. A complete test of this plant was not made, as the work with these wells is frequently reported upon by members of the faculty of the Agricul-

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tural College. Only sufficient tests were made to determine the specific capacity of the large well in order to make comparisons possible with the other pumping plants in the valley. At the time of the test a

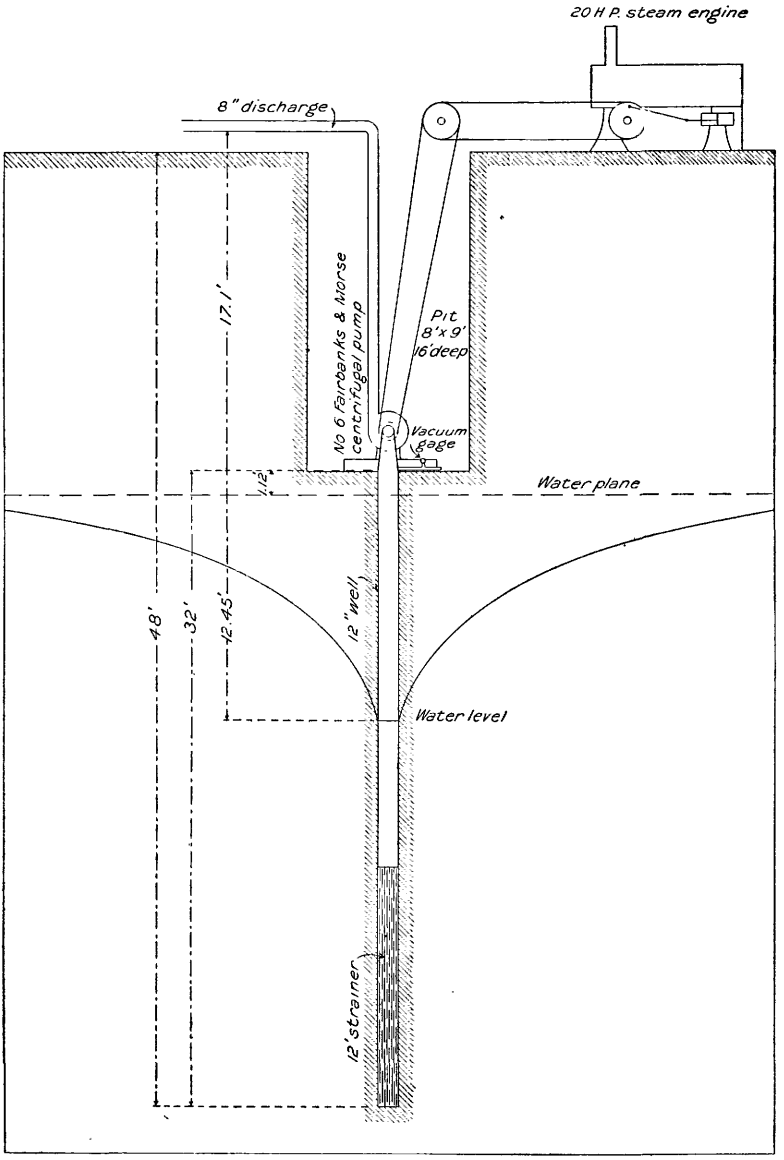

FIG. 27.—Diagram of Agricultural College 12-inch well, Mesilla Park, N. Mex.

No. 6 Fairbanks-Morse centrifugal pump was in use, but the pumps are frequently changed for experimental purposes. The pump is speeded so as to discharge 1,000 gallons a minute at the measuring

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weir, in order that a known amount of water may be provided for the experimental plats of ground.

At the time of the test there was in use a 30-horsepower steam engine, which has ample power to drive pumps placed on both wells. When both wells are used, about 1,800 gallons per minute can be obtained.

On August 25, 1904, the vacuum gage read 13 inches, which, corrected for altitude, is equivalent to 11 inches of mercury, or 12.45 feet of water. The lift above the vacuum-gage tap was 17.10 feet, making the total lift 29.55 feet. The water level in the well was lowered 11.37 feet by pumping, from which the specific capacity of the well is computed to be 88 gallons per minute. As the well strainer is 12 inches in diameter, 12 feet long, and 27.6 square feet in area, the specific capacity per square foot of strainer is 2.32 gallons per minute.

The cost of fuel per acre-foot, as given in the table on p. 35, is taken from the bulletin issued by Professors Vernon and Lester in 1903. These results were obtained with a 20-horsepower steam engine formerly used. These results are included in the table for the purpose of comparison with the results at other plants.

TESTS OF PUMPING PLANTS NEAR BERINO, N. MEX.

PLANTS OF HORACO RANCH COMPANY.

The Horaco Ranch Company has three plants in an east-west line on a ranch just west of Berino, N. Mex. The east well is No. 3, the middle well is No. 1, and the west well is No. 2.

Well No. 3 is 62 feet deep. It is cased with 9⅝-inch pipe and contains 18 feet of strainer made of 9⅝-inch casing drilled with forty 1½-

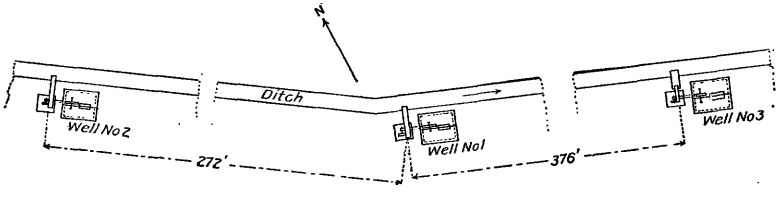

FIG. 28.—Plan of pumping plants of the Horaco Ranch Company, Berino, N. Mex.

inch holes to every linear foot of strainer and wound with No. 9 galvanized-iron wire wrapped so as to leave horizontal slots one-eighth of an inch in width. This strainer is locally known as the "Mott" strainer.

Water is obtained by means of a No. 5 Byron Jackson horizontal-shaft centrifugal pump, driven by a 12-horsepower Weber gasoline engine. The water is discharged through a 7-inch pipe, which rises

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at an angle of 45° from the pump in the well pit. The engine made 244 revolutions and 97 explosions per minute. The pump made 692 revolutions a minute, and was belted directly to the engine from a

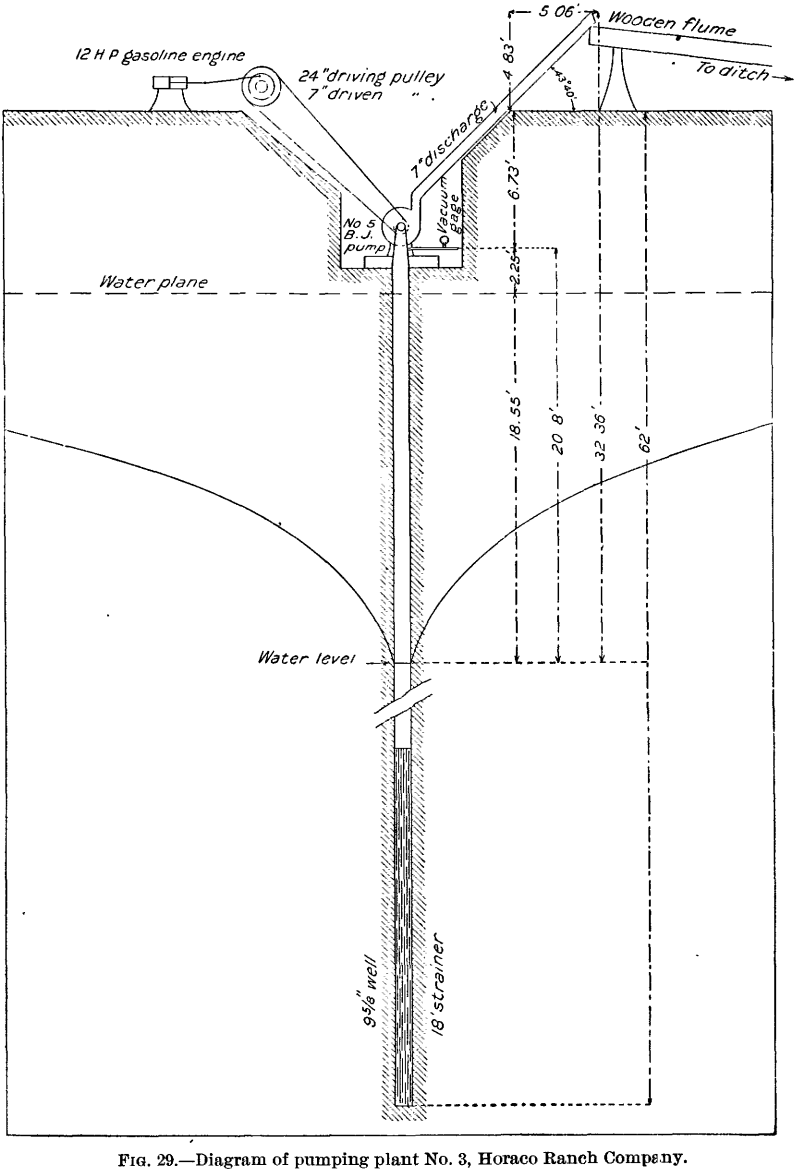

FIG. 29.—Diagram of pumping plant No. 3, Horaco Ranch Company.

24-inch driving pulley to a 7-inch driven pulley. On September 11, 1904, the water plane was 2.25 feet below the vacuum-gage tap, which was 11.56 feet below the end of the discharge pipe. The

vacuum gage read, after one hour's pumping, 19.8, which, when corrected for altitude, is equivalent to 17.8 inches of mercury, or 20.8 feet of water. The total lift of the pump was, therefore, 32.36 feet.

The discharge was measured by holding a small Price acoustic current meter in the mouth of the 7-inch discharge pipe. It was 1.71 second-feet, or 750 gallons a minute.

As determined by Mr. E. L. Houck, principal owner of the Horaco ranch, a barrel of 50 gallons of gasoline was consumed by the engine at well No. 3 in fifty-three hours. With gasoline at 17 cents per gallon the fuel cost of water was 16 cents an hour, or $0.00356 per 1,000 gallons, or $1.16 per acre-foot. Since the total lift of the pump is 31.76 feet, the cost of fuel for 1,000 foot-gallons is $0.000112, or one eighty-ninth of a cent. The consumption of gasoline at the time of the test was measured by noting the changing level of the gasoline in a cylindrical tank 1.85 feet in diameter. The change of level in one hour was 0.0867 foot. This is equivalent to 1.76 gallons an hour. On this basis the fuel cost of water was $2.23 per acre-foot, and $0.000314, or one forty-seventh of a cent per 1,000 foot-gallons.

Well No. 1 of the Horaco Ranch Company is 376 feet west from well No. 3. It is 75 feet deep, is cased with 7⅝-inch pipe, and equipped with 18 feet of Mott strainer. Water is delivered through a 7⅝-inch vertical pipe opening into a horizontal wooden flume. It is raised by a No. 5 Byron Jackson horizontal-shaft centrifugal pump, driven by a 12-horsepower Weber gasoline engine. The engine made 238 revolutions and 106 explosions a minute. The pump made 815 revolutions a minute and was belted directly to the engine from a 24-inch driving pulley to a 7-inch driven pulley.

The vacuum-gage tap was 0.43 foot above the water plane on September 11, 1904. It was 7.1 feet below the surface and 8.95 feet below the end of vertical discharge pipe. As the water jet rose 0.762 foot above the end of the discharge, the total lift above the vacuum-gage tap was 9.71 feet. The vacuum gage read 14.5, which, corrected for altitude, is equivalent to 12.5 inches of mercury, or 14.18 feet of water. The total lift of the pump was, therefore, 23.89 feet.

The discharge was measured by integrating with a Price acoustic current meter in the rectangular flume. The selected cross section had an average depth of 0.278 foot, an average width of 1.42 feet, and an area of 0.395 square foot. The average velocity of the water was 4.707 feet per second, giving a discharge of 1.86 second-feet, or 837 gallons per minute.

The area of the well strainer is 36 square feet. The water level in the well was lowered 13.75 feet during pumping, and therefore the specific capacity of the well is 60.8 gallons per minute, or 1.69 gallons per minute for each square foot of strainer.

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Although the amount of water obtained at well No. 1 is very much greater than at well No. 3, the cost for fuel is substantially the same. The consumption of gasoline is slightly less than 1.2 gallons an hour. With gasoline at 17 cents a gallon, the hourly cost is 20 cents. The

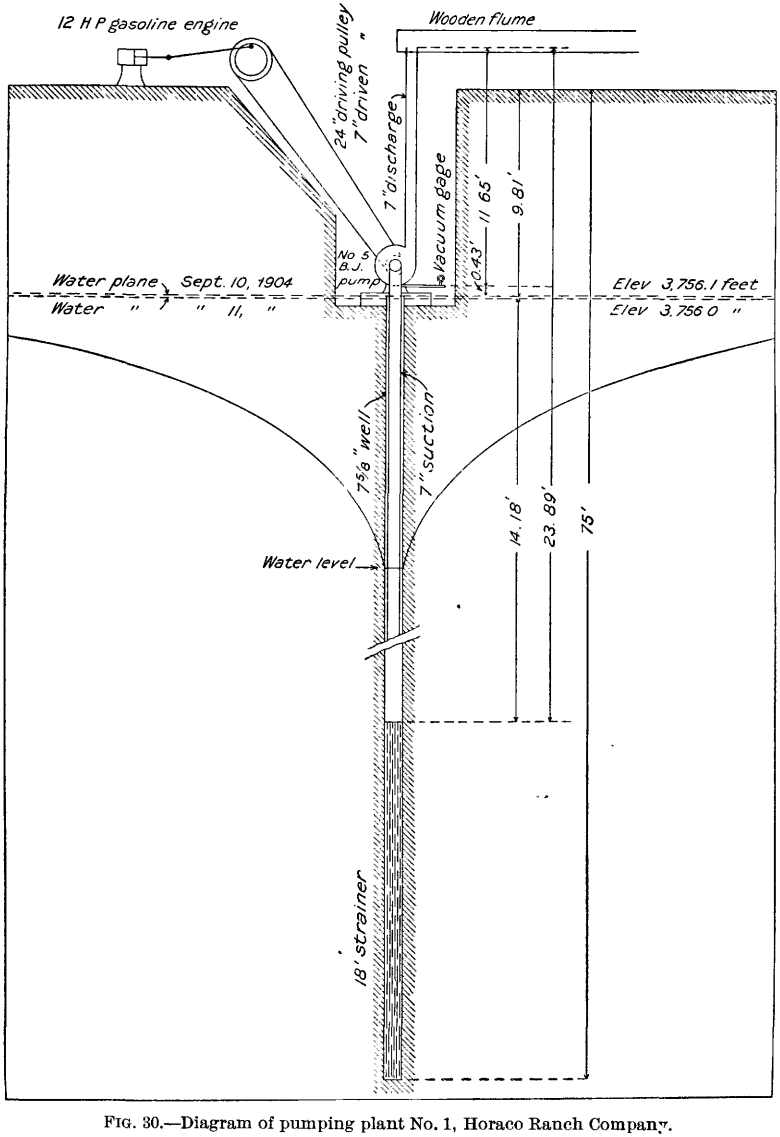

FIG. 30.—Diagram of pumping plant No. 1, Horaco Ranch Company.

amount of water obtained being 837 gallons a minute, or 50,220 gallons an hour, the fuel cost was $0.004 per 1,000 gallons, or $1.30 per acre-foot. The lift at well No. 1 being 23.89 feet, the cost of fuel for each 1,000 foot-gallons was $0.000167, or one-sixtieth of a cent.

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Well No. 2 of the Horaco Ranch Company is 376 feet west of well No. 1. It is 53 feet deep, is cased with $9\frac{5}{8}$-inch pipe, and is equipped with 18 feet of Mott strainer at the bottom. Water is raised by a No. 5 Byron Jackson horizontal-shaft centrifugal pump, driven by a

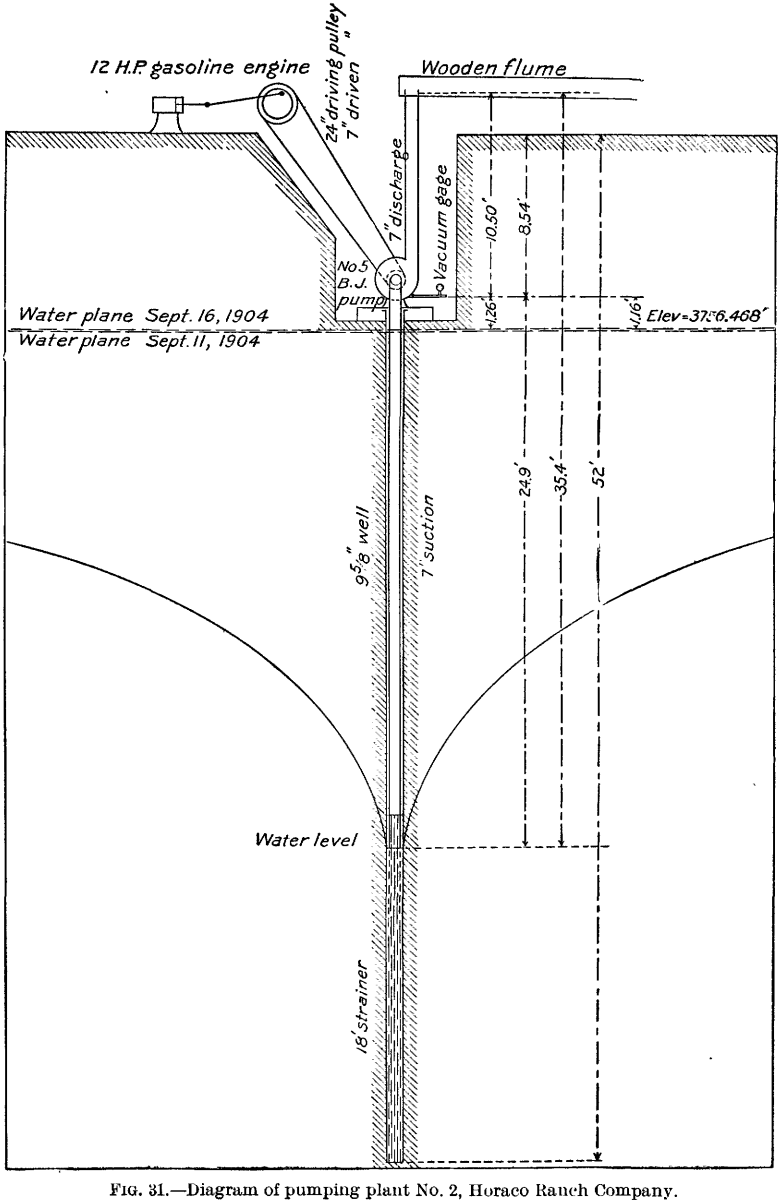

FIG. 31.—Diagram of pumping plant No. 2, Horaco Ranch Company.

12-horsepower Weber gasoline engine. It is taken from the well through a 7-inch suction and discharged through a 7-inch vertical pipe into a horizontal flume. The engine made 239 revolutions and

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103 explosions a minute. It was belted directly to the pump shaft from a 24-inch driving pulley to a 7-inch driven pulley. The speed of the pump was 700 revolutions a minute.

The vacuum-gage tap placed in the goose neck of the pump was 1.26 feet above the water plane and 10.02 feet below the top of the vertical discharge pipe. As the water jet rose 0.34 foot above the discharge pipe, the total lift of the pump above the vacuum-gage tap was 10.36 feet. The vacuum gage read 24 inches, which, corrected for altitude, is equivalent to 22 inches of mercury, or 24.9 feet of water. The total lift of the pump was therefore 35.26 feet.

The discharge was measured by integrating with a Price acoustic current meter in the rectangular flume. The selected cross section had an average depth of 0.251 foot, a width of 1.44 feet, and an area of 0.362 square foot. The mean velocity was 1.172 feet per second, which gives a total discharge of 0.425 second-foot, or 191 gallons per minute.

The water in the well was lowered 23.64 feet by pumping. This makes the specific capacity of the well 8.1 gallons per minute, or 0.178 gallon per minute for each square foot of strainer.

The consumption of gasoline by the engine at well No. 2 is known by comparison with that at well No. 3. Although the amount of water pumped is very much less than at well No. 3, the consumption of gasoline is as great, and even slightly greater, say 1.2 gallons an hour. With gasoline at 17 cents per gallon the hourly cost of fuel is 20.4 cents. The fuel cost of water is then 1.78 cents per 1,000 gallons, $0.000505, or one-twentieth of a cent per 1,000 foot-gallons, and $5.80 per acre-foot.

Mr. Houck gives the combined cost of the three pumping plants on the Horaco ranch as follows:

Cost of pumping plants on Horaco ranch.

Three 12-horsepower Weber gasoline engines, three No. 5 Byron Jackson pumps with piping, belting, etc., all in place	$2,100.00
Wells at $2.50 per foot	475.00
Well pits, buildings, flumes, etc., extra	400.00
	2,975.00

Depreciation at 10 per cent and interest at 8 per cent amounts to $536 per annum. For an irrigation season of one hundred days this averages $5.36 per day, or $1.80 a day for each plant.

The hourly cost of plant No. 1 may be figured as follows:

Hourly cost of pumping plant No. 1 at Horaco ranch.

Fuel (gasoline)	$0.16
Interest and depreciation	.18
Labor, lubricating oil, etc.	.10
Total	.44

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The last item is based on the supposition that one man can run the three plants.

At well No. 1 the yield of water is 837 gallons a minute, or 50,220 gallons an hour. The cost is therefore $0.00876 per 1,000 gallons, or $2.85 per acre-foot.

The cost at the other plants is much greater on account of poorer wells. The wells would probably show little difference in capacity or cost of the water if they were all as deep as well No. 1. The coarse gravels were not reached at all in well No. 2, and were not penetrated in well No. 3.

Mr. Houck made a careful test of the amount of gasoline used at pumping plants Nos. 1 and 3 in November, 1904. Each of the engines at these plants ran sixteen hours on 16 gallons of gasoline. These tests are in substantial accord with the former tests quoted above, but show a slightly smaller quantity of gasoline consumed.

Plants Nos. 1 and 3 were used on two occasions to irrigate 25 acres of land, consisting of 21 acres of alfalfa and 4 acres of orchard and garden, and sixteen hours of continuous run were required at each trial. This is equivalent to about 2¼ inches of water per irrigation.

An interesting observation was made of the effect of stopping the pumps during the night instead of making a continuous run as above. When this was done the pumps had to be run two and one-half hours longer to irrigate land that had previously been irrigated in sixteen hours.

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APPENDIX.

ANALYSES OF WELL WATER AND DATA CONCERNING WELLS AT AND NEAR EL PASO, TEX.

This information was furnished by Mr. A. Courchesne, of El Paso, Tex.

Water in corral at stone quarry above El Paso, Tex.

Analysis.	Parts per 100,000.	Probable combinations.	Parts per 100,000.
Silica	3.00	Silica	3.00
Alumina	2.00	Alumina	2.00
Lime	26.20	Carbonate of lime	34.00
Magnesia	6.11	Sulphate of lime	17.65
Soda	18.84	Sulphate of magnesia	18.30
Carbonic acid	15.00	Sulphate of soda	1.90
Sulphuric acid	23.70	Chloride of sodium	33.95
Chlorine (Cl)	20.60	Water of crystallization, etc.	1.20
Water of crystallization, or loss	1.20	Total solids	112.00
	116.65	Total hardness	62.20
Oxygen equivalent to Cl	4.65	Permanent hardness	28.20
Total solids	112.00		

This is not a good boiler water, though most of the solids will come down as sludge instead of sticking to tubes. Still there is enough in combination to make a hard seal of sulphate of lime and carbonate of magnesia. The water will corrode, but not badly.

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Analysis of water from mile 211, El Paso and Southwestern Railroad.

Constituent.	Parts per 100,000.	Probable combination.	Parts per 100,000.
Silica	7.00	Silica	9.00
Alumina	1.00	Alumina	1.00
Lime	6.70	Carbonate of lime	12.00
Magnesia	2.80	Carbonate of magnesia	3.62
Soda	16.40	Sulphate of magnesia	3.45
Sulphuric acid	13.65	Sulphate of soda	20.33
Carbonic acid	7.48	Chloride of sodium	14.35
Chlorine (Cl)	8.70	Water of crystallization	.25
Water of crystallization	25	Total solids	62.00
	63.98		
Oxygen equivalent to Cl	1.98		
Total solids	62.00		

This is a good locomotive water, and is a fairly good drinking water, very slightly medical from Glaubers salts.

Water from 70-foot well at ranch of A. Courchesne, near Ysleta, Tex.

Constituent.	Parts per 100,000.
Silica	3.00
Alumina and phosphate	10.00
Carbonate of lime	15.00
Carbonate of magnesia	3.01
Carbonate of soda	12.13
Sulphate of soda	7.80
Chloride of sodium	23.30
Organic and water of crystallization	1.76
	106.00

This water is comparatively soft and good for boiler use. It has too much organic matter in it for a safe drinking water. The dried solids blacken on ignition and smell badly. It is probably polluted with sewage.

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Water from lime quarry, El Paso, 30 feet deep.

Constituent.	Parts per 100,000.	Probable combinations.	Parts per 100,000.
Silica	2.60	Silica	2.60
Alumina	2.00	Alumina	2.00
Lime	44.72	Carbonate of lime	32.00
Magnesia	10.80	Sulphate of lime	65.30
Soda	65.80	Sulphate of magnesia	32.40
Sulphuric acid	60.00	Chloride of sodium	124.20
Carbonic acid	14.00	Water of crystallizatior	27.50
Carbonic	75.60	Total solids, 100 c	286.00
Water of crystallization	27.50	Total solids, grains per gallon (US)	167.00
	303.02		
Oxygen equivalent to Cl	17.02		
Total solids, 100 c	286.00		

This water is not good for drinking or boiler purposes. It will scale and corrode badly. It could be made usable for boilers by treatment with caustic and carbonate of soda, but it would not then be a good water on account of high proportions of common salt.

Analyses of waters from wells of El Paso ice plant.

Constituent.	Surface water.	300-foot well (grains per U. S. gallon).	80-foot well (grains per U. S. gallon.)
Organic	5.4	3.033	5.249
Silica	2.8		1.166
Sulphate of lime			35.003
Carbonate of lime	26.3	9.580	10.940
Carbonate of magnesia	5.3	1.102	.883
Chloride of sodium	36.9	6.102	52.464
Chloride of lime			4.391
Chloride of magnesia			9.802
Sulphate of magnesia			5.148
Sulphate of sodium	32.5	7.407	
Carbonate of sodium	5.2		
Iron and alumina	.6		
Total solids	115.0	27.224	125.046
Incrustants	34.9	10.682	47.992
Corroding salts			19.341
Rating for boiler purposes	Bad.	Good.	Very bad.

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Analysis from water from new 400-foot well of El Paso Ice and Refrigerator Company, El Paso, Tex.

Constituent.	Parts per 100,000.	Probable combinations.	Parts per 100,000.
Silica	0.50	Silica	0.50
Alumina	Tr.	Alumina	Tr.
Lime	2.23	Carbonate of lime	4.00
Magnesia	3.00	Carbonate of magnesia	6.30
Soda	8.98	Carbonate of soda	1.59
Chlorine	5.31	Sulphate of soda	7.90
Carbonic acid	5.72	Chloride of sodium	8.71
Sulphuric acid	4.45	Total solids	29.00
	30.19	Total hardness	11.5
Oxygen equivalent to Cl	1.19		
Total solids	29.00		

This is a good water. The hardness is rather high, but it is temporary, and only a small part (about 20 per cent) will incrust, the rest falling as slugs in the boiler, which can be blown out.

Analysis of El Paso well water.

Constituent.	Grains per U. S. gallon.
Incrusting solids:	
Calcium carbonate	3.20
Calcium sulphate	None.
Calcium chloride	None.
Magnesium carbonate	1.39
Magnesium sulphate	None.
Magnesium chloride	None.
Iron and alumina	.07
Silica	1.61
Suspended matter	Trace.
Total	6.27
Nonincrusting solids:	
Sodium sulphate	5.82
Sodium chloride	7.02
Sodium carbonate	4.19
Total	17.03
Alkalinity	9.33
Hardness	5.26
Carbonic acid	2.42
Pounds of incrusting solids per thousand gallons	.90

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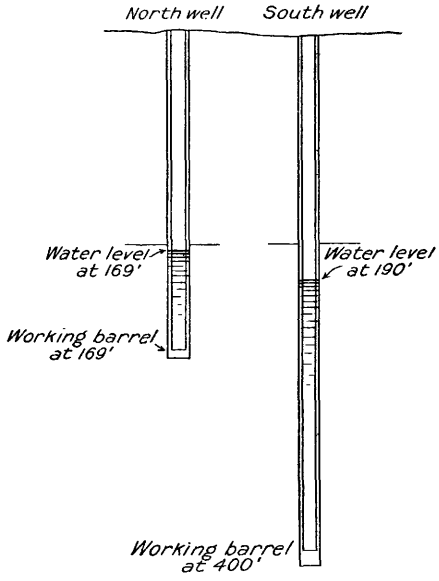

FIG. 32.—Wells at Fort Bliss station, El Paso and Northeastern Railroad.

Data concerning wells at Fort Bliss

NORTH WELL.

Completed: July 22, 1901.
Total depth: 249 feet.
Casing: 249 feet of 6-inch.
Depth of working barrel: 245 feet.
Water level: 169 feet below earth's surface.
Pump: 12 by 36 inches, Cook.
Tested capacity of well: 80,000 gallons per twenty-four hours.

SOUTH WELL.

Completed: 1901.
Total depth: 410 feet.
Casing: 410 feet of 6-inch.
Depth of working barrel: 400 feet.
Water level: 190 feet below earth's surface.
Pump: 10 by 36 inches, Cook.
Tested capacity of well: 30,000 gallons per twenty-four hours.

FEATURES COMMON TO NORTH AND SOUTH WELLS.

Contractor: William McLease.
Size of hole: 8 inches.
Pump column: 6-inch standard.
Working barrel: 5½-inch, Cook.
Well rods: No. 3; 3-inch hickory, 1½-inch straight pins.
Storage: 50,000 gallons, wooden tank.
Boiler: 30 horsepower, Economic.

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Analysis of Fort Bliss well water.

Constituent.	Grains per U. S. gallon.
Calcium carbonate (incrusting)	4.90
Magnesium carbonate (incrusting)	3.09
Silica (incrusting)	1.34
Oxides, alumina and iron (incrusting)	.06
Alkali carbonates (nonincrusting)	2.74
Alkali sulphates (nonincrusting)	2.62
Alkali chlorides (nonincrusting)	1.63
Alkali nitrates (nonincrusting)	.70
Sulphates, lime, and magnesium	Traces.
Total incrusting solids	9.39
Total nonincrusting solids	7.69
Pounds incrusting matter per 1,000 gallons	1.34
Pounds nonincrusting matter per 1,000 gallons	1.09

This water should be classed as good.

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PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 141.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian well prospects in the Atlantic coastal plain region, by N. H. Darton, Bulletin No. 138.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

SEPTEMBER, 1905.

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. . . Observations on the ground waters of Rio Grande Valley, by Charles S. Slichter. Washington, Gov't print. off., 1905.

83, iii p. illus., V pl., diagrs. 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 141)

Subject series: K, Pumping water, 11; O, Underground waters, 44.

Appendix: Analysis of well water and data concerning wells at and near El Paso, Texas.

1. Water, Underground—Texas. 2. Water, Underground—New Mexico.

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Series.

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no. 141. Slichter, C. S. Observations on the ground waters of Rio Grande Valley. 1905.

Reference.

U. S. Dept. of the Interior.

see also

U. S. Geological survey.

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THE

STATUTES AT LARGE

OF THE

UNITED STATES OF AMERICA,

FROM

NOVEMBER, 1903, TO MARCH, 1905;

CONCURRENT RESOLUTIONS OF THE TWO HOUSES OF CONGRESS,

AND

RECENT TREATIES, CONVENTIONS, AND EXECUTIVE PROCLAMATIONS.

EDITED, PRINTED, AND PUBLISHED BY AUTHORITY OF CONGRESS, UNDER THE DIRECTION OF THE SECRETARY OF STATE.

VOL. XXXIII.—PART 1.

PUBLIC ACTS AND RESOLUTIONS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

TX_MSJ_002189

LIST

OF THE

PUBLIC ACTS AND RESOLUTIONS OF CONGRESS

CONTAINED IN THIS VOLUME.

PART ONE.

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STATUTE II.—1903–1904.

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Louisiana Purchase Exposition copyrights. An act to afford protection to exhibitors of foreign literary, artistic, or musical works at the Louisiana Purchase Exposition. January 7, 1904 4

Mexican boll-weevil extermination. An act to amend the act entitled "An act making appropriations for the Department of Agriculture for the fiscal year ending June thirtieth, nineteen hundred and four," approved March third, nineteen hundred and three. January 15, 1904 5

Removing snow and ice, District of Columbia. An act making appropriations for clearing the Potomac River of ice and for the removal of snow and ice in the District of Columbia. January 15, 1904 6

Bridge, Mississippi River. An act to supplement and amend an act entitled "An act to authorize the construction of a bridge across the Mississippi River, at or near Grays Point, Missouri;" approved January twenty-sixth, nineteen hundred and one. January 18, 1904 6

Arizona, road bond issue. An act to enable the city of Phoenix, the town of Tempe, and the town Mesa, all in Maricopa County, Arizona Territory, severally to issue the bonds of said municipalities for the purpose of aiding in the construction of a freighting and wagon road from any convenient point in the Salt River Valley to the Salt River reservoir dam site in Maricopa County, Arizona. January 21, 1904 6

District of Columbia, Columbian College charter. An act supplemental to the act of February ninth, eighteen hundred and twenty-one, incorporating the Columbian College in the District of Columbia, and the acts amendatory thereof. January 23, 1904 7

District of Columbia, Pintsch Compressing Company. An act to amend an act entitled "An act to permit the Pintsch Compressing Company to lay pipes in certain streets in the city of Washington," approved May nineteenth, eighteen hundred and ninety-six. January 25, 1904 8

Port of entry, Chester, Pa. An act making Chester, Pennsylvania, a subport of entry. January 25, 1904 9

Perforated Congressional franks. An act to amend an act entitled "An act providing for public printing and binding and the distribution of public documents." January 30, 1904 9

Appraiser, Pittsburg, Pa. An act providing for the appointment of a customs appraiser at Pittsburg, Pennsylvania. January 30, 1904 9

Bridge, Saint Francis River. An act to authorize the county of Poinsett, in the State of Arkansas, to construct a bridge across the Saint Francis River at or near the town of Marked Tree, in said county and State. February 2, 1904 9

District of Columbia, sidewalks. An act in relation to business streets in the District of Columbia. February 2, 1904 10

District of Columbia, dental practice. An act to amend an act entitled "An act for the regulation of the practice of dentistry in the District of Columbia, and for the protection of the people from empiricism in relation thereto," approved June sixth, eighteen hundred and ninety-two. February 5, 1904 10

Naval officer, Chicago, Ill. An act providing for an additional officer in the district of Chicago, in the collection district of Indiana and Illinois. February 6, 1904 11

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District of Columbia, lunacy proceedings. An act to change the lunacy proceedings in the District of Columbia where the Commissioners of said District are the petitioners, and for other purposes. February 23, 1905 740

District of Columbia, Union Station. An act to amend an act approved February twelfth, nineteen hundred and one, entitled "An act to provide for eliminating certain grade crossings on the line of the Baltimore and Potomac Railroad Company, in the city of Washington, District of Columbia, and requiring said company to depress and elevate its tracks, and to enable it to relocate parts of its railroad therein, and for other purposes." February 23, 1905 740

District of Columbia, conduit, Seventh street. An act permitting the Washington Market Company to lay a conduit across Seventh street west. February 23, 1905 741

Pierre Charles L'Enfant, tombstone. An act to mark the grave of Major Pierre Charles L'Enfant. February 23, 1905 741

District of Columbia, water to charitable institutions, etc. An act authorizing the Commissioners of the District of Columbia to furnish Potomac water without charge to charitable institutions, and so forth, in the District of Columbia. February 23, 1905 742

District of Columbia, alley, square 806. An act to close and open an alley in square numbered eight hundred and six in the city of Washington, District of Columbia. February 23, 1905 742

Life saving on railroads, medals, etc. An act to promote the security of travel upon railroads engaged in interstate commerce, and to encourage the saving of life. February 23, 1905 743

Omnibus claims act. An act for the allowance of certain claims reported by the Court of Claims, and for other purposes. February 24, 1905 743

Public works, suits against contractors. An act to amend an act approved August thirteenth, eighteen hundred and ninety-four, entitled "An act for the protection of persons furnishing materials and labor for the construction of public works." February 24, 1905 811

Alabama, canceled homestead entries. An act for the relief of certain homestead settlers in the State of Alabama. February 24, 1905 813

Thomas Mason, Revenue-Cutter Service. An act to authorize the promotion of First Lieutenant Thomas Mason, Revenue-Cutter Service. February 25, 1905 813

Dam, Rainy River. An act relating to a dam across Rainy River. February 25, 1905 814

Dam, etc., Rio Grande. An act relating to the construction of a dam and reservoir on the Rio Grande, in New Mexico, for the impounding of the flood waters of said river for purposes of irrigation. February 25, 1905 814

Customs, deputy collector, Manteo, N. C. An act to authorize the Secretary of the Treasury to appoint a deputy collector of customs at Manteo, North Carolina. February 25, 1905 814

Court of Claims, lands in San Francisco. An act referring the claim of Hannah S. Crane and others to the Court of Claims. February 25, 1905 815

Saint Johns County, Fla., school land. An act making provision for conveying in fee certain public grounds in the city of Saint Augustine, Florida, for school purposes. February 27, 1905 815

Montana lands. An act confirming the title of the Saint Paul, Minneapolis and Manitoba Railway Company to certain lands in the State of Montana, and for other purposes. February 27, 1905 816

Twentieth New York Volunteers. An act for the relief of certain enlisted men of the Twentieth Regiment of New York Volunteer Infantry. February 27, 1905 816

Bridge, Red River. An act to authorize the construction of a bridge across Red River at or near Boyce, Louisiana. February 27, 1905 817

Bridge, Rainy River. An act to extend the time for the construction of a bridge across Rainy River by the International Bridge and Terminal Company. February 28, 1905 818

National banks, directors. An act to amend section fifty-one hundred and forty-six of the Revised Statutes of the United States in relation to the qualifications of directors of national banking associations. February 28, 1905 818

Nebraska, exchange of lands. An act to authorize the Secretary of the Interior to accept the conveyance from the State of Nebraska of certain described lands and granting to said State other lands in lieu thereof, and for other purposes. February 28, 1905 819

Life-saving station, Nome, Alaska. An act to establish a life-saving station at Nome, Alaska. March 1, 1905 819

Richmond, N. Y., light-house station land. An act for the conveyance of public lands belonging to the United States, in the State of New York. March 1, 1905 820

Boundary, South Dakota and Nebraska. An act establishing that portion of the boundary line between the State of South Dakota and the State of Nebraska south of Union County, South Dakota. March 1, 1905 820

American register "Brooklyn." An act to provide an American register for the steamer Brooklyn. March 1, 1905 821

American register "Pioneer." An act to provide an American register for the steam lighter Pioneer. March 1, 1905 821

Purcell, Ind. T., tax ordinance. An act legalizing a certain ordinance of the city of Purcell, Indian Territory. March 1, 1905 821

District of Columbia, police and firemen's pensions. An act to amend section four of an act entitled "An act relating to the Metropolitan police of the District of Columbia," approved February twenty-eighth, nineteen hundred and one. March 1, 1905 821

Immediate transportation, Gloucester, Mass. An act to make Gloucester, Massachusetts, a port to which merchandise may be imported without appraisement. March 1, 1905 822

Public lands, receivers. An act for the relief of certain receivers of public moneys, acting as special disbursing agents, in the matter of amounts expended by them for per diem fees and mileage of witnesses in hearings, which amounts have not been credited by the accounting officers of the Treasury Department in the settlement of their accounts. March 2, 1905 822

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February 25, 1905.
[H. R. 17331.]
[Public, No. 103.]

CHAP. 797.—An Act Relating to a dam across Rainy River.

Rainy River, Minn.
Rainy River Improvement Company to succeed to rights of former company.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Rainy River Improvement Company, a corporation organized under the laws of the State of Minnesota for the improvement of the navigation of Rainy River and Rainy Lake, and its successors and assigns, upon filing with the Secretary of War proof satisfactory to him of its succession to the rights and privileges granted to the Koochiching Company by the following Acts of Congress, namely: Chapter two hundred and thirty-eight of volume thirty of the Statutes at Large, "An Act permitting the building of a dam across Rainy Lake River," approved May fourth, eighteen hundred and ninety-eight; chapter three hundred and forty-six of volume thirty-one of the Statutes at Large, "An Act to amend an Act entitled 'An Act permitting the building of a dam across Rainy Lake River,'" approved May fourth, nineteen hundred; chapter thirteen hundred and five, volume thirty-two, of the Statutes at Large, "An Act relating to the construction of a dam across Rainy River," approved June twenty-eighth, nineteen hundred and two, shall have the right, subject to the restrictions, conditions, and terms of said several Acts, to construct and maintain the dam provided for therein, at such height as the Secretary of War may approve: *Provided*, That such dam shall be completed on or before July first, nineteen hundred and eight.

Vol. 30, p. 398.
Vol. 31, p. 167.
Vol. 32, p. 485.
Proviso.
Time of construction.

Proof of succession.

SEC. 2. That upon filing the proof of its succession to the rights of the Koochiching Company, and the approval thereof by the Secretary of the War, that officer shall issue to the Rainy River Improvement Company a certificate of such approval.

Amendment.

SEC. 3. That the right to alter, amend, or repeal this Act is hereby expressly reserved.

Approved, February 25, 1905.

February 25, 1905.
[H. R. 17939.]
[Public, No. 104.]

CHAP. 798.—An Act Relating to the construction of a dam and reservoir on the Rio Grande, in New Mexico, for the impounding of the flood waters of said river for purposes of irrigation.

Rio Grande, N. Mex.
Dam, etc., authorized under reclamation act.
Vol. 32, p. 388.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the provisions of the reclamation Act approved June seventeenth, nineteen hundred and two, shall be extended for the purposes of this Act to the portion of the State of Texas bordering upon the Rio Grande which can be irrigated from a dam to be constructed near Engle, in the Territory of New Mexico, on the Rio Grande, to store the flood waters of that river, and if there shall be ascertained to be sufficient land in New Mexico and in Texas which can be supplied with the stored water at a cost which shall render the project feasible and return to the reclamation fund the cost of the enterprise, then the Secretary of the Interior may proceed with the work of constructing a dam on the Rio Grande as part of the general system of irrigation, should all other conditions as regards feasibility be found satisfactory.

Location

Approved, February 25, 1905.

February 25, 1905.
[S. 4609.]
[Public, No. 105.]

CHAP. 799.—An Act To authorize the Secretary of the Treasury to appoint a deputy collector of customs at Manteo, North Carolina.

Customs.
Deputy collector authorized at Manteo, N. C.
R. S., sec. 2556, p. 505, amended.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Treasury be, and he is hereby, authorized and directed to appoint a deputy collector of customs at Manteo, in the district of Albemarle, North Carolina, who shall be empowered to grant enrollments and

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Records of the Bureau of Reclamation
Washington, D.C.

General Administrative and Project Records

1902 - 1919
RIO GRANDE 330B- - 348C

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330-B RIO GRANDE. CONTRACTS WITH ELEPHANT BUTTE IRRI. DIST.

TRANSFER CASE

330-B

TRANSFER CASE

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THESE ARTICLES OF AGREEMENT, made and entered into this 27th day of June, 1906, by and between the United States of America, acting in this behalf by Jesse E. Wilson, Acting Secretary of the Interior, party of the first part, and the Elephant Butte Water Users' Association of New Mexico, a corporation duly organized and existing under the laws of the Territory of New Mexico, and the El Paso Valley Water Users' Association, a corporation duly organized and existing under the laws of the [redacted] Territory of [redacted] Arizona, parties of the second part, their successors and assigns,

WITNESSETH, That whereas the Elephant Butte Water Users' Association of New Mexico is a corporation organized and existing under the laws of the Territory of New Mexico, and the El Paso Valley Water Users' Association is a corporation organized and existing under the laws of the [redacted] Territory of [redacted] Arizona, for the purposes mentioned in their articles of incorporation and by-laws, copies of which are appended to this agreement and are, for every purpose of the interpretation, construction and consideration of this agreement and of the rights of the parties hereunder, to be deemed, held, read and considered as if fully written out or printed herein, and deemed a part hereof; and

Whereas, the lands embraced within the area proposed to be irrigated, as described in said articles of incorporation or by-laws, are naturally desert and arid and incapable of proper cultivation without irrigation, and will to a greater or less extent remain unclaimed, unfit for habitation, and uncultivated, in which condition they, or a great part thereof, now are, unless the waters of the Rio Grande in New Mexico, and its tributaries, be impounded and the flow thereof otherwise regulated and controlled, and,

Whereas, the said Secretary of the Interior contemplates the construction of certain irrigation works under the provisions of an Act of Congress entitled, "An Act appropriating the receipts

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from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands", approved June 17, 1902, for the irrigation and reclamation of the lands described in the said articles or by-laws; and,

Whereas, the incorporators and shareholders of said Elephant Butte Water Users' Association of New Mexico, and El Paso Valley Water Users' Association are, and under the provisions of their articles of incorporation must be, owners and occupants of lands in said area, and in some cases are appropriators of water for the irrigation thereof, and in addition thereto such incorporators and shareholders and their successors or assigns must initiate rights to the use of water from the said proposed irrigation works, to be constructed by the said Secretary of the Interior as soon as such rights may be initiated, and thereafter complete the acquisition thereof in the manner and upon the terms and conditions to be prescribed therefor by the Secretary of the Interior, which rights shall be, and thereafter continue to be, forever appurtenant to designated lands owned by such shareholders; and,

Whereas, neither the relative priority nor the extent of the individual appropriations of such water heretofore made by said incorporators and shareholders for the lands described in said articles or by-laws, and which are now vested rights, have been ascertained or determined, but said incorporators and shareholders have agreed, among themselves, by the terms and provisions of said articles of incorporation and by-laws, upon the rules and principles by and upon which the relative priority and the extent of their several appropriations and vested rights to the use of such waters shall be determined:

Now therefore, it is agreed and understood by and between the parties hereto,

1, That if the said Secretary of the Interior shall authorize and cause the construction of said irrigation works, the said

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associations will take prompt action to secure the determination by the courts of the relative rights of their shareholders to the use of water for said lands, and that in the determination of such rights and of their respective rights to the use of water acquired under said Act of Congress, the rules and principles set out in said articles of incorporation and by-laws, for such determination, shall be deemed the established rules and principles for that purpose.

2. That only those who are or who may become members of said associations, under the provisions of their articles of incorporation and by-laws, shall be accepted as applicants for rights to the use of water available by means of said proposed irrigation works.

3. That the aggregate amount of such rights to be issued shall, in no event, exceed the number of acres of land capable of irrigation by the total amount of water available for the purpose, being (1) the amount now appropriated by the shareholders of said associations, and (2) the amount to be delivered from all sources in excess of the water now appropriated; and that the Secretary of the Interior shall determine the number of acres so capable of such irrigation as aforesaid, his determination to be made upon due and expert consideration of all available data, and to be based upon and measured and limited by the beneficial use of water.

4. That the payments for the water rights to be issued to the shareholders of said associations under the provisions of said Act of Congress, shall be divided into not less than ten equal annual payments, the first of which shall be payable when the water is first delivered from said works, or within a reasonable time thereafter, and after due notice thereof by the Secretary of the Interior to the associations, and that the cost of said proposed irrigation works shall be apportioned equally per acre among those acquiring such rights.

Provided, that the charges apportioned under the integral part

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of the said irrigation works, known as the Leasburg Diversion Dam and Canal, the construction of which is now proposed, shall be paid in ten equal annual instalments, upon the terms herein specified.

Provided further, that in the assessment of the charges under the main Rio Grande Project, when constructed, the Secretary of the Interior shall apportion equitably the charges therefor against the land irrigated under the Leasburg Diversion Dam and Canal, due allowance being made for the charges already paid under this agreement.

5. That the said Water Users' Associations hereby guarantee the payments for that part of the cost of the irrigation works which shall be apportioned by the Secretary of the Interior to their shareholders, and will promptly levy calls or assessments therefor and for the cost of maintenance and operation, as may be assessed from year to year by the Secretary of the Interior, and collect or require prompt payment thereof in such manner as the Secretary of the Interior may direct; that they will promptly pay the sums collected by them to the receivers of the local land offices for the districts in which said lands are situated; that they will promptly employ the means provided and authorized by the said articles of incorporation and by-laws for the enforcement of such collections, and will not change, alter or amend their articles of incorporation or by-laws in any manner whereby such means of collection, or the lien given to them by the shareholders to secure the payment thereof, or of any assessments contemplated or authorized thereby, shall be impaired, diminished or rendered less effective, without the consent of the Secretary of the Interior.

6. That the United States shall in no manner be responsible for the sums collected by said associations until they have been paid into the hands of the receiver of the local land office, as provided by the law, and in accordance with such regulations as may be prescribed by the Secretary of the Interior.

7. That for the purpose of enforcing said collections the

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associations will adopt and enforce proper by-laws, subject to the approval of the Secretary of the Interior, and not change them so as to in anywise impair their efficiency for said purpose, and will otherwise do any and all things they are authorized and empowered to do in the premises.

8. That the associations will adopt and enforce such rules and regulations as they are authorized by their articles of incorporation and by-laws to adopt and enforce, concerning the use of water by their shareholders and concerning the administration of the affairs of the associations, to effectually carry out and promote the purposes of their organization, within the provisions of said articles of incorporation and by-laws, which rules and regulations shall be subject to the approval of the Secretary of the Interior, and that if the associations fail to make and adopt such rules and regulations, then the Secretary of the Interior may prescribe them; but in such event the Secretary of the Interior shall impose no rule or regulation interfering with any vested right of the shareholders of the associations, as defined or modified by said articles of incorporation and by-laws.

9. That persons who are not now members of the associations, but who may be the owners or occupants of land to be irrigated, as described in their articles of incorporation or by-laws, or of added lands as therein provided for and to whom rights to the use of water from the proposed irrigation works may be issued by the United States, may, at the designation of the Secretary of the Interior, become members of the associations upon subscribing to the stock thereof and upon compliance with the other conditions prescribed for such membership.

10. That in all the relations between the United States and these associations and the members of the associations, the rights of the members of the associations to the use of water where the same have vested, are to be defined, determined and enjoyed in accordance with the provisions of the said act of Congress and of other acts of Congress on the subject of the acquisition and enjoy-

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ment of the rights to use water; and also by the laws of New Mexico and Texas, where not inconsistent therewith, modified, if modified at all, by the provisions of the articles of incorporation and by-laws of said associations.

11. That nothing contained in this agreement, or to be implied from the fact of its execution, shall be construed, held or deemed to be an approval by the Secretary of the Interior, nor an adoption by him of the articles of incorporation or by-laws of said associations in all their details as the form of organization of water users, contemplated and authorized by Section 6 of the said Act of Congress of June 17, 1902; but such approval and adoption is expressly reserved until the conditions prescribed in said Act, authorizing such approval and adoption shall have arisen; and that when the Secretary of the Interior shall make, approve and promulgate rules and regulations for the administration of the water to be supplied from said proposed irrigation works, such rules and regulations and such modifications thereof as the Secretary may, from time to time, approve and promulgate, shall be deemed and held to be obligatory upon these associations as fully and completely, and to every intent and purpose as if they were now made, approved, promulgated, and written out in full in this agreement, and the same are to be so read and construed.

12. It is further understood and agreed that the charges apportioned by the Secretary of the Interior for the construction of the Leasburg Diversion Dam and Canal against the lands irrigated thereunder, shall be upon the basis of the water available from the natural flow of the Rio Grande at said dam.

IN WITNESS WHEREOF, the undersigned have hereunto subscribed their names and affixed their seals the day and year first herein written.

Jesse E Wilson

Acting Secretary of the Interior,
For and on behalf of the United States of America,
PARTY OF THE FIRST PART.

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Elephant Butte Water Users' Association of New Mexico,

By _____ President.

Attest:

_____ Secretary.

El Paso Valley Water Users' Association,

By _____ President.

Attest:

_____ Secretary.

PARTIES OF THE SECOND PART.

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Water-Supply and Irrigation Paper No. 188

Series { B, Descriptive Geology, 108
0, Underground Waters, 66

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF THE

RIO GRANDE VALLEY IN NEW MEXICO

AND THEIR DEVELOPMENT

BY

WILLIS T. LEE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1907

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WATER RESOURCES OF THE RIO GRANDE VALLEY IN NEW MEXICO, AND THEIR DEVELOPMENT.

By Willis T. Lee.

INTRODUCTION.

The investigations described in this paper were undertaken for the purpose of gathering information which might aid in the development of the water resources of the Rio Grande Valley in New Mexico. Two general lines of observations were followed, one pertaining to underground waters and their utilization, the other to the storage and conservation of the surface waters. The work was done during the field seasons of 1904 and 1905 under the general direction of Mr. N. H. Darton. The area examined extends along the Rio Grande from the southern boundary of New Mexico northward to Santa Fe.

The valley of the Rio Grande, lying west of the Rocky Mountain uplift, extends in a north-south direction through a part of New Mexico which is characterized by comparatively small and more or less isolated mountain groups separated by basinlike depressions partly filled with rock débris. The valley is a part of the semiarid region of the southwestern part of the United States, in which the rainfall is insufficient for agriculture without irrigation.

A comparatively small amount of the water derived from the mountains to the north sustains a small but permanent flow in the river in the northern part of the region, but this water gradually disappears and the river bed in the southern part is often dry.

The Rio Grande is essentially a storm-water stream, subject to great and sudden floods. Within the area described only three permanent streams—the Rio Puerco, Rio Jemes, and Galisteo Creek—enter the Rio Grande, and their discharge, except in times of storm, is comparatively small. The rainfall in the region occurs principally in the form of violent showers or "cloud-bursts," which fill the dry stream courses with turbulent floods of short duration. When these showers occur simultaneously in many parts of the region they cause more or less destructive floods in the river. For these reasons the fertile irrigable lands along the river are sometimes unproductive

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for want of water and at other times crops are ruined because the fields are submerged or irrigation ditches destroyed by floods.

Much of the diminution in the volume of flow downstream is due to the fact that a large part of the water of the river sinks beneath the surface into the porous material of the valley bottom. Many of the tributary stream courses that are dry where they join the river contain flowing water in their upper reaches, the water sinking beneath the surface when it reaches the detrital material of the valley. The water entering the ground from the river and from the tributary streams is sufficient in volume to warrant its development for irrigation.

GEOGRAPHY.

RELATION TO OTHER REGIONS.

New Mexico consists of four general geographic provinces—the plains, occupying its eastern part; the Rocky Mountain province occupying its central part; the plateau province, in its northwestern part; and the basin range province, in its southwestern part. The Rocky Mountains proper terminate in northern New Mexico, but the general mountain uplift extends southward across the Territory as a succession of comparatively small mountain groups. These have not been generally recognized as parts of the Rocky Mountains, altho they belong to the same general system. The Rio Grande region lies between the Rocky Mountain province on the east and the plateau and basin range provinces on the west.

EASTERN MARGIN.

The crest of the Rocky Mountain uplift, consisting of the southern extremity of the Rocky Mountains proper, the Sandia and Montoso mountains, Sierra Oscura, San Andreas Range, and the Organ and Franklin mountains, form the eastern boundary of the area here described. The uplift becomes progressively lower toward the south, the maximum altitudes varying from 13,000 feet in the Rocky Mountains east of Santa Fe to 7,000 feet in the Franklin Mountains in the southern part of the region, and the minimum altitudes from 7,500 feet in Glorietta Pass near the northern end of the region to 3,700 feet at the southern end where the Rio Grande cuts through the uplift at The Pass. The rocks consist of granites and sedimentary rocks that range in age from pre-Cambrian to Tertiary.

WESTERN MARGIN.

The western margin of the Rio Grande Valley is much more irregular than the eastern margin, in both outline and altitude. It is formed by the Jemes Mountains at the north, by the Ladron, Socorro, Magdalena, and San Mateo mountains in the central part, and by the

Good Sight and Potrillo mountains farther south. These groups are more or less widely separated, either by undrained detrital plains like La Mesa, lying between the Potrillo Mountains and Cerro Magdalen, or by broad valleys like that of the Rio Puerco.

The older sedimentary formations extend over the same wide range of geologic age as those in the eastern margin, but the exposures are small, the greater part of the surface being occupied by effusive rock and unconsolidated detritus.

CENTRAL AREA.

MOUNTAINS.

Three large groups of mountains, the Caballos, the Fra Cristobal, and Cerro Magdalen (not to be confused with the Magdalena Mountains) occur within the limits of the Rio Grande region, and several small groups and isolated peaks, like the Dona Ana Hills, Cerro Robledo, and Cerro Cuchillo.

The Caballos and Fra Cristobal ranges consist of granite and overlying sediments dipping eastward beneath the Jornada del Muerto. (Pl. VI, *B*.) The Socorro Mountains, Cerro Magdalen, the Dona Ana Hills, and a large number of smaller hills in the central part of the region are of eruptive origin, but many of the hills, such as Cerro Robledo (see Pl. III), Tortuga, Cerro Cuchillo, and Sierra Ladron, are tilted blocks of sedimentary rocks.

PLAINS.

In the southern half of the Rio Grande region there are two broad plains, which, on account of their important bearing on questions connected with underground-water conditions in the Rio Grande region, require special description. These are the Jornada del Muerto and La Mesa. The Jornada has been described in a former water-supply paper,[a] but certain characters directly affecting the problems here discust require further consideration.

In the paper above cited[b] the Jornada del Muerto is regarded as including Mesilla Valley on the south and the plain lying northeast of San Marcial between Sierra Oscura and Cerro Montoso, thus comprising an area having a length of about 200 miles and an average gradient of 12 feet per mile. This extension of the Jornada proper may be advisable in describing the structural geology, but it is thought best to use here the name in its original meaning, applying it only to the high plain between Las Cruces and San Marcial, since, thus defined, it corresponds not only with the local usage but also with the ancient course of the Rio Grande described on page 21.

[a] Keyes, C. R., Water-Sup. and Irr. Paper No. 123, U. S. Geol. Survey, 1905.
[b] Ibid., p. 13.

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The Jornada del Muerto, according to this usage, is the nearly level detrital plain, 10 to 20 miles or more in width, extending from San Marcial southward to Las Cruces, between the San Andreas and the Caballos-Fra Cristobal mountain ranges—a distance of about 100 miles. It has no drainage lines except at the southern end, near the river, but throughout its length slight depressions occur near its center, in which storm waters gather and form small temporary lakes. The altitude of the plain at the northern end, near San Marcial, is about 4,700 feet, and at its southern end 4,250 feet, a difference in surface elevation of 450 feet in the 100 miles of length, or an average gradient of 4.5 feet per mile.

The rocks exposed in the mountain slopes on either side of the Jornada are the upturned sedimentary rocks forming the floor of the syncline described by Keyes in the report previously referred to. The central plain, however, is covered to a depth of at least several hundred feet with detritus, consisting of sand, gravel, and angular rock débris. As indicated by well records, the material in the central part of the Jornada is largely sand and rounded pebbles of quartzite and argillite, while angular detritus, consisting mainly of limestone and sandstone, is apparently more abundant near the sides.

The second plain, locally known as "La Mesa," lies in the southern part of the Rio Grande region west of Mesilla Valley, and extends from the vicinity of Las Cruces southward into Mexico. It is similar to the Jornada in many ways. Its altitude is the same as that of the southern end of the Jornada, and the two formed a single plain previous to the excavation of Mesilla Valley. La Mesa has a width of 20 miles or more and is undissected by erosion and entirely wanting in lines of surface drainage. It contains several broad, shallow depressions, but, unlike those of the Jornada, these do not retain storm waters for any appreciable length of time. Although inclined slightly to the south, the surface appears practically level over an area of more than 1,000 square miles.

To a depth of at least 945 feet, the depth of the deepest well, the material in La Mesa consists of clay, sand, and rounded pebbles of quartzite, argillite, and a great variety of hard igneous and metamorphic rocks, with a subordinate amount of angular débris. The surface is notably more sandy than that of the Jornada, and wells sunk in it encounter a greater proportion of fine material than occurs in the Jornada.

In the northern part of La Mesa there are gravel beds of considerable size at the surface, but these become less numerous toward the south, until near the Mexican boundary sand alone is exposed and the surface becomes practically level. The region was not explored south of the Mexican boundary for the purposes of this

report, but from the summit of the Potrillo Mountains the sandy plain appeared to continue southward unbroken as far as the eye could reach. It is probable that La Mesa is the northern extremity of the broad interior basin of northern Mexico, the lowest parts of which, containing undrained lakes, occur 25 to 50 miles south of the international boundary. At some former time this basin was probably occupied by a large lake, the northern extremity of which covered La Mesa.

SLOPES.

The greater part of the surface of the Rio Grande region is made up of long, corrugated slopes, extending from the bordering mountains to the river. East of the river the slope varies in length from 5 to 20 miles. Near Santa Fe it is 12 miles long and has an average gradient of 125 feet per mile. East of Albuquerque it is about 10 miles long and has a gradient of about 70 feet per mile, and east of Las Cruces it is 10 miles long and has a gradient of about 100 feet per mile. In places where the river is located near the mountains, as at the northern end of the Sandia and west of the Caballos Mountains (Pl. VI, *B*), the gradient is 250 to 300 feet per mile.

The slopes of the western part of the Rio Grande region are much more varied than those that lie east of the river. Some are short, steep, and deeply dissected; others are many miles in length and perfectly graded, and still others, like those drained by Arroyo Salado and Rio Puerco, are but slightly inclined.

The material exposed on the corrugated slopes consists of angular rock fragments derived from the mountains. These fragments vary in coarseness with the variations in the hardness of the rock from which they were formed and with the gradient of the slopes on which they are deposited. In general, they are large near the hills and on the steep slopes and small on the lower grades and near the foot of the slopes, where they are often found intermingled with sand and pebbles that have been rounded by stream action.

TERRACES.

The long slopes terminate more or less abruptly near the river in bluffs or terraces, two of which are more or less conspicuous throughout the Rio Grande region. The highest is not continuous. It is represented west of Santa Fe by the lava-capped detrital bluffs exposed in the canyon of Santa Fe Creek, where it forms a shelf 500 feet above a lower terrace and about 800 feet above the river, as shown in the Santa Clara sheet of the United States Geological Survey. West of Albuquerque it is represented by the broad, sandy plain upon which the lava flow from Albuquerque volcanoes rests, 500 feet above the lower terrace and 800 feet above the river. (See Pl.

II, *B*, and section D–D on Pl. III.) Near the southern end of the region a similar relation occurs, the high detrital plain west of Cerro Robledo being 500 feet higher than La Mesa and 800 feet higher than the river, as shown in the Las Cruces sheet of the United States Geological Survey. The ancient surface represented by these remnants apparently had the same gradient as the Rio Grande has at the present time.

On either side of the river, at altitudes about 500 feet lower than the isolated remnants of the high terrace, are well-defined terraces, which are practically continuous from White Rock Canyon to El Paso. They are remnants of a surface that was formed principally by aggradation and later dissected by the river and its tributaries. This surface is represented at Albuquerque by the wide shelf between the lava flow and the river, shown in the foreground of Pl. II, *B*. Farther south it is represented by the Jornada and La Mesa. (See sections of Pl. III.) The surface was formed, first, by the deposition of river sand and gravel; second, by the erosion of previously deposited gravels and volcanic tuffs, illustrated in Pl. II, *A;* third, by lava flows, such as those near San Marcial (Pl. IV, *A*) and San Acacia, and, fourth, by the planation of upturned sedimentary rocks, like those exposed at the surface along the eastern base of the Caballos Mountains in the vicinity of Engle, shown in Pl. IX.

EROSION BASINS AND CANYONS.

Introductory statement.—Along the Rio Grande there are erosion basins, separated by rock canyons, as shown in Pl. I, and limited in form and size by the character of the material in which they were excavated. These basins are parts of the valley of the Rio Grande that have been broadened on account of the easy erosion of unconsolidated material while the narrower canyons were being cut in the hard rock.

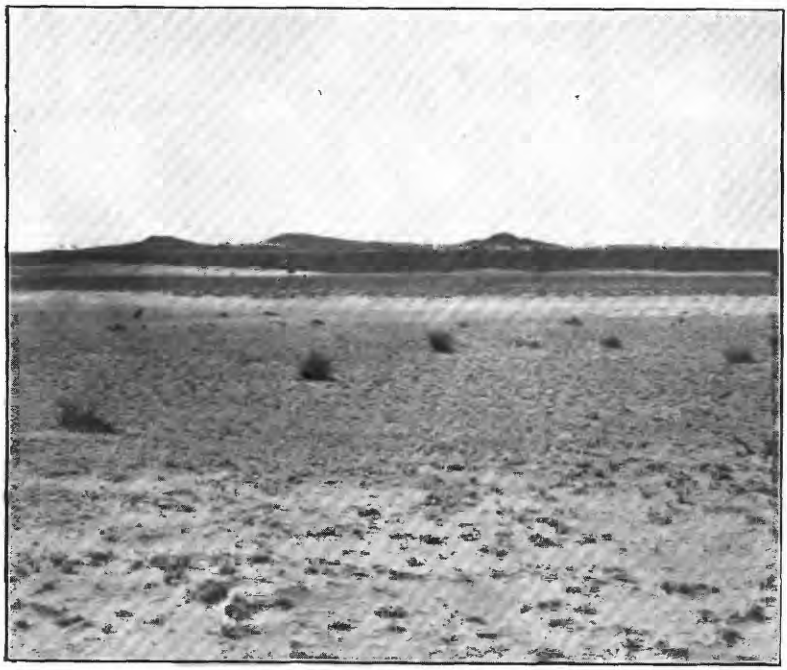
Espanola Valley.—This valley extends from the head of White Rock Canyon northward beyond the region here considered. The southern end of the valley has been described as a possible reservoir site,[a] and a contour map of it has been made. The valley is excavated in unconsolidated sand, gravel, and rhyolitic tuff. The gravel beds are exposed in bluffs several hundred feet high and are protected from erosion by the overlying igneous rock, consisting of rhyolitic tuff and basalt flows. The depth of the sands and gravels beneath the river is not known.

White Rock Canyon.—This canyon begins south of Espanola Valley, at a point where the Rio Grande enters a narrow gorge about 20 miles in length. The canyon owes its existence to sheets of hard igneous

[a] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1899–1900.

A. FACE OF TERRACE WEST OF CABALLOS MOUNTAINS.

Showing stratified sand and gravels overlain by rhyolitic tuff.



B. ALBUQUERQUE VOLCANOES AND LAVA FLOW.

Lower terrace, 300 feet above the river, in the foreground. Lava flow, capping the detritus, 800 feet above the river.

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rock, which protect the underlying sands and gravels. West of the river this rock is principally light-colored rhyolite, the color of which suggested the name White Rock Canyon, but east of the river it is basalt, of which there are two sheets, separated by a few feet of sand. The structure is indicated in a general way in fig. 2 and Pl. IV, *B*.

Near the mouth of the canyon a stream entering the Rio Grande from the east has carved a gorge, exposing about 400 feet of basalt. This gorge (Pl. IV, *B*), although comparatively small, illustrates the rugged character of the topography in the vicinity of White Rock Canyon.

Santo Domingo Valley.—This valley extends from the mouth of White Rock Canyon to a point 7 miles south of the Indian pueblo of Santo Domingo. It is 1 to 3 miles wide and contains about 13,000 acres of bottom land, which is owned mainly by the Santo Domingo Indians and has been irrigated by them for many years. The greater part of this land lies only a few feet above the bed of the river and is subject to frequent overflow.

San Felipe Canyon.—This is a short gorge separating Santo Domingo Valley from Albuquerque Valley. The canyon walls are composed of unconsolidated sand and gravel, capped by sheets of basaltic lava.

Albuquerque Valley.—This valley extends from San Felipe Canyon southward to Isleta, where it narrows on account of the basaltic lava which extends thence westward over a large part of the Sandia Mesa. The valley is about 35 miles long and 1 to 5 miles wide and comprises an estimated area of 70,000 acres of bottom land. It is terminated abruptly on either side by steep bluffs of sand and gravel forming the terraces previously described. The bluffs west of the valley consist of sand and clay, capped in places by sheets of basalt. Those to the east are composed of stratified sand overlain by coarse unstratified gravels separated from the underlying sands by erosional unconformities.

Isleta Narrows.—The constriction through which the river flows at Isleta is not properly a canyon. The broad Albuquerque Valley here narrows on account of the presence of the hard igneous rock of Isleta Volcano, an extinct volcanic cone west of the town. The lava occurs not only in the bluffs west of the river but extends nearly across the valley at the town of Isleta.

Belen Valley.—This valley, so named from the principal town within its area, extends from Isleta to San Acacia, a distance of about 45 miles, and contains an estimated area of 65,000 acres of bottom land. The Rio Puerco and the Arroyo Salado, the two largest tributaries of the Rio Grande, join the river in this valley. The Rio Puerco flows across the broad stretch of unconsolidated and horizontally bedded sand and gravel, locally known as Albuquerque Mesa.

It is a sluggish, muddy stream, practically impassable on account of quicksand, except at times of low water. The Arroyo Salado enters the valley through a canyon in the partly consolidated and upturned Tertiary strata illustrated in Pl. V, *A*.

San Acacia Gorge.—This is the narrows at the southern end of Belen Valley. The mesa east of the river near San Acacia is covered by a sheet of basalt, which originally extended farther northwestward across the present course of the Rio Grande. The river has cut thru an arm of this lava sheet, making a short narrow gorge, the walls of which, about 250 feet high, are composed of sand and gravel, protected by the cap of igneous rock.

The portion of lava left west of the river is less than one-half mile in length. West of this, and 75 feet higher than the river level, is a wide sand and gravel plain, which evidently marks the course of the Rio Grande previous to the time the river broke through the lava at the gorge. Still farther west the beds of loose sand and gravel give place to the Tertiary sediments shown in Pl. V, *B*.

Socorro Valley.—This valley, so named from its principal town, extends from San Acacia Gorge southward to San Marcial, a distance of about 40 miles, and includes an estimated area of about 60,000 acres of bottom land. It is similar to Albuquerque and Belen valleys, except that the mountains on its sides are nearer and the corrugated detrital slopes correspondingly steeper and more eroded than those bordering the valleys previously described.

Engle Valley.—This valley extends from San Marcial to Elephant Butte, a distance of about 40 miles. This valley differs from the others described in being very narrow, as shown in Pl. I, and in its lack of bottom land. The northern half has been described and mapped as a reservoir site.[a] From this map it appears that the contour marking elevations 100 feet above the river incloses a strip of land varying in width from about 800 feet to 2 miles. The southern half of the valley is somewhat wider in places. According to the reports of the United States Reclamation Service the maximum area to be submerged in the Engle reservoir, described on pages 26–29, is about 38,400 acres, contained in a strip 40 miles long and about 1½ miles in average width.

Altho Engle Valley is cut in detritus, it is not so broad as the valleys to the north and to the south. West of the rock hills, near Elephant Butte, the detrital beds extend continuously southward (Pl. VIII) and seem to present an easy passage for the river, but it does not follow the course thus afforded.

Elephant Butte Canyon.—A few miles north of Elephant Butte the river leaves the detrital beds and enters a narrow rock canyon, which

[a] Twelfth Ann. Rept. U. S. Geol. Survey, pt. 2, p. 203.

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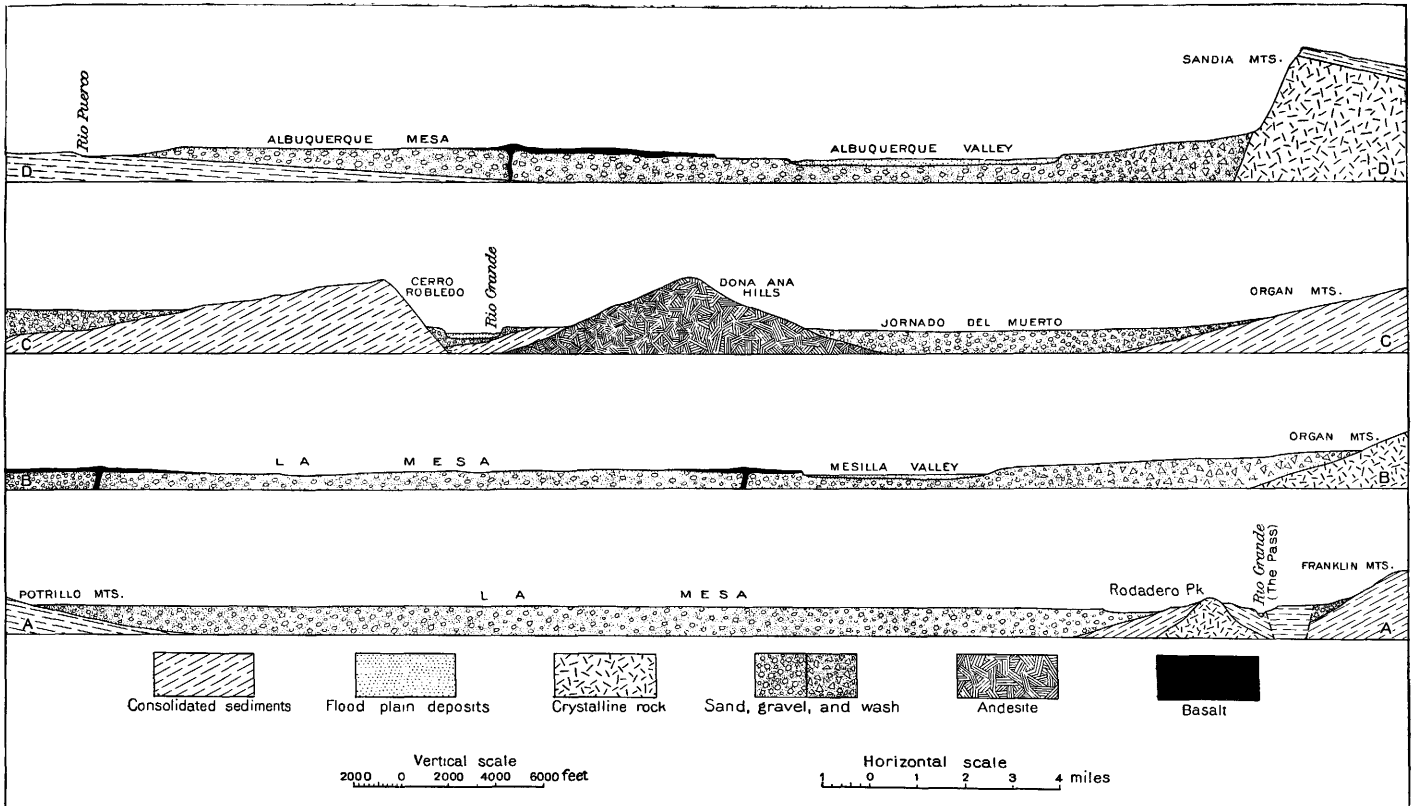

CROSS SECTIONS OF THE RIO GRANDE REGION.

A–A, at New Mexico-Mexico boundary; B–B, near Las Cruces; C–C, at northern end of Mesilla Valley; D–D, near Albuquerque.

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it occupies thence southward to the end of the Caballos Mountains. This canyon is described in detail as the Engle dam site (see pp. 26–29) and need not be further discussed in this connection.

Las Palomas Valley.—This valley, extending from Elephant Butte to Rincon, a distance of about 50 miles, is much broader than Engle Valley. The bottom lands form a part of the irrigable area, 26,000 acres in extent, under the proposed Engle reservoir. The terrace bluffs bordering this valley are especially conspicuous. West of the river they consist of well-stratified sands and gravels, but east of the valley they are more varied in both form and composition, containing not only stratified sand and gravel, but volcanic tuffs, as shown in Pl. II, *A*.

Selden Canyon.—This canyon, extending from Rincon to the head of Mesilla Valley, a distance of about 18 miles, is not so uniformly narrow as some of the other canyons. At some places, as at Penasco Rock, where a dike crosses the course of the river, the canyon is narrow. At other places it broadens to considerable dimensions. It contains about 8,000 acres of bottom land.

Mesilla Valley.—This is the largest of the erosion basins of the Rio Grande region, extending from old Fort Selden southward to The Pass, a distance of about 50 miles. It has a maximum width of 8 miles and includes about 150,000 acres of bottom land, of which 100,000 acres are irrigable. It contains the principal body of land to be irrigated from the proposed Engle reservoir, and has been surveyed in detail by the United States Reclamation Service, as shown in Pl. X. The valley is cut in the unconsolidated sand and gravel, typically exposed in the bluffs, 300 feet or more in height, bordering La Mesa on the west.

As in the Elephant Butte region, the detrital bed in which Mesilla Valley is cut extends uninterruptedly southward, west of the rock hills near El Paso; but the river, instead of following this seemingly easy course, abandoned the detrital bed and cut a canyon through the hard rock ridge at El Paso.

El Paso Canyon.—This is a rock gorge through which the Rio Grande, formerly a stream of the interior basin region of New Mexico and Mexico, past and became thenceforth a part of the Gulf drainage. The character of this canyon and its relation to the mountain ridge and the ancient course of the river—La Mesa—is indicated in section A–A of Pl. III. Rock terraces at the same altitude as the surface of La Mesa indicate that after the river had formed a graded surface over the region, principally by building up its course, it found a way across the rock ridge at The Pass. The epoch of erosion that followed was not of sufficient duration to cut more than the narrow canyon in the hard rock of The Pass, although the broad Mesilla Valley was excavated at the same time.

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El Paso Valley.—This valley is similar to Mesilla Valley in being a broad basin cut in unconsolidated sand and gravel. It lies outside of the Territory of New Mexico, and is therefore not properly included in this paper, although it contains part of the land included in the Rio Grande reclamation project. The valley has been described by Richardson[a] and by Slichter.[b]

GEOLOGY.

INTRODUCTION.

No attempt is made to discuss the geology of the Rio Grande region further than is necessary to give an understanding of the physical conditions likely to affect the storage of the surface waters and the occurrence and development of the underground waters; but in order to describe these conditions some knowledge of the rocks is necessary. Three kinds of rock are recognized in this report. The first consists of granites, gneisses, and consolidated sediments, including sandstones, limestones, and shales. The second consists of unconsolidated sediments or detritus of comparatively recent origin, including river sands and gravels and mountain wash. The third comprises effusive rocks, mainly of Tertiary and Quaternary age.

ROCK FORMATIONS.

CONSOLIDATED SEDIMENTS.

The older sedimentary rocks of the Rio Grande region include strata that range in age from Algonkian to Cretaceous and that are well exposed throughout the area described. These, together with the underlying granites, form the rock basins that contain the water-bearing formations and to some extent are themselves water bearing. The consolidated sediments have special importance near Elephant Butte, where the Rio Grande cuts a sharp gorge through them at the Engle dam site, and near El Paso, at the site of the proposed International dam.

UNCONSOLIDATED SEDIMENTS.

Unconsolidated material, consisting of clay, sand, and water-worn gravel, occurs generally in the lowlands along the river, in the terraces on either side of the Rio Grande Valley, in the central part of the Jornada del Muerto, and in La Mesa, west of Mesilla Valley. The slopes lying between the river and the mountains consist largely of angular rock débris, derived as wash from the mountains.

The older detrital beds are partly cemented, but the younger ones are wholly unconsolidated and allow water to pass freely through them.

[a] Richardson, G. B., Reconnaissance in trans-Pecos Texas: Bull. Univ. Texas No. 23, 1904, pp. 95-108.

[b] Slichter Charles S., Observations on the ground waters of the Rio Grande Valley: Water-Sup. and Irr. Paper No. 141, U. S. Geol. Survey, 1905, pp. 9-51.

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A. LAVA-CAPPED MESA AT SAN MARCIAL.

The sheet of basalt resting upon the sand and gravel is the edge of the great flow covering the north end of the Jornada del Muerto.

B. SIDE GORGE AT THE ENTRANCE TO WHITE ROCK CANYON, NEAR ESPANOLA DAM SITE.

Showing columnar basalt in the foreground, and the rhyolite west of the river in the background.

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The detritus has a great, though unknown thickness. A well at Santa Fe penetrates it nearly 1,000 feet; another at Sandia, N. Mex., 893 feet; one at Lanark, west of Mesilla Valley, 945 feet; and one in a neighboring basin,[a] near El Paso, 2,285 feet, but in none of these wells has bed rock been reached. Where the older and partly cemented beds have been upturned and exposed to view in Arroyo Salado, they have an observed thickness of several thousand feet. Their character is indicated in Pl. V, *A*, *B*. The younger or uncemented sands and gravels are well exposed in the terraces on either side of the river.

IGNEOUS ROCKS.

The igneous formations that are important in a discussion of the water supply are principally of Tertiary and Quaternary age, and occur in the form of massive flows, beds of tuff, volcanic necks, dikes and sheets, and crater cones. The older effusive masses, consisting of andesites, rhyolites, and other rocks closely related to these, occur in more or less isolated masses at many places throughout the Rio Grande region and are perhaps best represented by the thick beds of tuff on the eastern slope of the Jemes Mountains in the northern part of the Rio Grande region, by the Socorro Mountains and Cerro Magdalen in the central part, and by the Dona Ana Hills in the southern part. Their formation antedates the accumulation of at least the upper part of the detritus as fragments of the rock are contained in the detrital beds.

The younger igneous rocks consist of dark-colored basalts, occurring mainly in sheets capping the detritus and in crater cones which retain their original form in great perfection, as shown in Pl. VI, *A*. Basaltic rock also occurs in dikes and volcanic necks penetrating the older rocks. Among the more conspicuous sheets capping the detritus may be mentioned those west of Santa Fe, through which the river has eroded White Rock Canyon, those covering parts of the mesa west of Albuquerque (see Pl. II, *B*), the San Marcial flow (see Pl. IV, *A*,) and the basalt flows of La Mesa west of Mesilla Valley. The dikes and volcanic necks become important in the vicinity of the Engle reservoir (Pl. IX), where they will probably supply building stone for the proposed dam.

STRUCTURE.

GENERAL CHARACTERISTICS.

The geologic structure of the Rio Grande region is complicated, and much detailed investigation is necessary before it can be adequately described. The main structural features, however, are known in a general way. Great synclines, such as the Jornada del Muerto, occur,

[a] Richardson, G. B., Reconnaissance in trans-Pecos Texas: Bull. Univ. Texas No. 23, 1904, p. 96.

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and monoclinal mountains, formed by faulting and the tilting of crust blocks. The rocks thus flexed and faulted are mainly of pre-Tertiary age, but the Tertiary beds are strongly upturned in places, indicating that some crustal movement took place after these beds were formed. (Pl. V, *A*). The older valleys of erosion and the troughs formed by the tilted blocks have been partly filled with unconsolidated detritus consisting of sands, waterworn gravels, and angular mountain wash.

EASTERN BORDER.

The eastern part of the Rio Grande region is occupied by the Rocky Mountain uplift, which extends through central New Mexico. The southern end of the Rocky Mountains, terminated at the south by Glorieta Pass, is a granitic mass upon which lie strata that dip away from it to the east, south, and west. But south of this pass the underlying granite is covered, more or less completely, with sedimentary rocks dipping in various directions. The strata of Glorieta Mesa incline toward the south, and those of the Sandia Mountains, the Manzano Range, and Sierra Oscura toward the east. The strata of Chupadera Mesa are nearly horizontal, while those of the San Andreas Range and the Organ and Franklin mountains dip toward the west. Numerous faults occur, with displacements measured in hundreds of feet and several with displacements of thousands of feet.

WESTERN BORDER.

The western part of the Rio Grande region is less mountainous than the eastern part, and a greater proportion of it is covered with detritus, which obscures the structure to a large extent. In the Rio Puerco Valley strata dip to the east and are believed to pass beneath the Rio Grande Valley, while strata of the same geologic age occur in the Sandia Mountains, several thousand feet above the Rio Grande Valley, the difference in elevation being due to faulting along the western face of the Sandia Mountains and the eastward tilting of the Sandia block, as indicated in section D–D of Pl. III. On the other hand, the crust block forming Sierra Ladron, a few miles south of Rio Puerco, has been tilted steeply to the west.

In the western part of the region many of the mountain groups, such as Jemes and Socorro mountains and Cerro Magdalen, are composed principally of effusive rock.

CENTRAL AREA.

The structure of the Rio Grande region is best shown in the central portions, where the river has removed the detritus in many places, exposing the consolidated rocks. The Caballos and Fra Cristobal ranges, forming the western limb of the Jornada syncline, are cut off

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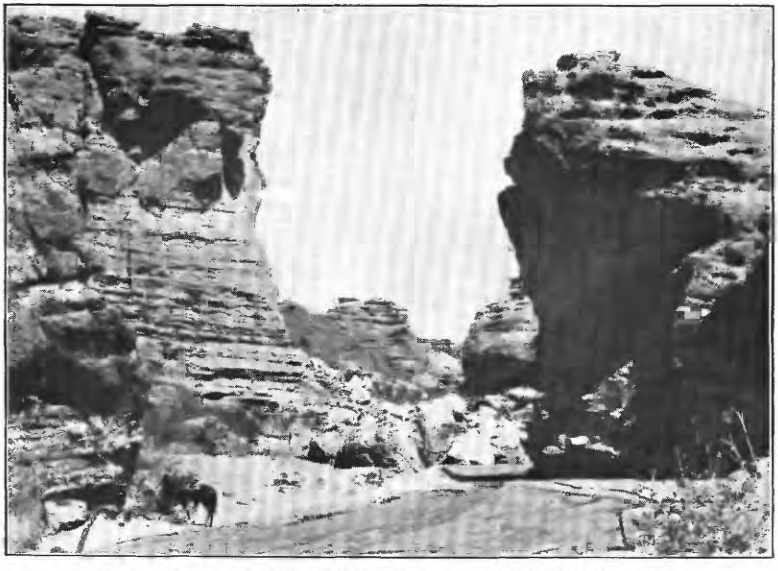
A. TERTIARY STRATA IN ARROYO SALADO AT THE BASE OF SIERRA LADRON.



B. CANYON IN TERTIARY SEDIMENTS WEST OF SAN ACACIA, N. MEX.

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abruptly on the west by great faults which are plainly exposed and traceable for longd istances. (See Pl. VII.) Cerro Robledo furnishes a characteristic type of structure. (See Pl. III.) East of the river Carboniferous limestone, dipping westward, passes beneath the Rio Grande Valley. The same limestone occurs in the hills to the west 2,000 feet above the river, the difference in altitude being due to faulting and the tilting of the Cerro Robledo block.

Displacements by faults much greater than that at Cerro Robledo are evident at a number of places. The western face of the Caballos Mountains (see Pl. VI, *B*) and the Fra Cristobal Mountains (Pl. VII) are fault scarps, and Cerro Cuchillo is an excellent example of a tilted block. With the exception of the Jornada del Muerto, the Rio Grande region may be properly said to consist of a series of block mountains with troughlike depressions intervening between them.

TOPOGRAPHIC DEVELOPMENT.

EROSION.

Altho the elevations and depressions constituting the Rio Grande region are due principally to crustal deformation, the topography has been more or less modified by erosion and deposition. Many of the mountain slopes are precipitous and show little modification by erosion, as illustrated in the Caballos Mountains. (Pl. VI, *B*.) Other slopes are comparatively mature. Along the eastern base of the Caballos and Fra Cristobal ranges, particularly in the vicinity of Engle, the stratified rocks dipping eastward beneath the Jornada have been practically base-leveled over a considerable area. Whether the base-level extends beneath the Jornada generally, as stated by Keyes,[a] or is local, can only be conjectured at the present time, as the older rocks within the syncline are exposed over a comparatively limited area, being for the most part buried to unknown depths by detritus.

SEDIMENTATION.

Tertiary.—The older portions of the detritus contained in the rock basins consist of well-stratified beds of sand, gravel, and mountain wash, more or less faulted in places and otherwise disturbed by crustal movements. They are undoubtedly of Tertiary age. In other places sediments, apparently of Tertiary age, are not separable at present from the younger or Quaternary deposits.

Quaternary.—The unconsolidated sands, gravels, and "wash" covering the greater part of the Rio Grande region is of Quaternary age and occurs in at least two distinctly separable formations. The more extensive one, locally known as the mesa gravels, occurs in the terraces along the river and forms the corrugated slopes lying between

[a] Keyes, C. R., Water-Sup. and Irr. Paper No. 123, U. S. Geol. Survey, 1905, p. 25.

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the river and the bordering mountains. The second occurs in the flood plains in all of the erosion basins previously described. In the Jornada del Muerto and La Mesa the sand and gravel beds belonging to this formation are not dissected by erosion, but lie practically as they were deposited, at an altitude 300 to 350 feet above the present bed of the river.

The mesa gravels originally filled the basins to altitudes represented by the terraces, and in them the erosion basins were cut. The depth to which these were excavated and later filled is not definitely known, but the general relations of the various gravel beds to each other and to the rock basins containing them are illustrated in fig. 1.

TERTIARY AND QUATERNARY HISTORY.

SURFACE DEFORMATION AND FIRST VOLCANIC ERUPTION.

The crustal movements that produced the structural and geographic features described began at the commencement of or sometime during the Tertiary period with the formation of monoclinal mountains and troughlike intermontane valleys. About the same

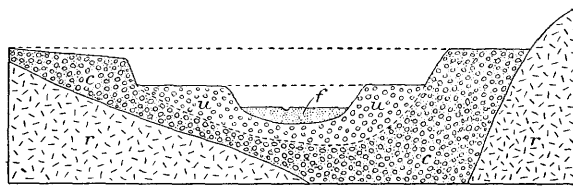

FIG. 1.—Sketch section illustrating the detrital deposits of Rio Grande Valley. *r*, Rock basin; *c*, detritus of the higher terrace; *u*, detritus of the lower terrace; *f*, flood-plain deposits.

time great masses of andesite and rhyolite were extruded, remnants of which are now found in the Jemes Mountains, the Socorro Mountains, the Dona Ana Hills, and elsewhere. This deformation and volcanic activity evidently occurred late in the Tertiary period, as Tertiary strata are upturned and in places intersected by rhyolite.

FIRST ACCUMULATION OF GRAVELS.

The structural troughs between the tilted mountain blocks formed natural lodgment areas for sediment. It can not be stated at present whether the sediments are partly of lacrustrine origin or wholly subaerial, nor is their maximum thickness known, but well records indicate a thickness of thousands of feet. The material exposed in the terraces and penetrated by the shallow wells, consisting mainly of coarse sand and gravel, is presumably of river origin, but some of the deep wells penetrate thick beds of sandy clay, possibly of lacustrine accumulation. The surface of this first gravel accumulation is preserved in a number of places, where it forms the upper terrace, 800 feet above the river, described on page 11.

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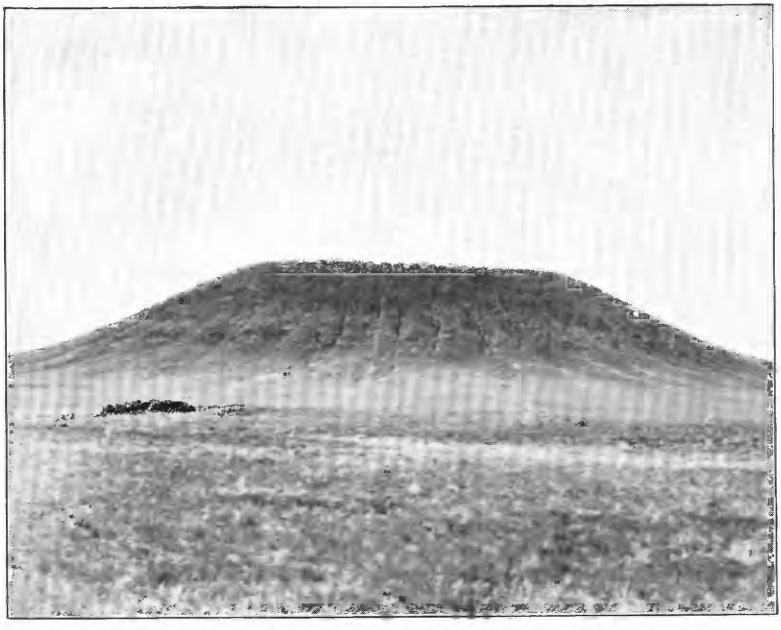

A. SANDIA VOLCANO, WEST OF ISLETA, N. MEX.

A volcanic cone of recent origin, composed of basaltic cinders.

B. CABALLOS MOUNTAINS.

Showing the western escarpment and the corrugated alluvial slope at its base.

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SECOND VOLCANIC ERUPTION.

After the depressions had been filled to altitudes represented by the upper terrace, extensive sheets of basalt were outpoured over the sands and gravels. In the lava fields west of Santa Fe, and in those near Bernalillo, two sheets of basalt occur, separated by a few feet of gravel, as shown in fig. 2. West of Albuquerque (Pl. II, *B*), and also in the extensive lava fields west of Isleta, the older sheets apparently belong to this epoch of eruption, and it is probable that many of the older masses of basalt in other parts of the Rio Grande region were extruded at about the same time.

FIRST EPOCH OF EROSION.

The second volcanic eruption was apparently accompanied by some change, possibly climatic, which caused the Rio Grande to erode its channel. During this epoch the river probably flowed through the Jornada del Muerto south of San Marcial, across La Mesa west of El Paso, and southward into the basin region of northern Mexico, eroding a valley 10 to 20 miles wide.

Ancient course of the Rio Grande.—Many facts point to the inference that the ancient course of the Rio Grande was not the same as its present course south of San Marcial. Some of the data leading to this inference have been given and others will be presented in the following paragraphs. Briefly stated, the facts are these:

The Jornada and La Mesa have the geographic position, form, surface elevation, and gradient that would be expected in a débris-filled valley; they contain unconsolidated sands and gravels as deep as wells have penetrated; their surface elevations and gradients indicate that they are parts of a graded surface that formerly extended throughout the Rio Grande region and is now represented north of San Marcial by the low terrace previously described, this ancient surface having the same gradient as that of the river at the present time.

At the point where the river leaves this old valley the surface is covered by an extensive basalt flow (the San Marcial lava sheet, covering about 160 square miles) resting on sand and gravel beds. The lava is not eroded at the surface and is covered only by wind-blown sand. Large quantities of loose shifting sand lie immediately north of the lava beds.

Engle and Las Palomas valleys are much narrower than the other erosion basins, and are cut in detritus which contains gypsum in places. The beds are cemented to some extent, and are associated with rhyolite, presumably much older than the basalt and its underlying detritus at San Marcial.

The measure of consolidation, presumably due to difference in age, is indicated in the size of the erosion basins. While the river cut can-

yons in hard rock it excavated narrow valleys in the cemented detritus west of Caballos and Fra Cristobal mountains and broad basins like Socorro and Mesilla valleys in the unconsolidated detritus to the north and south.

From these facts the inference is drawn that the ancient Rio Grande flowed through the Jornada and La Mesa into the interior basin of Mexico, and that in comparatively recent geologic time changes occurred which turned it out of its valley and away from the interior basin toward the Gulf of Mexico.

SECOND ACCUMULATION OF GRAVELS.

During the second epoch of deposition the river filled its valley with sand and gravel to the grade represented by the lower terrace (*uu* of fig. 1) and by the surface of La Mesa and the Jornada del Muerto. In La Mesa the ancient valley is about 20 miles wide and the filling is mainly fine sand near the surface and somewhat coarser sand and gravel beneath. In the Jornada del Muerto the filled valley is narrower and the material is coarser, many of the pebbles having a diameter of several inches. In Albuquerque Valley the quantity of filling during this epoch is much less than in La Mesa and the Jornada, and is best represented by the coarse gravel deposits of the bluffs near Albuquerque. Still farther north, in Santo Domingo Valley, near the northern end of the Rio Grande region, the deposits are very limited, and the river here was apparently employed mainly in broadening its valley.

The graded surface formed by the river during this epoch was one mainly of erosion in Santo Domingo Valley, where a broad shelf was cut 500 feet below the surface of the older gravels; one formed partly by erosion and partly by deposition in Albuquerque Valley; and one mainly of deposition in the Jornada and La Mesa. Throughout the Rio Grande region this surface, represented now by the terraced bluffs, is about 300 feet above the river, except where it has been cut down by later erosion.

THIRD VOLCANIC ERUPTION.

Near the close of the second period of sedimentation extensive volcanic disturbances occurred throughout the Rio Grande region, resulting again in the outpouring of great sheets of basalt. The most conspicuous of these are near San Marcial (Pl. IV, *A*) and on La Mesa west of Mesilla Valley. The San Marcial flow, covering about 160 square miles, was outpoured on the Jornada del Muerto, then occupied by the Rio Grande, and probably created a dam that formed a temporary lake in which were accumulated the great quantities of sand found on the Jornada north of the lava sheet.

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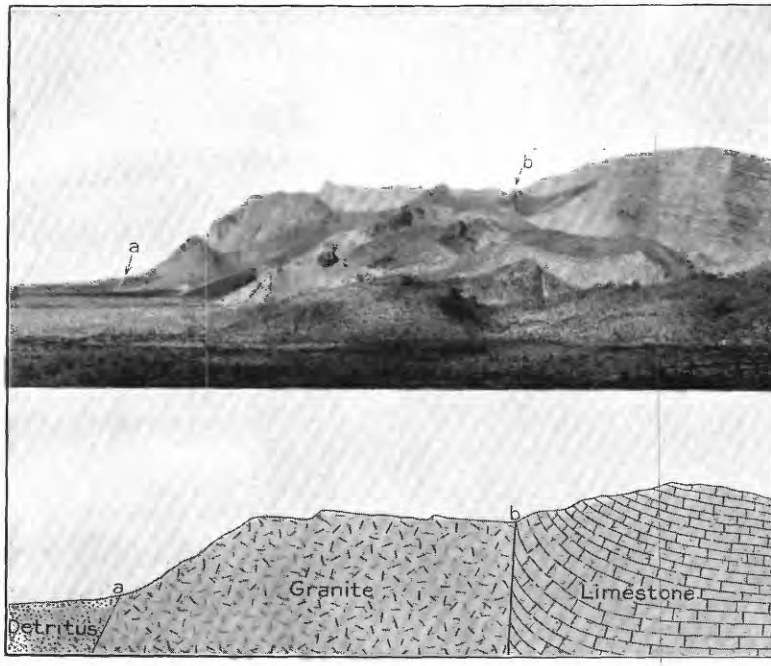

A. WESTERN FACE OF THE FRA CRISTOBAL MOUNTAINS.

Showing two faults, a and b.

B. FAULT PLANE AT THE WESTERN BASE OF FRA CRISTOBAL MOUNTAINS.

Showing near view of a, above.

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DIVERSION OF THE RIO GRANDE.

There is no evidence that the river ever flowed over the San Marcial lava sheet. The surface of this sheet is not eroded and, so far as observed, is devoid of foreign matter except a small amount of wind-blown sand. The volcanic dam, aided possibly by surface movements accompanying the volcanic eruptions, evidently diverted the river from its old valley in the Jornada to a new course for a distance of about 100 miles west of the Caballos and Fra Cristobal mountains. At Dona Ana it returned to the old débris-filled valley, which it crossed diagonally and abandoned again at El Paso.

Several phenomena which otherwise are difficult to explain are made clear by a recognition of this change in the course of the river.

First, as previously stated, the surface of the Jornada between San Marcial and Mesilla Valley has an average gradient of 4.5 feet per mile, which is practically the gradient of the river at the present time.

Second, the detrital beds cut by the river west of the Fra Cristobal and Caballos mountains are associated with rhyolite, apparently extruded at the same time as the rhyolites previously described as of Tertiary age, indicating that the detritus is older and probably more difficult to erode than the loose sands and gravels that were deposited later.

Third, near Rincon, and again in Selden Canyon, gypsum was noted in the detrital beds, but nowhere was any indication of gypsum found in the mesa gravels referable to the epoch in which the Jornada and La Mesa were filled.

Fourth, as previously stated, Engle Valley is much narrower than the other erosion basins formed at the same time—as, for example, Mesilla and Belen valleys, which have been excavated from river sands and gravels known to be of recent origin. This difference is due, no doubt, to the greater resistance to erosion of the older detritus.

SECOND EPOCH OF EROSION.

The volcanic eruptions and the change in the course of the river were followed by a second epoch of erosion. In again eroding a valley, the river worked principally in the unconsolidated sands and gravels previously deposited, excavating the erosion basins, but at a number of places where it had wandered from its old course it cut its channel in hard rock, forming the various canyons. The result is the succession of comparatively broad basins and short rock canyons that characterize the Rio Grande region.

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ACCUMULATION OF SILT.

The second epoch of erosion was followed by the deposition of the silt and sand that now form the flood plains of the erosion basins. The depth of this third valley filling is not great. Borings indicate a maximum depth of 85 feet at the International dam site in El Paso Canyon and of 72 feet at the Engle dam site, near Elephant Butte. The depth within the basins probably does not differ greatly from that in the canyons, but this can not be stated positively.

The well records given in the section on underground waters indicate that the mesa gravels (*uu* of fig. 1) are probably encountered at depths of 30 to 80 feet. The first "cemented sand" in the Albuquerque well (p. 34) is presumably a hardened layer of the Tertiary beds, and the gravel beds in the Mesilla Valley wells (pp. 41-46), encountered at depths of 30 to 75 feet, are interpreted as belonging to the mesa gravels. The depth of flood-plain deposit thus indicated corresponds well with the known depth of filling in the canyons.

The deposition of sand and silt in the erosion basins causes frequent changes in the course of the river, so that bayous, sloughs, and oxbow lakes are common in the bottom lands. This is well illustrated in Mesilla Valley (Pl. X), where many abandoned courses occur, particularly near the southern end, some still occupied by streams and others nearly filled with silt. A characteristic change in the channel of the river occurred in 1905 near the head-gate of Las Cruces canal, at the northern end of Mesilla Valley. During the spring floods of that year the river broke through the narrow neck of land on the western side of the valley, leaving the head-gates about a mile from the new channel.

B. M. Hall, supervising engineer of the United States Reclamation Service, in charge of the Rio Grande project, has made computations of the amount of silt carried by the Rio Grande. He arrives at the conclusion that the river carries, on the average, 14,580 acre-feet of mud a year, or enough when dry to cover 14,580 acres 1 foot deep. The computation, although made for the purpose of estimating the time required to fill the reservoirs with mud, is useful in this connection in indicating the possibilities of rapid accumulation wherever opportunity is offered.

During times of flood the river naturally carries its maximum amount of silt, which is thus admitted to the sloughs and overflow districts and gradually fills them to the common level of the flood plain. A similar action takes place in the irrigation ditches, which rapidly fill with silt. Some of the older ditches have thus been built up many feet above the level at which they were originally constructed.

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RESERVOIR SITES.

INTRODUCTORY STATEMENT.

The alternation of erosion basins and rock canyons in the Rio Grande Valley is especially favorable for the construction of reservoirs and the conservation and use of the flood waters of the river. Available dam sites occur in the canyons, while the broad basins are suitable for storage reservoirs or for irrigation, according to location and character. Several reservoir sites have been selected and the two most promising ones—the International reservoir, at the southern end of the region, and the Engle reservoir, west of the Fra Cristobal Mountains—have been investigated in detail.

INTERNATIONAL RESERVOIR.

The proposed International reservoir is located at the southern end of Mesilla Valley and was designed by its promoters to store water to be used in El Paso Valley, which lies partly in Texas and partly in Mexico. The dam site is in the canyon about 4 miles north of the city of El Paso.

El Paso Canyon is a narrow gorge carved in solid rock, consisting of Lower Cretaceous sediments and eruptive rocks. The strata have been considerably fractured and faulted. Rodadero Peak, to the west, has a granitic core overlain by highly inclined Lower Cretaceous sandstones, shales, and limestones. East of the river the strata lie more nearly horizontal, while in the Franklin Mountains, still farther to the east, strata older than Cretaceous dip steeply to the west. The shattered and faulted state of the rock is apparently the only geologic condition unfavorable to El Paso Canyon as a good dam site. The gorge is narrow, the rock abutments are firm, and the depth to bed rock in the channel is not prohibitive, as it is found at a maximum depth of little more than 80 feet. The site has been described in detail in the report of the International (Water) Boundary Commission.[a]

Although the dam site of the proposed reservoir is a good one, geologic conditions are not favorable to the successful storage of water in the southern part of Mesilla Valley. As previously pointed out, the old gravel-filled valley of the Rio Grande passes southward into Mexico west of Rodadero Peak. The water of the reservoir would be impounded in the basin eroded from the unconsolidated gravels of the old valley fillings and would undoubtedly escape to some extent through these gravels until such time as they might become impervious from silting. It is an open question how much time would elapse before this silting would become effective in preventing leakage.

[a] Proceedings International (Water) Boundary Commission, United States and Mexico, 1903, vols. 1 and 2.

ENGLE RESERVOIR.

LOCATION.

The proposed Engle reservoir site is located in Engle Valley, west of the Fra Cristobal Mountains, and is best reached from Engle, a small town on the Atchison, Topeka and Santa Fe Railway. The site of the proposed dam is in the rock canyon near Elephant Butte, a large volcanic neck standing near the river, as shown in Pl. IX.

ROCK FORMATIONS.

The rocks near the proposed reservoir are of several kinds. In the mountains, a few miles distant, there are pre-Cambrian granites overlain by Paleozoic and Mesozoic sandstones, shales, and limestones, and in the valleys there are Tertiary and Quaternary sands, gravels, and eruptive rocks. The rocks that will probably be of economic importance in building the proposed dam are the Carboniferous limestones and shales of the Caballos Mountains, the Cretaceous sandstones forming the abutments of the dam and comprising the greater part of the area mapped in Pl. VIII as "rock," also shown in the foreground of Pl. IX, and the basaltic rock found in Elephant Butte and in the dikes of that vicinity, as well as in the lava flows and crater cones on the Jornada to the east, shown in the distance in Pl. IX.

The unconsolidated sands and gravels of Tertiary and Quaternary age are mainly of negative importance, since they form the floor and confining walls of the reservoir and endanger leakage.

STRUCTURE.

The geologic structure in the vicinity of Elephant Butte has been described in a general way under the heading "Central area" (pp. 9–16), where it is shown that the face of the Fra Cristobal and Caballos mountain ranges (see Pl. VII) are due to faulting and that the detrital valleys are due to the filling of the troughs thus formed with rock débris. The structure is illustrated in detail in the Elephant Butte area, a map and cross section of which are given in Pl. VIII. The fault at the western base of the mountains passes through this region, separating the unconsolidated detrital beds to the west from the rock formations to the east. The rocks, consisting mainly of Upper Cretaceous sandstones and shales, are more or less fractured near the fault and incline in a general easterly direction, the dip varying from about 10° to 90°.

The high lava-covered surface, shown at the right in the section Pl. VIII and in the distance in Pl. IX, is the western edge of the Jornada del Muerto. About 300 feet below this level and 150 feet above the river a broad terrace is cut in the sandstones east of the fault line and in

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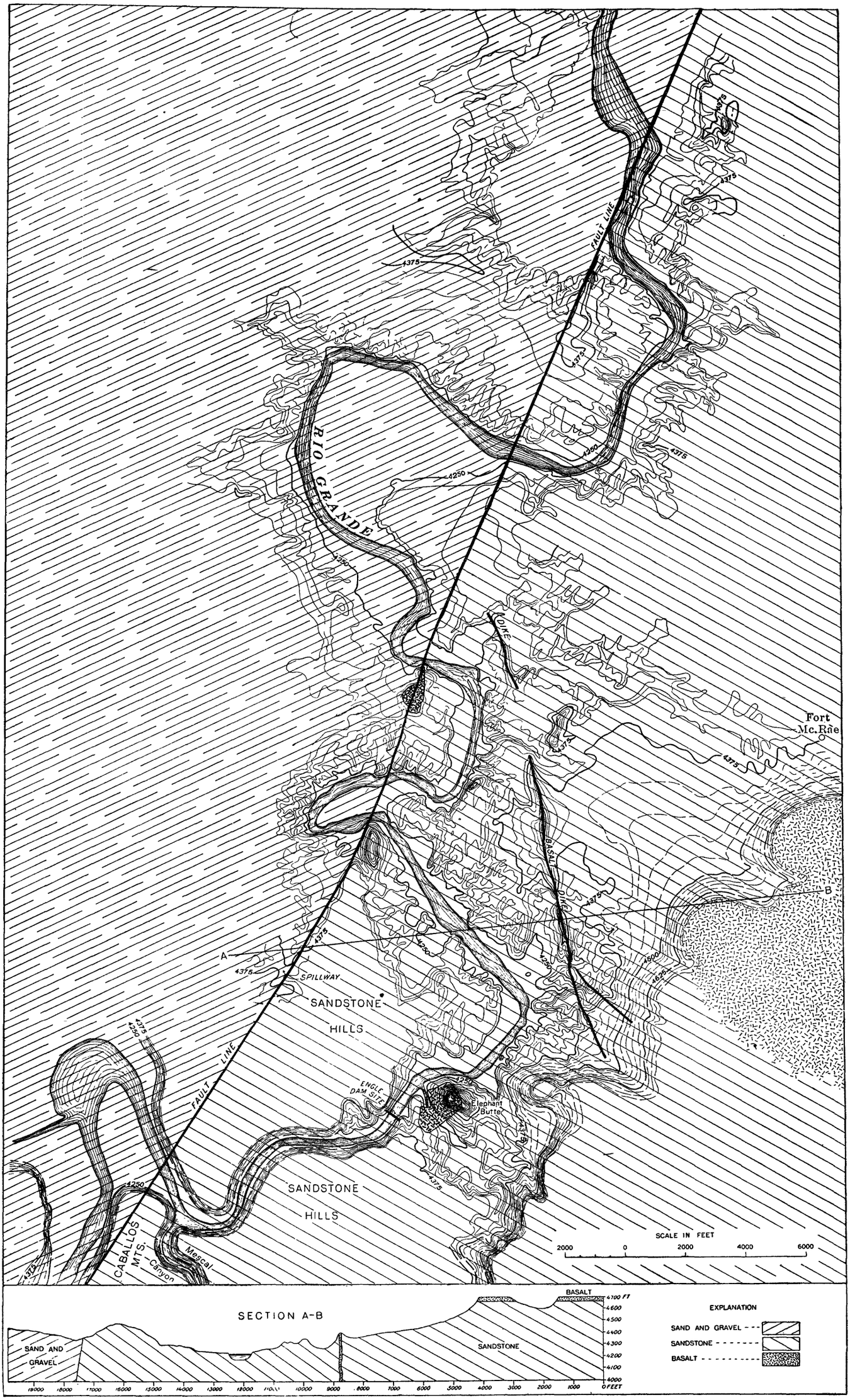

GEOLOGIC MAP OF ELEPHANT BUTTE REGION.

Showing the areal distribution of the rocks, the fault line between consolidated rock and detritus, and the superimposed course of the Rio Grande.

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the detrital beds west of the fault. This terrace is traceable throughout the length of Engle and Las Palomas valleys and is most conspicuous west of the river, where it forms a shelf several miles wide in places. It differs from the terraces illustrated in fig. 1 in being a surface mainly of erosion, probably formed at a time when the down cutting of the river was temporarily arrested, for some reason as yet unknown, during which time the river cut laterally, flowing in part over the rock and in part over the detrital beds to the west, crossing and recrossing the fault line. When the river resumed its down cutting it eroded a canyon partly in rock and partly in detritus, as shown in Pl. VIII, instead of taking the course to the west, where no hard rock would have been encountered.

SPILLWAY.

The ease with which erosion is accomplished in the detrital beds is well illustrated in the three oxbows formed west of the fault line, where the river passes from the rock into the detritus. The southern and middle bows are now only 2 miles apart and are separated by a ridge of detrital material already partly eroded away. The spillway of the Engle reservoir has been located tentatively in this depression. Considered from the topography alone the depression is an excellent location for a spillway, since the waters from the overflowing reservoir would escape at a point far enough away from the dam to insure the safety of that structure. The nature of the rock, however, must also be considered.

A small valley heading in the spillway at the summit of this ridge is indicated in Pl. VIII. The map was not completed to the south but a similar valley extends from the spillway southward to the bend in the river at the northern end of the Caballos Mountains. These valleys have been carved from the unconsolidated sediments by such temporary streams as result from the drainage of a very small area, a fact distinctly unfavorable to the location of the spillway of a great reservoir in material so easily eroded.

The proposed spillway is close to the fault line and it is possible that solid rock might be found at no great depth beneath the surface. In a small valley south of the spillway sandstones occur in a nearly vertical position. But whether these are near enough to the surface to warrant the establishment of a spillway at the point proposed remains to be determined.

A spillway constructed near the dam might have the disadvantage of greater cost, since it would require the excavation of a considerable amount of hard rock, but the advantage of greater durability and the absence of danger from rapid erosion along the course of the overflowing waters would probably more than compensate the additional cost.

CONSTRUCTIONAL MATERIALS.

Building stone.—Several varieties of building stone are found within the Elephant Butte area. Massive limestones and red sandstones of Carboniferous age occur in the Caballos Mountains, the northern end of which is 1½ miles distant from the site of the proposed dam. Massive sandstones of Upper Cretaceous age occur at the dam site in the walls of the canyon. Field observations indicate that these will probably prove valuable for purposes of construction. But the strongest and most durable as well as the most accessible building stone is the basalt of Elephant Butte, which occurs close to the dam site. (Pl. VIII.)

Cement material.—The problem of procuring cement for the construction of the dam is important. Cement must either be hauled about 12 miles from the nearest railway station or manufactured near the dam site. Cement material is available in the Elephant Butte area. In the northern end of the Caballos Mountains, at the mouth of Mescal Canyon, limestone and shale occur in abundance. Samples of each were taken and were analyzed in the laboratory of the United States Reclamation Service at Berkeley, Cal. The samples were not selected by one familiar with the technical requirements of cement manufacture, and probably more suitable material may be found. The analyses of these samples, given below, must be regarded as preliminary, but indicate that good cement materials may be found near the dam site.

Analysis of limestone from the northern end of Caballos Mountains.

[C. H. Stone, analyst.]

Silica (SiO_2) and insoluble matter	7.94	Soda (Na_2O)	0.28
Alumina (Al_2O_3) and ferric oxide (Fe_2O_3)	0.80	Sulfur trioxide (SO_3)	0.30
Lime (CaO)	44.99	Carbon dioxide (CO_2) calculated to combine with CaO	39.29
Magnesia (MgO)	1.23		95.30
Copper oxide (CuO)	0.38	Moisture	0.11
Potassa (K_2O)	0.09		

Analysis of shale from the northern end of Caballos Mountains.

Silica (SiO_2)	63.74	Soda (Na_2O)	Undet.
Ferric oxide (Fe_2O_3)	6.44	Potassa (K_2O)	Undet.
Alumina (Al_2O_3)	17.33	Sulfuric trioxide (SO_3)	Trace.
Lime (CaO)	5.51	Ignition loss (H_2O, CO_2)	
Magnesia (MgO)	1.86		94.88

RATIONAL ANALYSIS.

Clay substance	27.20
Quartz	3.25
Feldspathic detritus	69.55

ENGLE DAM SITE.

Showing Elephant Butte at the right, the edge of the Jornada del Muerto in the distance, the tilted Cretaceous sandstones in the foreground, and the dry bed of the Rio Grande.

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The ratio $\frac{SiO_2}{Fe_2O_3+Al_2O_3}=2.6$ is well within the limits of the ratio >2.3 or $<3,6$. The MgO content is low, and the absence of SO_3 makes this material one of the purer clays, considered from a technical point of view.

Coal.—Coal has been found in Mescal Canyon about 4 miles south of Elephant Butte. Where exposed at the surface the beds are only a few inches thick, but are associated with a considerable amount of carbonaceous shale. The coal is in the same formation that contains valuable deposits of coal at Carthage and other places farther north, but the prospects have not been developed.

SAN ACACIA RESERVOIR.

The narrow gorge at San Acacia is one of the proposed dam sites of the Rio Grande region. The broad Belen Valley, to the north, narrows abruptly at this point on account of the sheet of basalt which here covers the detritus. Measurements made at this point by Mr. R. H. Chapman, of the United States Geological Survey, indicate that a dam 50 feet high would be 1,200 feet in length and would flood about 18 square miles to an average depth of 25 feet, thus impounding about 288,000 acre-feet of water. A higher but longer dam might be constructed, but the maximum possible height is less than 75 feet above the river bed, the limiting factor being the broad sand gap to the northwest, the surface of which is about 75 feet above the river level.

Probably the most serious objection to San Acacia Gorge as a dam site is found in the nature of the rock. The hard basalt, which maintains the steep walls of the gorge, is a comparatively thin sheet resting on unconsolidated sand and gravel, cut by basalt dikes representing the vents through which the material of the sheet was extruded. Judging from surface indications, there is little prospect of finding solid rock sufficiently near the surface to be useful as a foundation for a dam, and the loose gravels would probably allow serious loss of impounded waters by leakage.

SAN FELIPE RESERVOIR.

Little can be added to the published description[a] of this gorge as a reservoir site. The proposed dam would be 2,350 feet long and would submerge only 1,511 acres. San Felipe gorge is similar to that at San Acacia in being formed by flows of basalt capping unconsolidated sands and gravels. At this point there are two flows of basalt separated by a few feet of sand, as shown in the cross section of White

[a] Newell, F. H., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 275–276.

Rock Canyon, given in fig. 2. The material to an unknown depth beneath the lava sheet is sand and gravel, rendering the gorge undesirable as a dam site.

ESPANOLA RESERVOIR.

The Espanola dam site, located at the head of White Rock Canyon, has been described[a] as consisting of clay beds in which blocks of basalt are embedded, the unconsolidated material extending indefinitely beneath the bed of the river. Near this site thick beds of rhyolite tuff, west of the river, and basalt, to the east, rest on the detrital beds, as shown in the section forming fig. 2 and in Pl. IV, *B*. The absence

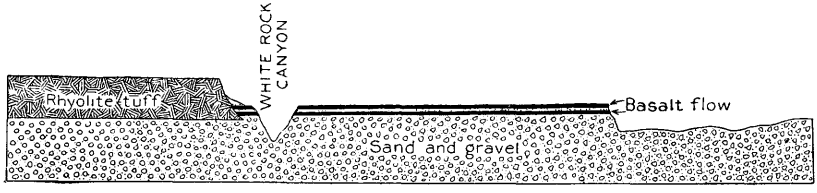

FIG. 2.—Section across White Rock Canyon near Espanola dam site.

of bed rock near the surface makes this locality of doubtful value as a dam site.

The proposed reservoir covers 5,437 acres and has a capacity of 186,861 acre-feet.

WATER SUPPLY.

SURFACE WATERS.

RAINFALL.

On account of the great differences in altitude of places that lie within short distances of one another in the Rio Grande region the amount of rainfall varies greatly from place to place, the mountain peaks serving as foci about which local storms gather. Few storms occur in which precipitation is uniform over a large area. The greater part of the rain falls as local showers close to the hills in which they originate. This fact is indicated quantitatively in the following table of rainfall, in which the stations nearest the hills show the greatest precipitation. At Santa Fe, situated at the base of the Rocky Mountains, the average yearly precipitation is 14.56 inches, while at San Marcial, situated near the center of the Rio Grande region and far from high mountains, the average is 4.84 inches and the minimum is only 1.17 inches.

[a] Newell, F. H., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 4, 1901, pp. 265-269.

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TABLE 1.—*Rainfall in the Rio Grande region, New Mexico, in inches.*

Locality.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	Average for the years recorded.
Albuquerque	7.02	9.74	6.39	(7.45)	5.90	10.19	4.94	5.83	6.82	4.20	6.85
Bernalillo	7.89	11.49	5.82	6.89	4.89						7.39
Cambray						7.71	6.64	8.02	11.46		5.96
El Paso	9.79	12.41	6.16	7.30	7.95	8.68	10.15	16.63	11.30	17.80	10.82
Engle	10.84	16.89	14.38	7.72	6.03	8.49					10.72
Espanola	8.08		7.78	6.25	10.20						8.08
Galisteo	12.22		9.30	(11.59)		16.49					12.30
Hillsboro	12.21	17.13	10.54	4.60	6.43						10.18
Los Lunas	7.65				6.05				10.45		8.71
Mesilla Park	7.99	8.96	11.21	9.67	8.40	11.96	10.90	10.29	10.13	17.09	10.65
Rincon		11.74	11.13								11.44
San Marcial	6.55			6.78		1.17					4.84
Santa Fe	14.28	20.40	12.97	10.15	15.89	17.41	13.36	9.79	14.19	17.22	14.56
Socorro		10.61		7.71	7.05	10.06				22.40	11.57

General average for the Rio Grande region 9.57

EVAPORATION.

Evaporation throughout the Rio Grande Valley greatly exceeds the rainfall. Records for only three years are obtainable, but these were made near the extremities of the region here considered, and probably represent adequately the evaporation for the entire area. The first was made at the International dam site near El Paso during the year 1890.[a] Those for the years 1900 and 1903 were made at the Climatological Laboratory of the University of New Mexico at Albuquerque.[b]

TABLE 2.—*Evaporation in the Rio Grande region, in inches.*

	At International reservoir site for 1890.	At Albuquerque for 1900.	At Albuquerque for 1903.		At International reservoir site for 1890.	At Albuquerque for 1900.	At Albuquerque for 1903.
January	2.0	2.04	1.81	August	11.4	10.21	11.73
February	2.0	2.63	2.07	September	9.2	8.00	9.65
March	7.0	6.17	5.21	October	6.8	4.38	6.62
April	7.3	6.82	10.05	November	4.6	1.73	4.21
May	10.8	10.08	10.98	December	2.9	1.40	1.88
June	11.2	12.63	11.33				
July	9.6	11.78	12.36	Total	84.8	77.87	87.90

Average for three years, 83.5.

DRAINAGE.

The drainage area of the Rio Grande north of El Paso, according to the reports of stream measurements made by the United States Geological Survey, is 38,000 square miles, of which 7,695 square miles lie north of Cenicero, Colo., leaving about 30,000 square miles as the area of the drainage basin within New Mexico.

The Rio Grande is mainly a flood-water stream and is subject to great fluctuations in volume. Its permanent flow is slight and is

[a] Thirteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1890–91, p. 411.

[b] Weinzirl, John, Bull. Hadley Climatological Laboratory, Univ. New Mexico, vol. 11, No. 10, 1905, pp. 5–8.

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derived mainly from the mountains north and east of the area described. The tributaries within the Rio Grande region yield little permanent supply, although Galisteo Creek and Rio Puerco contribute small volumes of water during the greater part of the year. Many of the tributary channels carry small permanent streams near their heads in the hills, but the water in most of these sinks beneath the surface before reaching the river.

The floods that supply the greater part of the flow of the Rio Grande are of two general kinds, one due to the annual melting of snows in the mountains, often accompanied by general rain storms, the other due to local showers or "cloud-bursts." The first occur regularly, but those due to local showers are very irregular, both in volume and in time of occurrence. Sometimes the river bed is dry for several months and at other times it carries disastrous floods, the yearly discharge, for example, at El Paso, varying from 50,768 to 2,011,794 acre-feet, or a proportion approximating 1:40.

The records of discharge kept by the Geological Survey since 1897 at El Paso, San Marcial, and Ildefonso, and since 1899 at Cenicero, near the Colorado and New Mexico boundary, are as follows:

TABLE 3.—*Monthly discharge of the Rio Grande, in acre-feet.*

EL PASO, TEX.

Month.	1897.	1898,	1899.	1900.	1901.	1902.	1903.	1904.	1905.
January	18,754	30,129	12,912	8,110	278	8,291	615	972	35,920
February	10,774	33,655	11,330	5,680	4,502	5,772	1,289	387	43,309
March	4,427	20,044	7,071	460	3,669	635	22,602	0	188,489
April	103,537	97,944	8,807	300	0	7,904	49,468	0	197,911
May	511,088	140,192	10,330	44,810	158,102	526	203,623	0	545,950
June	362,677	111,570	0	93,100	77,038	307	586,909	0	851,147
July	81,770	196,269	19,553	70	12,576	20	158,202	0	58,800
August	8,116	31,236	430	0	60,655	14,499	4,334	7,398	19,785
September	41,950	2,262	0	16,483	21,005	9,313	1,031	10,959	3,322
October	108,096	160	123	0	5,336	1,428	2,033	366,486	4,225
November	67,359	119	119	0	12,813	298	298	48,397	25,458
December	41,812	5,718	2,828	738	7,993	1,775	2,440	38,182	37,478
Year	1,360,360	669,298	73,503	169,751	363,967	50,768	1,032,844	472,781	2,011,794

Total for nine years, 6,205,066; average for nine years, 689,452.

SAN MARCIAL, N. MEX.

Month.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.
January	19,553	57,675	27,854	40,582	24,718	22,731	17,197	16,840	39,114
February	24,325	59,425	24,603	35,099	25,468	17,435	21,927	18,902	63,868
March	40,767	62,164	27,546	33,203	15,114	7,954	46,790	6,060	217,904
April	212,548	271,458	54,089	6,248	23,683	40,106	100,007	0	279,392
May	755,196	165,832	35,048	123,590	256,126	26,787	318,367	0	962,221
June	366,426	126,268	952	159,888	96,178	6,407	660,476	0	714,268
July	65,977	167,062	28,407	123	59,286	0	77,841	10,532	35,782
August	6,149	13,835	6,395	0	65,534	49,210	3,064	55,974	20,093
September	114,188	4,641	2,916	73,190	37,607	13,349	1,438	44,727	5,276
October	281,677	1,230	676	123	17,018	823	545	463,240	7,349
November	175,715	11,722	9,521	2,440	20,053	4,641	5,534	51,769	42,397
December	152,736	23,365	21,828	10,084	19,240	11,286	18,883	41,752	34,344
Year	2,215,257	964,677	239,835	484,570	660,025	200,729	1,272,069	709,796	2,422,008

Total for nine years, 9,168,966; average for nine years 1,018,774.

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TABLE 3.—*Monthly discharge of the Rio Grande, in acre-feet*—Continued.

ILDEFONSO, N. MEX.

Month.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.
January	28,715	21,705	26,009	36,770	24,410	29,643	23,127	20,910	43,470
February	30,101	24,936	35,599	32,322	36,543	27,183	24,724	24,220	51,590
March	60,750	33,449	81,164	52,818	45,624	33,709	75,193	21,340	158,100
April	303,113	265,864	176,430	51,531	83,425	97,577	172,324	27,310	218,900
May	702,254	200,328	117,687	211,517	319,367	73,567	406,612	24,160	785,200
June	366,128	223,973	23,742	173,395	130,850	28,215	709,468	17,020	572,700
July	97,274	161,590	36,647	18,262	44,824	16,730	136,780	15,130	53,740
August	27,423	39,168	22,197	10,145	50,850	34,165	26,563	91,990	38,680
September	40,463	19,279	53,137	42,605	34,512	28,790	22,314	148,300	23,150
October	136,196	21,890	26,563	23,796	30,190	17,157	21,828	252,800	25,950
November	71,881	35,583	44,985	25,289	27,491	18,386	25,170	49,450	37,960
December	32,220	39,168	38,184	29,022	28,468	19,220	23,611	35,420	37,940
Year	1,896,518	1,086,933	682,344	707,472	856,554	424,342	1,667,714	728,050	2,047,380

Total for nine years, 10,097,307; average for eight years, 1,121,923.

CENICERO, COLO.

Month.	1899.	1900.	1901.	1902.	1903.	1904.	1905.
January	(a)	39,229	36,524	32,035	1,537	18,820	59,640
February	(a)	42,153	32,267	42,097	1,388	23,990	66,370
March	(a)	35,847	22,443	33,757	2,091	7,563	53,490
April	(a)	20,826	16,542	18,744	18,684	9,104	44,270
May	(a)	87,927	103,299	30,129	123,713	1,322	399,300
June	(a)	84,734	61,408	6,783	379,339	1,208	507,600
July	2,582	1,783	5,041	1,353	72,432	1,076	15,860
August	3,259	1,353	3,689	1,045	2,890	8,608	9,469
September	6,069	1,845	2,975	1,547	5,355	11,660	3,725
October	7,194	2,275	3,320	1,968	3,935	97,770	6,044
November	15,412	9,223	4,284	1,785	12,674	24,750	12,850
December	19,553	35,109	20,721	2,275	18,569	53,310	31,730
Year	.....	362,304	312,513	173,518	642,607	259,181	1,210,000

[a] No record.

Total for six years, complete, 2,960,123; average for six years, 493,354.

UNDERGROUND WATERS.

The Rio Grande region embraces several more or less separate geologic provinces and the underground-water resources may be most conveniently described by districts.

SANTA FE DISTRICT.

The Santa Fe district is located in the Rocky Mountains region on the Rio Grande north of Galisteo Creek. The strata, composed of partially consolidated sands, gravels, and beds of mountain wash of Tertiary age, dip to the west away from the mountains. The inclination of the strata and their exposure in the region of greatest precipitation within the area described are favorable to the occurrence of artesian water.

Only two deep wells have been sunk in these deposits, and in neither of them was water found under notable pressure. The first one, drilled several years ago in search of artesian water, is 8 miles south of Santa Fe. In this no surface flow was obtained. The second,

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drilled in 1905 at the Santa Fe Indian School, is a 12-inch well, 989 feet deep, and penetrates angular wash principally except for 75 feet of conglomerate encountered at a depth of 225 feet. Water was found at a depth of 100 feet and rose 44 feet, but its volume is small and the supply is easily exhausted by pumping. Water was also obtained in the 75 feet of conglomerate and in several thin gravel strata not recorded. This well is on comparatively high ground, its altitude being about 7,000 feet, and near the eastern or highest part of the detrital formation. It is probable that on lower ground, nearer the river, water might be found under pressure sufficient to produce surface flows. Water emerges from this formation as springs along the river at an altitude about 1,500 feet lower than that at Santa Fe and along the lower reaches of Santa Fe Creek. At La Cienaga, 12 miles southwest of Santa Fe and about 700 feet lower, there are several springs of sufficient volume to irrigate a considerable tract of land.

Record of well at Santa Fe Indian School.

	Feet.
Mountain wash	0–225
Conglomerate	225–300
Mountain wash	300–989

ALBUQUERQUE DISTRICT.

The Albuquerque district may be considered as extending from Galisteo Creek southward to Isleta. The geologic formations, so far as they have been penetrated by wells, are composed of unconsolidated material and carry no water under pressure. Water saturates the flood-plain material to the level of the river and is found in abundance wherever wells penetrate to that level.

A few wells sunk on the "mesa" east of Albuquerque obtain water at horizons somewhat higher than that of the river. A well at the University of New Mexico,[a] 1 mile east of Albuquerque, is 240 feet deep and contains water at a depth of 200 feet, about 20 feet higher than the river level, while the "military well," 7 miles east of Albuquerque, contains water at a depth of 420 feet, or about 130 feet above the river level.

The deepest well in this district, 710 feet, is in Albuquerque, at the city waterworks. It is a 12-inch double-steel-cased well, to which water is admitted only below a depth of 350 feet. In addition to this deep well the water company owns seven 6-inch wells and one 12-inch well, each 291 feet deep, and a 65-foot dug well, from the bottom of which 25 pipes are driven to depths of 35 feet, the water being admitted only from the bottom of these pipes, or 100 feet below the surface.

[a] Weinzirl, John, Bull. Hadley Climatological Laboratory of University of New Mexico, vol. 10, 1905, p. 12.

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All the wells together yield an average of 3,000,000 gallons a day, or 2,083 gallons a minute.

The 710-foot well has been tested alone and yielded 600 gallons a minute, with a local depression of the water surface within the well of 18 feet.

Record of the city waterworks well at Albuquerque, N. Mex.

	Feet.
Soil	0– 10
Sand and coarse gravel	10– 35
Clay	35– 40
Sand and coarse gravel	40– 71
Cemented sand	71– 75
Clay	75– 80
Cemented sand and bands of "sandstone"	80–179
Sand and gravel	179–185
Clay	185–189
Cemented sand and clay	189–243
Yellow clay	243–292
Cemented sand	292–320
Yellow clay	320–362
Sand and clay	362–386
Shale and sand	386–397
Cemented sand	397–442
Yellow clay	442–456
Cemented sand	456–471
Sand and clay	471–487
Clay, sand, and gravel	487–572
Quicksand	572–614
Clay and cemented sand	614–710

BELEN DISTRICT.

GENERAL CONDITIONS.

The Belen district extends from Isleta southward to a point a few miles north of Socorro, where the Rio Grande Valley narrows between the encroaching hills, as shown in Pl. I. Through the center of this district extends the erosion basin known as Belen Valley. The surface of the broad flood plain formed by the deposits flooring the valley stands only a few feet above the river bed, and the material composing the deposits is saturated with water. Shallow wells throughout the bottom land reach this water at depths of 5 to 15 feet and readily obtain it in large quantity.

WELLS.

The Atchison, Topeka and Santa Fe Railway Company's well, 1.5 miles south of Belen, is the only one within this district from which a large and constant supply is pumped. It is a dug well, 15 feet deep and 20 feet in diameter, and contains 7 feet of water. It has yielded

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50,000 gallons a day, and would probably yield more if necessary. The well is situated on the flood plain of the river in gravel and coarse sand, and the water level in the well rises and falls with that of the river.

No important deep wells have been sunk on the lowlands of the Belen district. One at the Belen flour mill, 35 feet deep, owned by John Becker, and another at the Catholic Church, 85 feet deep, are the deepest.

Three deep wells have been bored in the mesa gravels. One at Colorado siding, on the Atchison, Topeka and Santa Fe Railway branch, known as the Belen cut-off, is 500 feet deep and contains 34 feet of water. This well is 9 miles southeast of Belen (altitude, 4,788 feet), at an elevation of 5,012 feet, or 224 feet higher than Belen, the water level in this well being 234 feet lower than the water at Belen.

Record of Atchison, Topeka and Santa Fe Railway Company's well at Colorado siding, New Mexico.

	Feet.
Soil	1–24
Sand	24–290
Light-colored clay	290–340
Red sandy clay	340–500

At Becker siding, 15 miles southeast of Belen, the railway company has a 6-inch bored well, 427 feet deep, with water standing 364 feet below the surface. The altitude at the well is 5,140 feet, or 352 feet above Belen, making the water level in the well 4 feet lower than that in the valley at Belen.

Record of Atchison, Topeka and Santa Fe Railway Company's well at Becker siding, New Mexico.

	Feet.
Cemented gravel	0–100
Red clay	100–150
Red clay and gravel	150–275
Red clay	275–290
Red clay and gravel	290–300
Red clay and gravel, with bowlders	300–340
Gravel	340–345
Red clay and gravel, with bowlders	345–378
Gravel	378–388
Red clay and gravel	388–400
Water bearing gravel	400–420
Gravel and clay	420–427

At Sandia, a siding on the main line of the Atchison, Topeka and Santa Fe Railway, west of Isleta, the railway company bored a 12-inch well 893 feet deep during the summer of 1905. It is in sand, gravel, and clay throughout, and encountered water at a depth of 445 feet.

Record of Atchison, Topeka and Santa Fe Railway Company's well at Sandia, N. Mex.

	Feet.
Unconsolidated sand	0–340
Sand, with clay bands	340–400
Clay	400–440
Sand	440–480
Gravel	480–490
Sand, with clay bands	490–530
Sand	530–585
Clay	585–640
Sand and clay	640–893

JORNADA DISTRICT.

GEOLOGIC STRUCTURE.

The Jornada district extends from San Marcial to Las Cruces, between the San Andreas and the Caballos-Fra Cristobal mountain ranges. The geologic structure of the Jornada del Muerto has been described[a] as a syncline, in which the older or consolidated rocks pass underneath the unconsolidated material which covers the surface.

Along the eastern base of the Caballos-Fra Cristobal range the upturned Cretaceous sandstones are truncated and exposed in such a way as to freely admit the water crossing them as streams from the mountains, as well as that falling upon them as rain. These sandstones are not exposed elsewhere within the Jornada district, and it is uncertain whether they occupy the entire trough of the syncline, as stated by Keyes.[b]

The Jornada del Muerto, as has been previously stated, is probably a part of the old Rio Grande Valley that has been filled with unconsolidated sands and gravels of comparatively recent origin. This material has been penetrated by wells to a depth of 360 feet, but its total depth has not been determined and very little is yet known of the underground conditions in this region. The Cretaceous sandstones may extend without interruption beneath the detrital filling, or, if they were originally present, may have been largely eroded away previous to the deposition of the detritus.

FLOWING WELLS.

In the vicinity of Engle flowing water is obtained from three wells, which penetrate the Cretaceous sandstones. One about 10 miles northwest of Engle, near the base of the Fra Cristobal Mountains, is said to be 260 feet deep. The flow is not sufficient to water a few hundred cattle for which it is used, and the water is pumped to increase the yield.

[a] Keyes, C. R., Water-Sup. and Irr. Paper No. 123, U. S. Geol. Survey, 1905.
[b] Ibid., p. 10 (geologic map).

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The other wells belong to the Santa Fe Railway Company and the water is pumped to Engle for railway use. The wells are located in the canyon leading from Engle to the Rio Grande. One near old Fort McRae was drilled to a depth of about 1,200 feet in search of coal. No coal was found, but water was encountered under pressure sufficient to produce a considerable surface flow but not great enough to raise it to the level of the town. From this well and a second one put down about 2 miles farther east water is pumped into a reservoir on the Jornada, from which it flows to Engle by gravity.

NONFLOWING WELLS.

A number of wells have been bored in the Jornada del Muerto, but definite records of only a few of them are obtainable. Those near the western border of the plain, along the railroad, penetrate the Cretaceous sandstones and find water under slight pressure, but the greater number have been bored in depressions along the center of the plain and penetrate only unconsolidated sand, gravel, and wash. The record of Mr. Linger's well may be taken as representative of the material found in the center of the Jornada.

Record of well of G. W. Linger & Company, 5 miles east of Upham.

	Feet.
Red clay	1–10
Cement	10–19
Sand and silt	19–235
Bowlders (maximum diameter, 8 inches)	235–240

Partial records obtained of a few of the wells are given in the following table:

TABLE 4.—*Records of bored wells in the Jornada del Muerto.*

Owner.	Location.	Total depth	Depth to water.	Power used.	Remarks.
		Feet.	*Feet.*		
J. D. Isaacks	Sec. 35, T. 20 S., R. 2 E.	265	250	Wind	Penetrates 35 feet soil; 23 feet sand and gravel
Do	Sec. 25, T 21 S., R. 2 E.	330	292	Gasoline	In sand and gravel.
Do	Sec. 13, T. 20 S., R. 2 E.	115	95	Wind	
J. W. Taylor	Sec. 17, T. 19 S., R. 2 E.	360	345	do	Penetrates 345 feet angular material, with 15 feet rounded bowlders
A., T. and S. F. Rwy	8 miles west of Engle	1,200	Flow.	Gasoline	In sandstone and shale.
Do	2 miles south of Upham	480	140	Steam	
Do	1 mile west of Alaman	400	No water		
L. Baldwin & Co.	Alaman	140	140	Steam	Water raised 100 feet.
Victoria Land and Cattle Co	4 miles north of Engle	200			In red sandstone.
Do	10 miles north of Engle	500	492	Gasoline	Water raised 327 feet.
G. W. Linger & Co.	5 miles northeast of Upham.	240	236	do	Sand and gravels (maximum 6 inches in diameter) at bottom. Water raised 102 feet.
Mr. Turner	18 miles east of Rincon	350	300(?)	do	In sand and gravel.

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INDICATIONS OF ARTESIAN WATER.

The occurrence of water under pressure in several wells near Engle indicates the presence of artesian conditions beneath a small area of the Jornada, but in areas lying beyond the immediate vicinity of Engle the presence or absence of artesian water must be inferred entirely from surface indications. Since water is found in the Cretaceous sandstones near Engle it might be expected in wells that penetrate these sandstones elsewhere, provided the sandstones extend uninterruptedly beneath the surface in this region. Their extent, however, and their depth beneath the surface over the greater part of the Jornada are unknown.

The water in the unconsolidated gravel beds may perhaps be confined beneath impervious layers, since the Jornada del Muerto slopes southward at an average rate of 4½ feet to the mile, but nothing now known proves either the presence or absence of such layers. The surface indications are moderately favorable to the occurrence of artesian water in certain areas, particularly at the southern end of the Jornada and still farther south, in the Mesilla Valley.

LA MESA DISTRICT.

La Mesa district lies in the southern part of the Rio Grande region west of Mesilla Valley. Wells have been sunk in various parts of this district, both for railroad use and for stock purposes. No solid rock was encountered in any of the wells, most of which find water in abundance, but at a considerable depth, as indicated in Table 5. The deepest well on La Mesa, 945 feet, was bored by the Southern Pacific Railway Company at Lanark. The company owns two other wells at the same place, one 648 feet and one 615 feet deep, the three yielding 50 gallons of water a minute. The material penetrated is sand with small waterworn pebbles, and contains water below a depth of 380 feet.

Since the altitude of Lanark is 4,156 feet, the altitude of the water surface is 3,776 feet, while that at Bosque Seco, in Mesilla Valley, 15 miles northeast of Lanark, is 3,800 feet—24 feet higher than at Lanark. At Noria, the altitude of which is 4,114 feet, the water surface, 358 feet below the surface of the land, is 3,756 feet above sea level. In the 12 miles between Lanark and Noria the water surface inclines to the south 20 feet, or at an average rate of 1.7 feet per mile. A line drawn through Bosque Seco, Lanark, and Noria would run somewhat west of the center of the old débris-filled valley of the Rio Grande for a distance of 27 miles. Along this line there is a fall of the water surface of 44 feet, or an average of 1.7 feet per mile. The gradient of the water table in Mesilla Valley between Bosque Seco (3,800 feet) and the southern end of

Mesilla Valley (3,680 feet), a distance of about 32 miles, is 3.7 feet per mile. It is evident from these facts that the surface of the underground water has a regular gradient down the old channel through La Mesa, although it is less than the gradient of the river. A line of wells a few miles farther east in the center of the old valley would probably show a steeper gradient of the water plane.

The facts upon which the determination of gradient rests are not sufficiently numerous to make it conclusive. The depths to water determined and the indications that La Mesa is a part of the ancient débris-filled valley naturally leads to the inference that the course of the underflow should be southward through the detritus of La Mesa. It is possible, on the one hand, that additional data will show a gradient steeper than 1.7 feet per mile. On the other hand, it is possible that the original course of the underflow down the old channel has been reversed by reason of the down cutting of the river in Mesilla Valley and the accumulation of surface water in the gravels of La Mesa. The latter possibility is strengthened by the facts that La Mesa is nearly level and the material so porous that rain enters it without producing even temporary streams.

TABLE 5.—*Records of bored wells in La Mesa district.*

Owner.	Location.	Total depth.	Depth to water.	Power used.	Material encountered.
		Feet.	*Feet.*		
Henry Brock	Sec. 30, T. 25 S., R. 2 W.	240	221	Gasoline	Sand and waterworn gravels.
Do	Sec. 7, T. 24 S., R. 1 W.	430	386	do	Do.
Do	T. 24	515			Clay.
Mr. Hawkins	5 miles west of Picacho Mountain.	218	170	Gasoline	
Robert Herrington	2 miles northwest of Noria.	435	350	do	Sand and gravel.
J. F. Kilburn	T. 27 S., R. 1 W.	[a] 478	408		Do.
Do	6 miles northwest of Lanark.	388	370	Gasoline	Sand and waterworn gravel.
S. P. Rwy. Co.	Lanark	945	380	Steam	Do.
Lewis Bros.	5 miles northeast of Lanark.	365	340	Gasoline	Sand and gravel.
J. B. Stahling	10 miles west of Lanark.	[b] 460	440		
Do	6 miles west of Lanark	350	311	Gasoline	
El Paso and S. W. Rwy.	Potrillo	240	220	do	Sand and clay.
Do	Noria	438	358	do	Sand and gravel.

[a] 170 feet in bottom of crater. [b] 200 feet in bottom of crater.

MESILLA DISTRICT.

LOCATION AND CHARACTER.

The Mesilla district is confined to Mesilla Valley, the southernmost of the erosion basins of the Rio Grande region. During floods the river submerges a large part of the valley floor, a level flood plain formed by the deposition of silt and fine sand. As previously stated (p. 24), Mesilla Valley was once deeper than it is now, and has been recently filled to some extent by flood-plain deposits. The geologic

formations and their relation to one another are indicated in the sections on Pl. III. The rock basin was partly filled with débris, in which a secondary valley was eroded and later partly filled with sand and silt.

WATER TABLE.

Underground water is found throughout Mesilla Valley at practically the river level. The depth to water was measured in the wells in the valley, and the results were plotted on the contour maps prepared by the United States Reclamation Service, and from these the map forming Pl. X has been prepared, which shows by contours the depth to water.

The water table changes position to some extent, according to changes in the volume of water in the river. Professor Slichter[a] has shown that the ground water of the valley is derived largely from the river and that the gradient of the water plane in a direction parallel to the river is practically constant at 4.64 feet per mile where measured near Mesilla Park, while the gradient away from the river varies from 0.4 foot per mile during low water to 2.3 feet in times of flood. A rise of the water table of 5 feet is reported near the river during the six months for which records were kept.

WELLS OF MESILLA VALLEY.

General statements.—A number of wells have been bored in Mesilla Valley for pumping water in large quantities, mainly for irrigation. Twelve of these have been carefully tested by Professor Slichter[b] with a view to ascertaining their capacity, the cost of pumping, etc. Some of his results are included in Table 6 (p. 47). It should be noted, in comparing the figures of the column showing depth to water with the map (Pl. X), in which depth to water is indicated by contours, that these wells are usually placed on ground high enough to allow the water to flow over the land to be irrigated. The depth to water is therefore somewhat greater than the average depth indicated on the map.

Wells at Agricultural College.—Several wells have been bored for the Agricultural College at Mesilla Park.

A bored well at the college building is 75 feet deep and 4 inches in diameter. Water was encountered at a depth of 43 feet in 1896, but in 1903 it was found to have lowered to 53 feet.

Another 4-inch well at the college machine shop is 120 feet deep. Saline water was found at this depth and the pipe was drawn back to 75 feet, where better water was found.

An irrigation plant was established in 1902 at the experiment station of the Agricultural College, consisting of one 12-inch and one

[a] Slichter, C. S., Observations on the ground waters of Rio Grande Valley: Water-Sup. and Irr. Paper No. 141, U. S. Geol. Survey, 1905, pp. 22-29.

[b] Slichter, C. S., ibid., p. 34.

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6-inch well, each 48 feet deep. This plant has been described by members of the college faculty[a] in a bulletin of the experiment station. The wells penetrate gravel beds, from which water is readily obtained, the yield being about 1,000 gallons a minute.

Record of experiment station well.

	Feet.
Soil	0– 5
Sand	5–32
Sand and gravel	32–47
Sand	47–48

During the summer of 1905 a pumping plant was installed on the horticultural farm near Mesilla Park station. A 12-inch well was bored 62 feet deep and an 18-foot strainer was placed at the bottom. A pit 8 feet square was dug to water level, 19 feet below the surface. It contains a centrifugal pump with gasoline engine, which discharges 1,000 gallons of water per minute.

Wells of F. C. Barker.—Mr. Barker has three pumping plants. One, at Las Cruces, pumps from a 6-inch well 53 feet deep, which is capable of supplying about 150 gallons of water per minute. The well penetrates a gravel bed 35 feet thick, which supplies the water.

Record of F. C. Barker's well at Las Cruces

	Feet.
Soil	0– 3
Sand	3–18
Gravel and bowlders	18–53

Mr. Barker's second pumping plant is situated about 1 mile south of Las Cruces and consists of a 6-inch well 48 feet deep, supplied with pump and gasoline engine which raise 131 gallons of water per minute.

Record of F. C. Barker's well, 1 mile south of Las Cruces.

	Feet.
Soil	0– 8
Sand	8–16
Sand and gravel	16–30
Coarse gravel	30–48

A third plant is reported to have been established during the summer of 1905 near the second. An 8-inch well was bored to a depth of 85 feet and supplied with centrifugal pump and gasoline engine, which raise a volume of water estimated at 800 gallons per minute.

Record of F. C. Barker's 8-inch well.

	Feet.
Soil	0–17
Quicksand	17–36
Sand and gravel	36–58
Gravel and bowlders	58–75
Caliche	75–79
Sand and gravel	79–85

[a] Vernon, John J., and Lester, Francis E., Bull. No. 45, New Mexico College Agric. and Mechanic Arts, Mesilla Park, N. Mex., 1903.

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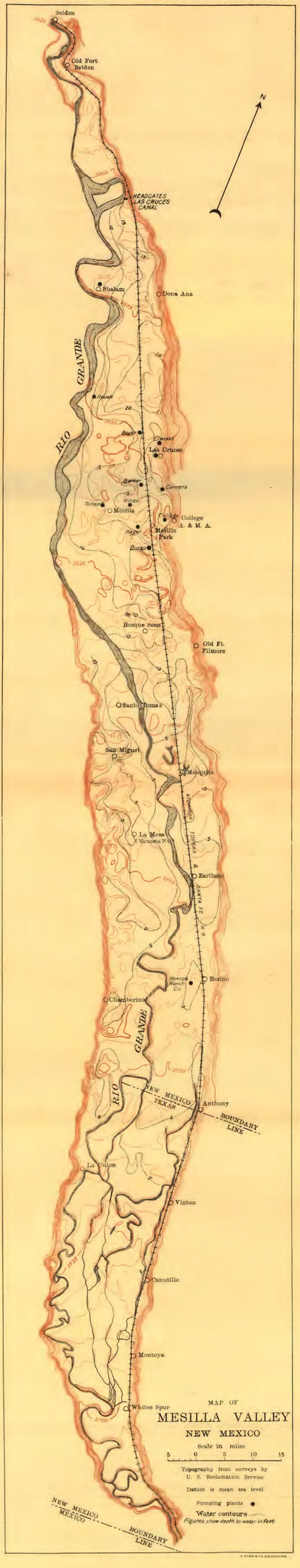

Well of Mrs. E. M. Boyer.—Mrs. Boyer's well is located on her ranch, about one-fourth mile north of the railroad station at Las Cruces. It is a 6-inch bored well, 52 feet deep, with a 12-foot strainer. Water is raised by a centrifugal pump and 12-horsepower gasoline engine at the rate of 658 gallons per minute.

Record of Mrs. E. M. Boyer's well.

	Feet.
Soil	0– 2
Sand	2–22
Sand and gravel	22–52

Well of Frank Burke.—Mr. Burke's well is located one-half mile south of Mesilla Park. It is a 12-inch well, 60 feet deep, with a 12-foot strainer. Water is raised by a centrifugal pump and 21-horsepower gasoline engine at the rate of 755 gallons per minute.

Record of Frank Burke's well.

	Feet.
Soil	0– 8
Sand	8–22
Sand and gravel	22–60

Well of J. C. Carrera.—Mr. Carrera's well is located about 1 mile south of Las Cruces. It is a 6-inch well, 58 feet deep, with a 15-foot strainer. Water is raised by a centrifugal pump and 8-horsepower gasoline engine at the rate of 648 gallons per minute.

Well of Robert Elwood.—Mr. Elwood, of Las Cruces, constructed a pumping plant for irrigation during the summer of 1905, in which two 8-inch wells 40 feet apart are connected with a 5-inch centrifugal pump and 12-horsepower gasoline engine. The first well was bored 100 feet deep, but the casing was later withdrawn to the 64-foot level, where the most productive gravel bed occurs. The second well is 64 feet deep, and both are supplied with 24-foot strainers. The yield is estimated at 800 gallons of water per minute.

Record of Robert Elwood's well.

	Feet.
Sand and gravel	0– 32
Clay	32– 35
Sand and gravel	35– 50
Cemented sand	50– 52
Coarse sand and gravel	52–100

Well of W. N. Hager.—Mr. Hager's well is located one-half mile west of Mesilla Park. It is a 10-inch well, 63 feet deep, with a 12-foot strainer. Water is raised by a centrifugal pump and 12-horsepower gasoline engine at the rate of 325 gallons per minute.

Well of A. L. Hines.—Mr Hines's well is located 1 mile northeast of Mesilla. It is a 6-inch well, 59 feet deep, with an 8-foot strainer.

Water is raised by a centrifugal pump and 8-horsepower gasoline engine at the rate of 271 gallons per minute.

Record of A. L. Hines's well.

	Feet.
Soil	0– 8
Sand	8–19
Quicksand	19–47
Sand and gravel	47–59

Wells of Horaco Ranch Company.—The Horaco Ranch Company has three wells separated by a few hundred feet and located west of Berino.

No. 1 is an 8-inch well, 75 feet deep, with an 18-foot strainer. Water is raised by a centrifugal pump and 12-horsepower gasoline engine at the rate of 837 gallons per minute.

No. 2 is a 10-inch well, 53 feet deep, with an 18-foot strainer. Water is raised by a centrifugal pump and 12-horsepower gasoline engine at the rate of 191 gallons per minute.

No. 3 is a 10-inch well, 62 feet deep, with an 18-foot strainer. Water is raised by a centrifugal pump and 12-horsepower gasoline engine at the rate of 750 gallons per minute.

Las Cruces city well.—During the summer of 1905 a pumping plant was constructed to furnish the city of Las Cruces with water. A 6-inch well was bored to a depth of 63 feet and an 18-foot strainer placed at the bottom of the pipe in a bed of gravel, occurring below the depth of 46 feet. A pit 8 feet square and 20 feet deep contains an Advance steam pump, which is placed 2 feet above normal water level. The water is drawn by suction from the capped casing at a rate of 300 gallons per minute.

The water drawn from a depth lower than 46 feet is apparently much better for domestic use than that obtained from the surface wells of Las Cruces. An analysis of the water made by Geo. W. Lord Company, of Philadelphia, Pa., is as follows:

Analysis of water from Las Cruces city well.

	Parts per million.		Parts per million.
Total solids	998	Chlorine (Cl)	133
Calcium (Ca)	156	Silica (SiO_2)	27
Magnesium (Mg)	19	Carbonate radicle (CO_3)	120
Sodium (Na)	159	Organic and volatile	Trace.
Sulfate radicle $(SO)_4$	338		

Well of Theodore Roualt.—Mr. Roualt's well is located on his ranch near the river, 3 miles northwest of Las Cruces. It is a 10-inch well, 48 feet deep, with a 10-foot strainer. Water is raised by a centrifugal pump and 18-horsepower steam engine at the rate of 351 gallons per minute.

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Well of Shalam Colony.—Several years ago an elaborate pumping plant was constructed for irrigation purposes at Shalam Colony, west of Dona Ana. A circular pit 18 feet in diameter was sunk to a depth of 30 feet and its sides and bottom were cemented. In the bottom of this pit five wells were bored, three of which are 6 inches in diameter and 90 feet deep (60 feet below the bottom of the pit), one is 12 inches in diameter and 90 feet deep, and one 6 inches in diameter and 197 feet deep. At a depth of 90 feet there is a 3-foot gravel stratum, which apparently yields the greater part of the water. The sand beneath this stratum entered the pipe so freely that it was impracticable to draw water from horizons lower than 90 feet.

A storage reservoir, covering an area of 1 acre and 5 feet deep, was constructed, and into this a 60-horsepower steam engine pumps water at the rate of 1,500 gallons per minute.

The ground water at this place is 9 feet beneath the surface, making a normal depth of 21 feet of water in the pit. The pump lowers the water surface 18 feet to a level at which it remains stationary, the flow from the wells equaling the discharge of the pump.

Well of J. R. Thompson.—Mr. Thompson's well is situated at the eastern edge of the valley, about 2 miles south of Earlham. It is a 6-inch bored well, 138 feet deep, and obtains water from the coarse sand at the bottom of the well. An accurate driller's record was obtained as follows:

Record of J. R. Thompson's well.

	Feet.
Sand and silt	0– 80
Clay	80–100
Sand	100–118
Clay	118–128
Coarse sand	128–138

Well of G. H. Totten.—Mr. Totten's well is located 1 mile west of Mesilla. It is a 10-inch well, 62 feet deep, with 24 feet of strainer. Water is raised by a centrifugal pump and 28-horsepower gasoline engine at the rate of 464 gallons per minute. When tested the well contained only 12 feet of strainer, which had been placed in the upper sand layer. Later the well was lowered and a second 12-foot strainer was added, greatly increasing the flow.

Record of G. H. Totten's well.

	Feet.
Soil	0–17
Sand	17–51
Clay	51–53
Sand and gravel	53–62

Samples of the waters were taken from both sand layers of this well to ascertain if they varied in quality. The analyses, made by Prof.

R. F. Hare, of the New Mexico agricultural experiment station, indicate that the waters vary in the amounts, but not in the kinds of salts they contain, that from the upper sand containing 1,566 parts and that from the lower sand 1,123 parts of total solids per million parts of water.

Table showing well records in Mesilla Valley.—The following table comprizes data concerning wells in Mesilla Valley. Descriptions of pumping tests for the first twelve wells of the table may be found in Prof. Charles S. Slichter's paper on ground waters of Rio Grande Valley:[a]

[a] Water Sup. and Irr. Paper No. 141, U. S. Geol. Survey, 1905, pp. 51-73.

TABLE 6.—*Records of wells in Mesilla Valley.*

	Owner.	Location.	Total depth.	Depth to water.	Yield per minute.	Water lowered by pumping.	Specific capacity per minute.	Specific capacity per square foot of strainer per minute.	Size of well.	Power used.	Use.	Cost of water per acre-foot.	Total lift in feet.
			Feet.	*Feet.*	*Gals.*	*Feet.*	*Gals.*	*Gals.*	*In.*				
1	F. C. Barker	1 mile south of Las Cruces	48	14	131	22.48	5.83	0.337	6	Gasoline	Irrigation	$13.20	45.58
2	Mrs. E. M. Boyer	Las Cruces	52	20	658	19.76	33.30	1.969	6	do	do	3.47	40.30
3	F. Burke	½ mile south of Mesilla Park	60	14	755	22.85	31.75	.930	12	do	do	4.87	40.45
4	J. C. Carrera	2 miles north of Mesilla Park	58		648	8.48	74.60	3.530	6	do	do	3.16	26.85
5	W. N. Hager	½ mile west of Mesilla Park	63		325	15.20	22.30	.760	10	do	do	9.57	34.77
6	A. L. Hines	1 mile northeast of Mesilla	59	20	271	14.08	19.20	1.790	6	do	do	8.95	36.05
7	T. Roualt	3 miles northwest of Las Cruces	48		351	23.86	16.00	.620	10	do	do	7.91	34.16
8	G. H. Totten	½ mile west of Mesilla	62	17	464	22.50	20.60	.760	10	do	do	8.19	43.35
9	Agricultural College	Mesilla Park	48		1,000	11.37	88.00	2.320	12	Steam	do	4.70	29.55
10	Horaco Ranch Co. No. 1	Berino	75	5	837	13.75	60.80	1.690	10	Gasoline	do	2.21	23.89
11	Horaco Ranch Co. No. 2	do	53	8	191	23.64	8.10	.178	10	do	do	10.90	35.26
12	Horaco Ranch Co. No. 3	do	62	8	750	18.55	40.40	.892	10	do	do	2.46	32.36
13	Academy Loretto	Las Cruces	66	26	300					do	Domestic		
14	P. S. Ames	do	51	21	130					do	Irrigation		
15	A., T. & S. F. Rwy	Earlham	25	10	40				120	Wind	Engines		
16	Agricultural College	Mesilla Park, west of railway	62	19	1,000				12	Gasoline	Irrigation		
17	F. H. Bascom & Co	Las Cruces	46	35	30				4	do	Factory		
18	F. C. Barker	Las Cruces, near station	53	18	150				6	do	Irrigation		
19	do	1 mile south of Las Cruces	85	16	800				8	do	do		
20	S. F. Bean	Las Cruces	64	34	35				6	do	do		
21	Catholic Church	do	36	34	50				Dug	do	do		
22	City waterworks	do	63	22	300				6	Steam	City		
23	R. Elwood	do	100	17	800				8	Gasoline	Irrigation		
24	W. S. Gilliam	Mesilla Park	52	16	800				10	do	do		
25	Doctor Lane	5 miles east of Fort Fillmore	260	Dry					6				
26	do	6½ miles east of Fort Fillmore	330	Dry					6				
27	L. Quintero	1 mile south of Las Cruces	35	20					6	Steam	Irrigation		
28	Shalam Colony	Las Cruces	197	9	1,500				6	do	do		
29	S. A. Steele	1 mile south of Las Cruces	83	17					8	Gasoline	do		
30	W. G. Stewart	2 miles north of Las Cruces	35	25	30				2	do	do		
31	J. B. Thompson	2 miles southeast of Earlham	138						6	Windmill	Domestic		

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UNDERFLOW OF THE RIO GRANDE REGION.

WATER PLANE.

In Mesilla Valley the surface of the ground water is practically at the river level, as has been previously stated. The water plane in the valleys farther north can not be accurately represented for lack of detailed topographic maps, but the depths to water in wells situated in the bottom lands throughout the Rio Grande region indicate that the surface of the ground water is always at or very near the river level. The water plane determined for Mesilla Valley and mapped in Pl. X is probably typical, and the map doubtless expresses with sufficient accuracy the relation of the water table to the river and to the land surface for the entire region.

QUANTITY OF UNDERFLOW.

The investigation of the quantity and rate of underflow in Mesilla Valley, carried on in 1904 by Professor Slichter,[a] shows (pp. 11–13) that there is practically no underflow through the canyon near El Paso, but (pp. 25–29) that near Mesilla Park, where a series of experiments were made, water enters the underflow both from the river and from the drainage of the mesas. His conclusions are tabulated as follows:

TABLE 7.—*Amount of water contributed to the underflow of the Rio Grande near Mesilla Park, N. Mex., between September 20 and October 23, 1904.*

Dates.	Number of days.	Amount of ground water contributed by each mile of the river.			Amount of ground water contributed by rainfall upon mesa east of the valley per mile of river valley.		
		Cubic feet of water per 24 hours.	Cubic feet per second.	Gallons per minute.	Cubic feet of water per 24 hours.	Cubic feet per second.	Gallons per minute.
September 20 to October 1	11	110,500	1.28	575	40,500	0.47	211
October 1 to 9[a]	8	640,000	7.40	3,330	152,000	1.76	794
October 9 to 16	7	248,000	2.87	1,290	29,900	.35	155
October 16 to 23	7	117,200	1.36	745	5,950	−.069	−31
	33	[b] 8,900,000	.....	.....	[b] 1,517,000	.....	.....
Average per day	.....	270,000	3.03	1,360	45,800	.515	232

[a] Heavy flood on October 5, 1904.
[b] Total amount contributed for each mile of the valley in thirty-three days. By converting cubic feet into acre-feet it is found that the river lost 204 acre-feet of water to the gravels of the underflow in thirty-three days, and that 34.8 acre-feet were contributed by the rainfall in the same period. These amounts are for each mile of the valley.

If the amounts shown by these figures are applied to Mesilla Valley as a whole the result is large. The valley is about 50 miles long, and if the seepage amounts to 204 acre-feet of water per mile a total of 10,200 acre-feet of water was contributed to the underflow of the valley by the river during the thirty-three days included in the table.

[a] Slichter, Charles S., Observations on the ground waters of Rio Grande Valley: Water-Sup. and Irr. Paper No. 141, U. S. Geol. Survey, 1905.

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During the same time a total of 1,741 acre-feet was contributed by the rainfall, making a grand total for the valley of 11,941 acre-feet in the thirty-three days, or about 362 acre-feet a day.

No measurements are available for the valleys farther north, but judging from the uniformity of conditions throughout the region a like amount probably enters the ground in the other valleys.

ORIGIN OF UNDERFLOW.

The waters of the underflow are derived mainly from the Rio Grande. The rainfall is comparatively unimportant as a source of supply, since the rains are usually violent and of short duration, and although the material upon which the rain falls is very porous the greater part of the water enters the river. According to Slichter's table just quoted, the local rainfall contributes about one-seventh of the underflow. The tributary streams evidently contribute some water, but since they are small and intermittent the amount is probably negligible, leaving the Rio Grande as the main source of supply. Measurements of the flow of the Rio Grande demonstrate the fact that the river is continually losing water, the greater volume of flow being measured at the upstream rather than the downstream gaging stations. This is made clear by an inspection of the tables of discharge previously quoted (pp. 31–33). For purposes of convenient comparison the following table of totals is given:

TABLE 8.—*Discharge of the Rio Grande in acre-feet.*

	El Paso.	San Marcial.	Ildefonzo.	Cenicero.
Total for 9 years—1897–1905	6,205,066	9,168,966	10,097,307	.....
Total for 6 years recorded at Cenicero	4,101,906	5,749,197	6,431,512	2,960,123

From this table it appears that during the nine years recorded a loss of 32 per cent of the flow at San Marcial occurred between San Marcial and El Paso, a distance of about 140 miles, and that within the same period a loss of 38 per cent of the Ildefonso flow, over and above the total amount entering the Rio Grande from tributary streams during those years, occurred in a distance of about 280 miles. This loss is due to evaporation, diversion for irrigation, and absorption into the gravels. It is probable that could the discharge of the tributary streams be included the loss would be about double that shown by the river alone. To illustrate: During the nine years recorded the river lost 3,892,241 acre-feet in the 280 miles between Ildefonso and El Paso, in addition to the total discharge of such important tributaries as Galisteo Creek, Rio Jemes, Rio Puerco, Arroyo Salado, and scores of smaller tributaries. It is evident that the actual loss is much greater than that indicated by measurements of river discharge alone,

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An effort has been made to determine what percentage of the known loss is due to irrigation and what to seepage and evaporation. The discussion may be found in the Proceedings of the International (Water) Boundary Commission, United States and Mexico, vol. 2, pp. 405–424. The results indicate that there is a notable loss of water over and above that diverted for irrigation. An average of three comparisons (p. 417) shows that 13 per cent of the San Marcial flow was lost by seepage and evaporation above El Paso.

COURSE OF UNDERFLOW.

All known facts point to the conclusion that a large amount of water is continually passing from the river into the underflow, and must either return to the surface and evaporate or find some underground passage by which to escape. Professor Slichter's[a] investigation proves that the escape is not through the canyon at El Paso.

The débris-filled valley west of El Paso and the apparently regular gradient of its water plane suggest that the course of the underflow may be down this old valley to the basin region of northern Mexico. On the other hand, the meager data available seem to show that this gradient is lower than that for Mesilla Valley, and that the flow should be toward the river rather than away from it, as would be the case if the course of the underflow was down the old valley. The data available at the present time are not adequate to solve this problem.

A more probable means of escape is by evaporation. Accepting Slichter's measurements of 362 acre-feet a day, contributed in Mesilla Valley, about 132,000 acre-feet of water would enter the gravels in a year. The evaporation of approximately 7 feet a year would remove from the 150,000 acres of Mesilla Valley about 1,050,000 acre-feet if the water were freely exposed, or about 8 times the amount of water entering the underflow. Over a considerable part of the valley the water plane is near enough to the surface for considerable loss by capillary action.

CHEMICAL CHARACTER OF RIO GRANDE WATERS.

MESILLA DISTRICT.

A large number of chemical analyses of waters of Mesilla Valley have been published by Goss.[b] Others have been collected from various sources and preserved in the records of the United States Geological Survey. It appears from these analyses that the total solids are not high as compared with those found in waters used elsewhere for irrigation, and that the salts are not those most deleterious

[a] Slichter, C. S., ibid., pp. 9-13.

[b] Goss, Arthur, Principles of water analysis: Bull. No. 34, New Mexico College of Agric. and Mech. Arts, 1900.

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to crops. "Black alkali" (Na_2CO_3) is wholly absent from both river and ground waters. "White alkali" is abundant and accumulates as incrustations of salts due to the evaporation of water brought to the surface by capillary action.

The well waters are not very satisfactory for domestic uses. The quantities of magnesium, sodium, and sulfuric acid, probably present in the form of Glauber's salt (sodium sulfate = Na_2SO_4) and Epsom salt (magnesium sulfate = $MgSO_4$), indicate that the waters of the valley in general are not very good for drinking purposes. The river water contains the same substances that are found in the wells, but in smaller amounts.

Waters obtained from the mesa gravels at El Paso, Deming, and elsewhere are much better for domestic use than those derived from gravels that are obviously supplied from the river. This is probably true of the Mesilla region, though not enough data are at hand concerning the mesa waters to permit positive statements. Two analyses have been made of samples of water taken west of Mesilla Valley. One, from J. F. Kilburn's well, contained 1,315 parts per million of dissolved solids, and is more saline than many in the valley; the other, from the railway well at Lanark, contained 585 parts per million of total solids, and is better than that from many of the valley wells.

OTHER DISTRICTS.

Little can be said of the chemical character of water from the Rio Grande region north of Mesilla Valley, few complete analyses being available. Those that could be obtained are included in Table 10. These analyses have been collected from various sources and are nearly all to be found in the records of the United States Geological Survey.

In the lowlands throughout the Rio Grande region the salts contained in the waters accumulate as white incrustations over the soil. In Albuquerque Valley these accumulations are particularly abundant and in many places prevent the growth of vegetation. This condition is probably caused by crude methods of irrigation. The land thus affected has been for many years in the possession of Mexican ranchmen, who seldom take proper care of the land.

TABLE 9.—*Analyses of Rio Grande water.*[a]

AVERAGE SAMPLES TAKEN DAILY FROM ACEQUIA NEAR AGRICULTURAL COLLEGE.

[Parts per million.]

Date.	Suspended matter.	Total solids.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Oxides of iron, aluminum, and silicon (Fe_2O_3, Al_2O_3, SiO_2).	Sulfate radicle (SO_4.)	Chlorine (Cl).	Carbonate radicle (CO_3).	White alkali.	Black alkali.
June, 1893	2,680	196	29	4	16	3	35	28	14	55	54	0
July, 1893	11,090	478	64	10	66	7	20	119	81	65	240	0
August, 1893	28,370	626	91	10	64	9	22	237	48	75	239	0
September, 1893	23,760	793	75	19	84	10	16	332	68	85	350	0
October, 1893	8,870	470	48	10	61	8	18	116	54	65	238	0
December, 1893[b]	2,610	417	54	1	73	6	19	101	62	72	226	0
January, 1894	2,570	439	60	11	57	8	12	95	68	85	230	0
February, 1904	2,160	360	35	9	65	6	7	108	68	46	245	0
March, 1904	3,380	462	56	1	84	7	15	103	74	71	242	0
April, 1904	4,360	360	51	9	40	6	24	84	42	71	170	0
May, 1904	5,860	267	39	7	30	16	21	56	23	65	129	0
June, 1904	4,070	426	55	6	59	7	14	120	49	74	224	0
Average of Rio Grande samples for 12 months	8,314	441	59	8	58	7	19	125	54	70	221	0
SAMPLES TAKEN FROM MIDDLE OF RIVER AT EARLHAM BRIDGE.												
July 23, 1899	107,800	1,615	230	39	194	22	5	830	100	94	827	0
August 13, 1899	123,960	1,911	225	43	242	18	10	1,033	101	79	1,013	0
December 4, 1899	11,470	536	65	12	75	16	6	181	60	64	295	0

[a] Goss, Arthur, Principles of water analysis: Bull. No. 34, New Mexico College of Agric. and Mech. Arts, 1900, p. 72.

[b] No water in river during November.

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TABLE 10.—*Analyses of well waters from the Rio Grande region.*

[Parts per million.]

Location of well.	Date of taking sample.	Total solids.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Fe_2O_3 Al_2O_3 SiO_2.	Sulfuric radicle (SO_4).	Chlorine (Cl).	Carbonic radicle (CO_3).	White alkali.	Black alkali.
Mesilla Valley.												
Agricultural College	July, 1894	6,700	131	16	54	14	16	118	60	194	255	0
Agricultural College, old pulsometer well	do	1,026	161	24	113	17	10	278	165	150	451	0
Agricultural College, old pulsometer farm well	May, 1904	960	131	28	131	18	26	251	145	194		0
Agricultural College, windmill well	Dec., 1901	1,041	181	34	136	17	25	25	133	135	621	0
Agricultural College, farm well	July, 1893	1,235	161	28	171	6	17	330	268	131	621	0
F. E. Lester, Mesilla Park	Aug., 1894	656	108	12	77	7	78	135	88	154	287	0
O. C. Snow, 2 miles west of Mesilla Park	Aug., 1894	633	105	14	74	7	5	142	76	154	287	0
Shalam Colony, 1½ miles west of Dona Ana	Aug., 1895	745	82	13	150	10	23	152	154	131	493	0
A. Goss, ¼ mile north of Agricultural College	May, 1900	1,912	246	39	282	39	7	506	399	161	936	0
1 mile northwest of Las Cruces	Oct., 1902	680	108	80	27		10	144	79	123		0
G. H. Totten, Mesilla [a]	Oct., 1904	1,566					Trace.	144	232	196		0
G. H. Totten, pumping plant [a]	do	1,123					Trace.	152	186	180		0
T. Roualt, near old Fort Filmore [a]	do	1,128	161	27	151	23	Trace.	159	176	215		0
Francisco Misques, Bosque Seco [a]	do	823	115	19	109	26	6	106	163	150		0
J. B. Barncastle, Dona Ana [a]	do	777	105	29	94	15	9	109	92	156		
La Mesa district.												
J. F. Kilburn, 9 miles west of Lanark [a]	do	1,315					Trace	109	200	315		0
Lanark, railway well		585	16	14				9	0	51		
Jornada district.												
Rincon	Sept., 1895	1,057	48	16	30	22	19	30	156	181		
Rincon, railway well		678	110	14				192		73		
Engle, railway surface well		573	40	7			Trace.	27	Trace.	165		
Engle, railway artesian well		898	4	2			Trace.	0	0	297		
San Marcial, railway well		579	86	8			Trace.	82	0	140		
Belen district.												
Belen		3,139	531	108		8	22	175	63	101		0
J. F. Chaves	Aug., 1896	2,820	443	146	76	12	33	1,420	13	172	894	
Isleta railway well		487	102	10			3	141	37	86		

[a] Samples taken by the writer and analyzed by R. F. Hare of the New Mexico experiment station.

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TABLE 10.—*Analyses of well waters from the Rio Grande region*—Continued.

Location of well.	Date of taking sample.	Total solids.	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).	Potassium (K).	Fe_2O_3 Al_2O_3 SiO_2.	Sulfuric radicle (SO_4).	Chlorine (Cl).	Carbonic radicle (CO_3).	White alkali.	Black alkali.
Albuquerque district.												
Albuquerque, city well	1905	307	41	8	40	.....	68	51	15	83	.....	.....
University well, 1 mile east of Albuquerque	1904	213	30	8	25	.....	45	28	10	70	.....	.....
Military well, 7 miles east of Albuquerque	1904	197	34	2	31	.....	30	24	2	75	.....	.....
Albuquerque, railway well	.....	326	61	8	.....	.....	.....	61	.....	71	.....	.....
Albuquerque, railway-shop well	.....	365	64	13	.....	.....	.....	36	.....	106	.....	.....
Bernalillo, railway well	.....	828	55	8	.....	.....	9	Trace.	Trace.	240	.....	.....
Thornton, railway well	.....	398	60	14	.....	.....	Trace.	Trace.	Trace.	175	.....	.....
Santa Fe district.												
Santa Fe city supply, from Santa Fe Creek	May, 1899	40	5	1	4	2	10	2	1	11	10	0
Do	Jan., 1900	85	14	4	3	3	8	1	6	27	14	0

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APPLICATIONS.

UTILIZATION OF UNDERFLOW.

Shallow wells.—The flood-plain material of the lowlands along the river, although saturated, does not, in general, allow the water to pass through it freely enough for the successful use of shallow irrigation wells. In certain places, however, as at Belen, where the railway well is dug in coarse sand, large volumes of water are readily obtained from this material.

Deep wells.—Beneath the fine silt of the flood plains there is coarser material, from which large quantities of water are obtained, as in the various irrigation wells in Mesilla Valley and the city wells at Albuquerque. A considerable amount of fine sand and silt occurs in the gravel beds as well as in the flood-plain deposits and prevents the rapid movement of water through them, causing the high lift and to a large extent the great cost shown in Table 6. In spite of its great cost, however, the pumping of water for irrigation has proved profitable in El Paso and Mesilla valleys. In the valleys farther north the gravels are apparently coarser and water could probably be pumped at less cost than in Mesilla Valley. In Mesilla Valley the quantity of water recovered might be greatly increased by additional wells, and pumping plants might be established with profit in Palomas, Socorro, Belen, and Albuquerque valleys. Although the data at hand show that in this region, as compared with other valleys of the Southwest, the underflow is small and the water not readily obtainable on account of the fineness of the material in which it is contained, enough water may be pumped from the sands and gravels to warrant development.

Seepage ditches.—The construction of seepage ditches as a means of obtaining the waters of the underflow has been proposed for the Rio Grande Valley, but no such ditches have been dug, and the large proportion of fine sand and silt is apparently unfavorable to this method of procuring the water.

WATER STORAGE.

The alternation of broad basins and narrow canyons along the course of the river is apparently favorable to the establishment of storage reservoirs, but at only two points are the rock formations suitable for the construction of masonry dams. These are in El Paso canyon, the dam site of the proposed International reservoir, and at Elephant Butte, the dam site of the proposed Engle reservoir.

From a geologic standpoint the Engle reservoir is much more favorable for water storage than the International reservoir. The most important geologic considerations favoring the location of a storage reservoir in Engle Valley are (1) a narrow canyon with hard rock

walls; (2) rock foundation for the proposed dam; (3) good building material near the dam site, and (4) a long, deep, narrow storage reservoir, in which loss by evaporation will be comparatively small and from which the mud may to some extent be removed by sluicing.

No other good reservoir sites were found within the Rio Grande region, nor are the geologic conditions favorable to the occurrence of good sites. Since the Rio Grande Valley is a succession of débris-filled intermontane troughs it is only where the river in its superimposed course has left the old filled valleys and cut channels in the hard rock that good dam sites are found. This action has occurred at only two places in the region described—one near El Paso and one near Elephant Butte. In the other canyons the unconsolidated detritus beneath the sheets of basalt extends to some unknown depth beneath the river and prohibits the construction of bed-rock dams.

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WS 188. Water resources of the Rio Grande Valley in New Mexico and their development, by W. T. Lee. 1906. 59 pp., 10 pls.

The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Pt. II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Pt. II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Pt. II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Pt. IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Pt. IV. Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Pt. IV; Artesian-well prospects in the Atlantic coastal plain region, by N. H. Darton, Bulletin No. 138.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JANUARY, 1907.

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RG 115 **FY 13**

Records of the Bureau of Reclamation
Washington, D.C.

General Administrative and
Project Records

1902 - 1919
RIO GRANDE 874A- - 690

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690 RIO GRANDE PROJECT. CORRES. WITH SECY OF STATE AND OTHER AS TO CLAIMS OF MEXICO JUNE 1, 1905 TO DEC 31, 1909 690

TRANSFER CASE

TRANSFER CASE

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Transfer Case.

690

CONVENTION

BETWEEN

THE UNITED STATES AND MEXICO

PROVIDING FOR

THE EQUITABLE DISTRIBUTION OF THE WATERS OF THE RIO GRANDE FOR IRRIGATION PURPOSES.

Signed at Washington, May 21, 1906.
Ratification advised by the Senate, June 26, 1906.
Ratified by the President, December 26, 1906.
Ratified by Mexico, January 5, 1907.
Ratifications exchanged at Washington, January 16, 1907.
Proclaimed, January 16, 1907.

See copy p. 221 – 5th Ann. Report U.S.R.S.

By the President of the United States of America.

A PROCLAMATION.

Whereas a Convention between the United States of America and the United States of Mexico, providing for the equitable distribution of the waters of the Rio Grande for irrigation purposes, and to remove all causes of controversy between them in respect thereto, was concluded and signed by their respective Plenipotentiaries at Washington on the twenty-first day of May, one thousand nine hundred and six, the original of which Convention, being in the English and Spanish languages, is word for word as follows:

The United States of America and the United States of Mexico being desirous to provide for the equitable distribution of the waters of the Rio Grande for irrigation purposes, and to remove all causes of controversy between them in respect thereto, and being moved by considerations of international comity, have resolved to conclude a Convention for these purposes and have named as their Plenipotentiaries:

The President of the United States of America, Elihu Root, Secretary of State of the United States; and

The President of the United States of Mexico, His Excellency Señor Don Joaquín D. Casasús, Ambassador Extraordinary and

Los Estados Unidos de América y los Estados Unidos Mexicanos deseosos de ponerse de acuerdo en la equitativa distribución de las aguas del Río Grande para fines de irrigación, y de alejar todas las causas de discusión entre ellos á ese respecto, y obrando por consideraciones de cortesía internacional, han resuelto celebrar una Convención con este propósito y han nombrado sus Plenipotenciarios, á saber:

El Presidente de los Estados Unidos de América, al Señor Elihu Root, Secretario de Estado de los Estados Unidos; y

El Presidente de los Estados Unidos Mexicanos, á Su Excelencia el Señor Don Joaquín D. Casasús, Embajador Extraordinario

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Plenipotentiary of the United States of Mexico at Washington;

Who, after having exhibited their respective full powers, which were found to be in good and due form, have agreed upon the following articles:

Article I.

After the completion of the proposed storage dam near Engle, New Mexico, and the distributing system auxiliary thereto, and as soon as water shall be available in said system for the purpose, the United States shall deliver to Mexico a total of 60,000 acre-feet of water annually, in the bed of the Rio Grande at the point where the head works of the Acequia Madre, known as the Old Mexican Canal, now exist above the city of Juarez, Mexico.

Article II.

The delivery of the said amount of water shall be assured by the United States and shall be distributed through the year in the same proportions as the water supply proposed to be furnished from the said irrigation system to lands in the United States in the vicinity of El Paso, Texas, according to the following schedule, as nearly as may be possible:

	Acre feet per month.	Corresponding cubic feet of water.
January	0	0
February	1,090	47,480,400
March	5,460	237,837,600
April	12,000	522,720,000
May	12,000	522,720,000
June	12,000	522,720,000
July	8,180	356,320,800
August	4,370	190,357,200
September	3,270	142,441,200
October	1,090	47,480,400
November	540	23,522,400
December	0	0
Total for the year	60,000 acre-feet	2,613,600,000 cubic feet

y Plenipotenciario de los Estados Unidos Mexicanos en Washington; quienes, despues de presentar sus plenos poderes respectivos, que se encontraron en buena y debida forma, han convenido en los artículos siguientes:

Artículo I.

Una vez que se hayan terminado la proyectada presa cerca de Engle, Nueva México, y el sistema auxiliar de distribución al efecto, y tan luego como haya agua disponible para el objeto en dicho sistema, los Estados Unidos entregarán á México un total de 60,000 acres pies de agua anualmente, en el lecho del Río Grande y en el punto en donde se encuentran ahora las obras principales de la Acequia Madre, conocida con el nombre de viejo canal mexicano, arriba de Ciudad Juarez, Mexico.

Artículo II.

Los Estados Unidos asegurarán la entrega de dicha cantidad de agua y la distribuirán durante el año en las mismas proporciones que la cantidad de agua que se proyecta proporcionar del expresado sistema de irrigación á los terrenos de los Estados Unidos en las cercanías de El Paso, Texas, de conformidad, y tan aproximadamente como sea posible, con la siguiente lista:

	Acres pies por mes.	Pies cúbicos de agua correspondientes.
Enero	0	0
Febrero	1,090	47,480,400
Marzo	5,460	237,837,600
Abril	12,000	522,720,000
Mayo	12,000	522,720,000
Junio	12,000	522,720,000
Julio	8,180	356,320,800
Agosto	4,370	190,357,200
Setiembre	3,270	142,441,200
Octubre	1,090	47,480,400
Noviembre	540	23,522,400
Diciembre	0	0
Total en el año	60,000 acres pies	2,613,600,000 pies cúbicos

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In case, however, of extraordinary drought or serious accident to the irrigation system in the United States, the amount delivered to the Mexican Canal shall be diminished in the same proportion as the water delivered to lands under said irrigation system in the United States.

En caso, sin embargo, de extraordinaria sequía ó de serio accidente en el sistema de irrigación en los Estados Unidos, se disminuirá la cantidad de agua que deba entregarse al canal mexicano, en la misma proporción que la que se entregue á las tierras sujetas á dicho sistema de irrigación en los Estados Unidos.

ARTICLE III.

The said delivery shall be made without cost to Mexico, and the United States agrees to pay the whole cost of storing the said quantity of water to be delivered to Mexico, of conveying the same to the international line, of measuring the said water, and of delivering it in the river bed above the head of the Mexican Canal. It is understood that the United States assumes no obligation beyond the delivering of the water in the bed of the river above the head of the Mexican Canal.

ARTÍCULO III.

La expresada entrega se hará sin gasto alguno para México, y los Estados Unidos convienen en pagar el total costo del depósito de la mencionada cantidad de agua que debe darse á México, de la conducción de la misma hasta la línea internacional, de la medición de dicha agua y de su entrega en el lecho del río, arriba de la boca del Canal Mexicano. Queda entendido que los Estados Unidos no asumen otra obligación que la de entregar el agua en el lecho del río, arriba de la boca del Canal Mexicano.

ARTICLE IV.

The delivery of water as herein provided is not to be construed as a recognition by the United States of any claim on the part of Mexico to the said waters; and it is agreed that in consideration of such delivery of water, Mexico waives any and all claims to the waters of the Rio Grande for any purpose whatever between the head of the present Mexican Canal and Fort Quitman, Texas, and also declares fully settled and disposed of, and hereby waives, all claims heretofore asserted or existing, or that may hereafter arise, or be asserted, against the United States on account of any damages alleged to have been sustained by the owners of land in Mexico, by reason of the diversion by citizens of the United States of waters of the Rio Grande.

ARTÍCULO IV.

La entrega del agua, como aquí se establece, no se considerará como un reconocimiento por los Estados Unidos de ningún derecho por parte de México á dichas aguas; y se conviene que, en consideración á dicho abastecimiento de agua, México retira cualquiera y todas las reclamaciones, sea cual fuere su objeto, á las aguas del Río Grande entre la boca del actual Canal Mexicano y Fort Quitman, Texas, y declara también completamente arregladas y extinguidas todas las reclamaciones hasta hoy presentadas, existentes ó que puedan después suscitarse ó presentarse contra los Estados Unidos á causa de cualesquiera daños que los propietarios de tierras en México aleguen haber sufrido con motivo de las desviación de aguas del Río Grande efectuada por ciudadanos de los Estados Unidos.

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ARTICLE V.

The United States, in entering into this treaty, does not thereby concede, expressly or by implication, any legal basis for any claims heretofore asserted or which may be hereafter asserted by reason of any losses incurred by the owners of land in Mexico due or alleged to be due to the diversion of the waters of the Rio Grande within the United States; nor does the United States in any way concede the establishment of any general principle or precedent by the concluding of this treaty. The understanding of both parties is that the arrangement contemplated by this treaty extends only to the portion of the Rio Grande which forms the international boundary, from the head of the Mexican Canal down to Fort Quitman, Texas, and in no other case.

ARTÍCULO V.

Los Estados Unidos, al celebrar este tratado, no otorgan con él, explícita ni implícitamente, ningún fundamento legal para reclamaciones que en lo futuro se aleguen, ó puedan alegarse, procedentes de cualesquiera pérdidas sufridas por los propietarios de tierras en México, ora se deba ó se alegue deberse, á la desviación de las aguas del Río Grande dentro de los Estados Unidos; ni convienen los Estados Unidos de ninguna manera en el establecimiento de ningún principio general ó precedente á causa de la celebración de este tratado. Quedan entendidas las dos Altas Partes Contratantes que el arreglo que se proyecta con este tratado sólo se extiende á la porción del Río Grande que forma el límite internacional, desde la boca del Canal Mexicano hasta Fort Quitman, Texas, y á ningún otro caso.

ARTICLE VI.

The present Convention shall be ratified by both contracting parties in accordance with their constitutional procedure, and the ratifications shall be exchanged at Washington as soon as possible.

In witness whereof, the respective Plenipotentiaries have signed the Convention both in the English and Spanish languages and have thereunto affixed their seals.

Done in duplicate at the City of Washington, this 21st day of May, one thousand nine hundred and six.

ARTÍCULO VI.

La presente Convención será ratificada por Ambas Partes Contratantes de acuerdo con las formalidades constitucionales de cada una de ellas, y se canjearán las ratificaciones en Wáshington tan luego como fuere posible.

En fe de lo cual, los respectivos Plenipotenciarios han firmado la presente Convención, tanto en inglés como en castellano, y han puesto en ella sus sellos.

Hecho en dos originales en la Ciudad de Washington, el 21 de Mayo, de mil novecientos seis.

ELIHU ROOT [SEAL.]
JOAQUIN D CASASUS [SEAL.]

And whereas the said Convention has been duly ratified on both parts, and the ratifications of the two governments were exchanged in the City of Washington, on the sixteenth day of January, one thousand nine hundred and seven;

Now, therefore, be it known that I, THEODORE ROOSEVELT, President of the United States of America, have caused the said Convention

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to be made public, to the end that the same and every article and clause thereof may be observed and fulfilled with good faith by the United States and the citizens thereof.

In testimony whereof, I have hereunto set my hand and caused the seal of the United States of America to be affixed.

Done at the City of Washington, this sixteenth day of January, in the year of our Lord one thousand nine hundred and seven, [SEAL.] and of the Independence of the United States of America the one hundred and thirty-first.

THEODORE ROOSEVELT

By the President:
ELIHU ROOT
Secretary of State.

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61st Congress } HOUSE OF REPRESENTATIVES { Document
3d Session } { No. 1262

FUND FOR RECLAMATION OF ARID LANDS

MESSAGE FROM THE PRESIDENT OF THE UNITED STATES TRANSMITTING A REPORT OF THE BOARD OF ARMY ENGINEERS IN RELATION TO THE RECLAMATION FUND

JANUARY 6, 1911.—Read; referred to the Committee on Irrigation of Arid Lands and ordered to be printed

WASHINGTON
GOVERNMENT PRINTING OFFICE
1911

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FUND FOR RECLAMATION OF ARID LANDS.

MESSAGE OF THE PRESIDENT.

To the Senate and House of Representatives:

The act of Congress approved June 17, 1902 (32 Stats., 388), set apart as a fund for the reclamation of arid lands the moneys received from the sales of public lands in certain of the States and Territories, excepting the 5 per cent of the proceeds of such sales theretofore set aside by law for educational and other purposes. The receipts into the reclamation fund to June 30, 1909, were $58,439,408.93, and the estimated total receipts to June 30, 1910, are $65,714,179.06. The total amount accumulated in the fund to date is estimated at $69,449,058.76, of which all but $6,241,058.76 has been allotted to the several projects. On June 30, 1910, the net investment in reclamation works amounted to $53,781,302.88, of which $52,945,441.03 had on June 30, 1910, been expended in the following primary projects:

States.	Project.	Net investment.
Arizona	Salt River	$8,430.959.16
Arizona-California	Colorado River	44,201.97
California	Orland	378,603.11
Arizona-California	Yuma	3,781,355.19
Colorado	Grand Valley	73,110.38
Do	Uncompahgre	4,166,639.04
Idaho	Boise	3,373,292.30
Do	Minidoka	2,900,896.56
Do	Snake River storage	69,142.75
Kansas	Garden City	378,316.07
Montana	Huntley	854,420.36
Do	Milk River	519,387.23
Do	St. Mary	2[illegible]5,874.03
Do	Sun River	599,958.59
Montana-North Dakota	Lower Yellowstone	2,888,899.93
Nebraska-Wyoming	North Platte	4,609,476.50
Nevada	Truckee-Carson	3,975,976.42
New Mexico	Carlsbad	617,665.56
Do	Hondo	346,024.76
Do	Leasburg	193,418.82
New Mexico-Texas	Rio Grande	76,060.58
North Dakota	Buford-Trenton	278,294.40
Do	Williston	528,171.31
Oklahoma	Cimarron	8,873.17
Oregon	Central Oregon	40,133.44
Do	Umatilla	1,155,983.22
Oregon-California	Klamath	1,830,600.39
South Dakota	Bellefourche	2,313,525.22
Utah	Strawberry Valley	913,177.91
Washington	Okanogan	538,281.41
Do	Yakima	3,116,333.48
Wyoming	Shoshone	3,378,387.87
Total		52,945,441.03

In addition, there had been invested in secondary projects June 30, 1910, $587,390.71; in town-site development, $10,955.49; in Indian irrigation, $198,704.21; and for general expenses, $38,811.44.

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The reclamation act requires the return to the reclamation fund of the estimated cost of construction, and therefore entrymen and private landowners receiving water from such projects are required to contribute their proportion of the cost of construction, operation, and maintenance of the projects wherein their lands are located. The total cash returns to the reclamation fund from water right building charges to June 30, 1910, were $902,822.25, and from water right operation and maintenance charges, $249,637.19. In addition, there was to June 30, 1910, an additional revenue of $2,086,173.73 derived from sales of town lots, sales of water, leases of power, etc., which are under the law credited as a reduction of the cost of the project from which the receipts are derived. On June 30, 1910, the Government was prepared to supply water in reclamation projects to 876,684 acres of land, and the area of lands included in the projects now under construction amounts to over 3,100,000 acres. No new projects have been undertaken since March 4, 1909, the efforts of the Government having been directed toward the completion of the 30 primary projects theretofore undertaken.

The additions to the reclamation fund from the sales of public land, while approximating between six and seven million dollars per annum since 1902, were found to be insufficient for the completion of existing projects with such expedition as the necessities of the settlers and land owners within the projects undertaken seemed to require. I accordingly recommended the issuance of certificates of indebtedness or bonds against the reclamation fund. The act of June 25, 1910 (36 Stats., 835), which authorized the issuance of not exceeding $20,000,000 of certificates of indebtedness repayable out of the reclamation fund, made the appropriation subject to the conditions that it should be expended upon existing projects and their necessary extensions, and that no part of the same should be expended until after the projects had been examined and reported upon by a board of Army engineer officers of the United States Army and approved by me as feasible, practicable, and worthy. The board of engineers selected spent the summer in field examinations of the projects and has submitted to me its report upon each of the projects heretofore undertaken, together with recommendations as to the allotment of the proceeds of the certificates authorized to be issued. In addition, pursuant to my request, the board has submitted its recommendations for the allotment of that part of the reclamation fund derived from the sales of public lands to supplement the $20,000,000 loan and to carry on worthy projects not participating in the distribution of the loan.

The report of the board is based not only upon its field examination of the various projects but upon information derived from personal conference with the field officers and employees of the Reclamation Service and data furnished by such officers and employees. In addition, settlers, landowners, and other parties interested in the projects were given an opportunity to be heard. The feasibility of the projects was considered from an engineering and economic standpoint, the board giving consideration to the character of the projects, whether international, interstate, or intrastate, the relative amounts of public and private lands capable of irrigation, the money already expended, the necessity of completion of the projects in order to secure its return, the existing contracts or agreements with water users' associations and private individuals, and the protection of water

rights. The board also points out the importance of certain additional legislation authorizing the sale of surplus stored water and the modification of conditions of payments for water rights on certain projects which will otherwise fail of returning their cost to the reclamation fund. The Secretary of the Interior in his annual report to me has recommended similar legislation.

The board recommended the allotment of the $20,000,000 provided by the act of June 25, 1910, to the following-named projects:

Salt River, Ariz	$495,000
Yuma, Ariz. and Cal	1,200,000
Grand Valley, Colo	1,000,000
Uncompahgre, Colo	1,500,000
Payette-Boise, Idaho	2,000,000
Milk River, Mont	1,000,000
North Platte, Wyo. and Nebr	2,000,000
Truckee-Carson, Nev	1,193,000
Rio Grande, N. Mex., Tex., and Mex	4,500,000
Umatilla, Oreg	325,000
Klamath, Oreg. and Cal	600,000
Strawberry Valley, Utah	2,272,000
Sunnyside } Yakima, Wash	1,250,000
Tieton } Yakima, Wash	665,000
Total	20,000,000

and that the interest on the loan as provided by said act be charged against the projects on the amounts contributed for their completion.

The recommendation of the board for the tentative allotment of the general reclamation fund among the various projects for the years 1911 to 1914, inclusive, was as follows:

Yuma	$2,380,462
Grand Valley (conditional)	500,000
Uncompahgre	2,045,000
Minidoka	528,000
Payette-Boise	4,585,435
Huntley	110,000
Milk River	2,950,000
Sun River	3,278,000
Lower Yellowstone (conditional)	578,000
North Platte	2,185,000
Truckee-Carson	1,594,000
Rio Grande	1,855,000
Missouri pumping (conditional)	270,000
Belle Fourche	480,000
Okanogan	13,000
Shoshone	2,000,000
Total	25,351,897

No allotments either from the loan or from the general reclamation fund were recommended for the following projects, except for necessary maintenance and operation: Orland, Cal.; Garden City, Kans.; Kittitas, Wapato, Benton (Yakima project), Wash.; Carlsbad, N. Mex.; Hondo, N. Mex.

The last-named projects are, with the exception of the Kittitas, Wapato, and Benton units of the Yakima project, completed or nearly completed. With respect to the said three units of the Yakima project, the board recommended development of a general system of storage reservoirs for the Yakima Valley, provided Congress authorizes the sale of excess stored water, so that the return of the cost of building of reservoirs may be secured, but did not recommend any

allotment of funds for the construction of reservoirs or canals specifically for the said units.

After careful consideration of the report of the Board of Engineers, I approved the same, believing that it sets forth a plan for the distribution of the loan and of the available reclamation fund, that, from an engineering and economic standpoint, will best secure the speedy completion of those projects, which, because of their character, the needs of the settlers, treaty or interstate relations, protection of water rights, and prompt return to the reclamation fund of the moneys invested, should be given the preference in construction and completion over such projects or parts of projects which are more remote and may properly wait until a later date for construction or may secure water through private canals in the event the Government is authorized to dispose of surplus water to the owners of such canals. My approval, however, is subject to the condition that the amounts allotted to the various projects may be adjusted and modified from time to time, as is found necessary for the intelligent and proper prosecution of the work and the advantage of the service. I have authorized the Secretary of the Interior to call upon the Secretary of the Treasury from time to time, as the same are needed, for the funds provided for by the act of June 25, 1910, in accordance with the allotments recommended by the board and approved by me.

Pursuant to the recommendations of the Secretary of the Interior and of the Board of Army Engineers, I earnestly recommend the enactment of a law which will permit of the disposition of any surplus stored water available from reclamation projects to persons, associations, or corporations operating systems for the delivery of water to individual water users for the irrigation of arid lands and the enactment of legislation which will give executive authority for the modification of conditions of payment for water rights on certain of the projects where, by reason of local conditions, the return of the cost of the projects to the reclamation fund will not be secured unless settlers are permitted to make payments on terms or conditions other than those specified in the public notices heretofore issued. In this connection attention is directed to the provisions of Senate bill 6842 now pending. Attention is also directed to the other legislation pertaining to reclamation projects recommended by the Secretary of the Interior, which legislation would aid in the administration of the reclamation projects.

With the funds now at our disposal and the enactment of the additional legislation suggested, it is hoped that the work upon the several projects for which allotments have been made, may proceed to an early completion and that the settlers and water users upon the projects upon being furnished with water for the irrigation of their lands may be enabled to return to the Treasury the sums expended in the construction of the projects. In accordance with the requirements of section 2 of the reclamation act, the Secretary of the Interior has already transmitted to Congress the ninth annual report of the Reclamation Service, and in order that Congress may be placed in possession of all the information at hand to date with reference to the reclamation projects and the estimated cost of their completion I transmit herewith for its further information a copy of the said report of the Board of Army Engineers.

WM. H. TAFT.

THE WHITE HOUSE, *January 5, 1911*.

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REPORT OF THE BOARD.

SECTION I.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *November 28, 1910.*

The board of officers of the Corps of Engineers of the United States Army detailed to inspect the various reclamation projects has the honor to submit the following report:

2. The board was convened by Special Orders No. 156, War Department, July 6, 1910, and directed to report to the Secretary of the Interior. The duties of the board, as originally outlined, are contained in the following letter of instructions:

DEPARTMENT OF THE INTERIOR,
Washington, July 21, 1910.

Col. JOHN BIDDLE,
Corps of Engineers, United States Army,
President Board of Army Engineers on Reclamation Projects,
Washington, D. C.

SIR: I have the honor to instruct the Board of Army Engineers, constituted under the provisions of an act of Congress, entitled "An act to authorize advances to the reclamation fund * * * and for other purposes," approved June 25, 1910, as follows:

The act itself indicates the scope and functions of the board in the following language: "*And provided further*, That no part of this appropriation shall be expended upon any existing project until it shall have been examined and reported upon by a board of engineer officers of the Army, designated by the President of the United States, and until it shall be approved by the President as feasible and practicable and worthy of such expenditure; nor shall any portion of this appropriation be expended upon any new project," and is interpreted by me to require such examinations of existing projects and methods, and of works and layouts on the ground as will enable the board to intelligently judge of the practicability of the project in an engineering sense, and to report facts and opinions deduced therefrom, in sufficient detail, to enable the President to judge finally of the feasibility and worthiness of such project in an economical sense.

The board will, at their meeting in Washington, consider such information, including printed or written projects, maps, and oral statements, as may be obtained by them, and will thereafter report on any projects that in their opinion may be finally reported upon without personally visiting the localities involved.

It will visit as a board, or by subdivisions of the board, any and all projects concerning which the information obtained is inadequate or unconvincing to the board; and in making such personal visits, inspections, and investigations the board, or its subdivisions, will first visit preferably the projects upon which work is most urgently demanded and in the order of urgency, whenever in its opinion the time and expense required in the examination in such order may justify.

Final reports of the board on individual projects should be sent in as soon as practicable after conclusions are arrived at to me, through Gen. Marshall, consulting engineer, who will indorse his views upon each report in forwarding it to me.

The board will determine for itself the projects to be actually visited and the order in which they will examine them with least hindrance and delay to the work of the Reclamation Service and of the War Department.

The members of the board will, when on duty under this detail, be paid their mileage from the reclamation fund. All other necessary expenses will be paid them through the War Department.

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Such civilian clerks, qualified as stenographer and typewriter, as may be necessary will be detailed to accompany the board.

This order is in lieu of order approved July 6, 1910, which order is hereby vacated.

Very respectfully,

FRANK PIERCE,
Acting Secretary.

Approved:
WM. H. TAFT,
July 28, 1910.

3. These written instructions were subsequently supplemented by oral instructions to investigate all matters connected with the Reclamation Service necessary to enable the board to report fully as to the conditions and needs of each project: to make recommendations as to the abandonment, continuation, or completion of each project; and as to the allotment of funds for future work, both from the regular reclamation fund and from the $20,000,000 loan.

4. The board met in Washington, D. C., July 20, 1910, and undertook a general study of the scope and conditions of the various projects as set forth in the printed reports and records of the Reclamation Service, supplemented by oral statements of the director made at the request of the board. As a result of the preliminary studies it was deemed advisable to inspect all of the projects before submitting a report. These inspections were made between July 28 and October 22, 1910, and, with a few exceptions, all of the projects were visited by all members of the board. Public hearings were held on each project.

5. The board was accompanied by the consulting engineer to the Secretary of the Interior and over most of the projects by the Director of the Reclamation Service. In each of the six geographical divisions into which the work is divided the board was also accompanied by the supervising engineer in charge of the division. The inspection of each project was made under the immediate guidance of the project engineer and his principal assistants. Excellent facilities were furnished by the Reclamation Service, or through it by the citizens living on the projects, which enabled the board to examine thoroughly and quickly all desirable features, including both the engineering structures and lands. The various railroads passing through the projects gave the board every assistance for proceeding rapidly from point to point.

6. In its inspection the board was impressed with the ability of the employees occupying positions of responsibility and desires to record its appreciation of the assistance rendered by them.

7. At the requests of the board there was compiled for each project a memoir containing a history and description of the project and its principal features and pertinent information relative to water supply, lands, costs, and estimates. From these memoirs, supplemented by the annual reports and certain special communications, the statistical data in this report were obtained.

8. Before proceeding to the detailed consideration of each project attention will be invited to certain general features of the work of the Reclamation Service.

9. Twenty-five projects have been undertaken, which involve, including extensions, the irrigation of 3,200,000 acres of arid or semi-arid land, at a cost approximately estimated at $145,000,000. About $60,000,000 have been expended to date and about 600,000 acres are now receiving water. Only part of this area has been formally opened, the

remainder receiving water from the Reclamation Service on a rental basis or through private canals not yet absorbed in the projects.

The reclamation fund to date aggregates $65,700,000, which includes $964,393 received to September 30, 1910, on account of repayment of building charges. The accretions to the reclamation fund during the next four years, as estimated by the Reclamation Service, are as follows:

Years.	Sale of public land.	Repayments.	Total.
1911	$6,000,000	$1,000,000	$7,000,000
1912	5,500,000	1,500,000	7,000,000
1913	4,500,000	2,500,000	7,000,000
1914	4,000,000	3,000,000	7,000,000

11. *Structures.*—The engineering structures are. as a whole. well designed and well built. Some of them, as the Pathfinder Dam, the Shoshone Dam, the Roosevelt Dam, and the Gunnison Tunnel, are monuments reflecting great credit on both designer and builder.

12. Some of the high earth dams, such as the Belle Fourche Reservoir Dam, which has a cross section approaching the limit of safety; the Bumping Lake Dam, the material of which is not entirely suitable; and the Lower Deer Flat Reservoir Dam, where the leakage is considerable, should be kept under close observation.

13. In some cases, for example, as the Lower Yellowstone Dam and the Laguna Dam, it is believed that equally suitable structures could have been constructed at less cost. At one or two places work has been pushed to completion under difficulties due to floods and weather, when reasonable delay would have effected a considerable saving without great detriment to the project.

14. Modern irrigation being a relatively new art in this country, much freedom was allowed local engineers in the design of minor structures. While this was a wise policy in the early stages of this work, it has resulted in some complicated and unnecessarily expensive structures. With the present knowledge of the comparative merits of the different types, it is believed that standard designs of the simplest satisfactory type should be adopted for all minor structures.

15. *Water supply.*—The most uncertain feature of nearly all the projects is the water supply. This is under State control, and in the prosecution of its work the Reclamation Service bears the same relation to the State as a private individual or corporation. In each case the filings have been made under State laws, and in some States special legislation has been enacted to prevent future encroachments on the filings of the Reclamation Service. All of the filings made by the Reclamation Service are, however, subject to the prior filings made by individuals and corporations. Where the water rights have been adjudicated the rights of the United States are well defined, but elsewhere they are uncertain and may prove to be materially different from that assumed.

16. It is recommended that, wherever possible, steps be taken to secure an early adjudication of water rights on all projects where such adjudications have not yet been made, and that, pending such action, expenditures be kept within the probable rights of the United States.

17. On some projects there is a surplus of stored water, which could be advantageously sold if that course were authorized by law. Legislation with this object in view is now pending in Congress. If the sale of surplus water were authorized, certain proposed extensions to cover private land by means of pumping could well be left to private enterprise.

18. *Land.*—In nearly all projects the land proposed to be irrigated will, with proper cultivation and treatment, bear the construction and operation and maintenance charges. In a few cases the payments will be burdensome. In the Garden City and Missouri River pumping projects it is asserted by the settlers that the cost of pumping is prohibitive, but with better farming methods this condition may be changed.

19. Some complaint was made that the adopted sizes of farm units on public land are too small. These vary from 10 acres on part of the Umatilla project to 40 and 80 acres on most of the others. The size of the farm unit was fixed after consideration of the productiveness of the soil, the climate, and the value of the crops that could be raised, the intention being to limit it to an area sufficient for the support of a family. In a few cases there appeared to be some justification for the complaints, but further experience is desirable before any general changes are made.

20. Several Government demonstration farms are maintained by the Reclamation Service at the expense of the projects on which they are located. As a rule, they are not self-supporting, and though the cost to the settlers is not large they form a cause of discontent. Except when self-supporting and needed to supply vegetables and forage for Government use, it is believed that the maintenance of such farms should be left to the Agricultural Department.

21. *Cost.*—The actual cost of completed work has almost invariably exceeded the original estimates, and in the case of some structures has been two or three times as large. This increase in cost has been the cause of much of the discontent among the settlers. It was partly due to a general increase in the cost of labor and materials, partly to underestimates and an insufficient allowance for contingencies, and partly to the necessity of doing more work than was originally contemplated.

22. *Estimates.*—The estimates of cost for completion adopted by the board are taken from the reports submitted by the supervising engineers, supplemented by estimates furnished by the Director of the Reclamation Service. These estimates are based on the experience gained on work already done. In some cases they are approximate only, and will require modification after further surveys and studies are made.

23. Some increase in estimates may be necessary, due to insufficient allowance for drainage. This is an important feature of the reclamation work, particularly when the farmers are not experienced in the economical use of water. The actual needs of the work in this respect can seldom be foreseen with any definiteness, and in consequence drainage on many of the projects has been left to be developed as the need arises.

24. In only a few of the estimates submitted by the Reclamation Service has any allowance been made for an interest charge. As interest at the rate of 3 per cent must, under certain conditions, be

paid on the whole or part of the $20,000,000 loan authorized by Congress to the reclamation fund, some additions to the estimates on this account will probably be necessary. Assuming that expenditures from this fund are made at a uniform rate during five years, that the repayments to the Treasury are made at a uniform rate during the following five years, and that interest must be paid for the entire period, the total interest charge would be equivalent to 3 per cent on $10,000,000 for 10 years, or $3,000,000. As it has not yet been determined whether this interest charge is to be spread over all the projects or parts of projects upon which the building charge has not yet been announced, or whether it is to be confined to projects upon which the loan is used, it is impracticable to state its effect on any particular project. It is believed, however, that the result of this added charge, whichever method is adopted, will not be sufficient to adversely affect the feasibility of any of the projects from an economic standpoint.

25. *Returns to the reclamation fund.*—The reclamation act contemplates the return to the fund of the estimated cost of the different projects and the work has been prosecuted on that basis. The estimated cost is held by the Reclamation Service to be that officially announced by the Secretary of the Interior when the project is opened, and not the preliminary estimates made when the project was undertaken, as was assumed by many of the owners of private lands within the projects. On the assumption that the announced building charge is the estimated cost contemplated by the act, the losses to the reclamation fund, except on four of the projects, which will be referred to hereafter, will be relatively small, though, by reason of the number and large size of some of the projects undertaken, the repayments will extend over many years. If, on the other hand, the term "estimated cost," as used in the act, should hereafter be judicially determined to mean the preliminary estimate made when the project was undertaken, very large losses to the fund will occur.

26. In many of the projects the announced building charge on certain units has been less than the actual cost, but it is expected to compensate for these losses by making the building charge on remaining units correspondingly larger than the actual cost. In the case of public lands such adjustments can undoubtedly be made, but in the case of private lands it is questionable whether they can be required to pay any more than the proper proportion of the actual cost of the work pertaining to the unit in which the lands are situated. If this be true, the probable losses to the fund will be considerably greater than is indicated in the detailed reports.

27. On nearly all of the projects the Reclamation Service deals with the landowner through a water users' association. This is an incorporated body, in which each member holds as many shares of stock as he has acres of irrigable land within the project. In most of the associations the par value of the stock was fixed at what was apparently the originally estimated construction charge per acre. The land covered by the stock subscriptions of its members is bound by means of a contract between the association and the Reclamation Service.

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28. The associations being formed in different States, vary in character and the contracts are not all alike. In most of them, however, it is provided that upon the formal opening of the project each holder of stock shall make a water-right application. If he does so, his land becomes bound for the repayment of the announced building charge. If he fails to do so, he can be dropped from the association and the lien foreclosed, but the liability in this case is apparently limited to the par value of the stock.

29. As the probable construction charges on many uncompleted projects will exceed the par value of the stock of the Water Users' Association, due regard for the security of the investment requires that the par value of the stock be correspondingly increased or other means taken that will accomplish the same purpose.

30. A positive loss will occur on the lower Yellowstone project even under the most favorable conditions of completion, and in the Missouri River and Garden City pumping projects and in the Hondo project large losses appear to be inevitable.

31. Under existing regulations the construction charges must be returned to the reclamation fund in 10 equal annual payments. This is regarded as a hardship by the settlers on some projects, who expressed a desire for a series of graduated construction payments increasing from 1 or 2 per cent the first year to 14 or 15 per cent the tenth year. Should this suggestion be generally adopted, it would mean a delay of several years in the return of the first half of the investment and a corresponding delay in the completion of other work.

32. On some of the projects in the semiarid regions such a modification in the terms of payment may be necessary to prevent an absolute failure of the project, but the general adoption of a system of graduated payments is not believed to be necessary or advisable.

33. *Ownership of land.*—Table No. 1 shows the amounts of public, State, and private land under the various projects. By public land is meant land in Government ownership, which has been or can be filed on subject to the terms of the reclamation act. In some cases land was entered shortly before withdrawal of adjoining land under the expectation that the project would be undertaken. The title in these cases did not become vested in the homesteader until several years after work on the project had been started, and in a sense such lands were quasi public. At that time, however, as the owners were under no obligation to enter the project and as they could not be compelled to reduce their holdings below the acreage specified for private lands, the lands so held were essentially in private ownership and have been so classed. It is stated by the Director of the Reclamation Service that the area of land so entered is not large.

34. State lands included within a project are not, as a rule, bound to repay the construction charge. In many cases, however, the State has agreed to dispose of its land in tracts of the size adopted for the farm units with the provision that the purchaser shall apply for water and assume the building charge. There is no method of enforcing the sale of such lands nor any assurance that they will be sold within a given time. In some instances, delays of this character may adversely affect water rights and delay or reduce anticipated returns to the reclamation fund. Closer cooperation between the State and the Nation seems desirable.

35. In forming its opinion as to the merits of the different projects, the board has been guided by the following general considerations:

(1) Feasibility from an engineering and an economic standpoint.

(2) Character from a geographic standpoint, whether international, interstate, or intrastate.

(3) The relative amount of public land entered or subject to entry under the reclamation act.

(4) The amount of money already expended and the necessity of completion in order to insure its return, regardless of the second and third considerations.

(5) The protection of water rights pertaining to desirable extensions as contemplated by the act of Congress authorizing advances to the reclamation fund.

(6) The existence of agreements with water users' associations, private individuals, and corporations.

36. In making the amount of public land one of these considerations the board is actuated by the belief that the primary object of the reclamation act was the reclamation of public land with incidental benefits to such adjoining private land as must, in nearly all cases, be included in the project in order to make it feasible from an economic or an engineering standpoint.

37. While the community as a whole will profit by the reclamation of private lands, the greater portion of the benefits resulting from such expenditures of Government funds accrues to the original owners, and this without any investment on their part. For instance, in the Tieton unit of the Yakima project, which involves only 6 per cent of public land, the inauguration of the project increased the value of private holdings from a merely nominal sum to about $150 per acre. These private holdings, some of which were large, are being divided up and sold to settlers, who will be required to pay the construction charge of $93 in addition to the above price.

38. In undertaking projects where the direct Federal interests are small it would seem no more than equitable to add an interest charge to the cost of reclaiming private land or to require that a percentage of the private holdings be deeded free of cost to the United States, the areas so deeded to be subsequently thrown open to entry under the homestead law as modified by the reclamation act.

39. A description of the various projects containing the recommendations of the board follows. It is supplemented by Table No. 2, giving the total estimated cost of each project, the allotments to date, and the suggested allotments.

Respectfully submitted.

JOHN BIDDLE,
Lieutenant Colonel, Corps of Engineers.
W. C. LANGFITT,
Lieutenant Colonel, Corps of Engineers.
WM. W. HARTS,
Major, Corps of Engineers.
C. W. KUTZ,
Major, Corps of Engineers.
H. BURGESS,
Major, Corps of Engineers.

The SECRETARY OF THE INTERIOR
(Through Consulting Engineer to the Secretary of the Interior).

TABLE No. 1.—*Lands.*

[To accompany Section I.]

Projects.	Total area.	Public lands subject to reclamation act.	Private lands.	State and school lands.	Lands under irrigation, 1910.	Lands open to entry, 1910.	Remarks.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	
Salt River	230,000		216,000	14,000	127,000		Area dependent on water supply.
Yuma	131,000	74,000	57,000		7,000		Includes mesa lands.
Orland	14,000		14,000				Proposed extensions not included. Partly under irrigation from privately operated ditches.
Grand Valley	53,000	30,070	22,930				
Uncompahgre	140,000	34,000	106,000		40,000		Present irrigation largely from private ditches.
Minidoka	124,500	101,600	3,100	19,800	62,000		
Payette-Boise	243,000	85,820	127,130	30,050	30,000		
Garden City	10,655		10,655				Part of land irrigated with flood water.
Huntley	32,844	28,754	4,090		12,000	6,000	
St. Mary Milk River	196,000	76,000	110,000	10,000	8,000		Area dependent on water supply. Irrigated at present with flood water.
Sun River	322,000	244,500	52,500	25,000	11,000	2,743	Area may be largely reduced on account of water supply.
Lower Yellowstone	62,280	17,000	43,280	2,000	7,000	1,600	
North Platte:							
North Side (interstate)	129,270	83,358	34,864	11,048	51,218	3,465	
Goshen Park	210,000	152,900	44,100	13,000			Area indefinite, as surveys are incomplete.
Truckee-Carson	206,000	120,000	86,000		32,000		Area dependent on water supply.
Carlsbad	20,047	20	20,027		14,000		
Hondo	10,000	240	9,760				A small area irrigated with flood water.
Rio Grande:							
New Mexico	110,000	12,000	98,000		50,000		Irrigated lands lie both in Texas and New Mexico.
Texas	45,000		45,000				
Missouri pumping:							
Buford-Trenton	12,035	1,400	10,635		400		
Williston	11,147	1,000	10,080	67	2,000		
Umatilla	25,000	4,120	20,880		15,319	2,000	Does not include proposed extension.
Klamath:							
Lower project uplands	37,000	700	36,300		18,471		Lower Klamath Lake marsh lands omitted.
Tule Lake	35,000	31,900	3,100				
Upper subproject	16,000	1,500	14,000	500			
Modoc subproject	18,000	9,000	8,000	1,000			
Bellefourche	100,000	44,500	50,000	5,500	23,500	2,946	
Strawberry Valley	60,000		60,000		30,000		Does not include proposed extension.
Okanogan	8,650	1,100	7,550		4,000		Do.
Yakima:							
Sunnyside	98,596	1,346	95,980	1,270	50,000		
Tieton	34,500	2,034	30,184	2,282			In part under flood irrigation.

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Kittitas	67,890	4,240	61,410	2,240	.....	.....	
Wapato	114,000	.....	114,000	.....	.....	.....	This is all Indian land and partly under flood irrigation.
Benton	150,000	50,000	90,000	10,000	.....	.....	Land unsurveyed and areas approximate.
Shoshone	164,000	153,000	1,500	9,500	15,000	14,347	Area may be largely reduced on account of water supply.
Totals	3,241,414	1,366,102	1,718,055	157,257	609,908	.....	

TABLE 2.

[To accompany Section I.]

Project.	Total estimated cost.	Allotments to Dec. 31, 1910.	Allotments required to complete.	Allotments recommended 1911–1914, inclusive.		Required to complete after 1914.
				Fund.	Loan.	
Salt River	$9,665,000	$9,170,000	$495,000	.....	$495,000	(1)
Yuma	7,700,462	4,120,000	3,580,462	$2,380,462	1,200,000	(1)
Orland	607,335	608,000	.....	.....	.....	(1)
Grand Valley	3,621,663	225,000	3,396,663	[2] 500,000	[2] 1,000,000	[2] $1,896,663
Uncompahgre	9,000,000	4,455,000	4,545,000	2,045,000	1,500,000	1,000,000
Minidoka	4,505,000	3,977,000	528,000	528,000	.....	(1)
Payette-Boise	10,852,435	4,267,000	6,585,435	4,585,435	2,000,000	(1)
Garden City	419,000	419,000	.....	.....	.....	(1)
Huntley	1,040,000	955,000	110,000	110,000	.....	(1)
Milk River	6,891,000	941,000	5,950,000	2,950,000	1,000,000	2,000,000
Sun River	10,000,000	722,000	9,278,000	3,278,000	.....	6,000,000
Lower Yellowstone	3,523,000	2,945,000	578,000	[2] 578,000	.....	(3)
North Platte:						
Interstate	5,070,000	5,135,000	14,835,000	2,185,000	2,000,000	10,650,000
Goshen Park	14,900,000					
Truckee-Carson	7,000,000	4,213,000	2,787,000	1,594,000	1,193,000	(1)
Carlsbad	605,000	605,000	.....	.....	.....	(1)
Hondo	359,000	359,000	.....	.....	.....	(1)
Rio Grande	9,665,000	1,310,000	8,355,000	1,855,000	4,500,000	2,000,000
Missouri Pumping	1,195,000	983,000	270,000	[2] 270,000	.....	(3)
Umatilla	1,650,000	1,325,000	325,000	.....	325,000	(1)
Klamath	4,470,195	2,334,000	2,136,195	.....	600,000	1,536,195
Belle Fourche	3,150,000	2,670,000	480,000	480,000	.....	(1)
Strawberry Valley	3,407,000	1,135,000	2,272,000	.....	2,272,000	(1)
Okanogan	590,000	603,000	13,000	13,000	.....	(1)
Yakima:						
Sunnyside	3,148,000	4,711,000	18,145,000	.....	1,250,000	(1)
Tieton	3,185,000			.....	665,000	(1)
Kittitas	4,525,000			.....	.....	4,525,000
Wapato	4,205,000			.....	.....	4,205,000
Benton	7,500,000			.....	.....	7,500,000
Shoshone	7,828,000	3,828,000	4,000,000	2,000,000	.....	2,000,000
Total	.....	61,885,000	88,664,755	25,351,897	20,000,000	43,312,858

[1] Completed. [2] Conditional. [3] Completed; conditional.

NOTE.—The allotments to December 31, 1910, include allotments for operation and maintenance.

FINANCIAL SUMMARY.

Balance unallotted	$3,000,000
Estimated receipts 1911–1914	28,000,000
Loan	20,000,000
Total	51,000,000
Allotments recommended	45,400,000
Operation, maintenance, and contingencies	5,600,000
Total	51,000,000

SECTION II.

SALT RIVER PROJECT, ARIZONA.

1. The board visited the Salt River project on October 8, 9, and 10, visiting the Granite Reef Diversion Dam on October 8, the Roosevelt Storage Dam on October 8 and 9, and the irrigated lands in the vicinity of Mesa and Phoenix on October 10. A public hearing was held in Phoenix on October 10.

2. *Location and description.*—The Salt River project is one of the larger projects of the Reclamation Service and involves many

engineering features of magnitude and difficulty. It is located on the Salt River in the vicinity of the towns of Mesa and Phoenix, Ariz., and contemplates the irrigation of about 230,000 acres of land, mainly in private ownership.

3. From an early date efforts were made by private owners of lands in the vicinity of Phoenix to divert water from Salt River to their lands, and a series of canals and ditches were constructed both north and south of the river heading from various diversion dams. The earliest canal, called the "Swilling," was commenced in 1868. In the course of time many thousands of acres, finally amounting to 151,000, were irrigated in a more or less insufficient manner.

4. The present site of the storage dam was originally in the hands of private owners, who expected to use it for the construction of storage works at some future time. The frequent destruction of the diversion dams by floods and the lack of financial means among the owners to build and maintain better structures and to provide storage led the Reclamation Service to undertake this project.

5. The waters of the Salt and Verde Rivers are used for irrigation. Owing to the large discharge during certain periods of the year and the low discharge in others, storage was found to be necessary to regulate the flow, the amount of water available being sufficient to irrigate large areas if properly conserved.

6. The project includes, first, a storage dam; second, a diversion dam to divert water into the canal system; and third, a system of distributing canals, carrying the water over the project.

7. In operating the works stored water is released into Salt River as needed and flows for a distance of about 60 miles in the natural channel to Granite Reef Diversion Dam, where the river flow is diverted both to the north and south sides of the river into the distributing system. This water supply is to be supplanted by electric pumping over a considerable area. The works of the project are now nearing completion.

8. *Transportation.*—Several railroads traverse the project, which furnish facilities for the transportation of products, the most remote points of the project being less than 15 miles from some railway station.

9. *Construction features.*—The most important feature of the project, and the only one contemplated at the beginning, is the storage dam. This was formerly called the Tonto Dam, but is now known as the Roosevelt Dam, and is located in the canyon of the Salt River a few hundred feet below the mouth of Tonto Creek. It is built in a narrow rock gorge, is 278 feet high, 235 feet long on the bottom, and 1,080 feet long on top, including spillways, and 680 feet excluding them. It is curved in plan, with a radius of 480 feet, and has a gravity section. It is built of uncoursed cyclopean rubble, except the faces, which are laid in 2 and 3 foot courses. The material is a quartzite which was obtained from the excavation for the spillways, one of which is located at each end of the dam. The spillways are crossed by reenforced concrete arch bridges, connecting the top of the dam with the banks and providing a roadway across the river along the top of the dam.

10. In the construction of this dam, which contains 341,244 cubic yards of masonry, a number of preliminary steps were necessary. A freight road to Mesa, 60 miles long, was built, one to Globe, 40 miles

long, and one to the nearest body of timber, about 30 miles distant, where 3,000,000 feet of lumber were cut on the public forest reserve for use on the project.

11. The high expense of transporting cement induced the reclamation engineers to build their own cement mill, after having found satisfactory material near by. This mill was put in operation in 1905, and supplied 338,452 barrels of cement. The total cost of this mill and its operation is given as $1,055,146, or about $3 per barrel.

12. Owing to the scarcity of fuel, power was supplied from a power canal about 19.5 miles long, taking water from the Salt River. The capacity of this canal is 250 second-feet, and it utilizes a fall of 226 feet. It was built through very difficult country and has 21 tunnels and 3,600 feet of twin concrete-steel conduits. It developes 4,400 horsepower.

13. The results seem to justify the wisdom of these steps. Considerable saving in the cost of cement is reported to have been made, and the electrical power was almost wholly depended upon during construction. When not needed at the dam site this power will be sold in the towns of Phoenix and Mesa, thus diminishing the expense of operation and maintenance after the completion of the system.

14. Sand for mortar and concrete was obtained by crushing the quartzite and dolomitic country rock for which sand crushers were installed.

15. Work on the dam under the contract was begun in 1905, and is now nearly finished. Its cost has been $3,009,991.33. The capacity of the reservoir is 1,284,000 acre-feet. Its area is 16,320 acres. Water may be released from the reservoir at three levels—first, through the sluicing tunnel in the bottom of the dam, by which the reservoir may be emptied; second, by the steel penstock, 10 feet in diameter, which is to supply water for the power house; third, a tunnel on the right bank at an elevation of 115 feet, to which water is to be admitted through three cast-iron pipes, 5 feet in diameter.

16. The water released from the storage dam is diverted into the distribution canals by the Granite Reef Diversion Dam. This dam is of mass concrete and raises the water surface 20 feet. It is an overflow weir, 1,000 feet long, 26 feet high, and has an apron 75 feet wide and 18 inches thick. At each end are canal headworks provided with sluicing gates in the main dam to remove silt from the canal entrance.

17. The canal system has practically all been purchased. The canals on the north side were bought by the Reclamation Service for $314,160.99, including the Arizona, Grand, Maricopa, Salt River Valley, and Cross-Cut Canals. Of these, the Arizona and Grand Canals are now being enlarged. On the south side of the river a new canal, called the South Canal, was built for a length of about 2 miles, to connect with the existing south-side system. Near its lower end a temporary by-pass admits water into the Consolidated Canal, supplying a private system, which was purchased for $187,000. This Consolidated Canal supplies the Utah and Mesa Canals and part of the Tempe Canal, and is now being enlarged. The East Canal heads in the South Canal near the by-pass, and has been constructed by the Reclamation Service. This was started under the "Certificate" plan of compensation, but this method of payment was stopped after $34,615.87 had been expended, and the canal was completed by the contractor at his own expense, and then sold to the Government for

$89,954.56. The minor structures now being built in the distribution system are usually of concrete and are simple and effective. In general, the engineering works on this project show careful design and construction.

18. *Water supply.*—Water is obtained for this project from the Salt and Verde Rivers, and from wells. Salt River has a drainage basin of 6,260 square miles, and the Verde River of 6,000 square miles, the average rainfall being 15 inches. The average annual run-off of Salt River at Roosevelt Dam is 800,000 acre-feet, and of the Verde River at McDowell, 580,000 acre-feet. The run-off fluctuates widely throughout the year, and the annual fluctuations are also large. From the Verde River only the unregulated flow is at present available. On Salt River, as already stated, storage has been provided in Roosevelt Reservoir for 1,284,000 acre-feet.

19. Discharge measurements of these rivers have been made since 1889, and assuming the reservoir as built at that date studies have been made by the Reclamation Service of the amount of water that would have been annually available from the unregulated flow of the Verde River and the annual draft on storage water necessary to supply an annual use of 760,000 acre-feet, this being the amount required for 190,000 acres at the assumed duty of 4 acre-feet per acre.

20. These studies show that during 15 years of the 20-year period under consideration there would have been a sufficient supply of water. During the remaining years, with an assumed evaporation loss of 4.42 feet, there would have been shortages as shown in the following table:

	Per cent.
1900	9
1901	6
1902	45
1903	28
1904	38

21. The evaporation loss of 4.42 feet per annum is that recently determined by the director of the experiment station at Tucson, Ariz., and is the net loss after subtracting the rainfall. Former measurements extending over a number of years indicated an evaporation loss of 7.58 feet. Had this loss been assumed, the shortages above indicated would have been correspondingly increased.

22. The above studies are also based upon the right of the United States to impound in Roosevelt Reservoir for use in the project the entire flow of Salt River at this point. This right, however, will not exist unless all of the irrigable land in the valley possessing prior water rights becomes a part of the project. By an adjudication of the water rights in this valley, dated March 1, 1910, the various claims to the flow of the Salt and Verde Rivers are defined as to amount and priority. These claims cover 151,000 acres of Class "A" land and a diversion of 45,325 miners' inches, equivalent to 1,133 second-feet. This adjudication limits the right to impound water in the Roosevelt Reservoir in the following terms:

The daily flow in the Salt River shall not be impounded by the Government by means of the Roosevelt Dam in the reservoir, except when the total intake in such reservoir, including the estimated loss thereto by seepage and evaporation between such intake and the conflux with the Verde River, added to the flow of the Verde River shall exceed the amount called for in Table 10 (45,325 miners' inches) plus the amount to be added thereto for loss by evaporation

and seepage in the canals, unless at the request or with the assent of the users of such water whose land is entitled thereto; and no water user entitled thereto shall be deprived against his consent of his proportionate share of the normal flow of the river by reason of such impounding dam. The Government, in times of flood water, shall not, by impounding water in the reservoir, lessen the proportionate share of such flood water of any individual landowner not a member of the water users' association and against his consent, nor shall it lessen the proportionate share of the Tempe and San Francisco Canals, or of either of them, to such flood water available to such canals, so as to deprive such canals of such proportion of such flood water desired when the land lying under such canals is in need of such water or any portion thereof and can avail of it and when such canal company shall notify the commissioner of its desire to divert such water or any portion thereof. The various parcels of land in the valley in cultivation are entitled to share equally, according to acreage, in the use of the flood water available; the proportionate share in the flood water of the Tempe and San Francisco Canals is therefore to be measured by their relative acreage under cultivation, since the share of the land under the other canals listed in the association in the flood water in the Salt River can now be stored for them in the Roosevelt Reservoir. The acreage under the Tempe Canal is found to be approximately 16 per cent of the total acreage in cultivation. The acreage under the San Francisco Canal is found to be approximately 3 per cent of the total acreage under cultivation. The amount of flood water to which the Tempe and San Francisco Canals shall be entitled to receive, as above stated, is therefore 16 per cent and 3 per cent, respectively, of the total amount of flood water available.

23. A large percentage of the users of water are members of the Salt River Valley Water Users' Association, and as such have agreed to merge their water rights with those of the United States, but as there are at least 20,000 acres of land under the Tempe and San Francisco Canals not yet included in the project, it is evident that not all of the flow at the Roosevelt Dam can be impounded.

24. To what extent a strict compliance with the court's decree will affect the storage possibilities of the reservoir can not be determined from the information available, but it will probably necessitate reducing the area under the contemplated gravity unit by at least 10,000 acres.

25. In the adjudication referred to above the duty of water at the farm is assumed at 1 miner's inch continuous flow for each 160 acres, equivalent to about 5 acre-feet per acre per annum. To determine the amount to be diverted, seepage and evaporation losses in the canals are added at the rate of 1 per cent per mile. The Reclamation Service assumes a duty of 4 acre-feet per acre, which, in view of the character of the land and the length of the season, is believed to be small.

26. The shortage that would have existed in the past had the entire flow of the Salt River been impounded, the necessary reduction in the amount impounded to provide for prior rights, and the high duty of water assumed all lead to the belief that the water supply is insufficient for the proper irrigation of the 190,000 acres under the gravity unit.

27. *Lands.*—The proposed total acreage under this project is 230,000 acres, the area to be irrigated depending upon the quantity of the water supply available, which has not yet been fully determined. There is more land suitable for irrigation than can be supplied with water. All of the land is in private ownership, of which 14,000 acres are school lands. It is expected by the Reclamation Service that about 190,000 acres will be irrigated by gravity and the remainder by pumping from wells. The power which is available at various points of the project is to be developed and used for this purpose.

28. Already some pumping from wells has been done under private enterprise in the valley, lifting the underground water to the surface for irrigation. The results are sufficiently promising to warrant the extension of this practice if the wells are sufficiently free from salt to be used for irrigation. Some of these wells are found to be decidedly alkaline, but by mixing the well water with the canal water it is hoped that it will be sufficiently diluted to be suitable for irrigation.

29. The elevation of the irrigated lands is about 1,200 feet above sea level. The range of temperature is from 20 to 120° F., a mean of about 70°, and the rainfall over the irrigated area varies from 3 to 10 inches, being entirely too small for any cultivation. The lands have practically no value unless irrigated.

30. The duty of 4 acre-feet at the farm is small, in view of the character of the land and the length of the season, but is acceptable to people interested, who prefer irrigation on this basis rather than having a greater quantity over a smaller area. Two crops are often raised in the same season from the same area.

31. There are at present 127,000 acres under cultivation. This area is largely made up of lands heretofore irrigated under private systems, which are now being furnished water under the present project. The land is very productive. Over 50 per cent of this land is planted to alfalfa, and returns from six to seven cuttings annually, varying from one to two tons a cutting per acre. Considerable success has also been met in raising citrus fruits and dates.

32. The land is valued at from $100 to $400 per acre, the average being about $160 per acre. The higher price is asked for bearing orange groves. The average value of land before the project was commenced was about $45 per acre. There seems little doubt that the land is able to return to the United States a reasonable expenditure for irrigation. This amount has not yet been determined, but will probably be between $45 and $55 per acre.

33. Until recently, the lands of the project have been irrigated under private canal systems. Those farmers who were formerly furnished an inadequate supply of water were, in consequence, desirous of subscribing for the more reliable supply of the Reclamation Service system, and formed the Salt River Water Users' Association in February, 1903, to facilitate the construction of the project. Those who have withheld from subscribing their lands have generally earlier water rights and a satisfactory supply. About 218,000 acres are already under agreement to take water, but the land under the Tempe Canal, amounting to about 25,000 acres, has one of the best water rights and, except about 7,000 acres, has been withheld. About 5,000 acres under the San Francisco Canal have also not been subscribed, nor have the lands of the Indian reservation, lying at the eastern end of the Arizona Canal, which have been allowed a prior right to 700 miner's inches by court decision. It is expected by the Reclamation Service that much of this land, both private and Indian, will gradually come under the project.

34. *Cost.*—The total cost of this project up to June 30, 1910, has been $8,959,760.54. There has been allotted from reclamation funds $9,170,000. The project is over 80 per cent completed.

35. Under an agreement with the property owners under this project, an assessment of $4.50 per acre is to be made for the completion of the power plants and the enlargement and construction of

canals to expedite the work. This will avoid the necessity of obtaining more money from the reclamation fund for this purpose. In consideration of this contribution the opening of the project has been delayed two years. The work to be done with these funds is as follows: First, the construction of the Salt Lateral, a lined ditch about 2½ miles long; second, the completion and enlargement of the present Grand Canal; third, the construction of the new Crosscut Canal connecting the Arizona and Grand Canals; fourth, the construction of a power house to develop 6,000 horsepower between the new Crosscut and the Grand Canals; fifth, the construction of a power house between the South and Consolidated Canals to develop 3,000 horsepower; sixth, the construction of a power house at the Arizona Falls on the Arizona Canal to generate 700 horsepower.

36. The remaining work necessary and the estimate of cost are as follows:

Enlargement, Arizona Canal	$72,000
Pumping plants and wells, Messa district	48,000
Purchase Consolidated Canal	87,000
Materials	15,000
Power substation, Mesa	10,000
Waste gates, Arizona Canal	20,000
Wells and pumping plant, Tempe district	60,000
High Line Canal for drainage	65,000
Division gates, Consolidated Canal	8,000
Miscellaneous	35,000
	420,000

If the Tempe Canal comes in, the following will be needed:

Wells and pumping plants for drainage	$30,000
Power substation	25,000
High Line Canal for drainage	20,000
Total	495,000

This amount added to $9,170,000 already allotted will make the total cost of the work $9,665,000. If the area to be irrigated be taken at 230,000 acres, as now assumed by the Reclamation Service, the cost of construction will be about $42 per acre. This does not include $4.50 per acre voluntarily contributed by the water users' association to facilitate the completion of the project.

37. If the supply of water should be insufficient for the area of 190,000 acres assumed as the amount of land which can be irrigated by the gravity system, this price would need to be raised. The amount of water available for the areas to be irrigated by pumping is unknown, and if this should fall short the charge per acre to cover the cost of construction would need to be further raised. This increase might be as much as 25 per cent.

38. *Power.*—Water power will be developed at various points in the project, as follows:

(1) Roosevelt Dam, through reservoir, maximum horsepower, 5,200.

(2) Tempe Crosscut, maximum horsepower, 6,000.

(3) South Canal, maximum horsepower, 3,000.

(4) Arizona Canal Falls, maximum horsepower, 700.

At the dam the power canal now completed has a maximum horsepower of 4,400.

39. In purchasing the existing canal system certain obligations were assumed by the Reclamation Service for the supply of electricity to the Phoenix Railway & Light Co. The power canal used in the construction of the Roosevelt Dam is now applied to the generation of electricity for this company, with whom a 10-year agreement has been made, the electricity being furnished at the rate of 1½ cents per kilowatt hour for this period. No restrictions were included in this agreement as to the amount this company should charge the people of Phoenix. The receipts are used to diminish the operation and maintenance of the canal system.

40. The enlargement of the canals has been expensive, owing to the necessity of carrying on work while the ditches were in use, as the irrigation season lasts throughout the entire year on this project.

41. *Summary.*—(1) This project is located within the limits of the Territory of Arizona.

(2) The area in the project amounts to about 190,000 acres under the gravity system and about 40,000 acres by pumping. There is no public land subject to the reclamation act.

(3) It is doubtful whether the water supply is sufficient for the whole area proposed.

(4) The total estimated cost is $9,665,000, of which about $9,000,000 has been expended. The project is over 80 per cent completed.

(5) The land can readily return a cost of construction of from $45 to $55 per acre.

(6) The project is feasible both from an engineering and an economical standpoint.

(7) The large expenditures already made and the benefit that will follow completion make it desirable to continue work as rapidly as economically practicable until finished.

(8) Allotments: The following allotment is recommended for the four years, 1911–1914, inclusive:

From the loan $495,000

SECTION III.

YUMA PROJECT, ARIZONA-CALIFORNIA.

1. This project was visited by the board on October 7, 1910, and a public hearing was held at Yuma in the evening of that day.

2. *Location.*—The project lies along the Colorado River between the Mexican boundary and a point 40 miles north of it, in Arizona and California. It is, therefore, interstate in character. The Southern Pacific Railway passes through the project from east to west, about one-third of the project lying to the north and two-thirds to the south.

3. *Description.*—A portion of the project, comprising 16,000 acres of Indian reservation land, lies in California, the remainder, 115,000 acres, lying in Yuma County, Ariz. Of this area, 55,000 acres are bottom lands between Yuma and the Mexican boundary; 20,000 are in the lower Gila Valley above Yuma; and 40,000 acres are mesa

lands south and east of Yuma. The water for the project will be taken from the Colorado River. The main engineering features of the project comprise a diversion dam in the Colorado River about 15 miles above Yuma; two main canals leading from it, one on each side of the river; a siphon across the Colorado River at Yuma; levees along the Yuma and Gila Rivers; and the subsidiary distribution systems. The canal leading from the dam on the California side of the river is the main canal of the project, having a capacity of 1,700 second-feet. As this canal passes through the Indian reservation laterals are led from it to irrigate the lands belonging thereto. At one point in this canal there will be a drop of 12 feet, at which it is proposed to develop 1,000 horsepower, which will be transmitted electrically and used to pump water for irrigating mesa lands. This canal is to be carried across the Colorado River in a concrete siphon, after which it divides and supplies water for the lands in the project below Yuma on the Arizona side of the river. The main canal on the Arizona side covers that portion of the project lying in the Gila Valley. The Laguna Dam, as the diversion dam is called, is of the Indian weir type and raises the water surface of the river at low water about 10 feet. In order to keep silt out of the canals, arrangements are made at the headworks on both sides of the river to admit only the upper layers of water and to sluice into the river below the dam any deposits in front of the canal headworks. The siphon consists of two shafts about 100 feet deep, one on each bank of the river, connected by a tunnel 14 feet in diameter, the shafts being 17 and 23 feet in diameter on the California and Arizona sides, respectively. There will be required 75 miles of levee to protect the irrigated areas, and of this amount 40 miles have been completed. A drainage system will also be necessary and is provided for in the estimates.

4. When this project was taken up there were in the valley four inefficient private irrigation systems, of which three were purchased by the Reclamation Service on account of their rights of way and the desirability of adding to the project the lands covered by them. One of these systems was operated by pumping, one had an abandoned pumping system, and one was a gravity system which had silted up. Since their purchase both pumping plants have been put in order and an additional pump added. The three pumps have been operated by the Reclamation Service. The first cost of these purchases was as follows:

Canal system and steam pumping plant	$63,260.60
Canal system and scoop wheel pumping plant	89,614.14
Additional pump	400.69
General expenses, undistributed	4,041.99
Total	157,317.42

5. *Water supply.*—The water supply is obtained from the perennial flow of the Colorado River without storage. Its drainage area comprises approximately 300,000 square miles. The rivers of the Colorado system receive their main supply from the melting snows on the mountains in Wyoming, Utah, and Colorado. The low-water discharge of the Colorado is from 3,000 to 4,000 second-feet, while the flood discharges, beginning in March and April and reaching the crest in June, may amount to 150,000 second-feet. The duty of

water is taken as 5.5 acre-feet per acre per year. The following table, furnished by the Reclamation Service from records made by its officials during 16 years, indicate the excess of water over that required by the project in the minimum monthly flow of the Colorado River at Yuma:

Month.	Minimum run-off (acre-feet).	Duty in feet.	Area of possible irrigation.
January	185,407	0.20	927,000
February	182,531	.25	730,000
March	367,702	.30	1,220,000
April	479,663	.41	1,170,000
May	1,670,000	.52	3,200,000
June	2,550,000	.70	3,650,000
July	1,411,995	.90	1,570,000
August	598,366	.80	750,000
September	386,456	.56	690,000
October	494,160	.38	1,300,000
November	321,271	.26	1,230,000
December	266,598	.22	1,210,000

[1] Area in project, 131,000 acres.

The amounts in the second column are the minimum run-offs that occurred during the months named in the 16 years of observation. There will be, therefore, ample water for the project, after satisfying prior rights, to cover 200,000 acres now irrigated under private enterterprise in the Imperial Valley below. The Imperial Valley Irrigation Co. has filed on 10,000 second-feet additional, but as beneficial use of it has not yet been made, the claim will probably not be allowed in full, but restricted to an amount that will cause no interference with the Yuma project.

6. *Lands.*—The irrigable land in the different units is as follows:

Units.	Public.	Private.
Gila Valley	10,000	10,000
Yuma Valley	10,000	45,000
Mesa lands	38,000	2,000
Indian lands	16,000	.....
Total	74,000	57,000

The average size of the private farms in the project is 120 acres. The average annual rainfall over the irrigable area is 2½ inches and its elevation above sea level is from 100 to 300 feet. Dry farming is not possible. The climate is semitropical, though temperatures below freezing have occurred. All the lands in this project except the mesa lands are " valley " lands of great depth and richness, and it is expected that they will produce alfalfa, grains of all kinds, pears, dates, figs, apricots, melons, citrus fruits, vegetables, grapes, small fruits and berries, and cotton. By proper alternation two or more crops a year can be grown. From 5 to 7 cuttings of alfalfa per year are usual. At the present time this is the only single crop of consequence, there being 1,500 acres devoted to it. In 1909 the gross value of the crops on the 7,000 acres irrigated by pumping was $87 per acre. Lands are now worth from $50 to $100 per acre without water, and land in alfalfa is selling at from $150 to $200 per acre. Citrus-

fruit lands will be much higher. The mesa lands are especially adapted to these fruits. There would seem to be no question but that the land will be able to bear the construction cost, and this was emphatically so stated at the public meeting, the main desire of all being the early completion of the work.

7. Drainage is necessary in some parts of the project, for which the United States will construct only the main ditches. Levees, as stated above, are necessary along the Gila and the Colorado Rivers to prevent overflow. The cost of both the drainage and the levees is included in the estimates of the cost of completion.

8. *Lands now irrigated.*—In the Yuma Indian Reservation there are 700 Indians. The law gives each Indian 5 acres, or a total of 3,500 acres, leaving 12,500 acres for settlement, but on account of the possibility of an increase of the acreage allowed to each Indian, only 6,500 acres have been opened for settlement. This was done in March last, and since then the land has all been taken up in 173 farms of approximately 40 acres each. During this year 425 acres were irrigated, and this amount will rapidly increase in succeeding years. The maintenance charge has been fixed at $1 per acre.

9. No part of the main system has yet been opened, nor has any building charge been fixed nor any water supplied by gravity from the dam, except to the Indian lands above noted. The two pumping systems purchased and the one small additional pump fitted up and operated by the Reclamation Service furnish an inadequate supply to 7,000 to 10,000 acres. The charge for this service has been about $1 per acre-foot, at which price, it is stated, the cost to the landowners will be from $5.50 to $10 per acre this year.

10. *Costs.*—The expenditures on this project to June 30, 1910, have been $3,714,462.08, of which $441,513.71, or 11.9 per cent, was for field engineering and superintendence; $87,607.42, or 2.5 per cent, for clerical services on the project; $24,787.72, or 0.7 per cent, for the supervising engineer's office; and $90,665.87, or 2.5 per cent, for the Washington and Chicago offices, expert engineers, etc. The estimate of the additional expenditures required to complete the project is given in the following table:

Siphon connections, etc	$43,000
Dam and main canal to Indian reservation	230,000
Main canal to siphon	540,000
Indian reservation canal	75,000
Colorado siphon and wasteway	165,000
Main canal and laterals in Yuma Valley	800,000
Drainage systems	150,000
Rights and property	175,000
Gila Valley main canal and laterals	340,000
Levees	368,000
Mesa land pumping station	500,000
Mesa land main and lateral systems	600,000
Total	3,986,000

The total estimated cost of the project is, therefore, $7,700,462.08.

11. *Returns to the reclamation fund.*—So far only 6,500 acres have been opened and construction charge for them has been fixed at $55. The returns from this area will be $357,500. The estimated total cost of completion is $7,700,462.08. Subtracting $357,500 from this leaves $7,342,962.08 to be obtained from the remaining lands, amounting to 124,500 acres. The building charge for these lands must therefore

be about $60 per acre, providing all lands, including the remaining Indian lands, pay full construction charges and the estimates for completion is not exceeded. There is no definite agreement with the Indian Service, and any other course would result in either the settlers paying an increased cost or the United States losing a portion of its investment. The mesa lands, comprising 40,000 acres, are not definitely included in the project, although California Canal, its head works, and the siphon have had given them, so far as constructed, sufficient capacity to carry the additional water for these lands. The omission of these lands will reduce the total cost by $1,100,581, but will increase the cost per acre on the remainder from $60 to $73. It would, therefore, seem desirable to include them in the project. Only about 5,000 acres within the project have not applied for water under the reclamation act.

12. *Comment.*—The engineering structures are well designed and constructed. The Laguna Dam diverting the water of the river into the two main canals is especially noteworthy. Its cost, however, was approximately $350 per foot of length, and it is thought that a less expensive dam might have served the purpose equally well. This was one of the first projects undertaken by the Reclamation Service. The farmers have long been expecting water, and it was stated that promises were made that water would be available by the time first named in the contract for the completion of the Laguna Dam, July 19, 1907. The contractors finally failed on this dam and it was completed by force account on March 20, 1909. Water, however, can not be supplied to their lands until the completion of the siphon, now under way, and the connecting canals. It is understood that the delay has been due to lack of funds. The main problems have all been solved. It is now simply a question of completion of more or less minor works whose total cost aggregates nearly $4,000,000.

13. *Summary.*—(1) The Yuma project is feasible, both from an economic and an engineering standpoint.

(2) It is interstate in character, lying in both California and Arizona.

(3) Of the 131,000 acres in the project, 74,000 acres, or 56.5 per cent, are public lands subject to the reclamation act.

(4) The water supply is sufficient.

(5) The total estimated expenditures on this project are $7,700,462.08, of which $3,714,462.08 were expended to June 30, 1910.

(6) The construction charge, approximately $60 per acre, can readily be borne.

(7) The project is an important one and worthy of early completion.

(8) The question of payment of construction charges by the remaining Indian lands should be determined.

(9) The mesa lands should be definitely included in the project.

(10) The following allotments are recommended for the four years, 1911–1914, inclusive:

From the fund	$2,380,462
From the loan	1,200,000
Total	3,580,462

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39. In purchasing the existing canal system certain obligations were assumed by the Reclamation Service for the supply of electricity to the Phoenix Railway & Light Co. The power canal used in the construction of the Roosevelt Dam is now applied to the generation of electricity for this company, with whom a 10-year agreement has been made, the electricity being furnished at the rate of 1½ cents per kilowatt hour for this period. No restrictions were included in this agreement as to the amount this company should charge the people of Phoenix. The receipts are used to diminish the operation and maintenance of the canal system.

40. The enlargement of the canals has been expensive, owing to the necessity of carrying on work while the ditches were in use, as the irrigation season lasts throughout the entire year on this project.

41. *Summary.*—(1) This project is located within the limits of the Territory of Arizona.

(2) The area in the project amounts to about 190,000 acres under the gravity system and about 40,000 acres by pumping. There is no public land subject to the reclamation act.

(3) It is doubtful whether the water supply is sufficient for the whole area proposed.

(4) The total estimated cost is $9,665,000, of which about $9,000,000 has been expended. The project is over 80 per cent completed.

(5) The land can readily return a cost of construction of from $45 to $55 per acre.

(6) The project is feasible both from an engineering and an economical standpoint.

(7) The large expenditures already made and the benefit that will follow completion make it desirable to continue work as rapidly as economically practicable until finished.

(8) Allotments: The following allotment is recommended for the four years, 1911–1914, inclusive:

From the loan $495,000

SECTION III.

YUMA PROJECT, ARIZONA-CALIFORNIA.

1. This project was visited by the board on October 7, 1910, and a public hearing was held at Yuma in the evening of that day.

2. *Location.*—The project lies along the Colorado River between the Mexican boundary and a point 40 miles north of it, in Arizona and California. It is, therefore, interstate in character. The Southern Pacific Railway passes through the project from east to west, about one-third of the project lying to the north and two-thirds to the south.

3. *Description.*—A portion of the project, comprising 16,000 acres of Indian reservation land, lies in California, the remainder, 115,000 acres, lying in Yuma County, Ariz. Of this area, 55,000 acres are bottom lands between Yuma and the Mexican boundary; 20,000 are in the lower Gila Valley above Yuma; and 40,000 acres are mesa

lands south and east of Yuma. The water for the project will be taken from the Colorado River. The main engineering features of the project comprise a diversion dam in the Colorado River about 15 miles above Yuma; two main canals leading from it, one on each side of the river; a siphon across the Colorado River at Yuma; levees along the Yuma and Gila Rivers; and the subsidiary distribution systems. The canal leading from the dam on the California side of the river is the main canal of the project, having a capacity of 1,700 second-feet. As this canal passes through the Indian reservation laterals are led from it to irrigate the lands belonging thereto. At one point in this canal there will be a drop of 12 feet, at which it is proposed to develop 1,000 horsepower, which will be transmitted electrically and used to pump water for irrigating mesa lands. This canal is to be carried across the Colorado River in a concrete siphon, after which it divides and supplies water for the lands in the project below Yuma on the Arizona side of the river. The main canal on the Arizona side covers that portion of the project lying in the Gila Valley. The Laguna Dam, as the diversion dam is called, is of the Indian weir type and raises the water surface of the river at low water about 10 feet. In order to keep silt out of the canals, arrangements are made at the headworks on both sides of the river to admit only the upper layers of water and to sluice into the river below the dam any deposits in front of the canal headworks. The siphon consists of two shafts about 100 feet deep, one on each bank of the river, connected by a tunnel 14 feet in diameter, the shafts being 17 and 23 feet in diameter on the California and Arizona sides, respectively. There will be required 75 miles of levee to protect the irrigated areas, and of this amount 40 miles have been completed. A drainage system will also be necessary and is provided for in the estimates.

4. When this project was taken up there were in the valley four inefficient private irrigation systems, of which three were purchased by the Reclamation Service on account of their rights of way and the desirability of adding to the project the lands covered by them. One of these systems was operated by pumping, one had an abandoned pumping system, and one was a gravity system which had silted up. Since their purchase both pumping plants have been put in order and an additional pump added. The three pumps have been operated by the Reclamation Service. The first cost of these purchases was as follows:

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Canal system and scoop wheel pumping plant	89,614.14
Additional pump	400.69
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5. *Water supply.*—The water supply is obtained from the perennial flow of the Colorado River without storage. Its drainage area comprises approximately 300,000 square miles. The rivers of the Colorado system receive their main supply from the melting snows on the mountains in Wyoming, Utah, and Colorado. The low-water discharge of the Colorado is from 3,000 to 4,000 second-feet, while the flood discharges, beginning in March and April and reaching the crest in June, may amount to 150,000 second-feet. The duty of

water is taken as 5.5 acre-feet per acre per year. The following table, furnished by the Reclamation Service from records made by its officials during 16 years, indicate the excess of water over that required by the project in the minimum monthly flow of the Colorado River at Yuma:

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[1] Area in project, 131,000 acres.

The amounts in the second column are the minimum run-offs that occurred during the months named in the 16 years of observation. There will be, therefore, ample water for the project, after satisfying prior rights, to cover 200,000 acres now irrigated under private enterterprise in the Imperial Valley below. The Imperial Valley Irrigation Co. has filed on 10,000 second-feet additional, but as beneficial use of it has not yet been made, the claim will probably not be allowed in full, but restricted to an amount that will cause no interference with the Yuma project.

6. *Lands.*—The irrigable land in the different units is as follows:

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Mesa lands	38,000	2,000
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Total	74,000	57,000

The average size of the private farms in the project is 120 acres. The average annual rainfall over the irrigable area is 2½ inches and its elevation above sea level is from 100 to 300 feet. Dry farming is not possible. The climate is semitropical, though temperatures below freezing have occurred. All the lands in this project except the mesa lands are " valley " lands of great depth and richness, and it is expected that they will produce alfalfa, grains of all kinds, pears, dates, figs, apricots, melons, citrus fruits, vegetables, grapes, small fruits and berries, and cotton. By proper alternation two or more crops a year can be grown. From 5 to 7 cuttings of alfalfa per year are usual. At the present time this is the only single crop of consequence, there being 1,500 acres devoted to it. In 1909 the gross value of the crops on the 7,000 acres irrigated by pumping was $87 per acre. Lands are now worth from $50 to $100 per acre without water, and land in alfalfa is selling at from $150 to $200 per acre. Citrus-

fruit lands will be much higher. The mesa lands are especially adapted to these fruits. There would seem to be no question but that the land will be able to bear the construction cost, and this was emphatically so stated at the public meeting, the main desire of all being the early completion of the work.

7. Drainage is necessary in some parts of the project, for which the United States will construct only the main ditches. Levees, as stated above, are necessary along the Gila and the Colorado Rivers to prevent overflow. The cost of both the drainage and the levees is included in the estimates of the cost of completion.

8. *Lands now irrigated.*—In the Yuma Indian Reservation there are 700 Indians. The law gives each Indian 5 acres, or a total of 3,500 acres, leaving 12,500 acres for settlement, but on account of the possibility of an increase of the acreage allowed to each Indian, only 6,500 acres have been opened for settlement. This was done in March last, and since then the land has all been taken up in 173 farms of approximately 40 acres each. During this year 425 acres were irrigated, and this amount will rapidly increase in succeeding years. The maintenance charge has been fixed at $1 per acre.

9. No part of the main system has yet been opened, nor has any building charge been fixed nor any water supplied by gravity from the dam, except to the Indian lands above noted. The two pumping systems purchased and the one small additional pump fitted up and operated by the Reclamation Service furnish an inadequate supply to 7,000 to 10,000 acres. The charge for this service has been about $1 per acre-foot, at which price, it is stated, the cost to the landowners will be from $5.50 to $10 per acre this year.

10. *Costs.*—The expenditures on this project to June 30, 1910, have been $3,714,462.08, of which $441,513.71, or 11.9 per cent, was for field engineering and superintendence; $87,607.42, or 2.5 per cent, for clerical services on the project; $24,787.72, or 0.7 per cent, for the supervising engineer's office; and $90,665.87, or 2.5 per cent, for the Washington and Chicago offices, expert engineers, etc. The estimate of the additional expenditures required to complete the project is given in the following table:

Siphon connections, etc	$43,000
Dam and main canal to Indian reservation	230,000
Main canal to siphon	540,000
Indian reservation canal	75,000
Colorado siphon and wasteway	165,000
Main canal and laterals in Yuma Valley	800,000
Drainage systems	150,000
Rights and property	175,000
Gila Valley main canal and laterals	340,000
Levees	368,000
Mesa land pumping station	500,000
Mesa land main and lateral systems	600,000
Total	3,986,000

The total estimated cost of the project is, therefore, $7,700,462.08.

11. *Returns to the reclamation fund.*—So far only 6,500 acres have been opened and construction charge for them has been fixed at $55. The returns from this area will be $357,500. The estimated total cost of completion is $7,700,462.08. Subtracting $357,500 from this leaves $7,342,962.08 to be obtained from the remaining lands, amounting to 124,500 acres. The building charge for these lands must therefore

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be about $60 per acre, providing all lands, including the remaining Indian lands, pay full construction charges and the estimates for completion is not exceeded. There is no definite agreement with the Indian Service, and any other course would result in either the settlers paying an increased cost or the United States losing a portion of its investment. The mesa lands, comprising 40,000 acres, are not definitely included in the project, although California Canal, its head works, and the siphon have had given them, so far as constructed, sufficient capacity to carry the additional water for these lands. The omission of these lands will reduce the total cost by $1,100,581, but will increase the cost per acre on the remainder from $60 to $73. It would, therefore, seem desirable to include them in the project. Only about 5,000 acres within the project have not applied for water under the reclamation act.

12. *Comment.*—The engineering structures are well designed and constructed. The Laguna Dam diverting the water of the river into the two main canals is especially noteworthy. Its cost, however, was approximately $350 per foot of length, and it is thought that a less expensive dam might have served the purpose equally well. This was one of the first projects undertaken by the Reclamation Service. The farmers have long been expecting water, and it was stated that promises were made that water would be available by the time first named in the contract for the completion of the Laguna Dam, July 19, 1907. The contractors finally failed on this dam and it was completed by force account on March 20, 1909. Water, however, can not be supplied to their lands until the completion of the siphon, now under way, and the connecting canals. It is understood that the delay has been due to lack of funds. The main problems have all been solved. It is now simply a question of completion of more or less minor works whose total cost aggregates nearly $4,000,000.

13. *Summary.*—(1) The Yuma project is feasible, both from an economic and an engineering standpoint.

(2) It is interstate in character, lying in both California and Arizona.

(3) Of the 131,000 acres in the project, 74,000 acres, or 56.5 per cent, are public lands subject to the reclamation act.

(4) The water supply is sufficient.

(5) The total estimated expenditures on this project are $7,700,462.08, of which $3,714,462.08 were expended to June 30, 1910.

(6) The construction charge, approximately $60 per acre, can readily be borne.

(7) The project is an important one and worthy of early completion.

(8) The question of payment of construction charges by the remaining Indian lands should be determined.

(9) The mesa lands should be definitely included in the project.

(10) The following allotments are recommended for the four years, 1911–1914, inclusive:

From the fund	$2,380,462
From the loan	1,200,000
Total	3,580,462

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SECTION IV.

ORLAND PROJECT, CALIFORNIA.

1. The board, by a committee of its members, examined this project and the reservoir sites for the proposed extensions on October 3, 1910, and held a public hearing at Orland on the evening of the same day.

2. *Location.*—The irrigable area of the Orland project lies in Glenn and Tahama Counties, and the storage reservoir in Colusa County, Cal. The town of Orland is within the project. Adequate transportation facilities are afforded by the Southern Pacific Railroad, and the Sacramento River, which is navigable in this vicinity, is also within a short distance.

3. *Description.*—The approved project includes a storage reservoir on Little Stony Creek at East Park, about 40 miles above Orland, the utilization of the bed of Stony Creek to carry water to the diversion dam at Miller Buttes and two canal and lateral systems, one on the north side to irrigate 6,000 acres and one on the south side to irrigate 8,000 acres in the vicinity of Orland.

4. The reservoir, which has a capacity of 45,600 acre-feet, is formed by a curved concrete dam of gravity section in Little Stony Creek Gorge. The maximum height of the dam is 139 feet above foundations and the length on top 250 feet. The foundations and abutments are hard conglomerate. The maximum pressure on foundations is 9.5 tons per square foot.

5. There are three gaps in the rim of the reservoir, in one of which the spillway is located. The remaining two are closed by low earth embankments. The spillway is built of concrete. It is of the arch and buttress type and has a capacity of 10,000 second-feet.

6. The diversion dam is about 9 miles above Orland, and is only partially completed. As planned, it will be a low concrete weir founded on sheet and round piling, the former driven through the gravel bed into the clay beneath. Floods bring down large quantities of heavy gravel, and the areas above those parts of the weir already built are completely filled. As this gravel will tend to choke up the canal intakes, it is probable that more or less difficulty will be encountered in maintaining a cheap and satisfactory diversion.

7. Prior to the beginning of work on this project by the Reclamation Service two private irrigation companies were diverting water to part of these lands. On the north side this was being done by the Lemon Home Water, Power, and Light Co. and on the south side by the Stony Creek Irrigation Co. The canals and ditches of both these companies were purchased by the Reclamation Service and are being enlarged, extended, and improved.

8. The north-side canal is to have a capacity of 92 second-feet and the south-side canal a capacity of 140 second-feet. The former will contain a drop of 40 feet and the latter a drop of 28 feet. At these drops 600 gross horsepower can be developed.

9. The principal structure in the distribution system thus far built is the inverted concrete siphon across Hambright Creek. Minor structures are also of concrete.

10. All of the completed structures are well built and suitable for the purpose intended.

11. *Water supply.*—Water for the project is obtained from Stony Creek, which has a drainage area above the diversion dam of 735 square miles and above the East Park reservoir of 102 square miles. The average annual run-off at the diversion dam is 750,000 acre-feet and at the reservoir 87,500 acree-feet, with a minimum at the latter point of 30,000 acre-feet in the season of 1909–10.

12. The duty of water varies from 36 inches to 42 inches, depending upon the soil. The demand also is variable during the irrigation season, nearly half of the total being required in July and August.

13. Discharge measurements have been made since 1901, and based upon average conditions during that period 36,000 acre-feet of storage would have been required to supply water for the project in accordance with the assumed demand. In this determination allowance is made for a 25 per cent loss in the creek bed and for a 20 per cent loss in the distribution system. The capacity of the reservoir exceeds the average requirement for stored water by 9,760 acre-feet, so that a supply can usually be carried over to make up deficiencies in dry years, such as 1910.

14. *Lands.*—The average elevation of the irrigable area is 225 feet above sea level, the average rainfall 17 inches, and the range of temperature from 26° F. to 120° F. The soil is a sandy loam, containing more or less gravel and silt. Experience in this valley indicates that 42 inches of water will be required on the gravelly, sandy land, amounting to 3,200 acres, and 36 inches on the remainder. Much of this land has been used in the past without irrigation for growing wheat, but in recent years the wheat crop has been very small. On the irrigated portions the principal products are alfalfa, citrus and deciduous fruits, small fruits, and vegetables. It is said that alfalfa yields six cuttings, or an average of 9 tons per acre per year, value at $7 per ton. Almonds, oranges, and grapes also yield large returns.

15. At the time this project was approved all the land under it, 14,000 acres, was in private ownership, and 8,960 acres of this amount was held by nine landowners. This land has been subdivided into 40-acre tracts and a large part of it sold. Before the project was undertaken the average price of land under it was $17 per acre. It is now about $100 an acre, not including the construction charge.

16. *Cost.*—The expenditures on the project to June 30, 1910, were $397,335, and the estimated cost to complete, subsequent to that date, is as follows:

Gravity system.

(1) East Park Reservoir	$5,000
(2) Diversion Dam	20,000
(3) North Side Canal	58,000
(4) High Line Canal	19,000
(5) Excavation, distribution system, under contracts	15,500
(6) Excavation, distribution system, to be contracted	15,500
(7) Structures for distribution system	30,000
(8) Special structures, Hambright Creek Siphon, Spillway, etc	5,000
Add 25 per cent for engineering and contingencies	42,000
Total to complete gravity system of the first unit	210,000

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This makes a total cost for the gravity system of 14,000 acres $607,335, or $43.38 per acre. The estimated cost of developing power at drops in the canals to pump water for the irrigation of 3,000 acres additional is as follows:

(1) Penstock and By-Pass	$4,000
(2) Power house and equipment	10,500
(3) Transmission line	11,000
(4) Pumping plant	7,200
(5) Development of wells	10,000
(6) Distribution system	19,500
Add 25 per cent for engineering, etc	15,550
Total to develop power at drops, first unit	77,750

17. The power and pumping plants have not yet been built, and are not an essential part of the project as originally undertaken. As in the main project, the land to be irrigated by them is in private ownership. This feature of the work is from an economic standpoint desirable, but owing to the demand for reclamation funds on other projects containing public land it is not advisable. Opportunity, however, should be afforded the Water Users' Association to do this work at its own expense, if it so desires. The construction charge on this project has not yet been announced, and it will probably be somewhat less per acre than that indicated above if the power and pumping plants are installed. If the power development only is undertaken and the power sold, the construction charge will be slightly increased, but, on the other hand, the receipts from the sale of power will reduce the annual cost of operation and maintenance. In any event the construction charge is not likely to exceed $45 an acre, which, considering the productiveness of the soil, is well within what the land can bear.

18. *Extensions.*—The Orland Project, as now outlined, uses only a small part of the run-off of Stony Creek, and investigations have been made by the Reclamation Service with a view to utilizing part of the remainder. Three additional reservoirs have been considered, each of which is to constitute, with the area to be irrigated from it, an additional unit of the Orland Project. These are the Stony Gorge, Stonyford, and Briscoe Reservoirs.

19. *Stony Gorge Reservoir.*—The site of this proposed reservoir is on the main branch of Stony Creek, 3 miles above the village of Elk Creek. Surveys made in 1910 show a possible storage capacity of 104,700 acre-feet, estimated to be sufficient for 30,000 acres. Based on a rock-fill dam, with a reenforced concrete core wall, the cost is placed at $1,123,782, equivalent to $10.70 per acre-foot. The total estimated cost of the second, or Stony Gorge, unit is as follows:

(1) Cost of storage works	$1,150,000
(2) Cost of diversion works	10,000
(3) Cost of canal system, at $6 per acre	180,000
(4) Cost of distribution system, at $8 per acre	240,000
Total	1,580,000

Or $53 per acre.

20. *Stonyford Reservoir.*—This reservoir is to be located on the main branch of Stony Creek, the dam site being 4 miles above the village of Stonyford. It has a possible capacity of 50,882 acre-feet,

estimated to be sufficient for 15,000 acres. Based on an earth and rock-fill dam, the cost is placed at $667,039, equivalent to $13.10 per acre-foot. The total estimated cost of the third, or Stonyford, unit is as follows:

(1) Cost of storage works	$667,039
(2) Cost of diversion works	10,000
(3) Cost of canal system, at $6 per acre	90,000
(4) Cost of distribution system, at $8 per acre	120,000
Total	887,039

Or $59.10 per acre.

21. *Briscoe Reservoir.*—This reservoir is to be located on Briscoe Creek, a tributary of Stony Creek. The dam site is 2½ miles above its mouth. It has a possible capacity of 19,052 acre-feet, estimated to be sufficient for 5,000 acres. Based on a concrete gravity dam, the cost is placed at $282,359, equivalent to $16.30 per acre-foot. The total estimated cost of the fourth, or Briscoe, unit is as follows:

(1) Cost of storage works	$282,359
(2) Cost of diversion works	5,000
(3) Cost of canal system, at $6 per acre	30,000
(4) Cost of distribution system, at $8 per acre	40,000
Total	357,359

Or $71.50 an acre.

22. The irrigable areas under the extensions adjoin the present project and will require about the same quantity of water per acre. Fifty thousand acres would therefore require the diversion of 195,000 acre-feet. The combined storage capacity of the three proposed reservoirs is 174,634 acre-feet. Allowing the same percentage of loss in stream bed as is assumed for the first unit, only 141,000 acre-feet of this amount could have been diverted, leaving 54,000 acre-feet to be supplied directly from the river. An examination of the records of average flow of Stony Creek during the past nine years shows, however, that only 31,600 acre-feet would have been available from this source after supplying the needs of the first unit. If an additional allowance is made for surplus reservoir capacity to tide over years in which the flow is insufficient to fill them, it is evident that the proposed reservoir capacity is too small for the irrigation of 50,000 acres.

23. The costs per acre, as given above, must therefore be increased, possibly as much as 25 per cent. The land under the proposed extensions is entirely similar to that under the existing project. It is of good quality and capable of bearing a construction charge of $60 to $75 an acre. All of it is in private ownership.

24. The extensions are independent of the existing project except that the same diversion dam and main canals would probably be used, the latter being first enlarged. All of the extensions are feasible from an engineering standpoint. The first two are feasible in that the probable cost would not exceed what the land can bear. Because of high cost the feasibility of the third, or Briscoe unit, is very doubtful. These extensions do not include any public land, nor are any interstate or international features involved. These facts, together with the need of reclamation funds for the completion of other projects now under way, lead to the conclusion that none of the extensions are advisable.

25. *Summary.*—(1) The Orland project lies wholly within the State of California.

(2) It covers the irrigation of 14,000 acres, all in private ownership.

(3) The water supply is ample for this acreage.

(4) It is feasible from an engineering standpoint, and the land can bear the probable construction cost—$45 per acre.

(5) Its completion is advisable, except for the installation of the power plants, which are not an essential part of the project as originally undertaken.

(6) Opportunity should be afforded the Water Users' Association to undertake this power installation at its own expense.

(7) The extensions known as the second, third, and fourth units are feasible from an engineering standpoint, but the first two only are economically feasible. None of them are advisable.

SECTION V.

GRAND VALLEY PROJECT, COLORADO.

1. The board visited the Grand Valley project on September 18 and 19, inspecting the lands now under irrigation and those to be irrigated in the vicinity of Grand Junction on September 18, and the irrigated lands and proposed line of new canals in the vicinity of Palisade on the 19th.

2. On September 19 public hearings were held by the board at Palisade and at Grand Junction, at which opportunity was given those interested to express their views with regard to the prosecution of work on this project.

3. *Location.*—Grand Valley lies in the western part of Colorado about 40 miles east of the Utah line. It was formerly a part of the Ute Indian Reservation, but in 1881 the Indians were removed, and in 1882 the Denver & Rio Grande Railway extended its line into Grand Junction. These events inaugurated a rapid settlement of the valley, especially as a good water supply was available and irrigation was practicable over large areas at moderate costs. Between that time and the present seven irrigation systems have been established, covering a total of about 60,000 acres of private land, most of which has proved very productive and is now held at a high valuation. The water supply for the project and the areas proposed to be irrigated lie within the limits of the State of Colorado.

4. *Description.*—The Grand River flows for many miles in Colorado through a narrow deep canyon. At the town of Palisade the valley widens, offering large areas of land suitable for cultivation when supplied with water. On the left or south bank there are being irrigated or being prepared for irrigation about 16,200 acres of land lying in a narrow strip above and below the mouth of the Gunnison River. On the right bank the bottom has a width of two to four miles, sloping up to gravelly mesas and thence extending back to broken adobe land at the foot of Little Book Cliffs. There are on this bank 97,000 acres of irrigable land, of which 44,000 acres are now being supplied with water by private ditches, leaving 53,000

acres which are not at the present time reached by any irrigation systems. The purpose of the present project is to supply water to the 53,000 acres still unprovided for.

5. This project early attracted private enterprise, but owing to the difficult nature of the ground in which a canal for this area must necessarily lie and the distance upstream it must extend to obtain sufficient elevation for a gravity canal, this project was considered a very expensive one. It was the intention of the Reclamation Service in 1902 to commence work on this project among the first, but at the request of individuals who stated that companies would undertake the work, the project was temporarily abandoned until it was ascertained by the companies that the time was not propitious for securing capital. Request was made that the Reclamation Service resume operations on this project and accordingly a camp was established, a site for a diverting dam selected, a line of canal tentatively adopted, and other plans made. At this time the work was stopped by direction of the Secretary of the Interior, pending the settlement of the controversy over damages for rights of way through private property in the vicinity of Palisade, and no further work has been done.

6. The project, as at present outlined, is confined to the irrigation of the high land bordering the Little Book Cliffs and areas farther down the valley, all on the north side of the river. It will require a diversion dam in the canyon several miles above Palisade, and a canal partly in open cut and partly in tunnel, to conduct the water down the canyon to the main canal line bordering the cliffs. This canal line, as proposed, will have a capacity of 1,000 second-feet at its upper end.

7. *Transportation facilities.*—The main line of the Denver and Rio Grande Railroad traverses the project from end to end. No farm unit of the project is more than 10 miles from some railroad station. In addition, an electric line between Grand Junction and Fruita will be able to switch standard cars from the railroad, thus affording additional facilities.

8. *Water supply.*—The area of the watershed of the Grand River above Grand Junction is 8,644 square miles, and the average annual precipitation over this area is 15 inches. Records of the flow of the Grand River have been kept at either Grand Junction, Glenwood, or Palisade since 1897. From these records figures for the flow at Palisade have been developed. They show that in normal seasons a minimum of about 1,450 second-feet may be expected, and that in exceptionally dry years the minimum may drop to 950 second-feet in August and September. A hydrograph showing the daily flow during the average or representative years 1903 and 1906, and the years 1902, 1905, and 1910, which are years of low flow, is appended hereto. This hydrograph and the analysis of the water supply therewith were prepared by the Reclamation Service.

9. From them it appears that a sufficient water supply for this project depends, first, upon an adjudication of water rights not radically different from that assumed by the Reclamation Service; second, upon the acquisition by purchase, by contract agreement as to substitution of gravity water for pumped water, or by condemnation, of the right to use for irrigation the water now used in the development of power by the Palisades irrigation district, the Mesa

County irrigation district, and Smith Bros. (Orchard Mesa Power). These aggregate 1,091 second-feet.

10. While the assumption as to prior rights is deemed reasonable, the board believes that this project should not be undertaken until these rights have been adjudicated. As such an adjudication is now in progress, and as a decision is expected by March, 1911, there will be a delay of only a few months, the disadvantage of which will be more than offset by the advantage of knowing definitely what the prior appropriators are entitled to. The right to condemn power water for irrigation purposes has been sustained by the Colorado courts, so there is no reason to assume that the second of the two conditions can not be met.

11. *Lands.*—The land which it is proposed to irrigate amounts to 53,000 acres, as above mentioned, of which 30,070 acres are public land, 20,720 acres are private land, and 2,210 acres are homesteaded public land not subject to the reclamation act. It is thus seen that public land is approximately 60 per cent of the total. It should be added, however, that this public land fringes the cliffs or lies at the lower end of the project and includes the areas which are of lower value for cultivation because of poorer soil or greater difficulty of irrigation. It joins, however, land under cultivation which is now returning the owners large profits. Peaches are said to have yielded as high as $700 per acre per year in the vicinity of Palisade. Apples are said to have yielded as high as $600 per acre. Cantaloupes and melons are often profitably grown between trees in the orchards. Sugar beets are extensively raised. A beet-sugar factory at Grand Junction pays $5 per ton for beets delivered on the cars. Lands under cultivation in ordinary farm crops in the vicinity of Grand Junction are held at $200 to $400 per acre. Lands planted with bearing apple or pear trees sell at from $1,200 to $1,500 per acre.

12. The average elevation of the irrigable area is about 4,700 feet above sea level. The average rainfall is 8 inches and the temperature ranges from a maximum of 100° to a minimum of 15° below zero. Although nothing can be raised in the Grand Valley without irrigation, it is so protected by the bluffs that large areas now irrigated have been devoted to the raising of apples and, in the vicinity of Palisade, to peach cultivation. The gravelly land of the mesa seems well adapted to fruit raising. The lower bottom lands yield good crops of grain, sugar beets, and alfalfa, but are not so well adapted to fruit culture.

13. Under the various private irrigation systems now in operation, the building cost per acre for water has reached from $66 to $150, and from $2.50 to $6 for maintenance and operation. It seems clear that the project lands can pay back the estimated cost of this project without hardship.

14. *Cost of project.*—No construction work has been done on this project, all expenditures having been for examinations and surveys except a small expenditure made for machinery and supplies after work was authorized and prior to its suspension. The total expenditures have been $74,170.80. The total estimated cost of completion of what is known as the "low line" is $3,621,663, or about $69 per acre, which includes $200,000 for right of way through existing fruit orchards in the vicinity of Palisades. The estimated cost of a line of canal 25 feet higher up, selected to avoid injury to these orchards,

is $4,685,741, or about $89 per acre. The following table, furnished by the Reclamation Service, sets forth the comparative estimates for completion of the project on the alternative locations:

Items.	Lower line through canyon.	Higher line through canyon.
Headworks	$200,000	$200,000
Canal head gates to Palisades	944,597	1,637,546
Canal, Palisades to Little Salt, Wash	727,025	961,673
Remainder of main canal	341,239	341,239
Laterals (43,560 acres)	260,000	260,000
Power plant at Palisades	20,000	32,000
Power plant at drop	.....	120,000
Right of way	200,000	.....
Engineering	180,000	190,000
Unforeseen contingencies	200,000	300,000
Administration	122,914	160,118
Pumping plants	141,065	119,065
Headquarters building and storage yard	15,000	15,000
Interest	269,823	349,100
	3,621,663	4,685,741
Unit cost, 53,000 acres	68.40	88.50

15. Although estimate of damage of $200,000 has been included, the difference between the costs of the two proposed lines is about $1,000,000. If the high line should be built this difference must be paid by the owners of lands irrigated by it. This difference will amount to nearly $20 per acre.

16. *Comments.*—No engineering problems of special difficulty present themselves in connection with this project. The diversion dam in the Grand River can readily be constructed on the selected site. The canal line down the canyon must pass through three tunnels, requiring expensive construction, but in view of the character of the material no special difficulties are expected. About 9,500 acres above the high-line canal are to be supplied by pumping. Electric power is now being sold in the valley by private companies at moderate prices, and this power is relied upon for operating the pumps. This power may be supplemented by electricity generated in drops in the main canal.

17. The principal question to be decided in connection with this project is which of the two canal lines shall be selected, the high line or the low line. Both of these lines have been surveyed and are now staked out on the ground. So far as the amount of land to be irrigated is concerned, the two lines differ very little, the higher line covering only a few acres more than the lower. The advantage of the low line is the large saving of approximately $1,000,000 which would result from its adoption. The high line was located with a view to avoiding the destruction of highly developed orchards, which would be necessary if the low line were selected. At one time an agreement was reached between the Reclamation Service and the owners of the lands through which the low-line canal is to run, fixing the amount of the damages to these lands at $154,000. This appraisal was not approved by the department, and a later estimate made by the Reclamation Service placed the total amount of damages which the United States was legally bound to pay at $75,138. A new appraisal was then made by the owners, who increased their claim to $404,188.25. An estimate transmitted to the board by the owners on October 24,

1910, again increased the estimate of the damages to $540,335. The construction of the lower line involves the occupation of about 150 acres of orchard, running in value from $350 to $3,500; but the right of way is already vested in the United States in accordance with the stipulated conditions under which the land was opened to homestead entry. Therefore no payment can be legally demanded for the land itself.

18. From these figures it appears that to avoid damages to the highly developed orchard lands the land which it is proposed to irrigate will have to pay an additional construction cost exceeding the highest estimate for the damages by about $660,000, or over $12 per acre for the 53,000 acres in the project. The board, therefore, is of the opinion that the low line should be selected as the location for the canal. The estimates of the owners as to the extent of damages to be incurred appear to be high, and if negotiations do not result in an agreement for a considerably smaller amount, then condemnation proceedings should be resorted to for the determination of the damages.

19. *Summary.*—(1) The project is feasible from an engineering and an economic standpoint.

(2) It lies within the limits of a single State—Colorado.

(3) It contains 53,000 acres, of which 60 per cent is public land subject to the reclamation act.

(4) The water supply will be sufficient for this project if the adjudication of water rights when made is not radically different from what is assumed by the Reclamation Service and after the water now used by certain private owners for power has been acquired for irrigation by agreement or condemnation. No extensive work should be done until the water supply is thus assured.

(5) The estimated cost of completion of the high line is $4,685,741, and of the low line is $3,621,663, of which $74,170.80 has been expended mainly in surveys and plans.

(6) The lower-line canal should be adopted, and if a reasonable estimate of damages to permit this can not be obtained by agreement then condemnation proceedings should be instituted.

(7) The productiveness of the land makes it probable that the construction cost of about $69 can be readily borne, or even $89, if the high line should be adopted.

(8) The prosecution of this project is recommended conditional on an adjudication of water rights not materially different from that assumed by the Reclamation Service.

(9) Subject to the above condition the following allotments are recommended for the four years 1911–1914, inclusive:

From the fund	$500,000
From the loan	1,000,000
Total	1,500,000

SECTION VI.

UNCOMPAHGRE PROJECT, COLORADO.

1. This project, including the proposed reservoir site at Taylor Park, was inspected by the board as a whole, or by commitees, between September 20 and September 23. Public hearings were held at Montrose on September 20 and at Delta on September 22.

2. *Location.*—The Uncompahgre Valley lies in western Colorado near the mouth of the Uncompahgre River, which is a branch of the Gunnison River. This latter flows into the Grand. The entire project, including sources of the water supply, lie within the State of Colorado; the lands are located in Montrose and Delta counties.

3. *Early irrigation in valley.*—The Uncompahgre Valley was first settled about 1882, and plans were made by private parties for irrigating about 100,000 acres from the Uncompahgre River. Ditches were constructed, but it was found that there was not enough water, and in 1904 only 30,000 acres were under cultivation, and these with insufficient water. About the year 1900 the State Legislature of Colorado appropriated $25,000 to bring water by tunnel from the Gunnison River into the Uncompahgre Valley. The tunnel was started, but the appropriation being exhausted the uncompleted work was turned over to the Reclamation Service. The location of the tunnel was found unsuitable, and it was not used.

4. *Description.*—The project, as undertaken by the Reclamation Service, provides for irrigating land lying in the Uncompahgre Valley with the water of the Uncompahgre River, supplemented by the water brought from Gunnison River. In case this does not suffice, a storage reservoir at Taylor Park on the Taylor River has been proposed. No suitable reservoir site has been found on the Uncompahgre River.

5. The water from the Gunnison River is diverted into the Gunnison Tunnel. On leaving the tunnel it flows through the South Canal for eleven miles and is dropped into the Uncompahgre River. By laterals from the South Canal 13,600 acres will be irrigated. From the Uncompahgre River, the water of that river, supplemented by that from the Gunnison, will be diverted at different points into six canal systems. The upper one, called the West Canal, irrigating 7,200 acres, is yet to be constructed. The Montrose and Delta Canal system, covering 33,600 acres, and the Loutsenheizer system, covering 24,600 acres, have been acquired by the Reclamation Service and are being enlarged and extended. Negotiations are in progress to acquire the Selig system, 9,000 acres; the Ironstone system, 26,000 acres, and the Garnet system, 4,000 acres. In addition, a new system, called the East Canal system, covering 22,000 acres, and connected with the Loutsenheizer Canal, is to be built.

6. Negotiations are also in progress to acquire a few additional minor canals belonging to private parties. These canals will be abandoned and the land irrigated by one of the above-mentioned systems.

7. The Gunnison Tunnel is 6 miles long and has a capacity of 1,300 cubic feet per second. It is completed excepting the diverting weir on the Gunnison River and the lining of the tunnel for 13,000 feet. It has been carrying water during the past season. The South

Canal is practically completed. Final agreements as to the acquisition by the United States of the remaining private canal systems have not yet been completed. It seems probable that these can be satisfactorily arranged, as the sentiments expressed at the public hearings were strongly in favor of the acquisition by the United States of all the canal systems. The secretary of the Water Users' Association stated that all private land in the project, except about 5,000 acres, had subscribed for water, and, while the exact figures were not verified, it is believed that less than that acreage will remain permanently out of the project.

8. *Water.*—A discussion of the water supply is appended. There were numerous previous water rights aggregating 40 different ditches, of which 10 were of considerable size. On the assumption of the acquisition by the United States of the ditches within the project limits with their water rights, and making allowance for other rights, it appears that there will usually be sufficient water on the basis of 2½ to 3 acre-feet at the farm when the Gunnison Tunnel is runnnig full—that is, about 1,300 second-feet. There will be years when the supply will be scant, and to insure what is needed a storage reservoir for Gunnison River water will, it is thought, prove necessary. The rainfall on watershed is from 7 to 20 inches.

9. *Land.*—The total irrigable area under the project is 140,000 acres, of which 106,000 are in private ownership and 34,000 acres public land, subject to the reclamation act. The larger part of the land withdrawn subject to the reclamation act has been entered for settlement. It is possible that these areas may be somewhat modified, as all of the private land has not yet been signed up for water. Most of the public land is generally on the higher benches and will, therefore, be the last to be brought under irrigation.

10. The land irrigated this year has been about 40,000 acres, practically all under cultivation before. Water was sold at a fixed price per second-foot. While the full quantity of water desired was not supplied this year, it is stated that, due to the extra water from the Gunnison River, an additional crop of alfalfa and larger crops of fruits and vegetables were obtained. No crops can be raised without irrigation.

11. Of the 140,000 acres under the project, about 60,000 acres are of red disintegrated sandstone, a sandy soil particularly adapted to the raising of fruits and vegetables; 80,000 acres of adobe, or clay loam, which gives good crops of alfalfa, grain, sugar beets, and other farm products. Alfalfa is the main crop. Potatoes and onions have been raised with marked success. It is claimed that the clay soil, after several years of cultivation, develops into good fruit land. There is a considerable portion of waste land. About 40,000 non-irrigable acres, of which 20,000 acres are private, are included within the limits of the project, but not counted as irrigable area.

12. The bottom land shows evidences of "swamping" in a number of places, some of which have been reclaimed by the construction of drainage ditches, and it is thought that all of it can be reclaimed. The land lying on the benches is not so much subject to "swamping," but it is probable that some drainage ditches will be required. An estimate of $210,000 is proposed by the Reclamation Service for drainage. There are not many indications of alkali.

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13. Before the inauguration of the project lands without water were worth from $2 to $25 per acre. Lands under irrigation, used for alfalfa, grain, etc., were worth from $50 to $150 per acre. Prices are now $40 for land on the outskirts of the project and up to $800 for fruit-bearing orchards.

14. The Denver & Rio Grande Railroad runs through the project, so that there is good railroad transportation.

15. *Engineering structures.*—The Gunnison Tunnel is about 6 miles long, and cost about $100 per running foot. This is rather a high price, due to its great length, the difficulties under which is was constructed, the failure of the contractors and the necessity of taking it up by force account, the flooding at different intervals, the large amount of gas encountered, etc.

16. The South, or main supply, Canal is for a considerable portion of its length lined with concrete, and at many points the earth thrust has forced the lining out of place. This is not considered serious. The drops in this canal are somewhat more costly than would seem to be necessary, but apparently fulfill their purpose. There is some leakage, but it is expected that this will be stopped by the gradual deposit of silt.

17. No work has been done at the Taylor Park reservoir site, and no borings made, so that the cost of the dam is difficult to determine, and the estimate of $2,000,000 must be considered only as an approximation. The storage capacity is estimated at 105,000 acre-feet. An examination indicates that a sufficiently good reservoir site exists at this point, but that further investigations are desirable. As a whole the engineering features seem to be well studied out and carefully executed, economy being observed as far as conditions permitted. The proposed plan for completion appears satisfactory.

18. *Cost.*—The total allotments to date aggregate $4,455,000, of which about $3,000,000 was applied to the construction of the Gunnison Tunnel and the remainder to the purchase and enlargement of private canals, construction of South Canal, and for minor features. The cost of completion is estimated at $4,500,000, or an estimated total cost of $9,000,000, including $2,000,000 for the Taylor Park Storage Reservoir. The detailed estimate for completion is as follows:

1. Gunnison River weir	$40,000
2. Gunnison Tunnel lining	305,000
3. Betterments, South Canal	50,000
4. South Canal lateral system	25,000
5. Betterments and lateral system, Montrose and Delta Canal	135,000
6. Enlargements and lateral system, Ironstone Canal	260,000
7. Cedar Creek lateral (part of South Canal system)	25,000
8. West Canal and lateral system	350,000
9. Enlargement and lateral system, Loutsenheizer Canal	325,000
10. Enlargement and lateral system, Selig Canal	45,000
11. East Canal and lateral system	350,000
12. Betterments, Garnet Canal	10,000
13. Purchase of existing old rights and canals	225,000
14. Taylor Park Reservoir	2,000,000
15. Contingencies	[1] 400,000
	4,545,000

[1] This item covers possible drainage systems, extensive renewals, etc.

19. Independently of the storage system, the estimated final cost would be about $7,000,000, which for 140,000 acres would give a building charge of about $50 per acre. It is desirable, however, to include in the construction cost the reservoir, which is believed to be necessary. Due to uncertainties in the estimates, and possible increases in the unit costs, as well as to the uncertainty as to the amount of land which can be included, it would seem safe to estimate on a construction cost per acre of at least $70.

20. The fruit land could stand this charge of $70 per acre, and probably all of the irrigable areas could do so in time. The cost of operation, when completed, is estimated at $0.75 to $1. It was the generally expressed opinion of the landowners that the land could bear these costs, except that some homesteaders felt that the burden would be heavy. This would seem, however, to be near the limit of construction cost that the land can bear.

21. *Returns to reclamation fund.*—No returns have been received up to the present time except rent for water. Due to the large proportion of land now under cultivation and the probability of early settlement of public land when thrown open, practically all land should begin to pay construction costs as soon as the different canals and laterals are completed.

22. *Summary.*—(1) The project is feasible from an engineering and economic standpoint.

(2) All the project, including the water supply, lies within the State of Colorado.

(3) The total irrigable area is 106,000 acres, of which about 32 per cent is public land subject to the reclamation act.

(4) On the assumption of the unification of private water rights and their acquisition by the United States, the water supply will be sufficient, though a storage reservoir is probably necessary.

(5) The estimated expenditure, including storage reservoir, is $9,000,000, of which $4,455,000 have been allotted to December 31, 1910.

(6) The land can bear the construction cost estimated not to exceed $70 per acre.

(7) The board believes the project to be worthy. All matters connected with the acquisition of private canals should be settled as early as possible, and definite and binding agreements should be made as to repayment of building charges before large additional expenditures are authorized.

(8) The following allotments are recommended for the four years, 1911–1914, inclusive:

From the fund	$2,045,000
From the loan	1,500,000
Total	3,545,000

Section VII.

MINIDOKA PROJECT, IDAHO.

1. *Inspection.*—The board inspected this project, except the storage dam at Jackson Lake, Wyo., on September 10 and 11, including in the inspection a private project on the south side of the river at Twin

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Falls, Idaho. From September 12 to 14, inclusive, was spent by a committee of three members of the board in going to, inspecting, and returning from the reservoir site at Jackson Lake. A public hearing was held on September 10 at Burley, Idaho.

2. *Location.*—The project is located in Lincoln and Cassia Counties, Idaho, and lies on both sides of the Snake River. The Minidoka & Southern Railroad runs through the project, leaving the main line at Minidoka, with terminus at Buhl.

3. *Description.*—The lands are to be irrigated partly by gravity and partly by pumping, of which, under the latter method, there are three units, all on the south side of the river. The main features comprise a storage and diversion dam 6 miles from Minidoka, Idaho, called the Minidoka Dam, the storage lake being called Lake Walcott, a generating power plant at Minidoka Dam, distributing canals, three pumping plants for the pumping units, and a storage dam at Jackson Lake, Wyo., about 275 miles above the Minidoka Dam. The essential features of the dam and power plant at Minidoka Dam and of the pumping plants are given in Appendix 1 to this section.

4. The distribution system takes its origin at Lake Walcott, two main canals leading from it, one on each side of the river. The north-side main canal extends westwardly from the dam and lake a distance of 13 miles, where it divides into two systems, one covering the area south of the railroad and the other the area north. This main canal has at its origin a capacity of 1,400 second-feet and serves the 68,500 acres of the north-side gravity system. This distribution system is almost completed. The south-side main canal, with a capacity of 850 second-feet, pursues a southwesterly course for 13 miles, minor laterals being taken out at intervals, serving 7,500 acres by gravity. At the end of this canal is placed the pumping works for the first pumping unit. These pumps lift 500 second-feet to the main canal for this unit, which carries 110 second-feet in a westerly course 18 miles, irrigating 10,500 acres of land. Just beyond the first pumping unit is placed the second unit, lifting 375 second-feet to the main canal of this unit, which in turn extends westerly 22 miles, carrying 160 second-feet and irrigates 16,000 acres. A short distance along the main canal of the second lift is located the third pumping unit, lifting 200 second-feet to the main canal of this unit. This canal has a full length of 25 miles and irrigates 22,000 acres. The lift at each plant is 30 feet. On the north side of the river only the main laterals are constructed by the United States, the construction of the farm laterals being left to the landowners. On the south side, however, owing to the more difficult nature of the ground, the laterals are carried to each farm unit.

5. During the winter months the pumping plants do not require power, therefore arrangements have been made to dispose of the electrical power to the towns on the project. Transmission lines, substations, etc., are being put in and delivery of power is expected to begin this fall. Additional charge is made for power and heat during June, July, and August. The returns from this sale of power after reimbursement of cost of special installations therefor, and their operation and maintenance will go to reduce the operation and maintenance charges.

6. There are three Government town sites on this project—Acequia, Rupert, and Hayward—on the north side of the river. There is a private town site—Burley—on the south side.

7. *Water supply.*—The water supply for this project is taken from the Snake River, having a watershed above the diversion dam of 22,000 square miles. The average elevation of the watershed is 6,000 feet above sea level, with an estimated average annual rainfall of about 21 inches. The duty of water on this project is taken at 3 acre-feet per annum, measured on the land. The rainfall on the irrigable area averages 14 inches per annum, but on account of the character of the soil this amount is too small to allow profitable cultivation without irrigation.

8. Allowing for prior filings, the natural flow of the river is not sufficient to supply the needs of the project for irrigation during the low water. This deficiency is supplied by storage at Lake Walcott and Jackson Lake. At Lake Walcott storage for about 52,000 acre-feet is now provided, and at Jackson Lake works are now in process of construction which will provide storage for 380,000 acre-feet, or a total of 432,000 acre-feet. The flood flow of the river occurs during the earlier half of the irrigation season, and therefore the storage will not be drawn upon until the early part of July nor required after the middle of October. It would appear, as shown in Appendix 2 to this section, that the storage provided is ample to supply the needs of this project for the lands involved. As the low-water flow of the Snake River up to 3,400 second-feet must pass over the Minidoka Dam, supplying the Twin Falls projects farther down the river, it is evident that the power rights at Minidoka Dam, for which filing was made January 30, 1909, for 2,500 second-feet, are amply protected.

9. *Lands.*—The average elevation of the irrigable area is 4,200 feet above sea level and the average yearly rainfall 14 inches. Dry farming is not successful. The total amount of land under this project is 124,500 acres, of which 101,600 are public, 19,800 State, and 3,100 private. Under the gravity system are 76,000 acres, of which 68,500 are on the north side and 7,500 on the south side. Under the pumping system are included three lifts covering 48,500 acres on the south side. A fourth pumping unit, also lifting 30 feet, comprising 5,000 to 7,000 acres, was considered. If the lift in this unit is reduced to 15 feet, 2,500 acres could be covered. The lands in this project are shown on the accompanying map. Owing to the practicability of large extensions to the power facilities at Minidoka Dam, it is possible to irrigate by pumping about 100,000 acres in addition to the areas now included in the project. This would involve, of course, the construction of other reservoirs. The size of the farm unit is 40 acres near town sites and 80 acres farther out. The private-land unit is 160 acres. Of the State lands under the pumping unit about 10,000 acres have been sold in 40-acre tracts, but the State is making no effort to sell the remainder of its lands. It is suggested that an effort be made to induce the State to dispose of these lands, as otherwise the water rights of the United States may be adversely affected through lack of beneficial use. The value of the lands is reported to be $100 per acre under irrigation, and at the public hearing it was stated that a construction charge of $50 per acre could be easily carried. The soil is clay, disintegrated lava,

sandy loam, and loose sandy soil underlaid with lava rock at depths varying from 1 to 100 feet. The crops are alfalfa, grains, corn, vegetables, some fruits, with a probability that sugar beets will be found a profitable crop. A demonstration farm is maintained by the Reclamation Service on an unsold portion of the town site of Heyburn.

10. On the south side the lands slope well toward the river and possibly will not need drainage for some years. On the north side the land is undulating and disposal of waste water is more difficult. A drainage ditch has been started, which will pass through the entire tract on this side if found necessary. Underlying these lands are found porous beds of lava and gravel, and drainage of some of the low basins has been tried by sinking drainage wells to depths of 200 feet into these porous beds. These have been fairly successful where tried, but are as yet only an experiment.

11. *Cost.*—The cost of the project to June 30, 1910, was $3,330,770 for irrigation and $42,955 for drainage. The estimated subsequent expenditures are as follows:

General expense	$47,550
Diversion dam and headworks	22,610
Main south side canal	88,140
Power station	67,330
Pumping stations	193,750
Transmission lines	17,620
Telephone lines	4,600
South side pumping and distribution system	44,720
Office buildings and quarters	10,700
Small extensions and miscellaneous	50,580
Commercial light and power	14,280
Lake Walcott storage	21,000
Equipment and material in stores	89,650
Jackson Lake storage	281,000
Total	774,230
Waste water or drainage system	357,045

The estimated total cost is, therefore, $4,105,000 for irrigation and $400,000 for drainage.

12. The building charge for lands under the pumping system has not yet been announced, but will probably be in the neighborhood of $50 per acre. It is proposed by the Reclamation Service to fix the charge so that the total expenditures on the project will be returned to the United States. The building charge for the gravity system was first set at $22 per acre. This was found to be too low, and in order to make up a part of the deficit thus caused, on March 30, 1909, the Secretary of the Interior announced that for the gravity unit on all public lands (including relinquishments) thereafter entered and on all unsold State lands the building charge would be $30 per acre. Data furnished do not enable a precise determination of the amount of land that is affected by this advance, but it appears that approximately 70,000 acres will pay $22 and 6,000 acres $30. With these figures and the estimated costs above given, it is evident that the charge (not yet announced) to the lands under the pumping units must be over $49 in order to return to the United States the total expenditures on the project. If the drainage system, estimated to cost $400,000, be included in the construction charge for the 68,500

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acres on the north side served by it, $6 per acre should be added to the charge for those lands. It would, of course, not be proper to add any of the cost of this drainage to the construction charges for the pumping units or to those for the south side gravity unit. It must be collected from the 68,500 acres benefited, either as a supplemental construction charge or in the form of increased operation and maintenance charge on them. If divided over 10 years, this extra cost would be in either case about 60 cents per acre per annum.

13. During the season 1909 about 30,000 acres in the gravity unit were actually irrigated and 3,600 acres in the pumping units. For 1910 the corresponding figures are 48,000 and 4.000 acres. The charge for operation and maintenance for 1910 is $0.60 and $1.50 per acre for the gravity and pump lands, respectively. The total estimated cost of operation and maintenance to December 31, 1910, is placed by the project engineer at $132,105 (assuming the experimental farm to be self-supporting), and the accruals to the same date are estimated at $130,600. In ensuing years there should be no deficit in operation and maintenance. At the public hearing a request was made for an extension of the project to include a fourth pumping unit. This unit had been considered in the earlier studies of the project, and lands under it had been reserved under the reclamation act. Settlers have taken up lands under the act and are naturally anxious to have the works extended to cover them, but on account of the large construction cost the Reclamation Service decided that it would be impracticable to do so. The correctness of this decision is concurred in. All of these lands should be released, if this has not already been done.

14. The construction of the Minidoka Dam necessitated the abandonment of the water wheels used in irrigation of the Howell ranch, just below the dam site on the south side of the river. A contract has been made with the owner by which the Reclamation Service agrees to furnish water for 156 acres for $50 rental price yearly.

15. *Comments.*—The engineering work on this project seems to have been well done. At Jackson Lake a temporary crib dam was constructed in 1906–7 to supply storage, pending design of permanent works and decision as to whether the offer of private parties to combine in the construction of large storage dams to serve both their own needs and those of the Government should be accepted. This dam was washed out in 1909, and immediate replacement was necessary. The design of the new structure, providing for the needs of the Government only, is well adapted to the site. The method of changing the Minidoka Dam from a plain diversion dam to include storage is somewhat unusual in design, but appears to be successful, the only thought being that in the form constructed it may be subject to damage from ice or drift. The construction of the power house over the part of the dam containing the sluice gates, which were put in for the purpose of draining the reservoir, renders it impossible to use these sluice gates without removing the draft tubes in front of the sluices which it is desired to use.

16. *Summary.*—(1) The Minidoka project is feasible from an engineering and economic point of view.

(2) This project is interstate in character in that, while the irrigable area lies in Idaho, a large part of the water for it is stored in another State, Wyoming.

(3) Of the total area of 124,500 acres in the project, 101,600 acres, or 83.2 per cent, are public, subject to the reclamation act.

(4) The water supply is ample.

(5) The total estimated expenditures are $4,505,000, of which $3,373,725 had been expended to June 30, 1910.

(6) The land will bear the construction charges. In the case of the pumping units, these charges approximate very closely the sum which the land can at present bear, but future increases in value and better knowledge of irrigation methods may, perhaps, render this charge more easily borne. For the gravity unit, the construction charge has been announced at $22 per acre for 70,000 acres, more or less, and at $30 per acre for 6,000 acres, more or less. For the pumping units the charge, not yet announced, is estimated at $50, approximately.

(7) This project should be completed as rapidly as funds will permit.

(8) None of the extensions should be undertaken until the project as now defined has been completed.

(9) The following allotment is recommended for the four years 1911–1914, inclusive:

From the fund $528,000

SECTION VIII.

BOISE PROJECT, IDAHO.

1. The board visited this project by a committee of three members on September 8 and 9, 1910, inspecting on those dates the principal features. On September 8 a public meeting was held at Nampa, Idaho, and on September 9 one was held at Caldwell, at both of which great interest was shown in the early completion of the project. A committee of the board inspected the site for the proposed storage dam on the headwaters of the Boise River on September 25, 1910.

2. *Location.*—The project is located in the southwestern part of Idaho in the valleys of the Snake and Boise Rivers, in Ada and Canyon Counties. Its limits are wholly within the State of Idaho. The project is served by the Oregon Short Line, the Idaho Northern Railroad, and by the Boise Valley and the Boise and Interurban electric lines. The principal towns are Boise, Nampa, and Caldwell.

3. *Description.*—The original Payette-Boise project included an area of 402,700 acres and was divided into four subdivisions, as follows:

First. The Payette division, comprising lands in the Payette Valley and part of the Boise Valley, the total area being 72,000 acres, of which 60,000 were desert and 12,000 under cultivation.

Second. The North Side Boise unit, comprising lands on the north side of the Boise River under Farmers Union Canal, the total area being 33,000 acres, of which 25,000 acres were desert and 8,000 cultivated.

Third. The South Side Boise unit, comprising 272,000 acres, of which 109,000 acres were already irrigated or provided with canals of sufficient capacity therefor.

Fourth. The Succor Creek division, comprising lands on the south side of Snake River near the Idaho-Oregon State line, the total area being 25,700 acres, of which 10,000 acres were to be served by reservoirs on Succor Creek and 15,700 by pumping from the Snake River, the power for which was to be obtained from the proposed Payette Canal.

4. Owing to the lack of funds and legal complications, and in response to petition of settlers in the North Side and Payette subdivisions, three of these subdivisions have been abandoned for the present, as well as certain portions of the third subdivision aggregating 29,000 acres. Forty thousand acres of land, reserved for the Payette division, have been restored to entry, and settlers are proposing to take up this work by private enterprise.

5. The project as now defined lies within the third subdivision above enumerated, and comprises a total of 243,000 acres, of which 164,000 are new lands and 79,000 are old lands already under irrigation from private ditches. The relationship existing between the owners of these canals and the Government will be described later. A map of the locality showing the lands to be irrigated is herewith appended.

6. The main works are: The diversion dam in the Boise River, the Deer Flat Reservoir, the distributing system, and the proposed storage dam on the headwaters of the Boise River. The diversion dam in the Boise River lies about 8 miles above the city of Boise, and from it leads a small canal on the north side supplying a small area on that side, and a main canal on the south side with a capacity of about 2,500 second-feet. This latter canal extends in a southwesterly direction and empties into Indian Creek. The waters flow down Indian Creek for a distance of 9 miles, where they are again diverted by means of a dam and headgates to the second stretch of the main canal 8 miles in length, terminating in the Deer Flat Reservoir, the available capacity of which is 170,000 acre-feet. This main canal was acquired from the New York Canal Co., and besides supplying the reservoir irrigates the company lands and certain new lands. To serve these purposes suitable enlargement is now being made. The reservoir is formed in a natural depression by two embankments containing about 1,000,000 cubic yards each. From it are led three distributing canals to various parts of the project. A certain amount of storage will be necessary on the headwaters of the Boise River to fully irrigate the area comprised in this project. A brief description of the Deer Flat embankments will be found in the appendices to this section, together with the report of the committee of the board which inspected the storage site on the Boise River.

7. *Water supply.*—The source of the water supply for this project is the Boise River, the watershed of which, above the diversion dam, is approximately 2,610 square miles, with an average rainfall of about 25 inches. The maximum run-off of the Boise River is about 3,000,000 acre-feet, the mean about 2,000,000 acre-feet, and the minimum 1,000,000 acre-feet. The flood season covers generally the months of March, April, May, June, and a portion of July, and during these months there is usually ample water for all purposes without storage. After the flood season is past the normal flow of the river must be supplemented by storage. The duty of water is taken at 2½ acre-feet per acre per annum measured on the land. Within the project are

two private irrigation districts, as well as the land owned by the New York Canal Co. The districts consist of the Pioneer irrigation district, controlling the Phyllis and Caldwell Canals, covering 36,000 acres, all irrigated, and the Nampa and Meridian district, controlling the Ridenbaugh Canal, covering 25,000 acres, irrigated, and 30,000 acres of unirrigated land. The latter will be irrigated through the district distributing system by water furnished by the Government. The New York Canal Co. owns 18,000 acres under irrigation lying under the main canal of the project. All of these lands have adequate flood-water rights, and the total low-water flow of the river has been appropriated many times over. The adjudication of water rights in the valley has been before the courts and the total prior appropriation was determined, amounting to 2,754.8 second-feet. The Reclamation Service regarded this adjudication as excessive in amount and appealed to the superior court. The case has been remanded for retrial and a temporary decree handed down fixing the private appropriations at a total of 60 per cent of this amount. The final adjudication of these rights is important, inasmuch as upon it will depend the amount of storage necessary on the headwaters of the Boise River for a given amount of land, or will determine the total acreage that can be irrigated under the Government project with the storage now proposed.

8. The United States has acquired rights under Idaho State laws to a flow of 1,647 second-feet from the Boise River for the use of the main south side canal and has applied for 3,553 second-feet additional water for use in the main south side canal, Deer Flat Reservoir, and Boise River Reservoir when constructed.

9. In making a study of the water supply the following assumptions are made by the project engineer, viz: That there is a 10 per cent loss in filling Deer Flat Reservoir; that there is a 30 per cent loss in the lateral system above the reservoir and a 30 per cent loss in the distributing system below the reservoir; that seepage losses are 0.5 acre-foot per month for each acre of submerged area in the Deer Flat Reservoir; that evaporation losses equal 5.33 acre-feet for the entire year; and that the rainfall is not considered. Based on these assumptions and on the measured discharges of the river, there is available for storage on the headwaters not less than 200,000 acre-feet. The amount required to be stored in this reservoir for the project for the years given would have been as shown in the following table:

1895	184,000
1898	151,000
1902	167,000
1903	144,000
1904	100,000
1905	226,000
1906	124,000
1907	97,000
1908	86,000
1909	40,000

The mean of these amounts is 131,000 acre-feet. If a storage of 150,000 acre-feet is provided, sufficient water would be available for the project seven years out of the ten, and for the remaining three years in only one, 1905, would the deficiency have been serious, and even for that year the lack of water would not have been sufficient to have prevented fair crops being grown. On account of the high cost

of this storage, reservoir capacity beyond this amount does not seem warranted.

10. *Lands.*—The average elevation of the irrigable area is 2,500 feet above sea level, and the average rainfall is about 13 inches, an amount too small to permit successful dry farming in this locality. At the present time the distribution system is capable of delivering water to 187,338 acres. Of these, 108,338 acres, comprising 1,237 farm units, are new land. There remain 652 farm units, comprising an area of 55,806 acres, for which the distribution system is not completed. During the present season 30,000 acres were irrigated, of which 18,000 acres are under the New York Canal, receiving water under agreement described below, and 12,000 acres were new lands. Of the 243,000 acres, 85,820 are entered subject to the reclamation act, 30,059 are State lands, and 127,130 are private lands.

11. With regard to the lands under the old canals, the status is as follows:

(*a*) An agreement was made with the New York Canal Co., dated March 3, 1906, by which the United States is to carry in its main canal, which was the main canal of the New York Canal Co., 277.86 second-feet of water, subject to the priority determined by the courts for the stockholders of this company, as a consideration for the use of the canal and its right of way. This water is to irrigate the lands originally under the New York Canal and they are to pay an equitable portion of the annual cost of operation and maintenance of this project, but otherwise receive their water without cost, so far as the United States is concerned.

(*b*) An agreement was also entered into with the Idaho-Iowa Lateral & Reservoir Co., dated March 3, 1906, based on the carrying rights held by their company in the New York Canal, in consideration for which the Reclamation Service is to fill annually from the unregulated flow of the Boise River certain reservoirs, total capacity not to exceed 10,000 acre-feet, with specific allowances for seepage and evaporation losses. The company is to pay its proportionate part annually of the cost of delivering water to the entire reservoir system along the main canal.

(*c*) Another agreement, with the Nampa-Meridian Irrigation district, dated April 1, 1909, provides for the enlargement and construction of irrigation canals in that district by the Reclamation Service, for the delivery of the water into the canals of the district by the Reclamation Service, and the distribution by the district of this water to the Government users in the district. The water users are to pay the Reclamation Service for the construction and the general operation and maintenance charges and the Reclamation Service is to pay the district for its services in delivering water to the lands.

12. Members of the Riverside, Pioneer, and Nampa-Meridian districts subscribed to stock of the Payette-Boise Water Users' Association under contracts allowing a credit to them of $14 per acre, or a proportional part thereof depending on the water rights, as the value of the works and water rights of the subscribers, who were in due course to be supplied with full water from the project by the United States. These credits and the method of proportioning them were accepted by the department and appropriate provision is to be made in the public notice opening these portions of the project. Dur-

ing the present year the Riverside Irrigation was released from its contract at its own request. Should the present arrangement be carried out with the other two districts, it is estimated by the project engineer that 30,000 acre-feet additional of stored water will be needed. Owing to the difficulty and high cost of obtaining this additional storage, it would be advisable to terminate the contracts of the Pioneer and Nampa-Meridian districts by mutual consent, if practicable. For these reasons neither the lands concerned nor the water supply for them have been further discussed in this report.

13. *Cost.*—The expenditures on this project to June 30, 1910, have been $3,404,327.18. The estimated additional cost to complete is as follows:

General expense	$356,000.00
Examinations and reconnoissances	7,000.00
Diversion dam	8,000.00
Main south side canal	482,115.00
Distribution system from main canal	675,414.93
Storage, Deer Flat Reservoir	107,000.00
Distribution system, Deer Flat Reservoir	382,619.00
Storage on Boise River	5,200,000.00
Penitentiary Canal	1,960.00
Irrigable lands	13,000.00
Operation and maintenance	200,000.00
Telephone system	15,000.00
Total	7,448,108.93

The total estimated cost of completion is therefore $10,852,435.11. This estimate contains an item for storage on the headwaters of the Boise River which is approximate only, as full data regarding it have not yet been obtained. Field parties are now at work investigating various sites for this storage. From the information already gathered it is evident that this work will be costly per acre-foot of storage. It may also be remarked that the storage required can not yet be definitely determined as the final adjudication of the water rights on the Boise River has not yet been made.

14. If we assume that this total cost is divided among 164,000 acres of land, the construction cost per acre will be about $66. This expenditure will be divided approximately equally between the Boise River storage and the remainder of the project. As this storage contemplates a capacity of 150,000 acre-feet, it is seen that it will cost about $35 or more per acre-foot. This high cost can not be avoided, because of the unfavorable condition for storage existing on the headwaters of the Boise River.

15. No amount has as yet been fixed by the Reclamation Service for the construction charge, but from facts developed at the hearings and from information received by the board during its inspection, the board is of the opinion that the lands will be able to bear the construction charge that may result from the completion of the project with reasonable economy. Lands in the project without water are selling at from $50 to $75 per acre. Lands under cultivation with fairly good water rights under the old canals are selling at from $150 to $250, and even as high as $500 per acre. The soil is fertile, easily worked, and the climate is well adapted to fruit raising, as well as to the growing of grains and alfalfa. Large crops are the rule, with sufficient water for irrigation. Owing to the fact that

flood water irrigation under a rental basis is being taken up by the farmers as fast as the distribution system is completed, these farmers are raising small crops and will have no difficulty, with reasonable foresight and care, in meeting the payments as they fall due.

16. As the construction cost has not yet been announced, there should be no loss to the United States, as it can be fixed so as to return to the fund the total cost. At present the operation and maintenance charges are partially met by a rental charge of $0.75 per acre to lands receiving water through the partially completed system, the receipts for 1909 being $12,708.71 and the expenditures $40,327.52. The deficit is charged to construction account and an item of $200,000 is included in the estimate to cover such deficit until the project becomes self-supporting.

17. *Comments.*—Generally speaking, it is believed that the works have been constructed with due regard to sound engineering principles. There is no serious engineering difficulty to be overcome, and the project is feasible. While neither of the Deer Flat embankments has as yet been subjected to any very great head of water, some leakage is shown through or under the upper one, and it is believed that they should both be watched with care as the water rises in order to determine whether the leakage increases to any alarming extent. Attention is also invited to the probability of leakage through the bottom of the reservoir. The cost of the proposed storage on the upper Boise will be high, and the board believes that it will be wise to defer the construction of this reservoir until the water rights have been finally adjudicated and until the quantity of water necessary to be stored in this reservoir is determined with more exactness.

18. *Summary.*—(1) The Payette-Boise project is feasible from an engineering and an economic standpoint.

(2) It lies wholly within the limits of the State of Idaho.

(3) Of these lands, amounting to 243,000 acres, 35 per cent is public land subject to the reclamation act.

(4) The water supply is sufficient in all except very dry years, during which there may be some lack of water.

(5) The total estimated cost is $10,852,435.11, of which $3,404,327.18 had been expended to June 30, 1910.

(6) The lands can bear the construction charges, approximately estimated at $66 per acre.

(7) The project is worthy of completion at such rate as funds can be allotted and the work economically performed.

(8) The contracts now existing for supplying water to members of the Nampa-Meridian and of the Pioneer irrigation districts should be terminated by mutual consent, if practicable.

(9) The following allotments are recommended for the four years, 1911–1914, inclusive:

From the fund	$4,585,435
From the loan	2,000,000
Total	6,585,435

SECTION IX.

GARDEN CITY PROJECT, KANSAS.

1. The board visited this project on October 19, 1910, inspecting the power plant, one of the pumping units, the concrete conduit, and a portion of the irrigable lands. A public meeting was held at Garden City on the same day, at which the directors of the Finney County Water Users' Association were present.

2. *Location.*—This project is located on the Arkansas River, in Finney and Kearney Counties, in the western part of Kansas. Transportation facilities are furnished by the Santa Fe Railway, and there is also a short railroad connecting Garden City, the principal town in the project, with Scott City, Kans.

3. *Description.*—Prior to the adoption of this project by the Reclamation Service there was already a cooperative irrigation system which included most of the lands now in the project. This old system consisted of a canal, called the Farmers' Ditch, about 17 miles long, heading in the Arkansas River about 1½ miles east of Deerfield. During flood stages in the river water was diverted into the canal and from the canal was distributed by laterals to the lands. There was no permanent diversion dam, but at low stages a temporary barrier was built, when needed, to give sufficient head for a flow in the canal. For the larger part of the irrigation season the flow in the river was insignificant. About 20,000 acres of irrigable land could be reached by the ditches, but not all of it was included in the system, only about 8,600 acres being served with the occasional irrigations.

4. The object of the works of the Reclamation Service is to supplement this insufficient irrigation by pumping from the underground flow of the Arkansas, the pumped water being turned into the Farmers' Canal near its head. The water users retain ownership and direction of the distribution system and control of the water after it is discharged into their canal. The works constructed by the Reclamation Service consist of a central electrical power plant, located near Deerfield, and 23 electrically operated pumping units. Oil is used for fuel. The capacity of the plant is 600 horsepower. The 23 pumping units are located about 1,000 feet apart, along a concrete-lined canal about 20,000 feet long. Ten of these stations are on the north side of the river and 13 on the south side. Water from the south part of the concrete canal passes under the river in a wooden-stave pressure pipe. At each of 3 of the pumping stations there is a group of twelve 15-inch wells, and at the other 20 stations the groups consist of 9 wells each. At each station the wells are connected by suction pipe to a vertical-shaft centrifugal pump driven by a 25-horsepower motor. The power house is built of concrete and pressed brick and the pumping stations of concrete. The power house and the installations therein, the pumping stations, and the concrete canal appear to be well built and in good condition. The farmers' ditches were not inspected by the board, but the reclamation officials state that they are in very poor condition.

5. *Water supply.*—Each of the 23 pumps has a rated capacity of 5 second-feet under the maximum head expected, and the calculations of the reclamation engineer indicated that the yield from each battery of wells would more than supply the pump. The entire pumping plant

was designed to supply 100 second-feet for an irrigation period of 150 days, or a total of 30,000 acre-feet. The duty of water is taken at 2 acre-feet at the farm, and allowing one-third loss for seepage, 30,000 acre-feet would suffice for the 10,000 acres in the project even though no water was obtained from the flood flow of the river. It was intended that the pumping should be discontinued whenever there was sufficient water diverted from the river. So far as the board is aware, no data were available when the project was undertaken to show what had been the average quantity of water diverted per irrigation season.

6. An appropriation of 200 second-feet of the underflow of the Arkansas at Deerfield was made on July 7, 1905, on behalf of the United States, and notice was duly filed and posted as required by the laws of Kansas. Subsequent to this filing the United States Sugar & Land Co. installed at Deerfield, above the Government line of pumping stations, a pumping plant to furnish water for irrigation of lands owned or controlled by the company. As the pumping at this place was apparently injuring the underground flow to the Government pumps, suit was instituted against this company in the State courts. It is understood that the suit has been withdrawn without having come to trial.

7. The records of the Reclamation Service show that under continuous operation the plant can not deliver the expected supply of water. During the season of 1909 the amount of water supplied to the irrigated lands from the several sources is given in the following table:

Months.	Length of time pumps were operated.		From pumping plant.	From Arkansas River.	From rainfall.
	Days.	*Hours.*	*Acre-feet.*	*Acre-feet.*	*Inches.*
April	22	12	1,227	.....	0.20
May	20	2	1,632	.....	2.06
June	12	17	1,036	1,265	3.28
July	19	18	1,745	1,818	6.22
August	19	4	1,810	1,844	.81
September	2	12	105	3,144	1.20
Total	96	17	7,555	8,071	13.77

This pumping represents an average rate for the 96.7 days of about 39 second-feet, but the available records do not show whether this represents the maximum possible output for long periods of pumping. The Director of the Reclamation Service stated in one of his printed reports:

> With the available water supply, and without assistance from river water or rainfall, it is believed that not more than 4,000 acres could be properly irrigated.

From the above information the board concludes that the supply of water, including both river and pumped water, will be insufficient in dry seasons for the full irrigation of the area included in the project.

8. Shortly after they were installed a test of the pumps showed that they had the rated capacity, and the shortage in the anticipated output must be due to the failure of the wells to furnish water to the pumps. The continuous operation of the pumps soon lowers the water level in the vicinity of the wells, and the flow through the sub-

soil is not sufficiently rapid to prevent this. Whether the proximity of the plant of the sugar company affects this supply to the pumps is not known; nor can it be stated what effect a more widely distributed location of the wells would have on the output. The indications are, however, that the deficiency is due to a much slower rate of underground flow than was estimated when the plans for the project were adopted and that a wider dispersion of the wells would have produced better results.

9. The experiment has been made of operating the pumps in groups, the object being to allow the water plane to recover its normal level at the idle groups, the pumps actually operating thus having less lift for a limited time. These experiments are reported as promising better results than has been possible when all the pumps are working together. It is not believed, however, that the present plant when operated either on this plan or operated continuously can deliver sufficient water for the irrigation of the 10,656 acres in the project.

10. *Lands.*—There are in the project 10,656.41 acres of irrigable land, all of which is in private ownership. Only 9,625 acres of this area is covered by the contract with the water users' association for the return to the reclamation fund of the cost of the project. The project was opened by public notice of March 6, 1908, the construction charge being announced at $35 per acre and the operation and maintenance charge at $2.75 per acre per year. On November 30, 1908, another public notice was issued, which raised the construction charge to $37.50 per acre for land which had not made application for water and for such lands which, having made application under the first notice, desired to come under the second notice in consideration of a delay of one year in the collection of the first installments. It has not been ascertained what proportion of the area is subject to the $37.50 charge and what to the $35 charge. The total number of acres covered by water right applications is 6,976, divided into 75 holdings.

11. The average elevation of the irrigable area is about 2,900 feet above sea level. The range of temperature is from —20° to 105° F. The average annual rainfall on the irrigable area is 20 inches, and in normal years it is sufficient to permit farming without irrigation. The irrigations ordinarily obtainable during the summer reenforce the rainfall, and it is only in the occasional very dry years that fair crops can not be obtained without the aid of pumped water. Under average conditions, however, additional water is necessary for a full irrigation, and a full irrigation means larger yields from the land. The pumped water therefore serves in ordinary years to increase the yield per acre and in dry years is an insurance against failure of crops. The rainfall during the season of 1910 has been above the normal, and while no pumped water was supplied to the lands in the project good crops were produced. The character of the soil in the project is fertile, black, sandy loam. The principal products are alfalfa, sugar beets, melons, sweet potatoes, small fruits, and grains. Alfalfa can be depended on for from two to four cuttings per year and sells at from $6 to $10 per ton in the stack. Sugar beets average about 9 tons to the acre, and can be sold to the Garden City Sugar Beet Factory at $5 per ton.

12. *Present conditions.*—After the end of the irrigation season of 1909 only one irrigator paid the assessment for operation and maintenance, and therefore his lands were the only ones entitled to receive water during the season of 1910. In January, 1910, a conference was held between officials of the Reclamation Service and the directors of the water users' association, following which the directors stated in writing to the supervising engineer that—

> it would be unwise for them to recommend any action without a further consultation with the stockholders of the association; that they are not warranted, from the opinions expressed by the farmers, under the project in recommending any further expenditure for the purpose of experimenting with a view of increasing the water supply; and that in their opinion it is utterly impossible for the farmers to pay the running expenses of the pumping plant during the coming year for the amount of water which could probably be furnished.

As the association failed to provide for operating the plant or to agree to its operation on a rental basis, the plant was prepared for nonuse and—

> its operation discontinued until such time as the landowners made application for its operation and were willing to pay for the construction and operation of same and made some arrangement for the proper distribution of water.

13. There is now pending in Congress a bill which, if passed, will permit a readjustment of the terms of the contract with the water users' association. It is desired by the Reclamation Service that such agreement shall provide for sufficient Government supervision over the farmers' distribution system to insure less wasteful and unequal distribution of pumped water, and for the continuous operation of the plant throughout the irrigation season, with the requirement that the farmers shall "take the water in steady volume, day in and day out, whether it rains or not, and whether the river is in flood or not." Concessions by the Government would doubtless include the operation of the plant for several years, with assessments on the lands only for operation and maintenance and with no payments on the construction charges until the plant had passed the experimental stage and the irrigation system was being successfully operated. Whether or not the water users would accept the terms of a new contract on that basis is uncertain. At the meeting which the board held with the directors of the water users' association there was submitted a copy of a resolution unanimously adopted by the stockholders at their annual meeting on October 5, 1910. The substance of this resolution is that the "Government be asked to abandon the said project so far as this association is concerned, and we ask that all contract liens so far as the Government is concerned be released." Complaint was made to the board that the project has cost much more for construction and for operation and maintenance than had been promised; that the annual charges were more than the lands could pay; and that the capacity of the pumping plant was wholly inadequate; but no desire was expressed for any other form of settlement than the release of the lands from the liens and the abandonment of the project. They stated that they did not believe it would be just for the Government to make them pay for an experiment in pumping which had failed so far as their lands were concerned, but which was more or less useful as an experiment in the installation of pumping plants elsewhere.

14. Alternatives to the starting up again of this pumping plant are its sale by auction as it stands or the dismantling of the plant and the transfer of the machinery to other reclamation projects. Either of these steps would make necessary the cancellation of the contract with the water users' association and would result in a large loss to the reclamation fund. The board, therefore, considers that it is advisable to allow matters to remain as they are now until definite action has been taken by Congress on the bill referred to; and in the event of its becoming a law that an agreement be reached, if practicable, with the association which would permit the resumption of the operation of the plant, even though it be necessary in the agreement to provide for a considerable extension of the period in which building costs must be returned.

15. *Costs.*—The total of allotments on this project to December 31, 1910, is $419,000, of which there was on June 30, 1910, a small balance; but this balance will be exhausted during the lay-up of the plant by the salary of the caretaker and small incidental expenditures. Of the total expended, $21,817.07, or 5.6 per cent, was for field engineering and superintendence; $19,262.38, or 5.2 per cent, for clerical services on the project; $856.38 for the supervising engineer's office; and $11,990.58 for the Washington and Chicago offices, expert engineering, etc. Since only $142.50 has been collected to date for installments on building charge, and $104.50 for operation and maintenance, the total of the allotments, $419,000, approximately represents the investment of the United States. If the lien on the lands is regarded as of value equal to the charges against the lands, then the following table represents in an approximate measure the financial standing of this project:

Investment of the United States		$419,000
Building charges:		
4,885 acres (estimated), at $35.00	$170,975	
4,740 acres (estimated), at $37.50	177,750	
Charges against lands for operation and maintenance	18,466	
		367,191
Loss to fund		51,809

16. If the entire 9,625 acres of land under agreement are bound by the charge named in the second public notice, $37.50, the loss to the fund will be about $40,000. Thus, there will be a loss to the reclamation fund even though the lien on the land has a real value equal to the charge against the land.

17. *Summary.*—(1) This project lies entirely within the State of Kansas.

(2) The entire irrigable area of 10,656 acres is in private ownership.

(3) The power house and power installations, the pumping stations and the concrete canal appear to be well built and in good condition.

(4) The capacity of the pumping plant under continuous operation would be sufficient to supply the full amount of water needed for irrigation, provided the flow of water to the wells was sufficient to supply the pumps, but under the conditions actually existing the pumping plant can not supply sufficient water to irrigate more than a small part of the contemplated area. It can, however, be used to supplement the flood irrigations from the Arkansas River.

(5) The plant having been prepared for nonuse and its operation having been discontinued, the board believes that it should be kept in this condition until definite action is had by Congress on a bill now pending which will permit readjustment of the terms of the agreement with the water users' association, and that if this bill becomes a law, a new agreement should, if practicable, be reached with the association, which will provide for the resumption of operation of the plant, with suitable government supervision of the distribution of water, and for a delay in the collection of past assessments of building charges until the system is in successful operation.

(6) There will be a loss to the reclamation fund even though the lands repay all the charges assessed against them.

SECTION X.

HUNTLEY PROJECT, MONTANA.

1. The board visited this project on August 13, 1910, inspecting the engineering structures, the distribution system, and the irrigable lands. A public hearing was held at Huntley on the same day.

2. *Location.*—This project is located on the south bank of the Yellowstone River in Yellowstone County, Mont. Good transportation facilities are furnished by the Northern Pacific and the Burlington Railroads, both of which traverse the project.

3. *Description.*—The water for this system is taken into the main canal from the Yellowstone through concrete headworks, located about 2 miles above Huntley, no diversion dam being required to direct the necessary flow into the canal. The main canal has an initial capacity of 400 second-feet, is about 23 miles long, and supplies water for the laterals of the distribution system as well as for the high-line canal, which heads at the pumping station 1 mile east of Ballantine. Between the headworks and the town of Huntley the main canal passes through three concrete-lined tunnels, having an aggregate length of 2,654 feet. At the pumping station, located at a 34-foot drop in the main canal, there is installed an automatic pumping unit, consisting of a turbine wheel and a centrifugal pump mounted on the same vertical shaft. The pumping unit lifts 56 second-feet to a height of 45 feet, the pumped water being discharged into the high-line canal. This canal is 6 miles long and through its laterals supplies the bench lands between Ballantine and Fly Creek. The aggregate length of laterals in the system is 240 miles. Other important engineering structures are the wasteway at tunnel No. 3, the culvert carrying the main lateral under the new channel of Pryor Creek, the Fly Creek Syphon, and the channel for Pryor Creek. All of these works, as well as the headworks, the pumping station, and the drops and turnouts on the main canals, are built of concrete. The minor structures, on the laterals, are generally built of wood. All of the engineering structures, as well as the distribution system, were found to be well designed and well constructed. No evidence of leakage was observed in the main canals, and no extensive leakage in the laterals. Such leakage as was observed will,

doubtless, practically disappear as the ditches become seasoned. The project is stated to be 96 per cent completed.

4. *Water supply.*—The Government filing is for 750 cubic feet per second, which is more than sufficient for all irrigable lands which can be reached by the present system and its extensions, and the minimum discharge of the river at this point during the irrigation season is sufficient to render this filing secure.

5. *Lands.*—There is included in this project an irrigable area of 28,809 acres, all of which is public land subject to the reclamation act except about 3,190 acres. The project was opened by public notice dated May 31, 1907, the building charge being fixed at $30 per acre and the charge for operation and maintenance at $0.60 per acre per year. Approximately 6,000 acres of the public land is still open to entry. All of the land under this project was formerly within the ceded strip of the Crow Indian Reservation, and the public lands in this area must pay, in addition to the building charge, $4 per acre to the Crow Indians. One dollar of this is to be paid when the land is entered and the remaining $3 in four equal annual installments. The private land includes Indian allotments and lands purchased from the Indians. The farm unit for the public land is 40 irrigable acres and for the private land 160 irrigable acres. Water-right applications now cover 17,396 acres, but only 12,000 were actually cultivated during the season of 1910.

6. The average elevation of the irrigable area is 3,000 feet above sea level, and the range in temperature is from —35° to 100° F. The average annual rainfall is 12 inches, which is so distributed during the year as to permit dry farming, but only with very limited success. The lands are easy to put into cultivation and to prepare for irrigation. The ground water level is rising and drainage ditches will be required for part of the land.

7. The soil is of good quality and varies from sandy loam to clay. The principal crops are grain. potatoes, alfalfa, and sugar beets, the latter being one of the best paying crops and easily disposed of near by at the Billings (Mont.) sugar factory. Land not in reach of water is valued at about $4 per acre, while sales of land included in the project have recently been made at $50 per acre, with construction charges still to be paid. The land values and crop returns indicate that the land will readily bear the announced construction charge, plus the $4 to be paid to the Crow Indians, and that the public land would have been entered under the land laws even had the building charge been as high as $35 per acre.

8. The size of the farm unit appears generally to be satisfactory and to be regarded as sufficient for supporting a family, although several statements were made that 40 acres was insufficient for that purpose and that for the least desirable lands in this project the farm unit should be increased to 80 acres.

9. *Operation and maintenance.*—Due to the fact that new canals are usually more or less pervious, several years of operation are required before the canals are well seasoned, and therefore the annual cost of repairs is higher at first. The first few years of operation also develop, as a rule, the necessity for certain betterments—for example, the necessity for the extension of concrete linings at drops, for additional check weirs, for additional control gates, etc. This, so far, has been the condition of the Huntley project, and in conse-

quence the annual cost of operation and maintenance on the project has considerably exceeded the collections therefor. Another reason for this annual deficit is that only a portion of the irrigable area is taken up and is assessed for operation and maintenance, while the actual cost of operating and maintaining the system is practically the same whether or not all the lands are being irrigated. For 1909 the excess of cost over collections for operation and maintenance was about $36,000, and for 1910 it is estimated at about $14,000 to $15,000. Now that the ditches are fairly well seasoned and a large part of the necessary betterments have been made, the total annual cost of operation and maintenance should hereafter be less, while the number of acres contributing will increase from year to year. Since the project has been opened, 60 cents per acre has been charged each year for operation and maintenance. The Reclamation Service states that in a few years the actual cost per acre per year will not be more than 50 cents, and if the 60-cent rate is continued the difference can be applied toward reduction of the deficit for operation and maintenance.

10. *Costs.*—The following table shows the probable deficit on this project at the end of the present calendar year:

Debits:		
Building costs to June 30, 1910		$842,887.10
Operation and maintenance costs to June 30, 1910		89,497.86
Deficit for 1910 for operation and maintenance (estimated)		15,000.00
		946,644.23
Credits:		
Building charges returnable, 28,809 acres, at $30	$864,270.00	
Sale of town sites	12,657.25	
Collected or accrued for operation and maintenance to June 30, 1910	15,795.15	
		892,722.40
Difference		53,921.83

This probable deficit may be reduced by additional sales of town sites. On the other hand, it will probably be increased somewhat during the next year or two by excess of expenditures over collections for operation and maintenance.

11. *Extensions.*—It is proposed to extend both the high line and the main canal to cover additional irrigable lands. The total area to be added by the proposed extensions is 4,035 acres, of which all is public land except about 900 acres of private land or Indian allotments. Since the intake, the main canals, and other works have sufficient capacity for this increased acreage, the proposed extension of the distribution system should be regarded rather as the completion of the project than as an extension. It is estimated by the Reclamation Service that the proposed work will cost approximately $110,000. It is believed by the board that the irrigable lands within the proposed extensions will bear a construction charge of $35 per acre, or possibly more, plus the payment of $4 per acre to the Crow Indians. If this area is opened at $35 per acre, the probable deficit on this project will be considerably reduced. This extension is regarded by the board as feasible from both an engineering and an economic standpoint, but it is not considered advisable that the work be undertaken until the larger part of the remaining public lands are taken up.

12. *Summary.*—(1) This project is entirely within the State of Montana.

(2) Of the 28,809 acres of irrigable land in the project about 89 per cent is public land subject to the reclamation act.

(3) Of the 4,035 acres of irrigable land in the proposed extension about 78 per cent is public land subject to the reclamation act.

(4) All of the engineering structures, as well as the distribution system, are well designed and well constructed.

(5) The Government filing for water is more than sufficient for all irrigable land in the project and its proposed extension, and the minimum discharge of the river at this point is sufficient to render this filing secure.

(6) The lands within the project will readily bear the announced building charge of $30 per acre, and those in the proposed extension will bear a charge of $35 per acre, or possibly more, plus the $4 per acre required to be paid to the Crow Indians.

(7) The proposed extension is regarded by the board as feasible from both an engineering and an economic standpoint, but it is not considered advisable that the work be undertaken until the larger part of the remaining public irrigable lands are taken up.

(8) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the fund $110,000

SECTION XI.

MILK RIVER PROJECT, MONTANA.

1. The board visited the lower part of this project on August 18 and 19, 1910, inspecting the Nelson Reservoir site, the Dodson Dam, the Dodson South Canal, and the irrigable lands; and on August 24, 25, and 26 inspected the sites for the St. Mary Lakes Storage Dams, that of the St. Mary River Diversion Dam, that of the Swift Current Diversion Canal, and the line of the St. Mary Diversion Canal. Public hearings were held at Hinsdale, Saco, and Malta on August 18, and at Harlem, Chinook, and Havre on August 19.

2. *Location.*—The irrigable area of this project lies in a narrow strip on both sides of the lower Milk River, in the counties of Valley and Chouteau, Mont. The storage and diversion works for the water supply from St. Mary Lakes are in the Blackfeet Indian Reservation, in western Montana. The Great Northern Railway traverses the entire irrigable area, and with its numerous stations gives short wagon hauls for the farm products.

3. *Description.*—The approved plans for the development of this system provide for the diversion of a part of the flow of the St. Mary into the headwaters of the Milk River. This diverted water is to supplement the water in the Milk River in the irrigation of lands in the lower valley of the latter stream.

4. *River systems.*—St. Mary River has its source in the two large lakes of the same name, whence it flows north through Canada into

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Hudson Bay. Milk River has its sources near the St. Mary Basin, but is separated therefrom by a glacial ridge. Milk River flows north into Canada, thence east for about 200 miles, finally turning south and reentering the United States. A treaty was signed in 1909 between the United States and Great Britain which provides for the division of the waters of the two river systems on the following basis: These streams are to be treated as one stream for the purposes of power and irrigation; the waters thereof are to be apportioned equally to the two countries, but in order to afford a more beneficial use to each country, more than half may be taken from one stream and less than half from the other by either country; the prior right is recognized of the United States to 500 second-feet of the flow of the Milk River from April 1 to October 31 each year, or so much of such amount as constitutes three-fourths of the natural flow, and a similar prior right of Canada is recognized to the St. Mary flow; and, further, the United States may use the channel of Milk River lying in Canada for passing through Canadian territory the water diverted from the St. Mary.

5. *Diversion canal.*—Water is to be diverted from the St. Mary River to the North Fork of the Milk River, through the proposed St. Mary Canal, which will be entirely within the United States. The canal is to have a capacity of 850 second-feet, and will be 26 miles long. The principal structures will be the headworks tunnel and controlling works; Duck Creek crossing, Terror Creek siphon, and sluiceway; Hall Coulee siphon, and the drop into the North Fork. The formation through which the canal will be constructed shows evidence of having slipped, and considerable difficulty may be anticipated from slides. About 3 miles of the canal near its upper end may have to be lined with concrete. Some work has been done on this canal near the head and on another section a few miles from the lower end.

6. *Storage.*—The natural flow of the St. Mary is not sufficient to supply the prior rights of Canada and at the same time to permit the diversion to the Milk River of the additional amount of water required in that stream for the irrigation of the contemplated acreage. The approved plans, therefore, contemplate storage in the St. Mary Lakes. These two lakes are about 1¼ miles apart, and are connected by a small stream, the difference in the elevation of the two lakes being 12 feet. It is proposed to provide storage in the two lakes for about 218,000 acre-feet. Several plans for such storage were proposed, but the one now regarded by the Reclamation Service as the most desirable is the construction of a dam at the outlet of each lake, and of a canal connecting the lakes sufficiently low in elevation to permit the drawing down of the upper lake to a lower level than is now possible. The proposed storage dams are to be of the earth-fill type, with surfaces covered with riprap. A spillway is to be provided for each dam. It is the expectation that the construction of the dams will be postponed until storage becomes necessary.

7. To increase the available water, it is proposed to divert Swift Current Creek into St. Mary Lake above the storage dam by means of a canal and a diversion dam in the Swift Current.

8. *Milk River.*—This division of the project includes all works for the utilization of the water for irrigation in the lower Milk River

Valley. The works which have been under consideration for this division of the project are:

(1) *Chain Lakes Reservoir.*—The site for this reservoir is at the Chain Lakes on the Milk River. The earlier plans contemplated a high dam, forming a reservoir with about 750,000 acre-feet capacity, but examination indicated that the foundations are not suitable for a high dam. It may, however, be safe and practicable to construct a low dam at the foot of these lakes, if additional storage on Milk River becomes necessary.

(2) *Nelson Reservoir.*—This reservoir is to be formed by an earth embankment across the outlet of a natural depression south of the Milk River. The reservoir thus proposed will have an effective storage capacity of 142,000 acre-feet, and will be filled by water diverted from the Milk River through a feeder canal. The embankment will have a length of about 15,000 feet and a maximum height of 33 feet. The side slopes proposed are 3 to 1 upstream and 2 to 1 downstream; top width, 16 feet.

(3) *Chinook Diversion Dam.*—The proposed location of this dam is in the Milk River, about 3 miles below Chinook. The dam has not been designed, but is to be of the same type as the Dodson Dam.

(4) *Chinook North and South Canals.*—These canals are to head at the Chinook Dam, and are to supply water for the Chinook division, which lies on both sides of the river. The north canal is to be 38 miles, and the south canal 24 miles long.

(5) *Dodson Diversion Dam and Headworks.*—The Dodson Dam is located in the Milk River, about 3 miles above Dodson, and is completed except for the proposed automatic crest. The concrete headworks on the south bank have been completed, but no work has so far been done on the headworks for the north bank. This dam is a rock-filled, timber-crib structure.

(6) *Dodson North and South Canals.*—These canals are to head at the Dodson Dam, and are to supply water for the Dodson division. The north canal is to be about 28 miles long and have an initial capacity of 200 second-feet, supplying water for the Dodson north unit. The south canal has been completed for 9½ miles, and partially completed for an additional length of 8 miles. It is to have a total length of 42 miles, an initial capacity of 900 second-feet, and will supply water for the Dodson south unit, for the Bowdoin Canal, the Ashfield Canal, and Nelson Reservoir. The Bowdoin and Ashfield Canals are to carry water for their respective units. In the Dodson south unit the system of laterals has been constructed for about one-half the unit.

(7) *Nelson Reservoir South and North Canals.*—Both of these canals will head in Nelson Reservoir. The south canal is to be about 22 miles long and have an initial capacity of 250 second-feet. It will supply water to the Nelson Reservoir south unit, and, when necessary, to the Milk River for use in the Vandalia unit. The north canal will have a length of 47 miles, and an initial capacity of 250 second-feet, and will supply the Nelson Reservoir north unit, which lies on the north side of the Milk River. The canal will cross the river in a reinforced concrete siphon.

(8) *Vandalia Dam.*—The site for the proposed dam is in the Milk River, about 4 miles west of Vandalia. The dam has not been designed, but will be of similar type to the Dodson Dam.

(9) *Vandalia Canal.*—This canal will head at the Vandalia Dam, and will supply water to the Vandalia-Glasgow unit. The canal will be about 38 miles long, and will have a capacity depending on the acreage of the unit, which has not yet been determined.

9. *Comments on engineering structures.*—The completed structures in the Dodson division were found by the board to be well constructed. Most of the structures proposed for the complete system are only tentatively designed at present, but no engineering works of special difficulty are contemplated. The St. Mary Diversion Canal will probably be difficult to maintain on account of the expected movement in the material in which the canal is to be cut. This remark applies especially to the second 3 miles from the head, where considerable sliding has already taken place. It is proposed to provide good open drainage to prevent saturation of the slopes above the canal and thereby reduce the tendency to slide.

10. *Water supply.*—The Reclamation Service has made a comprehensive study of the water supply of the project, and a summary of that study with comments thereon is appended to this report. It is found that after satisfying Canada's prior right 850 second-feet can be diverted from St. Mary River for a period of seven months each year if suitable storage is provided in St. Mary Lakes. The amount of storage that would have been required to maintain this flow during the period 1903–1909 varied from 75,000 acre-feet to 175,000 acre-feet. The plans contemplate 218,000 acre-feet of storage in these lakes, thus providing for even a lower flow in St. Mary River than has occurred since 1903.

11. The study also shows that during the same period the part of the natural flow of Milk River to which the United States is entitled by treaty, augmented by the 850 second-feet from St. Mary River, would have been sufficient to provide water for 215,000 acres at the assumed duty of 1½ acre-feet per acre measured at the farm, and that this amount of water could have been delivered to the land through the canal and reservoir system as planned.

12. In this study a uniform rate of delivery of water to the lands during a period of seven months is assumed. As the growing season is only about five months it is questionable whether such deliveries would meet irrigation requirements. The storage provided in Nelson Reservoir would serve to regulate deliveries in accordance with the demand so far as the lands below it are concerned, but this storage must also serve to equalize the variable run-off of different years.

13. While the amount of water available is sufficient for the needs of the project, it seems probable that additional storage on Milk River will be necessary if the delivery of water is to be limited to the growing season. It further appears that the terms of the treaty will be complied with, as the quantities of the combined flow of St. Mary and Milk Rivers proposed to be used in the United States both for this project and to satisfy prior rights will not exceed one-half of the combined flow of these streams as measured at the international boundary.

14. The supervising engineer stated, "Before the United States can safely undertake the construction of any extensive irrigation works, it will be necessary that the rights of the various appropriators of water from Milk River and its tributaries be definitely fixed and made a matter of court record." The board believes that necessary steps to obtain such adjudication should be taken at once.

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15. *Lands.*—The irrigable lands of the project logically fall into three principal divisions and one smaller division. In the table below are given these divisions with their natural subdivisions, which, for convenience, are designated as units. The acreage of irrigable lands has been variously stated, but the figures given are those on which the construction estimate is based. In the table is shown also the acreage of lands now included in private and Indian irrigation systems, but which, it is expected, will come into the Government project:

Chinook division:			
(1) Chinook north unit—			
Under private canals	16,000		
Not under private canals	22,000		
		38,000	
(2) Chinook south unit—			
Not within Indian reservation—			
Under private canal	9,000		
Not under private canal	4,000		
Within Indian reservation—			
Under Indian canal	10,000		
Not under Indian canal	20,000		
		43,000	
			81,000
Dodson division:			
(3) Dodson north unit—			
First half unit	6,000		
Second half unit	8,000		
		14,000	
(4) Dodson south unit—			
Head to Malta divide	15,000		
Malta Divide to Ashfield Canal	5,000		
		20,000	
(5) Bowdoin unit		17,000	
(6) Ashfield unit		10,000	
			61,000
Nelson Reservoir division:			
(7) Nelson Reservoir south unit		20,000	
(8) Nelson Reservoir north unit		20,000	
			40,000
Vandalia Canal division:			
(9) Vandalia-Glasgow unit			14,000
Total			196,000

16. In the Dodson south unit about 8,000 acres are now in reach of flood water, supplied through the Dodson South Canal, but no land has been officially declared open for irrigation.

17. The status of the lands as to ownership was furnished to the board only for an assumed acreage of 248,000 acres. Assuming that the relative proportions of the different classes of land is approximately the same for the reduced as for the larger acreage, the following represents the approximate classification of the lands: Public lands entered, subject to the reclamation act, 64,000 acres; public land unentered, 12,000; State land, 10,000 acres; private land and Indian land, 110,000 acres. In addition to this area of 196,000 acres, there are other areas within the boundaries of the project now under private ditches taking water from Milk River or from Willow and Rock Creeks, but these can not be irrigated from the proposed Government canals.

18. The average elevation of the irrigable area is about 2,200 feet above sea level and the range of temperature is from —45° to 100° F.

The average rainfall on the irrigable area is about 13 inches. Although dry farming is possible, it is not usually successful. A single flood irrigation sometimes is sufficient to insure a good crop. The soil is a fertile sandy loam, well adapted to raising hay, grain, alfalfa, and vegetables. Some alkali is present in places, and drainage ditches will be required for part of the area in order to prevent swamping. Statements from local sources indicate a valuation of land without water of about $20 per acre and of land under irrigation of $75 to $100 per acre. None of the area has yet been opened and no construction charge has been fixed. The water users' association, which covers the lands below the Dodson Dam, has petitioned for water at whatever the necessary cost may be. It is believed by the board that in view of the probable returns from the lands when under full irrigation the land will readily bear any reasonable building charge.

19. *Costs.*—To June 30, 1910, there has been expended on the St. Mary storage and diversion $265,842.95, and on the Milk River irrigation system $538,396.74. The estimates for completion of this project, as prepared for the board, are as follows:

(*a*) St. Mary storage and diversion:		
Swift Current diversion		$30,000
Temporary St. Mary Diversion Dam		10,000
Out-take tunnel		59,123
Regulating works		10,810
Duck Creek controlling works		9,011
Division 1 of canal		613,700
Division 2 of canal		107,700
Division 3 of canal		126,500
Division 4 of canal		158,200
Halle Coulee siphon		55,160
Bridges, spillways, drops, etc		59,500
Storage dam, Lower St. Mary Lake		238,620
Department expense, engineering, and contingencies, 20 per cent		295,665
Total		1,773,989
Deductions:		
Work done on canal	$150,000	
Equipment on hand	15,000	
		165,000
Additional expenditures required		1,608,989
(*b*) Milk River irrigation system:		
Automatic crest Dodson Dam		10,000
Dodson North Canal, laterals, etc		104,000
Dodson South Canal, laterals, etc		344,000
Bowdoin Canal, laterals, etc		267,000
Vandalia Dam, canal, laterals, etc		475,000
Dodson South Canal extension, laterals, etc		363,000
Nelson Reservoir		380,000
Nelson Reservoir, south canal, laterals, etc		330,000
Ashfield Canal, laterals, etc		155,000
Dodson North Canal extensions, laterals, etc		160,000
Nelson Reservoir, north canal, laterals, etc		435,000
Chinook Dam		75,000
Chinook North Canal, laterals, etc		470,000
Chinook South Canal, laterals, etc		556,000
Total estimated future expenditures		4,124,000
Allotments to June 30, 1910		593,000
Total estimated cost to complete		4,717,000

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20. In the above estimate the proposed storage dam for the upper St. Mary Lake is not included nor the amount already expended for surveys, etc., in connection with the St. Mary storage and diversion. For these items approximately $400,000 should be added, making the total estimated cost of the St. Mary storage and diversion about $2,174,000 and the total estimated cost of the whole project about $6,891,000. The total of allotments to December 30, 1910, on the project is $941,000, and therefore additional allotments to the amount of about $5,950,000 are required for the completion of the project.

21. Since the above estimates are more or less approximate, and since the irrigable acreage to be included in the project is more or less uncertain, only a rough approximation can be made as to the probable building charge per acre. Based on the above estimates and on an acreage of 196,000, and assuming that the lands of the present private irrigation system will come into the Government project at one-half the acre building charge, then the probable building charge will be $38 to $39 per acre.

22. *Comments.*—Owing to the international features of this project it has just claim for national assistance. The large amount of money already expended, which would be lost if the project were not completed, the relatively large amount of public land, the productiveness of the land and its ability to pay the probable building cost, all make it desirable to continue work on the project until completion. Attention is invited to the fact that the par value of the stock of the water users' association is only $25 per share. As this amount is said to be the limit of the recorded lien against the land, it would render the security for the cost of the project more certain if the par value of the stock is raised to a figure which will cover the probable building charge.

23. *Summary.*—(1) The irrigable land of this project lies entirely within the State of Montana, but the project is international in character because of the division of the flow of St. Mary and Milk Rivers between Canada and the United States and the conveyance of the water belonging to the United States through Canadian territory.

(2) Of the total area of 196,000 acres which it is proposed to include in the project, about 39 per cent is public land subject to the reclamation act.

(3) The project is feasible, both from an engineering and an economic standpoint.

(4) The amount of water available, with the storage proposed, is sufficient for the needs of the proposed project, but additional storage may be needed on Milk River if the delivery of water is limited to the growing season. The proposed use in the United States of the combined flow of St. Mary and Milk Rivers, both for this project and for satisfying prior rights, will not exceed one-half of the combined flow of these streams, as measured at the international boundary.

(5) The total estimated cost of this project is about $6,891,000, of which $941,000 has already been allotted.

(6) The land will bear the construction charge, which is estimated to be about $38 to $39 per acre.

(7) In view of the international features of this project, the large amount of money already expended, the large amount of public land included, and the value of the land and its ability to bear the prob-

able building charge, the project is a worthy one and work should be continued at an economical rate until completion.

(8) The following allotments are recommended for the four years 1911–1914, inclusive:

From the fund	$2,950,000
From the loan	1,000,000
Total	3,950,000

SECTION XII.

SUN RIVER PROJECT, MONTANA.

1. The board, on August 21, visited the Fort Shaw unit, Willow Creek Reservoir, the lands on the Greenfield Bench, the line of the High Line Canal and other proposed canals in that vicinity; on August 22, the sites of the diversion dam at Sun River Canyon and of the Warm Springs Dam; on August 23, the line of the proposed North Supply and Teton Slope Canals, the site of the Pishkun Reservoir and the lands adjacent. Hearings were held at Fairfield on August 21, and Chouteau on August 23.

2. *Location.*—The Sun River project is designed to irrigate lands lying in the valleys of the Sun River and the Teton River in western Montana just east of the Rocky Mountain divide. The lands and the water supply are entirely within the State of Montana.

3. A branch of the Great Northern Railway passes north and south through the eastern part of the project. The nearest station to the Fort Shaw unit is Vaughn, distant 6 miles. It is expected that a branch will be constructed up the Sun River Valley and that probably a transcontinental road will within a few years cross the divide by way of the valley of the South Fork of the North Fork.

4. *Description.*—Water for this project will be taken mainly from the North Fork of the Sun River. A storage reservoir will be constructed near Warm Springs on the North Fork of the North Fork. The supply in this reservoir will be increased by water brought by canal from the South Fork of the North Fork and by tunnel and canal from Bowl Creek on the west of the Continental Divide. After leaving the reservoir the water will flow about 12 miles in the channel of the North Fork until it reaches the North Fork Canyon, where it will be diverted by a concrete dam built in the canyon. From this point it will be carried in two canals, one on each side of the river, called the North Supply and the South Supply Canals. Additional storage capacity will be provided by two reservoirs, the Pishkun Reservoir at the end of the North Supply Canal, and the Willow Creek Reservoir, supplied by the South Supply Canal. The water supply is to be augmented by various secondary streams, such as the South Fork of the Sun River, Willow Creek, and Deep Creek. The Pishkun Reservoir will discharge—first, into the High Line-Greenfields Canal; and, second, by a different opening and at a lower level, through Deep Creek into the Teton Slope Canal. Willow Creek Reservoir discharges into the Sun River, and the water is thence

diverted into the Fort Shaw Canal. The water stored in the Willow Creek Reservoir is to be used for the Fort Shaw unit and also for the private irrigation lands on the Lower Sun River, thus permitting all of the North Fork water to be taken into the Government system instead of allowing a portion of it to pass down the river to satisfy these prior rights. A possible extension of the project is the use of Lake Benton as a reservoir supplied from the Teton Slope Canal to irrigate lands in the vicinity of Great Falls. It would use surplus flood water when available. Willow Creek Reservoir is now under construction, with a temporary height of dam of 70 feet, to store the waters of Willow Creek and tributaries. The dam will later be increased in height to provide for additional storage for the surplus waters of the North Fork. The canal and lateral system of the Fort Shaw unit is practically complete. No work has been done on the other parts of the project, except the necessary surveys.

5. *Water supply.*—The annual run-off of Sun River ranges from 500,000 acre-feet to 1,000,000 acre-feet. To provide for years of low water, it is proposed to increase the supply of water by diversion from Bowl Creek, on the west side of the divide, which has an estimated run-off of 8,000 to 9,000 acre-feet. Stream gaugings at a number of points have been made since 1905, but the data even for this period are not sufficiently complete to warrant any definite conclusions as to the supply that can be made available for this project through the reservoir and canal system as planned.

6. In an analysis, prepared by the supervising engineer, which is appended, the run-off of certain parts of the watershed has been assumed, the assumptions being based on the size of drainage area and the character of the topography as compared with the known run-off of certain other areas. It has also been assumed that the winter flow of the South Fork of the North Fork can be diverted into the Warm Springs Reservoir during 10 months each year, and that that of the North Fork below the Warm Springs Reservoir can be diverted into the north and south supply canals during the same period. It is believed, however, that eight months' use of these canals is all that can be counted upon in this climate. Based on these assumptions, it was found that, after satisfying prior rights and providing for the Fort Shaw unit, there would have been available for north side lands the following quantities of water:

Total available supply for north side lands.

1905	322,700
1906	305,500
1907	740,000
1908	757,000
1909	784,000
1910	540,000

7. The duty of water is assumed to be 1½ acre-feet per acre measured at the farm corresponding to a diversion duty of 2 acre-feet per acre. On this basis there would have been a sufficient supply in 1906 for 152,000 acres, while during 1907, 1908, and 1909 there would have been sufficient for 350,000 acres.

8. The proposed reservoirs will permit a certain amount of water to be carried over from years of high run-off to years of low run-off, but these reservoirs must also act as equalizers of the annual flow.

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Further information as to the distribution of the run-off throughout the year at different points of the system is necessary before the hold-over capacity of the reservoirs can be determined. As the limited gauge readings show two successive years of low run-off, only half of the hold-over capacity can be relied upon to supplement the flow in such years. Assuming the hold-over capacity at 200,000 acre-feet, it does not seem wise with the system as planned to count on an annual supply of over 400,000 acre-feet, or sufficient for the irrigation of 200,000 acres.

9. *Land.*—The rainfall on the irrigable area is about 12 inches. The average elevation is 3,700 feet above sea level. The amount of land to be irrigated has been variously estimated, and as there is much more land of good quality than water available, it will depend on the water development. The number of acres proposed in the project is from 283,000 to 322,000, divided as follows:

	Acres.
Fort Shaw unit, lying along south bank of the Sun River	16,000
High Line and Greenfields unit along north bank of the Sun River and on divide between Sun and Teton Rivers	94,000
Teton Slope and Muddy Creek	173,000
Proposed extension in vicinity of town of Power	14,000
Lake Benton system	25,000
	322,000

These areas are not very definitely determined. The ownership is distributed about as follows:

	Acres.
Public land withdrawn from entry	138,000
Land entered under reclamation act	93,000
State land	25,000
Private land	50,000
Fort Shaw unit under irrigation	16,000
	322,000

10. The land is of good quality, especially on the benches. The soil is sandy loam, clay, gravel, and alluvium. Water is necessary to insure good crops, dry farming giving uncertain results, though practiced in several localities. The land lies well for irrigation, includes but few nonirrigable areas, and permits economical development of canals and laterals. Drainage ditches will be necessary. Below the Fort Shaw unit private land has been under irrigation for some years, and large areas have become swamped due to over irrigation and lack of drainage. As this region is only semiarid, a duty of 1½ acre-feet at the farm is considered sufficient. The crops are hay, alfalfa, grain, vegetables, and in the future probably sugar beets.

11. Land without water is worth $5 to $20; with water, $75 to $100 an acre.

12. About 1900 the construction of a canal called the Kilmore Co-operative Canal was begun in order to irrigate the Greenfields bench, and about 4 miles of canal were constructed. The withdrawal under the reclamation act in 1903 of the public lands caused a suspension of this work, leaving the settlers without the anticipated water.

13. *Fort Shaw unit.*—The only land opened for settlement in this project is the Fort Shaw unit, an abandoned military reservation, opened May, 1908. This unit comprises 16,000 acres, of which 13,500 acres are public and 2,500 acres private land. There are 206 public

farms, averaging 88 acres of total area and 61 acres of irrigable area. There have been entered 163 farms, or 9,500 acres of public land, and 225 acres of private land have made water applications. In addition, 1,200 acres of Indian school reserve land receive water.

14. The Government unit is 40 to 80 acres, dependent on location and soil. While this land does not produce high-priced crops, there does not seem to be any objection to the small-size farms, as 40 per cent of the farms entered contain 40 acres or less of irrigable land, 59 per cent 60 acres or less, and only 10 per cent over 80 acres.

15. The assessed cost of construction for the unit is $30 per acre and of operation and maintenance $0.50 per acre per year.

16. *Engineering structures.*—The only completed portion of this project is the Fort Shaw unit. Water is taken through concrete headworks from the Sun River and distributed by a system of canals, of which one-third mile has a capacity of greater than 300 second-feet, 17 miles of between 50 and 300 second-feet, and 88 miles less than 50 second-feet. The turnouts are mainly of timber. The drops are of concrete. The slope of several of the laterals is large and erosion of the banks frequent. This can be readily corrected by insertion of drops, or by other means.

17. The Willow Creek Dam is now under construction to a temporary height of 70 feet, and side slopes of 3 to 1. When additional storage is needed it will be raised to a final height of 110 feet, with a top width of 20 feet, upstream slope of 3 to 1 and downstream slope of 2 to 1. The spillway for the lower dam will be through a gap in the surrounding hills. This will be closed by a dike when the dam is raised, and the spillway will be through another and higher gap. The outlet is by a tunnel passing around the end of the dam. The subsoil is glacial drift, 15 feet or less in depth, lying over sandstone. Four cut-off trenches are excavated to the underlying rock and filled with selected puddled material. The storage capacity when the dam is completed to full height will be 84,000 acre-feet. The capacity of the temporary reservoir is 16,700 acre-feet.

18. The proposed Pishkun Reservoir Dam and other earth dams are low and offer no difficulties of construction.

19. The diversion dam in the Sun River Canyon will be of concrete of about 72 feet maximum height, and a top length of 150 to 160 feet.

20. The site of the proposed dam for the Warm Springs Reservoir is located on the North Fork of the North Fork, about 12 miles above the canyon. It is planned to be a rock-fill dam backed with earth placed by the hydraulic process. The upstream slope is 3 to 1. It was first proposed to make the downstream slope 1 to 1, and the estimates were made by the Reclamation Service on that basis. It is now proposed to make it 1½ by 1. The outlet will be by tunnel. Ample spillway is provided through a depression in the surrounding hills. Rock is found at a small depth below the creek bed. The material for construction is to be clay, coarse and fine gravel, sand, and some bowlders. The capacity is to be 156,800 acre-feet.

21. Descriptions of Willow Creek and Warm Springs Dams with estimates are appended.

22. *Comments.*—The works in the Fort Shaw unit are well designed and constructed.

23. While it is at present proposed to raise the Willow Creek Dam from its present proposed height of 70 feet to a height of 110 feet,

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this increase will not be needed for several years, and it is possible that the full height of 110 feet may not be needed. The reason given for adopting a rock-fill dam at Warm Springs is the high cost of a masonry structure constructed at such a distance from the railroad. As this dam will not be constructed for several years, possibly better railroad facilities will then exist, a further consideration is recommended of the type of this dam. The south side supply canal, as proposed, is to have a capacity of 1,100 second-feet. As is shown in Table 4 of the water-supply analysis, the maximum yearly amount that would have passed through the canal during the period 1905–1910 was 52,000 acre-feet, or only 24 days' flow when running full. As this amount can readily be diverted during the nonirrigating season with a canal of much less capacity, a further study is suggested.

24. *Costs and estimates.*—There has been allotted to December 31, 1910, $672,000, which has been used in constructing the Fort Shaw unit, in beginning the Willow Creek Reservoir, and in surveys and examinations for the complete project. The total estimate of cost, including work already done, is as follows:

Fort Shaw unit, including share of storage cost and examinations	$672,000
Willow Creek Reservoir, to complete	266,600
Bowl Creek Canal	25,000
Warm Springs Reservoir	664,100
Canyon Headworks	118,500
North Supply Canal	1,157,700
South Supply Canal	130,300
Pishkun Reservoir	183,600
High Line and Greenfields Canals and extensions	1,528,200
Teton Slope Canal and extensions	2,427,100
Muddy Creek extension	319,900
Power extension	210,000
Benton Lake system	432,600
	8,135,600

25. This estimate is for the completion of the proposed project of 322,000 acres. If the Power extension and the Benton Lake system are omitted this will reduce the total estimated cost to $7,493,000 for 283,000 acres.

26. It is thought by the board that this estimate is too low. In the Warm Springs Dam the unit costs for rock fill, earth fill, and riprap are all considered low, and in addition the proposed flattening of the rock-fill slope will increase the quantities. In the Canyon Headworks and the Willow Creek Dam some of the estimates of unit costs are also low. As the details of the project have not been worked out, the size of canals are not determined, and estimates on the canal system must be approximate. Having in view the uncertainties of much of the work, an item of 20 per cent for contingencies would be better than the 15 per cent adopted. It would be safer to make the estimate of the total cost as approaching $10,000.000 for the larger project and $9,000,000 for the smaller. The chief engineer of the Reclamation Service, in a communication dated October 29, 1910, makes approximately this recommendation.

27. These figures would make the cost of construction per acre from $30 to $32. As stated above in the discussion of the water supply, it does not appear certain that over 400,000 acre-feet can be counted on. This is sufficient for about 200,000 acres of land, and it may be necessary to reduce the project to this acreage. As the cost of the storage system is relatively small, it may be taken as approxi-

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mately proportionate to the amount of land, and as all the land lies equally well for irrigation, the relative cost of the distribution system should be about the same for the smaller acreage. It may be assumed, therefore, that the building cost of 200,000 acres would be about $35 per acre. It is thought that the land could bear a cost not to exceed this amount. Further investigations with regard to the water supply and further surveys of the land to be irrigated are necessary before reliable estimates can be made.

28. *Summary.*—(1) The project is feasible from an engineering and economic standpoint.

(2) The lands and the water supply lie entirely within the State of Montana and to the east of the Rocky Mountains, except that a small proportion of the water may be diverted from the west side of the Divide.

(3) The total amount of land in the project will vary from 200,000 to 322,000 acres, dependent upon the amount of water available. Of this, about 70 per cent is public land subject to the reclamation act.

(4) The amount of water is sufficient for 200,000 acres, and it may prove after further investigation that it is sufficient for a larger area.

(5) The estimated cost may vary from about $7,000,000 to $10,000,000, depending on the amount of land included in the project. Of this $672,000 has been spent for the completion of the Fort Shaw unit and for surveys and examinations.

(6) The land can bear the cost of construction, estimated at about $35 per acre.

(7) The project is considered worthy and should be continued as soon as funds are available.

(8) Further examinations of the water supply and surveys of the land will be necessary in order to determine the extent of the project.

(9) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the fund $3,278,000

SECTION XIII.

LOWER YELLOWSTONE PROJECT, MONTANA AND NORTH DAKOTA.

1. The board visited this project on August 16 and 17, 1910, inspecting the principal engineering structures, the distribution system, and the irrigable lands, and held public meetings at Sydney and Valley View, Mont.

2. *Location.*—This project is located on the west bank of the Yellowstone River, partly in Montana and partly in North Dakota. It lies between the Northern Pacific and the Great Northern Railroads, but the center of the irrigable area is about 35 miles from the nearest railroad station. A new railroad is projected which, when built, will give good railroad facilities to the entire project. At present the railroad station for the southern part of the project is Glendive, Mont., and for the central and northern parts, Mondak, Mont.

3. *Description.*—The water for this project is taken from the Yellowstone River through concrete headworks, a diversion dam giving

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the necessary head to cause a flow in the canal at low water. The dam and headworks are located about 17 miles below Glendive. The structures are described in the appendix to this section. Through the openings in the headworks the water passes into the main canal, and thence through the laterals and sublaterals to the lands to be irrigated. The main canal has a capacity at its head of 847 second-feet, and is now 62 miles long and ultimately will be about 70 miles long. There are now about 138 miles of laterals and sublaterals, with capacities of from 1 to 90 second-feet, and for the completion of the system 63 miles additional will be required. Important structures along the line of the main canal are the flume carrying the waters of Linden Creek over the canal, the Burns Creek sluiceway, the Burns Creek conduit, and the Fox Creek siphon and spillway, all of which structures are of concrete. These structures, as well as the canals and laterals, appear to be well constructed. Wood is the material ordinarily used for construction of turn-outs and other minor works on the laterals. Generally the engineering structures seem to have been constructed economically, although based on experience elsewhere in the United States the cost of the diversion dam appears to be high. It is thought that a dam equally secure and equally suitable could have been built for a more reasonable expenditure. The completion of the approved project involves, in addition to the extension of the distribution system, the installation of a pumping unit for raising water to the high-line lateral located at one of the drops in the distribution system.

4. *Water supply.*—The water supply for this project is more than ample, the minimum discharge being 4,500 second-feet, while the maximum capacity of the main canal is about 850 second-feet. The Government filing, made on October 30, 1905, is for 1,000 second-feet. The duty of water is figured at 2½ acre-feet per acre at the farm. The average annual rainfall on the irrigable area is 16 inches.

5. *Lands.*—Under the project as outlined and approved there is a total irrigable area of 62,280 acres, of which about 2,000 acres are State lands, about 5,000 acres belong to the Northern Pacific Railway, about 17,000 acres are public, the remainder being in private ownership. The railroad land is under agreement to be sold off in farm units. All the land is to be irrigated by gravity, except 2,314 acres, which are to be supplied by pumped water. Of the total acreage in the project, 35,395 acres were opened under the public notice of December 21, 1908, the building charge being fixed at $42.50 per acre. Practically all of this area is deeded land or land which has been taken up under the terms of the reclamation act, there being only about 20 farm units still open, and these are in the poorest part of the valley. The public land taken up in this project has been homesteaded in 160-acre tracts, which, under the terms of the reclamation act, must be reduced to conform to the size set for the farm unit—that is, 80 acres. Acreage in excess of 80 irrigable acres must be returned to the Government and lands so returned will give further opportunities to new settlers.

6. Before the project was started a large proportion of the owners of the private land entered into an agreement with the Government to take water from the system, and, in accordance with the law, all public land included in the project was so pledged. Since the Reclamation Service has been prepared to supply water for the 35,395

acres opened, only a small proportion of the farmers have filed application for water, there being now only about 13,000 acres for which the applications for water have been perfected, of which only 7,000 acres were actually irrigated this year. This failure to utilize the irrigation system is believed to be due partly to the fact that for several years the rainfall has been sufficient to produce fair crops, causing the farmers to postpone their applications; and, secondly, to the dissatisfaction with the construction charges, which the farmers very generally claim to have been promised would not be more than $30 per acre. The season of 1910 has been an unusually dry one, and unirrigated crops were mostly total failures. Many of those not using water would doubtless have applied for it this season had it not been that before water would have been furnished it was required that amounts due for operation and maintenance for 1909 must be paid. For the next season this condition will be more severe, since before water will be furnished one installment of the construction charges and two years' charge for operation and maintenance, a total of $8.50 per acre, will be required. The large majority of the farmers claim that few of them will be able to meet the installments of the construction charges as now required, but state that under a system of graduated payments they will be able to do so. It is understood that a bill is now before Congress which, if it becomes a law, will permit a readjustment of the terms for repayment of building charges after they have already been fixed by the Secretary of the Interior. The situation of the farmers under this project appears to justify some readjustment in this case. Dissatisfaction is also expressed with the requirement that homesteaders must give up all of their holdings except 80 irrigable acres, many claiming that they did not so understand the law when they entered their land. They state that they would be satisfied to sell the excess holding, but that it is unjust to require them to give it up without compensation for improvements. This condition, however, seems to be a consequence of their ignorance of the terms of the law.

7. The average elevation of the irrigable land is about 1,900 feet above sea level; the range of temperature is from —30° to 100° F., and the average annual rainfall is about 16 inches. The land lies on well-defined benches, is as a rule well adapted to irrigation, and is easily drained. The bottom lands are more or less covered with brush and are more liable to be uneven, and it is therefore more difficult to prepare them for irrigation. The soil is a deep, sandy loam, apparently fairly uniform in quality and easy to work. There is little alkali. The soil and climate are suitable for grain, alfalfa, etc., but the long wagon haul to market greatly decreases the net returns from these crops. Considering the certainty of a crop on irrigated land in dry years, as well as the more bountiful crops in ordinary years, the board believes that the land will bear the construction charges which have been set, and more readily so after the projected railroad is built. This charge of $42.50 per acre is, however, considered to be close to the limit of costs which the land will bear. Under present conditions it does not appear to be probable that farmers who are now two or more years in arrears for building charges and for operation and maintenance can perfect their applications for water. The accumulation of back charges, the quality of the land, which at present produces only hay and grains, the distance to the railroad, the

poverty due to the failure of this year's crop, have produced a condition which it seems can be remedied only by some modification of the present requirements which would permit the farmers to obtain one irrigated crop prior to any demand for back charges, or which would provide for a system of graduated payments.

8. The board believes that the farm unit of 80 acres is sufficient to support a family if it is properly worked. While the actual cost per acre for operation and maintenance has so far been much greater than the charge, which has been set at $1 per acre per year, it is probable that when the canals are well seasoned and when the bulk of the land is under irrigation that the cost per acre will not exceed $1, which appears to be a reasonable charge.

9. *Completion of the system.*—No extensions are proposed, but it is contemplated that the approved project shall be completed. The completion will involve only the extensions of the present and the construction of some additional laterals and the installation of the pumping equipment. The board regards the completion of the system as feasible and practicable, but it does not regard it as desirable that further large expenditures be made for this purpose until it is demonstrated that most of the acreage now in reach of the irrigation water is actually being irrigated and with satisfactory results; and, furthermore, that it will be wise to await the completion of the railroad before completing the system so as to render more probable successful results.

10. *Returns to the reclamation fund.*—The aggregate of allotments to date is $2,910,000, and the supervising engineer states that additional allotments to the amount of $613,000 will be required to complete the work, making a total of $3,523,000. Since the costs of operation and maintenance are paid out of the allotments from the reclamation fund, and since collections to cover such costs are returned to the fund through the land offices, the total of allotments for a project must be decreased by the collections (or accruals) for operation and maintenance in order to show the amount properly chargeable to construction. In the case of the Lower Yellowstone project, however, the collections for operation and maintenance to date have been only $12,067, which will probably be barely sufficient to cover the deficit for operation and maintenance for the next season. For this reason it is believed to be advisable to take $3,523,000 as the probable total construction cost of the completed system.

11. The 35,395 acres already opened at $42.50 should return $1,504,287.50. Subtracting this from the estimated total cost, the remainder is $2,018,712.50. If it is assumed that the lands not yet opened are to repay this amount, then the charge for construction would have to be fixed at about $75 per acre. On the other hand, assuming that the remaining area is to be opened at $42.50 per acre, the total expected return from the 62,280 acres will be $2,646,900. Under this assumption the loss to the reclamation fund will be $876,000. It is possible that before the remaining area is opened conditions will justify a charge per acre above $42.50, but in any event it seems inevitable that there will be a large loss on this project to the reclamation fund. Since for an estimated additional expenditure of $613,000 an area of 26,885 irrigable acres will be added, the completion of the project will, if the lands repay the charges, reduce the deficit from what it would be if the project was restricted to the area already opened.

12. *Summary.*—(1) This project is interstate in character, being partly in Montana and partly in North Dakota.

(2) Out of an area of 62,280 irrigable acres in the project only 17,000 acres, or 27 per cent, are public, subject to the reclamation act.

(3) The engineering structures and the distribution system are well constructed and economically designed and constructed, with the possible exception of the diversion dam and headworks.

(4) The completion of the project as outlined is feasible.

(5) No large expenditures should be made toward the completion of the project until the area already open is utilized with success.

(6) In the event of such successful utilization the project should then be completed as outlined.

(7) In the opinion of the board the farm unit of 80 acres is sufficient to support a family.

(8) If permitted by law some modification should be made in the terms of the contract with the farmers on this project which will enable them to obtain one irrigated crop prior to any demand for back charges, or which will provide for a system of graduated payments.

(9) There will be a large loss on this project to the reclamation fund.

(10) The estimated final cost of the project is about $3,523,000, of which approximately $2,900,000 had been expended prior to June 30, 1910.

(11) The following allotment is recommended for the four years 1911–1914, inclusive:

From the fund ---------- $578,000

SECTION XIV.

NORTH PLATTE PROJECT, WYOMING AND NEBRASKA.

1. The board visited the Pathfinder Dam on August 1 and 2, the proposed site for the new diversion dam at Guernsey on August 3, and the line of the proposed Goshen Park Canal on August 4 and 5. The diversion dam at Whalen and the Interstate Canal were inspected on August 6. Public hearings were held in Casper and Torrington, Wyo., and in Mitchell and Bridgeport, Nebr.

2. *Location.*—This project is located in eastern Wyoming and western Nebraska, and lies on both sides of the North Platte River. It extends along the river from Whalen, Wyo., to Bridgeport, Nebr., a length of 98 miles, and varies in width from 4 to 20 miles. Its main water supply and the greater part of the irrigable lands under the complete project lie in Wyoming. The lands in the unit now under construction lie in Nebraska. A branch line of the Chicago, Burlington & Quincy Railroad traverses the project from end to end, furnishing good railroad facilities.

3. *Description.*—The project includes a storage reservoir above the Pathfinder Dam, which is located 3 miles below the junction of the Sweetwater and North Platte Rivers; the utilization of the channel of the North Platte River for a distance of about 180 miles to conduct the stored water to the area to be irrigated; diversion dams at

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several points in the lower river; and the main canals and laterals necessary to distribute the water over the lands. Of this project the completed portions are: The Pathfinder Dam (nearly finished), the diversion dam at Whalen, and the main canal, 95 miles long, heading at the Whalen Dam, known as the Interstate Canal, which with its laterals is now largely in use irrigating the greater part of the first unit on the north side of the river. The parts still to be built include a diversion dam at Guernsey, to divert water into a proposed south canal for irrigating the Goshen Park area, the extension of the Interstate Canal and its laterals, and perhaps the construction of a proposed south canal heading at the Whalen Dam, and known as the Fort Laramie Canal.

4. Before this work was undertaken by the Reclamation Service several canals had been built by private enterprise. The Whalen Falls Canal, heading in the river near Whalen, was built to irrigate about 28,000 acres, partly Carey Act lands, and the Tri-State or Farmers' Canal, heading just east of the Nebraska-Wyoming State line. Other private canals were the Mitchell and Gering Canal, Castle Rock, Hillside, Winter Creek, Bayard, and Alliance. The right of way of the Whalen Falls Canal, about 45 miles long, was purchased by the Reclamation Service and used for the Interstate Canal. The areas irrigated under the Interstate Canal include, by special agreement, the lands formerly irrigated under the canals which were absorbed by the Government and the lands lying to the eastward included between the Tri-State and the Interstate Canals.

5. *Engineering features.*—The main engineering feature of the project is the Pathfinder Dam and Reservoir. The dam is about 54 miles from Casper, Wyo., and is located in the bed of the North Platte River in a narrow gorge having granite walls. It is of the arch type, the radius of its center line being 150 feet, and is built of uncoursed cyclopean granite masonry except the two faces, which are laid in 2 and 3 foot courses. The height is 214 feet above the river bed. It is 432 feet long on top and 80 feet long on the bottom. The top width is 14 feet, providing a 10-foot roadway, and the bottom width is 90 feet. A spillway 700 feet long at the north end is under construction. This spillway is being cut in the rock abutment and will be provided with a low concrete weir. The area of the reservoir at the level of the spillway is 21,774 acres, and its capacity is 1,025,000 acre-feet.

6. It was the original intention to release all the water through the tunnel cut in the natural rock on the north side used to pass the river flow during construction. This tunnel is 481 feet long, 10 feet by 13 feet in cross section, and has a capacity of 7,000 second-feet under full head. It is closed by four sliding cast-iron gates separated by concrete piers, the tunnel being widened to maintain ample sectional area. These gates are under 180-foot head when the reservoir is full. Although this head has never been reached, the force of the water while being discharged under less head was such as to damage the tunnel lining and an additional outlet at a higher level was decided upon. This will be 60 feet higher, will be 360 feet long and 12 feet by 13 feet in cross section. Water will be admitted by six needle or balanced-pressure valves 5 feet in diameter. This tunnel is nearly completed.

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7. The rock abutment of the dam on the left bank is continuous to high ground, but on the right bank the rock surface drops and the abutment is connected with the high ground by a long, flat ridge of gravel and sand in layers, the rock surface not being found at depths of 60 feet below the surface. This gravel ridge has a long gap which is lower than the spillways. To close this gap an earth dike is now being constructed. This dike is strengthened by using a concrete core wall, by the selection of impervious material for the interior, and by heavy paving on the reservoir side.

8. The Whalen Diversion Dam is a concrete overflow weir of the ogee type with a height of 26 feet at the highest place and a length of 300 feet. Head gates are provided at each end, one set of which is in use at the head of the Interstate Canal, and the other set is intended for the Fort Laramie Canal if it should be constructed.

9. The Interstate is the main canal. It has a calculated carrying capacity of 1,400 second-feet for the first 28 miles, after which the capacity is reduced. It was designed for a velocity of 2.8 feet per second, which was exceeded when the canal was put in operation, and a system of check gates was necessary throughout its entire length. Three reenforced concrete siphons of the box type were constructed to carry the canals under Rawhide, Spotted Tail, and Dry Spotted Tail Creeks.

10. The plan of irrigation comprises three districts in addition to the land formerly irrigated under private systems. A series of three reservoirs is contemplated, having capacities of 13,000, 27,000, and 90,000 acre-feet, to enable more water to be saved from the flood flow of the river.

11. *Water supply.*—This project gets its water from the North Platte River, which has a drainage area of 12,000 square miles, an average annual rainfall over the drainage basin of 20 inches, and an average run-off of 1,500,000 acre-feet. Many private canals using the waters of the North Platte River have water rights that antedate the filings of the Government and an adjudication of these rights by the State engineers of Wyoming and Nebraska has recently been made, allowing 463 second-feet in Wyoming and 4,618 second-feet in Nebraska. The Reclamation Service believes that the latter is excessive and that 3,000 second-feet would more than cover the amount of the priorities put to beneficial use. A study of the water supply has recently been made by the Chief Engineer of the Reclamation Service, and is attached hereto. From the assumptions made therein the conclusions are reached that the supply is ample for the irrigation of the Interstate unit and the Goshen Park unit, with a surplus sufficient for 30,000 acres additional, and as much more as the return seepage can supply. The assumptions seem reasonable and the board agrees with the conclusion that there will be sufficient water for the Interstate and the Goshen Park units. The acreage irrigable by the available supply is so dependent on how much water can be legally claimed by prior appropriators that these assumptions may be materially changed when the prior rights are definitely known. Large extensions of the project should not be made until all the water rights are settled by court decision.

12. *Lands.*—The average elevation of the irrigable area is 4,100 feet above sea level, the range of temperature is from 25° below zero to 100° Fahrenheit, and the average annual rainfall is 15 inches. Dry

farming is usually not successful. The lands of the project are in two main units, the Interstate and the Goshen Park units.

13. *Lands in the Interstate unit.*—The lands now under irrigation extend along the North Platte from Whalen to Bridgeport, much of the land, amounting to about 90,000 acres, west of Red Willow Creek in the lower part being irrigated by private canals. The areas to be supplied under the project are all north of the river and are divided into four sections. The first includes about 17,870 acres of land in Wyoming formerly irrigated under a private system, partly under the Carey Act, which land is now furnished with water under special agreement without charge for construction and with a fixed charge of 40 cents a year for 10 years for maintenance and operation. The next two districts, known as the first and second lateral districts, cover 36,760 acres and 34,100 acres, respectively. These areas are now largely under irrigation. The next is the third lateral district of 38,000 acres, in which the canals and laterals are now being built. The total of the Interstate Canal unit, including several small areas reserved, is 129,270 acres. Of this area 2,179 acres are under the Carey Act, 3,369 acres are school lands, 34,864 acres are privately owned, and the remainder are under the reclamation act. There are 88,716 acres ready for water, and 51,218 acres were irrigated in 1910.

14. The Interstate Canal as it flows eastward approaches a privately owned canal known as the Tri-State, and the irrigable area lying between is narrowed. At Red Willow Creek the canals come near enough together to permit the irrigation of the land lying east of this creek by an extension of either canal.

15. The principal products are alfalfa, cereals, corn, sugar beets, and potatoes. The soil is a light sandy loam and is easily drained. But little trouble from swamping is expected.

16. The value of the land under this unit before irrigation was from $5 to $25 per acre, and after irrigation from $75 to $100. From a consideration of the land values and its productiveness, the board believes that a construction charge of about $60 per acre can probably be borne. This amount is near the limit which the land can bear and with this charge the public lands will probably be slowly taken up for settlement. The farm unit is 80 acres.

17. *Lands in the Goshen Park unit.*—All the lands of this unit lie south of the river. The irrigable area is stated as about 210,000 acres. No work has been done beyond land surveys and canal locations. To irrigate this area it will be necessary to build a dam in the river above Guernsey, about 100 feet high. This dam would divert the water through a tunnel into a main canal which would skirt the highlands for a length of about 148 miles. Recent surveys show that a part of the area of this unit can be irrigated more economically by a lower canal heading in the river at the Whalen Dam. This proposed canal, known as the Fort Laramie, would supply 60,000 acres.

18. About 75 per cent of the area of this unit is public land, 5 per cent State land, and 2,500 acres are occupied under the Carey Act. In 1908 all unpatented public lands were withdrawn from entry to prevent settlement until again opened.

19. Some land on the south side of the river, amounting to about 40,000 acres, has been irrigated under private canals. Of this amount, the Mitchell and Gering Canal irrigates about 28,000 acres.

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20. In general, the land is superior to that on the north side of the river, as there is less sand. When irrigated it sells at from $100 to $150 per acre. Without water it is worth only a few dollars per acre for grazing. The land of this unit, in the main, lies well for drainage, but some ditches for this purpose will probably be necessary in the lowlands near the river and occasionally elsewhere, as in Cherry Creek Valley.

21. *Cost.*—The cost of the reservoir has been $1,408,838.21 up to June 30, 1910. There has been allotted to this work $1,640,000. It will require for completion about $110,000 additional, as follows:

Completing dike	$20,000
Completing south side tunnel	75,000
Completing north tunnel lining and spillway	15,000
	110,000

This will make the total cost of the reservoir about $1,750,000.

22. The expenditures on the Interstate unit were $3,210,835.18 up to June 30, 1910. Allotments amounting to $3,495,000 have been made up to December, 1910. The estimate for completion is $1,075,000 additional, as follows:

Dam of Reservoir No. 1	$60,000
Dam of Reservoir No. 1½	35,000
Extending main canals and laterals	130,000
Dam of Reservoir No. 2	260,000
Dam of Reservoir No. 3	300,000
Canal and lateral system, Dam No. 3	260,000
Lateral system for isolated tracts	30,000
Total	1,075,000

This will make the total cost of the unit about $4,570,000. If part of the cost of the reservoir, amounting to $500,000, be added as the proportionate share of this unit the cost will be $5,070,000, which is the amount to be returned to the reclamation fund by payment of the construction charges. Construction charges were announced on this project under several public notices between 1907 and 1910. The first price set was $35 and applies to a small area, but this was found to be too low and was later changed to $45. Repayments are expected by the Reclamation Service under these notices as follows:

551 acres are to pay $35, or	$19,285
68,718 acres are to pay $45, or	3,092,310
69,269	3,111,595

There are 17,870 acres which pay no construction charge, leaving the remaining land of the project, 42,131 acres, to repay about $1,958,405, or about $46.48 per acre. Either the construction charge on this unit will have to be raised to at least $46.48 or there will be considerable loss to the reclamation fund.

23. Surveys for a high-line canal to irrigate 150,000 acres have been completed, and the estimated cost of construction is about $12,000,000. Surveys for the Fort Laramie Canal, to irrigate 60,000 acres, are not yet completed, but it is estimated that the cost will not exceed $3,000,000. This would make a total cost for the irrigation of the 210,000 acres of $15,000,000, or about $70 per acre. It is thought that under present conditions this is more than the land can bear, as it is suitable only for ordinary farm products. Moreover, it is stated

by the Reclamation Service that about 40,000 acres of this is second-class land and would cost about $20 per acre to bring it under cultivation, and that suitable provision will have to be made for drainage, estimated to cost about $3 per acre. Under present conditions, therefore, it does not seem practicable to construct a high-line canal either for the entire area or for 150,000 acres. The Fort Laramie Canal will cost $3,000,000 for 60,000 acres, or not to exceed $50 per acre. Of this 60,000 acres, 30,200 are public land subject to the reclamation act, 6,000 acres State lands, and 23,800 private lands. It is recommended that the Fort Laramie Canal be constructed. If it is found at a later date that the remaining lands in the Goshen Park unit can stand a construction charge of $70 to $80 per acre, a high-line canal can be subsequently built, or, if not, the surplus water from the Pathfinder Reservoir can be sold to the various private canals along the river that desire to make use of it should this course be authorized by law.

24. Since commencing irrigation the operation and maintenance charges have amounted to $351,306.28 up to June 30, 1910. Except for the collection of $2 per acre from 551 acres and 40 cents per acre from 17,874 acres, the cost of operation and maintenance has been added to the construction charge.

25. The cost of operation and maintenance in 1908 was $175,430.88, or an average of about $2 per acre for all the irrigable land within reach of water. This amount is high, but as additional areas are brought under the system and as the canals and laterals become seasoned this unit cost should be reduced.

26. *Comments.*—At the public hearing at Bridgeport the landowners in the vicinity expressed a desire to have the Government extend the Interstate Canal eastward to supply considerable areas east of Red Willow Creek. If the development of the Goshen Park area south of the river is determined on, such an extension would probably not be practicable, as it is doubtful whether the water supply will be sufficient for both. It would also require an increase in the carrying capacity of the Interstate Canal and some of its structures. The area in the Goshen Park unit is largely public land, and its irrigation is regarded as preferable to that of the Bridgeport extension of the Interstate unit.

27. The board believes that it is desirable to complete the Interstate unit for the full 110,000 acres of the three lateral districts, as at present proposed, that the water rights be adjudicated by court decision, and that 60,000 acres in the Goshen Park unit, under the Fort Laramie Canal, be irrigated.

28. *Summary.*—(1) The project is feasible from an engineering and economic standpoint.

(2) It is interstate in character, lying partly in Wyoming and partly in Nebraska.

(3) The area in the part of the project at present approved, the Interstate unit, is 129,270 acres, of which about 64 per cent is public land subject to the reclamation act. The area of the Goshen Park unit (not yet approved) is about 210,000 acres, of which about 75 per cent is public land subject to the reclamation act.

(4) The water supply available depends on the prior rights. There is a sufficient supply for the present Interstate unit and probably for the entire Goshen Park unit. Any considerable extension beyond the

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present approved unit should not be begun until the water rights on this stream are adjudicated in the Federal courts and the rights of the Government definitely known.

(5) The total estimated cost of the Pathfinder Reservoir is $1,750,000, of which $1,408,000 has been expended. That of the Interstate unit is $5,070,000, of which $3,211,000 has been expended. The Interstate unit is about 80 per cent completed.

(6) The land in the Interstate unit can bear the construction charge of about $46.50, and that in the proposed Fort Laramie unit can bear the probable charge of $50 per acre. The large probable cost of $80 per acre for the remainder of the Goshen Park unit is believed to be in excess of what the land can bear at present.

(7) Owing to the large expenditures already made, the comparatively large amount of public land, and the interstate character of the project, the Interstate unit should be continued at an economical rate of progress until completed; the Fort Laramie unit should be undertaken, but the remainder of the Goshen Park unit should not be commenced at present. If this land should not increase in value sufficiently after the development of the Fort Laramie unit to warrant its irrigation, the surplus water should be used on other irrigable areas in order to repay the proportionate cost of the reservoir.

(8) The following allotments are recommended for the four years 1911–1914, inclusive:

From the fund	$2,185,000
From the loan	2,000,000
Total	4,185,000

SECTION XV.

TRUCKEE-CARSON PROJECT, NEVADA.

1. The Truckee-Carson project was visited by the board on September 27 and 28. The head works in the Carson River near Hazen and the irrigated lands in the vicinity of Fallon were visited on the former date. Churchill Valley, the lower Carson Reservoir site and the dam site for this reservoir, together with Truckee River diversion dam and the main Truckee Canal, were inspected on the latter date. On the evening of September 27 a public hearing was held in the town of Fallon.

2. *Location and description.*—The Truckee-Carson irrigation project provides for supplying water over large areas of land, at present barren, lying in the vicinity of Fallon, Hazen, and Fernley, Nev. For this purpose it is proposed to use the waters of the Truckee and Carson Rivers, which now flow into natural depressions in the bed of the primeval Lake Lahontan and disappear. The irrigating water comes mainly from snowfall on the mountains of eastern California, supplemented by rains in the drainage basin of the Truckee and Carson Rivers. The project is interstate in character, as part of the water supply and much of the storage are within the State of California, while the irrigated lands are in Nevada.

3. The project involves the diversion of a part of the natural flow of the Truckee River through a canal into the Carson River, together

with such stored water as may be conserved in Lake Tahoe. In addition to the flow from the Truckee River it is proposed to use the water of the Carson River, collecting the flow of both streams in a reservoir to be formed by a dam in the Carson below the outlet of the Truckee Canal. From this reservoir the supply will be released into the Carson River and again picked up at a diversion dam lower downstream, where the main distribution system commences. The completed work includes a diversion dam in the Truckee River, near Clarks, diverting water into the main Truckee Canal; the construction of the main Truckee Canal, 31 miles long, having a capacity of 1,200 second-feet; borings and other investigations for the Carson River storage dam and for the outlet works for Lake Tahoe; the construction of the Carson River diversion dam, about 4 miles from the lower end of the Truckee Canal; the construction of two irrigating canals, one of 1,500 second-feet capacity and the other of 450 second-feet capacity; the extension of laterals and minor ditches of the distribution system.

4. *Transportation facilities.*—The main line of the Southern Pacific Railway passes through Hazen, one of the towns of the project, and a branch line to Fallon affords transportation facilities for the greater part of the project. The most distant farm unit from a railway station will require a 15-mile haul to place its products upon railway cars.

5. *Construction features.*—The waters of the Truckee River are diverted into the main Truckee Canal by a dam about 20 miles below Reno. This dam is of concrete and is supplied with sluice gates, 16 in number for passing the river flow and 9 for controlling the flow into the canal. There is no overfall section in the river portion, the entire river passing through the sluiceways. The main Truckee Canal empties into the Carson River a short distance above the site for the storage dam to be built later. This dam will collect the waters of both the Truckee and Carson Rivers. About 4 miles below this dam site is the diversion dam for the distribution system. It is similar to the Truckee Dam, but has headworks at each end for controlling the two canals. The river flow is passed through 23 sluiceways, the dam having no overflow section. The main distributing canal lies on the right bank and has a capacity of 1,500 second-feet. The one on the other bank has a capacity of 450 second-feet. These two canals with their smaller laterals cover an area of country extending about 25 miles eastward and about 20 miles north and south. There are four tunnels on the main Truckee Canal.

6. *Water supply.*—Water is supplied from the Carson and Truckee Rivers, the combined annual run-off amounting to about 1,000,000 acre-feet. The area of the drainage basin is 3,450 square miles. Its average elevation above sea level is about 8,000 feet. The rainfall is about 25 inches. The average annual discharge from Lake Tahoe into the Truckee River for 10 years from 1900 to 1909 amounted to 317,000 acre-feet, the minimum being 112,730 acre-feet, and the maximum being 704,200 acre-feet. The average annual discharge of the Truckeet River at Vista below the town of Reno for 10 years was 865,840 acre-feet, the minimum being 391,000 acre-feet in 1900, and the maximum 1,813,000 acre-feet in 1907. The average annual discharge of the Carson River at Empire for nine years, 1901 to 1909, was 397,797 acre-feet, the maximum 703,900 in 1907, and the mini-

mum 141,650 in 1908. In order to utilize the large discharge of these rivers considerable storage capacity is necessary, and several suitable sites are available. The most important of these is Lake Tahoe, one of the sources of the Truckee River. This lake is situated at an elevation of 6,230 feet above sea level and has an area of 193 square miles. The drainage area above the lake outlet is 519 square miles, and below its outlet the river receives the drainage of about 1,000 square miles more.

7. The storage capacity of the lake between the limits of natural variation is upward of 600,000 acre-feet. By regulating the outlet this lake is relied on to furnish storage capacity for at least 200,000 acre-feet for use on the project. It is proposed to construct a storage reservoir in the lower Carson River by building a rock-fill dam. This reservoir will have a capacity of 290,000 acre-feet. Another depression in the Carson River near the town of Dayton, known as Alkali Flat, may be used for storage if later found necessary. Its capacity will be about 228,000 acre-feet.

8. On this project it may be stated that the amount of land of suitable character is far in excess of what can be supplied with water. There are about 40,000 acres of land irrigated under private canals in the near vicinity of Reno. The water for this land is taken from the summer flow of the Truckee River, and is probably a prior right to that of the Government, but it does not include any stored water. Some private land in the upper Carson Valley is also irrigated under prior rights. The water rights on the Truckee River have not been adjudicated, but it is stated that this is now in progress.

9. From the records there is apparently more water available than is necessary for the present proposed acreage of the project, which might permit some expansion, but a study of the precipitation records shows that the years of recorded discharge were years of more than usual rainfall, so that a considerable margin for safety is allowed by the Reclamation Service.

10. The adopted plan assumes a regulated flow in the Truckee River. In the absence of such regulation, either by means of Lake Tahoe or other reservoirs on the Truckee River, not more than 150,000 acres could be irrigated in an unfavorable year as 1908, the year of the minimum recorded flow.

11. Utilizing the storage capacity of Lake Tahoe and regulating the Truckee River flow both depend upon effecting some agreement with the prior claimants to the waters of this lake. The principal one of these is the Truckee River General Electric Co., which claims to have prior rights to about 400 second-feet of the flow for power. This company claims to own the outlet of the lake and desires to regulate the flow in its own interests. The company proposed last year to construct a new outlet to the lake, build the necessary controlling works, rebuild the old outlet works, and accept the responsibility for all damages in connection therewith if the Reclamation Service would pay one-half the cost of rebuilding the old works (this share amounting to about $20,000), operate the headworks at both outlets, furnish the company with 475 second-feet daily through the new outlet, and protect the company from suits after the new plant was installed. They offered to furnish water from other sources than Lake Tahoe for irrigating large areas around Reno, now being supplied partly

from Lake Tahoe by private companies. They proposed also to construct a reservoir at Washoe Lake of about 168,000 acre-feet capacity to hold the water used during the winter months for power development, which, under present conditions, is wasted. The old lake outlet would be used only to regulate the flow whenever necessary.

12. This agreement was not approved by the Secretary of the Interior. The use of Lake Tahoe for storage, while not an essential part of the project, is a very desirable one. The regulation of the flow of Truckee River, without using Lake Tahoe, could possibly be affected by storage elsewhere, but at a largely increased cost. A fuller discussion of the water supply is appended hereto.

13. *Lands.*—The amount of land under this project is 206,000 acres, to which must be added 13,000 acres which have a vested water right recognized by the Government and three or four thousand acres concerning which no agreement has been made. About 60 per cent of the project is public land. Only the first unit of 92,018 acres has been completed, of which 32,000 acres were furnished with water this year. In this unit there are 46,110 acres of public land, 45,908 acres of private land, of which 10,147 acres belong to the railroad and are now being sold in small tracts with the requirement that water be applied for under the reclamation act. There are included in the irrigated portion 4,600 acres of Piute Indian lands, for which the Indian Office pays the regular charge. The land is at an elevation of about 4,000 feet and has an average annual rainfall of 4 inches. It is worthless for cultivation unless irrigated. The duty of water is 3 feet on the land. The temperature ranges from 0° to 105° F. The farm unit is 80 acres if public land and 160 acres if in private ownership. The land lies in the bed of an old lake and has a slight slope sufficient for irrigation. Drainage has been found necessary, but where open drains are used swamping seems to be prevented. Alkali is found in some localities.

14. The soil is sandy loam, clay, and adobe loam. The crops are alfalfa, sugar beets, grains, and vegetables. A beet-sugar factory is under construction at Fallon. Land without a water right is practically valueless, but with a good water right it is often valued at over $100 per acre. Seventy-five dollars per acre would be about an average price. The public land is not being rapidly taken up, partly due to the undeveloped condition of the country. It was stated by the Truckee-Carson Farmers' Association that $50 was about the limit of construction charge that the land could bear. There is no water users' association, the agreement as to the use of water being between the Government and the individual farmer. The settlement of land under this project has been slow but has now reached a point where the adequate supply of water for greater area is not practicable without storage.

15. *Cost.*—The total expenditure under this project up to June 30, 1910, was $4,082,233.11, of which $137,000, or 3.4 per cent, was for examinations and surveys; $442,700, or 10.8 per cent, was for superintendence, engineering, and clerical services on the project; $5,668.55, or 0.14 per cent was for the supervising engineer's office, and $167,070.10, or 4.9 per cent, was for the Washington and Chicago offices, expert engineering, etc. The estimated cost of the completed project

is $7,000,000, or about $3,000,000 in addition to expenditures up to the present time. The items for this additional expenditure are:

Lake Tahoe Reservoir	$20,000
Lower Carson Reservoir Dam	1,250,000
District 5, distribution system	61,000
District 3, distribution system	94,000
District 4, distribution system	228,000
Carson Lake extension	316,000
Alkali Flat Reservoir	400,000
Pyramid Lake extension	500,000
Churchill Valley	131,000
Total	3,000,000

16. There has been allotted to this project $4,178,000 up to December 31, 1910. The construction charges were first set at $22 per acre, and 24,000 acres were taken up at this figure. Later the charge was raised to $30 and 6,000 acres were taken up. Thirteen thousand acres pay no construction charges. There are, therefore, 43,000 acres which are to return $708,000 to the reclamation fund. To return the cost to the reclamation fund, the remaining 176,000 acres will have to return $6,292,000, or an average of about $36 per acre, assuming that all the land will be disposed of at this figure and the estimates for completion are not exceeded. A later estimate for completion has been submitted by the chief engineer, dated October 29, 1910, amounting to $3,500,000, which it is thought will all be needed. On this basis the charge per acre would be about $39 to return the cost to the fund. The arrangement of charges suggested by the Reclamation Service is as follows:

First unit settled, 24,000 acres, at $22	$528,000
Second unit settled, 6,000 acres, at $30	180,000
Area to be opened before Alkali Flat Reservoir is constructed, 142,000 acres, at $35	4,970,000
Area to be opened after constructed, 34,000 acres, at $40	1,360,000
Total, per 206,000 acres	7,038,000

17. The cost of operation and maintenance in 1909 was $39,452.12, and the return was $20,920.90, leaving a deficit of $18,531.22. The charge for operation and maintenance has now been raised from 40 cents per acre per annum to 60 cents. The actual cost should be less than 60 cents when a large area is under irrigation, so that the deficit may ultimately be reduced by retaining the higher charge after the cost of operation is lowered.

18. *Comment.*—The diversion dams at both the Truckee and Carson Rivers are constructed without spillway, the river flow being passed through a series of gates. In both cases accidents have occurred, due to the blocking of the high-water flow by drifts or other causes, the river cutting around one end in one case and both ends in the other. This would indicate that the type was not particularly well adapted to the purpose for which designed. With this exception, the engineering features visited by the board seem to be well suited to the purpose for which intended.

19. *Summary.*—(1) The project is feasible in an engineering and economic sense.

(2) It is interstate in character, the water supply and storage being mainly in California and the irrigable area in Nevada.

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(3) The total area involved is 206,000 acres, of which about 60 per cent is public land.

(4) The water supply is sufficient with the storage proposed.

(5) The estimated cost of completion is $7,000,000, of which $4,082,233.11 has been expended.

(6) The land can return the construction charge, which is now estimated at $35 to $40, but which may have to be increased.

(7) The project is a worthy one; is now more than 60 per cent completed, and should be continued at an economical rate of progress until finished.

(8) The following allotments are recommended for the four years 1911–1914, inclusive:

From the fund	$1,594,000
From the loan	1,193,000
	2,787,000

Section XVI.

CARLSBAD PROJECT, NEW MEXICO.

1. The board visited this project on October 15, 1910, inspecting the reservoirs McMillan and Avalon, the Dark Canyon Siphon, the river aqueduct, the distributing system, and the irrigable lands. In the evening of that day the board held a meeting with the water users' association.

2. *Location.*—This project is located on the Pecos River, in Eddy County, N. Mex. The project is traversed by a branch of the Santa Fe Railway, which gives good transportation facilities for the entire irrigable area.

3. *Purchase.*—This irrigation system was constructed by the Pecos Irrigation Co., which operated it until a flood in October, 1904, destroyed the dam at Lake Avalon. The company being unable to rebuild the dam, the people living on the project appealed to the Government, and early in 1906 the property and rights of the irrigation company were purchased for $150,000 allotted from the reclamation fund.

4. *Description.*—The Pecos River supplies the water for the lands, and since the low water discharge is insufficient for the area irrigated, two reservoirs have been constructed for storage. These reservoirs, Lakes McMillan and Avalon, with their dams and controlling works, constitute the principal engineering structures of the system. Lake McMillan is formed by an earth and rock-fill dam across the old river channel and is provided with two spillways and with concrete head gates. The head gates discharge into a canal cut in rock, which in turn discharges into the river bed a short distance below the dam. The head gates were constructed since the United States purchased the reservoir and the Reclamation Service has also reenforced the dam, reconstructed the spillways, and constructed a dike within the reservoir to prevent the stored waters from reaching the bordering bed of gypsum where a large leakage had existed. Lake Avalon is also formed by an earth and rock-fill dam across the river bed, the dam being provided with a concrete and sheet pile diaphragm or cut-off wall. The combined head gates and spillway is a concrete

structure, and there are two other spillways which spill over rock at low places in the rim of the reservoir. The dam, head gates, etc., were constructed by the Reclamation Service, the old dam having been destroyed by a flood prior to the purchase of the system by the United States.

5. The main canal of the system heads at Lake Avalon, on the east bank of the river, and about 3 miles below it is carried across the Pecos by a concrete flume or aqueduct. This flume was built prior to the purchase, but has since been extensively repaired by the United States. A main lateral, called the East Canal, takes out a short distance above the river crossing and covers the small irrigated area on the east bank. The main canal covers the lands west of the river, and after crossing the river it is called the Southern Canal. This canal crosses Dark Canyan in a reenforced concrete inverted siphon constructed by the United States. The minor structures of the distribution system are generally of wood, but where these have needed repairs by the Government they have been replaced with concrete. The main canals and laterals have been partially enlarged and improved by the United States. The main canal is designed for a maximum flow of 500 second-feet, the Southern Canal for 400, and the Eastern for 100 second-feet (the capacities of the Southern and Eastern being reduced in their lower portions). The assistant engineer in local charge, however, under date of September 14, 1910, in a report to the supervising engineer, states: "The present safe capacity of our main canal (Southern) to the siphon is 350 second-feet when the channel is reasonably clean. We have found from the experience of the past three seasons that the canal can not be expected to carry over 200 to 250 second-feet with safety for more than 10 days at a time during the hot summer, on account of the channel filling up with aquatic growth." The lateral which supplies the so-called Black River system; that is, the lands south of Black River, has been relocated since the United States took charge, the new portion being partially concrete lined, the lateral discharging its waters into the Black River Channel through a concrete drop.

6. The various engineering works done by the Reclamation Service in the improvement of the system appear to be well designed and well executed. However, the entire system prior to its purchase by the United States, as well as now, has been characterized by excessive losses by leakage, both in the reservoirs and in the ditches. The dike constructed in Lake McMillan has greatly reduced the leakage in that reservoir, but it is still large and evidently passes through the gypsum beds in the bluffs on the east side, north of the dike. A large part of this leakage, it is believed by the Reclamation Service, reenters the river above the Avalon Dam. But by far the most important and injurious leakage occurs in the distribution system, especially in certain portions of the Southern Canal and in the East Canal. The excessive leakage in the distribution system is believed to be due to the presence of gypsum in the soil, and it seems that the only certain remedy for it is the lining of the canals or a large portion of them with concrete. The comparatively clear water taken into the canals from Lake Avalon does not contain sufficient silt to seal the porous canal banks, most of the material carried by the river water being deposited in Lake McMillan. The subject of leakage is discussed further in the following paragraphs.

7. *Water supply.*—Water is obtained from the Pecos River, under two appropriations, one made in 1888 by the Pecos Irrigation Co. for approximately 75,000 to 100,000 acre-feet, and one made in 1905 by the Reclamation Service for 300,000 acre-feet. During the period of 1905–1910 the average run-off of the river at Dayton, above Lake McMillan, was 330,000 acre-feet, with a maximum of 915,000 acre-feet and a minimum of 154,000 acre-feet. The two reservoirs have an estimated aggregate storage capacity of about 34,000 acre-feet, Lake McMillan having a capacity of 29,000 acre-feet and Lake Avalon of 5,000 acre-feet. Since the hydrographs show a summer as well as a winter peak, the available storage is more valuable than on a stream with only one period of high-water run-off. A third reservoir site between lakes McMillan and Avalon has been under consideration and is described on page 277 of the Fourth Annual Report of the Reclamation Service. Doubt is there expressed as to the feasibility of constructing a reservoir at this point, owing to the presence of beds of gypsum and to questionable foundations at the proposed dam site. Pending a more complete examination, no opinion can be expressed by the board as to the feasibility or the cost of such a reservoir.

8. As stated above, the leakage losses in the system are very great. During 1909–10 measurements showed a loss of 40 to 44 per cent between the gauging station at Dayton and a station just below Lake McMillan. Much of this loss, however, was returned to the river above the Avalon Dam, so that the net loss between Dayton and the head gates of the main canal was only about 10 per cent. Taking 10 per cent as the net loss by leakage in the reservoirs, the average annual run-off at the Avalon head gates is approximately 300,000 acre-feet.

9. Taking the combined safe capacity of the two branches of the main canal at 275 second-feet, the canals in their present condition can divert in an irrigation season of nine months only about 148,000 acre-feet. The discharge in the year of minimum recorded run-off is about 140.000 acre-feet at the Avalon head gates, so that in the minimum year (with no water held over in the reservoir from previous years) the canal can receive at the Avalon head gates 140,000 acre-feet and in the average year 148,000 acre-feet. The measured losses in the distribution system in 1909 averaged 64 per cent of the diverted water. Applying this percentage to the above figures, we have for the delivery of water to the farms in the minimum year 50,000 acre-feet and in the average year 53,000 acre-feet. The lining of the main canals, as hereafter mentioned, will probably reduce the losses from all sources in the distribution system to not more than 25 per cent, and at the same time will increase the safe carrying capacity of the canals, so that, with the present storage capacity of the reservoirs, probably 90,000 to 100,000 acre-feet could be carried to the farms in the minimum year and up to 120,000 acre-feet in an average year.

10. This, however, brings up the question of the silting up of the reservoirs. The capacity of Lake McMillan, and to a lesser extent that of Lake Avalon, is being annually reduced by the accumulation of silt brought down by the river. Measurements made by the Reclamation Service in 1904 show a silting up of Lake McMillan during the preceding 10 years of 4 per cent per annum, and it seems fair to assume that the same rate will be maintained in the future, making the probable life of this reservoir about 25 years, with a material reduction of its usefulness long before that time. Without storage

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not more than 70,000 to 80,000 acre-feet can be diverted in years of low run-off. Applying the 64 per cent factor of loss in the distribution system, there would reach the farms only 25,000 to 29,000 acre-feet, and applying a 25 per cent loss factor, there would reach the farms 52,000 to 60,000 acre-feet. The above figures indicate that under present conditions of canals and reservoirs sufficient water in an average year can be brought to the farms for the irrigation of 20,000 acres of land, and that even in a year of low run-off there will not be a very serious shortage; and, further, that with a complete silting up of the reservoirs, sufficient water from the perennial flow can be delivered to the farms in years of low run-off for the irrigation of 20,000 acres, provided the canals are put in such condition that the loss in the distribution system is reduced to not more than 25 per cent. In other words, the area which can be irrigated from the system with storage capacity and unlined canals does not differ materially from that which can be irrigated through lined canals from the perennial flow without storage. It does not seem advisable, therefore, that any increase be made in the irrigable area unless provision is made both for additional storage and for reduction of losses in the distribution system.

11. *Lands.*—In this project, as outlined and approved, there is a total irrigable area of 20,047 acres, all of which is private land except 20 acres (which has been taken up under the terms of the reclamation act). All of the private land had water rights from the appropriation of 1888 and was included in the project because it had these rights. Not all of this area has applied for water, but about 14,000 acres are now under irrigation, and it is expected by the local reclamation officers that at least 16,000 acres will be under irrigation next year. The entire 20,047 acres are, of course, under agreement to apply for water, and in the meantime the annual charges for operation and maintenance are being accumulated against them.

12. The average elevation of the irrigable area above sea level is about 3,100 feet and the range of temperature is from 0° to 110° F. The soil is of good quality and usually quite deep on most of the project. In other parts there are from 2 to 3 feet of soil over gypsum, and this also is considered good land. Where the gypsum, however, comes more nearly to the surface the land is of little value. There is a considerable area of such land within reach of water, but it is not counted as part of the irrigable area. The average annual rainfall on the irrigable area is 15 inches, but farming can not be practiced successfully without irrigation. The duty of water is based on 3 acre-feet of water per acre per year, but it is not believed that crops will suffer if, in occasional years, only 2½ acre-feet of water is supplied. The leakage in the distribution system referred to above has interfered during the past season with full supply of water to the lands at the time it was desired, and this leakage is injuring the system in another way—that is, by the swamping of lands near them. It is stated that before the destruction of the old Avalon Dam about 3,000 acres of irrigable land had been injured by seepage. The discontinuance of irrigation resulted in the lowering of the ground water level in the swamped land; but the seepage from the canals is again injuring this land, and if this seepage is not materially reduced the area of swamped lands will become as large or larger than before. The prevention of this excessive leakage is, therefore, one of the most important reasons for lining the main canals.

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13. The growing season at Carlsbad is long and there is a wide diversification of crops. Among the best paying crops are alfalfa, cotton, grain, vegetables, and, probably, peaches. From statements made to the board as to the average net receipts per acre from such crops it seems to be quite certain that the land will readily bear the announced building charge of $31 per acre, as well as an additional assessment of $12 to $15 per acre to cover the estimated cost of improving the main canals by partially lining them with concrete. Statements from local sources indicate that lands not in reach of water are worth about $5 per acre; while lands having water for full irrigation are worth from $50 to $150 per acre.

14. *Proposed extension and improvement.*—The outlined project is stated to be 99.8 per cent completed. The area of good quality land which can be reached by the present distribution system is, however, considerably in excess of the 20,047 acres included in the project, and, if the water supply justified, a considerable additional area could be brought under water. It has been proposed by the water users' association that the present distribution system be improved by lining the main canals where necessary, thus greatly reducing the leakage and benefiting the present irrigable lands by eliminating the swamping and by preventing a shortage of water when the demand is at the maximum, and at the same time securing a sufficient saving of diverted water to provide for the irrigation of an additional 5,000 acres of land. The association has proposed further that the entire cost of this improvement, which is estimated by the project engineer at $250,000, be charged to the 5,000 acres to be brought in. The board believes that, should the water supply justify, the 5,000 acres so brought in would be benefited sufficiently to enable them to return a construction charge of $50 per acre. As stated above, however, the uncertainty as to the effect the silting in Lake McMillan will have on the amount of water which can be made available for use during the irrigation season and the uncertainty as to whether the third or intermediate reservoir is feasible, renders it very doubtful if more than 20,000 acres can be given full irrigation after silting in Lake McMillan has left it with little storage capacity, even though the losses in the distribution system have been reduced to 25 per cent.

15. The lining of the main canals with concrete, wherever found necessary, is nevertheless regarded by the board as a necessary improvement both to conserve water and to prevent the swamping of land. It has been suggested that this improvement be gradually made, taking up first the lining of those places where the leakage is most serious and that it be paid for by assessments against the 20,047 acres now in the project, the assessments to be included in collections for operation and maintenance and to be so distributed in the different years that the annual aggregate amount to be paid be not too burdensome. This plan would benefit the present irrigated lands at the expense of such lands and would require no advance of money from the reclamation fund, since the improvement could be carried on only so fast as the actual collections of the assessment would justify. By the water users thus assessing themselves, say at the rate of $2 per acre per year, they would secure, in six or seven years, freedom from water logging of lands by seepage from the canals, a more certain supply of water at the farms, and possibly a surplus of avail-

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able water which could probably be disposed of on a water-rental basis to lands now in reach of the present distribution system or extensions thereof, but not now included in the project, the returns from such rental partially offsetting the assessments for the improvement. The cutting off of the seepage losses would keep pace with the gradual loss of storage capacity in McMillan Reservoir and would possibly more than offset this. At the end of six or seven years much more would be known as to the available storage capacities of the system, and if conditions then justified an additional area of irrigable land could be permanently taken into the project. The board regards with favor this method of carrying on the work of lining the canals. It does not regard it as advisable that an allotment be made for this purpose from the reclamation fund.

16. *Returns to the reclamation fund.*—The project was formerly opened by public notice, dated December 17, 1907, the building charge being announced at $31 per acre, and the charge for operation and maintenance at $0.75 per acre per year. The latter subsequently (public notice dated June 2, 1909) being raised to $1.35 per acre per year. There has been allotted to this project a total of $705,000, which is practically all expended. Of this $604,738.62, or, say $605,000, was charged to construction and the remainder to operation and maintenance. Taking the irrigable area at 20,000 acres, the expected return from the building charge of $31 per acre is $620,000. There has been charged to operation and maintenance about $100,000, for which there has been collected (or accrued) to June 30, 1910, about $33,000. The excess of operation and maintenance over collections therefor is due principally to the betterments paid for under that head. The construction charge already having been announced, betterments such as the dike in Lake McMillan, were made under an agreement with the water users' association, the substance of which being that the cost of such betterments should not all be included in the collection for a single year for operation and maintenance, but should be held as an open account and gradually returned at the rate of $0.35 per acre per year. This deficit should, under the agreement be returned in about nine years. The above figures indicate that this project will return its entire cost to the reclamation fund.

17. *Summary.*—(1) This project, both as to lands and water supply, lies entirely within the Territory of New Mexico.

(2) Out of the 20,047 acres of irrigable land all is under private ownership except 20 acres.

(3) The various engineering works done by the Reclamation Service in the improvement of this irrigation system appear to be well designed and well executed.

(4) The system is in good condition, except for the excessive leakage in the reservoirs and the distribution system, and for the reduction in carrying capacity of the canals caused by the aquatic growths, conditions which are practically the same as before the purchase of the system.

(5) The board believes that, under present conditions, in a year of average run-off sufficient water can be carried to the farms for the 20,047 acres now in the project, and that even in a year of low run-off there will not be an injurious shortage; and further that with

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a complete silting up of the reservoirs there will be sufficient water from the perennial flow to irrigate 20,047 acres, provided the losses in the distribution system are reduced by lining the canals, to approximately 25 per cent.

(6) The estimated final cost of this project is about $605,000, all of which had been expended prior to June 30, 1910.

(7) This project can reasonably be expected to return its cost to the Reclamation Fund.

(8) In the opinion of the board it is not advisable to take an additional acreage into the project unless provision is made both for reduction of losses in the distribution system and for additional storage.

(9) No opinion can be expressed as to the feasibility of obtaining additional storage until a more complete examination is made by the Reclamation Service of the "Third" reservoir site.

(10) The board believes that the lining of the main canals with concrete, to reduce the leakage, is a necessary improvement; that such work should be paid for by assessments by the water users' association on the lands now in the project; and that no allotment should be made for this purpose from reclamation funds.

SECTION XVII.

HONDO PROJECT, NEW MEXICO.

1. The board visited this project on October 16, 1910, inspecting the reservoir, the inlet canal and controlling works, the outlet canal and controlling works, a portion of the irrigable area and of the distribution system, as well as the Hondo River in the vicinity of the point where the proposed canal is designed to take out from the river. The board also examined the area east of Roswell, irrigated by artesian water. During the day and in the evening, at a meeting in the rooms of the Commercial Club, informal discussions were held with local people interested in the project.

2. *Location.*—This project is located on the lower part of the Hondo River, in Chaves County, N. Mex., the only town in the project being Roswell. A branch of the Santa Fe Railway passes through Roswell, giving transportation facilities to this project, the most distant farm unit of which is less than 12 miles from Roswell.

3. *Description.*—In the development of this system the Hondo River is the source of the water supply. The river in this portion of its channel has no low-water flow, and a reservoir was therefore necessary for the storage of the flood waters of the stream. This reservoir is formed by six earth dikes, having an aggregate length of 16,500 feet, constructed to close the low places in the rim of a natural depression. A short earth-fill diversion dam with rock-protected slopes diverts the water from the Hondo into the inlet canal, which is provided with concrete spillways, a silt-catch basin, and sluicing gates for the removal of silt. This canal discharges into the reservoir through a rock cut. There are two spillways for the reservoir, both being the natural rock at low places in the rim. The water is taken out of the reservoir through the outlet canal, which connects the low places in the reservoir with the old river channel, the water passing

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through the main dike or dam in two 36-inch cast-iron pipes embedded in concrete, suitable valves and operating devices being provided. From the river the water is diverted by three short diversion dams into the four main canals of the system. The minor structures, such as drops and turn-outs, are of concrete. The canals and laterals are of the usual type of unlined earth ditches. The reservoir embankments, the outlet and inlet canals, and the earth-fill diversion dam appear to be well designed and well constructed. The soil about the reservoir is in places impregnated with gypsum, the presence of which within the reservoir has caused considerable expense in the repair and maintenance of the bottom to keep it water tight. This expense is not yet ended, as so far there has not been sufficient water in the reservoir to thoroughly test the bottom. The efficiency of the structures designed to keep silt out of the reservoir and to remove it from the inlet canal has not been tested because of the very limited amount of flood water during the two seasons since the completion of the reservoir, and the board does not believe it to be certain that these devices will be successful in accomplishing their object. While the diversion dam and the minor structures of concrete do not show the economy of design ordinarily noted on such works of the Reclamation Service, they will undoubtedly serve their purpose.

4. *Water supply.*—The drainage area of the Hondo River above the reservoir is about 1,000 square miles, and much of it is said to be rough and broken, with a correspondingly large run-off. The available records of rainfall on the watershed are given in the following table:

Years.	Fort Stanton, N. Mex.	Roswell, N. Mex.
	Inches.	*Inches.*
1856	16.8	.....
1857	28.7	.....
1858	18.8	.....
1859	23.8	.....
1860	13.7	.....
1869	22.8	.....
1870	18.0	.....
1871	20.5	.....
1872	23.8	.....
1882	6.8	.....
1884	23.5	.....
1885	12.6	.....
1886	20.2	.....
1887	16.8	.....
1888	18.0	.....
1889	14.5	.....
1890	11.9	.....
1891	14.7	.....
1892	11.3	.....
1893	15.8	.....
1894	12.1	.....
1895	14.5	16.3
1896	.....	13.2
1897	16.4	15.3
1898	22.5	21.0
1899	14.4	16.6
1900	17.8	19.8
1901	18.1	17.9
1902	9.9	16.6
1903	9.5	8.0
1904	16.9	14.1
1905	22.6	19.3
1906	17.0	15.3
1907	17.2	13.5
1908	13.8	9.6
1909	11.7	7.7

NOTE.—No records available for missing years.

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Fort Stanton is on the Bonito Branch of the Hondo, at an elevation above sea level of about 6,000 feet, and Roswell is below the reservoir near the mouth of the Hondo, at an elevation above sea level of about 3,700 feet. It is not known to what extent these records are representative of the rainfall throughout the Hondo watershed.

5. Prior to 1869 the Hondo River had a perennial flow through its entire course, but due to increased use for agricultural purposes in its upper reaches the lower portion of the Hondo became dry except during floods. This was the situation at the time the project was first investigated by the Reclamation Service. No discharge measurements had been made and the only evidence as to the amount of run-off lay in the frequent flooding of the town of Roswell. The natural channel at this point is hardly more than 20 feet wide and from 6 to 10 feet deep, and its carrying capacity is small.

6. Based on this evidence, the record of rainfall at Fort Stanton, and the character of the topography of the watershed, the project was undertaken in 1904, and the reservoir constructed with an available capacity of 40,000 acre-feet. It was completed in August, 1906. Since that date the run-off has not been sufficient to permit the storage of any water. In 1907 a small quantity was furnished from the flood flow of the river directly to a small portion of the land under the project. In 1908, 1,753 acre-feet were so furnished; in 1909, 731 acre-feet; and in 1910 a small amount.

7. With the purchase of 800 acres of land for reservoir purposes, the water rights appurtenant thereto were acquired, the date of the appropriation being 1887 or 1888. In January, 1906, an additional filing for 80,000 acre-feet was made by the Reclamation Service. There are numerous other water rights on this stream, most of which antedate those of the Reclamation Service. Such of these rights as pertain to land below the storage reservoir and within the limits of the project are to be merged with those of the United States, under the terms of the contracts between the United States and the Hondo Water Users' Association. Much of the flow of this river is used in its upper reaches under appropriations which also antedate those of the United States. No adjudication of the water rights on the Hondo or its tributaries has yet been made, though suit with this object in view is now pending in the Territorial courts.

8. At a point in the river about where the Diamond "A" gauging station was located there was observed by the board a considerable flow of water which was lost by seepage into the bed of the river, the bed at the diversion dam being dry. This loss was measured by the Territorial engineer and found to be, for the 12 months from May 1, 1908, to April 30, 1909, about 10,000 acre-feet, equivalent to an average discharge of about 14 second-feet. In his report on this subject he states that this loss is at times as much as 33 second-feet. The suggestion to divert this water into the reservoir through a concrete-lined canal will be considered under the head of "Betterments." In 1909 an effort was made by the residents of the upper valley to file on this water which is now going to waste. This attempted appropriation has been temporarily held up by the Territorial engineer; but it is urged by the Hondo Water Users' Association that unless steps be taken by the United States to use it beneficially it will be awarded to others.

9. The data at hand as to the water supply for this project, as set forth above, is not sufficient to justify the board in drawing any conclusions as to whether or not, under normal conditions, there will be a sufficient supply of water for the irrigation of the 10,000 acres in the project.

10. There are included in this project 10,000 acres, of which all is under private ownership except 240 acres of public land. In the Eighth Annual Report of the Reclamation Service it is stated "Temporary water-rental contracts were entered into with individuals during 1908, and about 1,200 acres were served with an inadequate supply of water. No water has been available in 1909. Some alfalfa, head grains, and fruit trees are under cultivation and are being maintained with great trouble." It is understood that the conditions in 1910 are about the same as in 1909.

11. The average elevation of the irrigable area above sea level is about 3,750 feet, and the range of temperature is from 0° to 100° F. The average rainfall on the lands is about 16 inches, but this is not distributed throughout the year so as to permit successful dry farming. The duty of water is figured at 2½ feet delivered on the farm. The lands under this project are of good quality, the soil being deep and varying from sandy loam to adobe. The land requires very little work to put it under irrigation and cultivation, and it is believed that the slopes are such as to insure good drainage. The growing season is long. The principal crops grown in this vicinity are alfalfa, fruits, head grains, etc. The returns from the irrigated lands in the artesian district adjoining Roswell on the east, as well as the values of these lands, indicate that with a full supply of water the lands in the Hondo project would readily bear a construction charge of $44 to $50 per acre.

12. *Cost.*—There has been allotted to this project to date $359,000, of which over $349,000 was expended prior to June 30, 1910. Of this amount, $33,347.72, or 10 per cent, was for field engineering and superintendence; $3,900.52, or 1 per cent, for clerical services on the project; and $12,280.55, or 3.6 per cent, for the Washington and Chicago offices, expert engineering, etc. The balance, it is expected, will be exhausted by the end of 1910. About $2,900 has been collected from the sale of such water as was available, so that by the end of the year the net investment of the United States will be approximately $356,000. The project was completed by May, 1907, but, because of the lack of water, it has not yet been declared open and no building charge has been announced. The betterments referred to below are roughly estimated to cost $60,000. Adding this to the net cost, we have $416,000, to which should be added, say, $24,000, to provide for operation and maintenance until the project is self-supporting, and for contingencies. The total of these is $440,000, which for 10,000 acres will give a building charge of $44 per acre.

13. *Proposed betterments.*—It has been suggested that an impervious canal of approximately 60 second-feet capacity be constructed connecting the inlet canal with the Hondo at or near the Diamond "A" gauging station. Such a canal would be about 12 miles long, and a short diversion dam in the Hondo would also be required to divert water into it. The cost of this betterment has been roughly estimated by the project engineer at $60,000. The purpose of this canal is to bring down to the reservoir the water now lost by seepage into the

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bed of the Hondo which, in the 12 months beginning with May, 1908, was found to be about 10,000 acre-feet. If the adjudication by the courts indicates that this amount of water can be obtained annually, the water so saved and brought down to the project lands will probably serve to keep alive and render more or less productive the alfalfa fields and orchards now on the project lands. If this water be sold to these lands at a fixed price per acre-foot, it will produce a return probably more than sufficient to pay for the maintenance of the system while it is awaiting a formal opening. In case the rainfall in the watershed of the Hondo shall increase sufficiently to justify the opening of the project, this canal will still be useful, as the water saved by it will about make up for evaporation loss in the reservoir, and as this water, in years of shortage, may be sufficient to keep alive the larger acreage of perennial crops which may then be on the project. The merit of the suggested betterment seems to rest chiefly, therefore, on whether approximately 8,000 to 10,000 acre-feet can be secured after all prior rights (as determined by the adjudication now under way) are satisfied. The board considers favorably such a betterment under the conditions cited as to amount of water expected to be saved and as to cost. An argument against this expenditure is, that should it be necessary to abandon the project altogether the amount of money lost to the United States will be increased by about $60,000. For this reason the board believes that as a prior condition to the allotment of money for this work the landowners be required to make an additional contract with the Government to insure the return of this expenditure whether or not conditions justify the opening of the project as originally outlined. If the landowners prefer to construct this canal at their own expense rather than to enter into the additional contract with the Government, the board believes that they should be permitted to do so, under such conditions as will protect the rights of the entire body of owners under the project as well as those of the United States.

14. *Summary.*—(1) This project, both as to the lands and the water supply, lies entirely within the Territory of New Mexico.

(2) All of the irrigable land in the project is private land except 2.4 per cent.

(3) In general the engineering structures appear to be well designed and well executed, but the board does not believe it to be certain that the devices for handling the silt problem will be successful.

(4) At the time the project was started the data as to water supply appear to have been insufficient to warrant the undertaking, and such data are not now sufficient to justify the board in drawing conclusions as to whether or not under normal rainfall conditions there will be sufficient water for the irrigation of the 10,000 acres in the project.

(5) The returns from the irrigated lands in the artesian district adjoining this project, as well as the values of these lands, indicate that with a full water supply the lands in the Hondo project would readily bear a construction charge of $44 to $50 per acre.

(6) The construction of a small concrete-lined canal from the inlet canal to the river at a point above the Diamond "A" gauging station to save the water now lost by seepage is regarded by the board as a desirable betterment, provided further examination, after the water rights have been adjudicated by the courts, indicates that

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approximately 10,000 acre-feet can be saved thereby for use on the lands of the project and that the cost of this additional work will not exceed $60,000 to $70,000. Under such conditions it is recommended by the board that an allotment be made for this work, provided the landowners will enter into an additional contract with the United States to insure the return of such an allotment independently of the success or nonsuccess of the project as originally outlined.

(7) Pending the court adjudication, should the landowners prefer to make this improvement at their own expense, the board recommends that they be permitted to do so under such conditions as will protect the rights of the entire body of landowners as well as those of the United States.

(8) The estimated final cost of this project is about $359,000, of which over $349,000 was expended prior to June 30, 1910.

SECTION XVIII.

RIO GRANDE PROJECT, NEW MEXICO-TEXAS.

1. This project was inspected by the board on October 11, 12, and 13, public hearings being held at El Paso, Tex., and Las Cruces, N. Mex.

2. *Location.*—Part of the project lies in New Mexico and part in Texas; and it includes the furnishing of water to the Republic of Mexico. It is therefore international as well as interstate in character.

3. Transportation facilities are afforded by the Atchison, Topeka & Santa Fe, El Paso & Southwestern, Southern Pacific, and Texas & Pacific Railroads. The scope of the project and its relation to the above railroads is shown on the accompanying map.

4. *Description.*—The project as outlined consists of a storage reservoir on the Rio Grande, about 9 miles from the town of Engle, with a capacity of 2,368,490 acre-feet, sufficient to fully control the run-off of the river at this point: four diversion dams lower down in the river; and four distributing systems heading at these dams and covering the irrigable lands in the United States.

5. The international features of the project are covered by a treaty, dated May 21, 1906, between the United States and Mexico, which provides that upon completion of the project the United States shall deliver to Mexico a total of 60,000 acre-feet of water annually in the bed of the Rio Grande at the headworks of the existing Mexican canal above the city of Juarez, Mex. In return the Mexican Government waives all of its claims to water in the Rio Grande above the town of Fort Quitman, Tex., and all claims for past damages from shortage of water. In 1907 Congress appropriated $1,000,000 toward the construction of the necessary storage dam and provided that—

> The balance of the cost of said irrigation project over and above the amount herein appropriated shall be allotted by the Secretary of the Interior as may be needed and as may be available from time to time from the reclamation fund, etc.

6. One of the diversion dams, that at the head of the Mesilla Valley, in New Mexico, has been built, together with 6 miles of main

canal leading from it. The dam is of rubble concrete, partly reenforced, and rests on a pile foundation. Its length is 600 feet and its height 9 feet, as measured from a point 4 feet below the original stream bed. The top which is 3 feet and the bottom width 30 feet, of which 24 feet is in the form of an apron, 2 feet thick. It is built on a bed of gravel, 16 to 20 feet thick, underlaid with clay. Two rows of triple-lap sheet piling, one row under each toe, prevents underflow. Concrete headworks at the left abutment, founded on rock, provide for the diversion of 500 second-feet. This dam is well built and suitable for the purpose intended.

7. Reservoir sites on this river were first surveyed in 1889, and since that date a number of different projects for storing and utilizing its flood waters have been advocated. Comparative studies of these projects, supplemented by additional surveys and investigations in 1903 and 1904, led to the selection of the Engle site as offering the greatest number of advantages and the fewest disadvantages. It is the only proposed reservoir large enough to utilize the entire flow of the drainage basin; it does not submerge any railroads nor any area of valuable valley lands; it is sufficiently low in the basin to intercept practically all the water and sufficiently high to command enough land for the available water supply.

8. The reservoir is to be formed by the construction of a masonry dam near Elephant Butte. This reservoir when full will be 40 miles long and have an area of 40,000 acres. Ownership of the area to be submerged has been acquired by condemnation and a construction railroad is being graded from Engle to the dam site, but no work of a permanent character has been done on the dam. A limited number of borings have been made at the dam site and preliminary designs of the dam prepared. These designs contemplate a straight concrete dam of gravity section faced with concrete blocks. The dam will be 1,255 feet long on top, 260 feet high above foundation, 206 feet high above river bed, 200 feet thick at maximum point, and will have a maximum pressure on foundations of 16.27 tons per square foot.

9. The dam is to be founded on sandstone rock, which preliminary borings in 1903 and 1904 showed at depths below the surface ranging from 50 to 65 feet. The abutments are of similar material more or less shattered and seamy on the surface. Additional wash and diamond drill borings are now being made to develop more exactly the contour of the rock foundations.

10. From the data available the proposed dam appears to be feasible, but further information is desirable concerning the foundations and abutments, the crushing strength of the sandstone, and the crushing strength of concrete made from the available materials.

11. The large capacity of the reservoir is intended mainly for the solution of the sediment problem, which is a difficult and serious obstacle to the utilization of the flood waters of this river. Observations of the silt-bearing capacity of this stream have been made since 1897 under the supervision of the United States consulting engineer of the International Boundary Commission. For the first part of this period, 1897–1904, the observations indicated that silt formed 1.8 per cent of the total discharge. Since 1904, the measurements show an average of 1.2 per cent.

12. If the higher percentage is assumed, together with an average annual run-off of 1,000,000 acre-feet, the reservoir capacity would diminish at the rate of 18,000 acre-feet a year. Sixty-five years would, therefore, be required to half fill the reservoir and until that condition exists its usefulness for storage and regulation would still be large.

13. By the construction of silt barriers above the reservoir, either in the main river or in some of the principal silt-bearing tributaries, the life of the reservoir can be materially extended, but the need for such auxiliary structures is so remote that the burden of erecting them can equitably be left to the future.

14. *Water supply.*—The drainage area above the reservoir dam is 30,000 square miles and the average annual run-off at this point since 1895 has been about 1,000,000 acre-feet. The run-off is very irregular, varying from a minimum of 200,000 acre-feet in 1902 to a maximum of over 2,000,000 in 1897. The flow during the year is also very irregular, varying from no flow to a maximum of 30,000 second-feet. Storage and regulation are therefore essential features of the project.

15. The Reclamation Service has prepared service tables for the proposed Engle Reservoir covering the period 1895 to 1909. One of these tables is based upon an annual use of water for irrigation of 750,000 acre-feet after 1896 and an annual evaporation on the reservoir of 7.07 feet. The other is based upon an annual use of water for irrigation of 800,000 acre-feet after 1896 and evaporation on the reservoir of 5 feet. Both tables are based upon a deposit of silt in the reservoir equal to 1.8 per cent of the inflow and upon a variable demand for water during the irrigation season. The contents of the reservoir at the beginning of each month of the period is increased by the inflow and decreased by use, evaporation, and overflow for the month to get the contents at the beginning of the next month. The tabulated results show that with an assumed use of 750,000 acre-feet and an evaporation loss of 7.07 feet there would have been a deficiency in 1903 of 5 per cent, and in 1904 of 18 per cent, with no deficiencies in other years. With an assumed use of 800,000 acre-feet and an evaporation loss of 5 feet there would have been a deficiency in 1903 of less than 8 per cent, and in 1904 of 25 per cent, with no deficiencies in other years.

16. As recent observations in the Imperial Valley, Cal., and in Salt River Valley, Ariz., indicate that the evaporation loss on large bodies of water in this part of the United States is more nearly 5 feet than 7 feet, there seems to be an assured annual supply of 750,000 to 800,000 acre-feet provided the flow of the river at this point is not decreased by an increased use above this point and provided the existing rights below the reservoir are merged with those of the United States. The latter condition has practically been met, as the owners of nearly all the land now being served by private ditches have signified their assent by joining the water users' association.

17. To guard against increased use of water in the upper reaches of the Rio Grande, particularly in the San Luis Valley, Colo., the Department of the Interior has prohibited the acquisition by residents of this valley of reservoir sites upon Federal lands. Without such reservoirs to store flood waters no increased use is probable. The question

of limiting the use of Rio Grande water in Colorado in the manner above indicated will be referred to hereafter.

18. The duty of water is 3 acre-feet per acre measured at the farm. Allowing for a 20 per cent loss in the distribution system, there will be required for diversion to lands in the United States 581,250 acre-feet, to which must be added the 60,000 acre-feet required by treaty to be delivered to Mexico, making a total of 641,250 acre-feet. In addition to losses in the distribution system there will be losses in transit between the reservoir and the diversion dams. With a 20 per cent allowance for this loss, approximately 800,000 acre-feet of reservoir water would be required. The losses in transit, however, will be partly offset by the return seepage in upper parts of the valley, which will be available for diversion lower down. It, therefore, appears that the available supply accords closely with the demand.

19. *Lands.*—The average elevation of the irrigable area is 3,700 feet above sea level and the average annual rainfall 9½ inches. The total area in the project is 155,000 acres, of which approximately 12,000 acres are public land subject to the reclamation act; 110,000 acres lie in New Mexico, and 45,000 acres in Texas. All of the public land is in New Mexico.

20. The soil is good, and is described as sandy loam and fertile alluvium. Much of it has been irrigated in the past, but during the last 20 years the area cultivated has gradually decreased from about 100,000 acres to 50,000 acres with an insufficient water supply for even the present area. This decrease in acreage is due to decrease in the flow of the river and this in turn is alleged to be due to increased use of the waters of the Rio Grande in San Luis Valley, Colo.

21. Three of the private ditches in the Mesilla Valley are receiving water through the Leasburg Canal constructed by the Reclamation Service. Pending completion of the project the deliveries are made on a rental basis. The Franklin Canal, serving land below El Paso, is owned by an English company, but the El Paso Water Users' Association holds it under lease and has an option for its purchase.

22. These canals, as well as other private canals in the area covered by the Rio Grande project, are to be absorbed and become a part of the project, the existing water rights being merged with those of the United States.

23. The principal products are alfalfa, corn, wheat, melons, fruits, and vegetables, and with sufficient water it is claimed that net returns of $50 an acre can be secured.

24. Before the Rio Grande project was considered, unimproved agricultural land in this valley had an average value of from $5 to $10 per acre, and improved land $35 to $50 per acre. With an assured water supply it is estimated that the value of the land will be $200 to $300 per acre.

25. *Cost.*—The expenditures on this project to June 30, 1910, were:

General project (including plant)	$463,960
Leasburg unit	201,079
	665,039

26. The estimated cost of completion is $9,000,000. This estimate, as presented to the board, is very general in its terms, the details of the project not having been determined upon. It includes $1,000,000 for electrical development, but until more detailed surveys are made

and the amount of power that can be developed at different points is determined no opinion can be expressed as to the advisability of this part of the expenditure.

27. Assuming the total cost at $9,665,000, and deducting $1,000,000, the amount appropriated by the United States to cover the cost of meeting its treaty obligations with Mexico, there will remain $8,665,000 to be paid by the owners of the 155,000 acres in the project, equivalent to $56 an acre. The character of the soil and its productiveness when irrigated are such that the land can bear this charge.

28. Two water users' associations have been organized on this project, and the par value of the stock in each is $40 per acre. Provision is made in the by-laws for increasing the par value of the stock if the building charge per acre exceeds this amount. As this seems probable and as the liability of the land for an amount greater than the par value of the stock is questionable, the water users' associations should be required to increase the par value of the stock to not less than $56.

29. *Comments.*—As stated under the heading "Water supply," it has been thought necessary in the interest of this project to interfere with the extension of irrigation in the San Luis Valley, Colo., near the source of the Rio Grande, by prohibiting the acquisition, under the laws of the United States, of reservoir sites upon Federal lands in this valley.

30. The people of San Luis Valley regard this as an unnecessary interference with their rights and oppose the construction of the Engle Reservoir on the following grounds:

(1) That a large part of the land to be reclaimed lies in Texas, in which State the Federal Government owns no land; that Congress is without authority to provide for the reclamation of any land within a State in which the Government does not own any land, and that, therefore, the act of Congress extending the reclamation act to Texas is unconstitutional.

(2) That the proposed Engle Reservoir is needlessly large and that its construction involves a waste of public funds.

(3) That it is not an economic proposition in view of the rate at which it will be filled with sediment.

(4) That the irrigable land under consideration can be reclaimed by the maintenance of a uniform flow in the Rio Grande to be secured by the construction of several small and comparatively inexpensive reservoirs at different points along the river.

(5) That the most effectual way of securing uniformity in flow is by encouraging irrigation in the upper reaches.

31. In reference to these objections it may be said:

(1) That this project is international as well as interstate in character; that it has been specifically sanctioned by Congress; and that there is no reason to assume that Congress is without power to fulfill its treaty obligations, even though incidental benefits are conferred upon land in private ownership.

(2) That a study of the duty of the reservoir, assuming it to have been built in 1895, shows it to be no larger than is necessary for the irrigation of the lands within the project.

(3) That the rate of silting up will probably be less than that assumed by the Reclamation Service, and that by the construction of silt barriers above the reservoir its life can be materially extended.

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(4) That an equivalent amount of storage divided among a number of small reservoirs would probably cost more per acre-foot than storage in Engle Reservoir.

(5) That while irrigation does tend toward uniformity of flow, experience in a number of irrigated regions, indicates that the return flow is only a small percentage of the amount diverted.

32. The flow of the Rio Grande at El Paso during the irrigating season has gradually decreased during the past 20 years, with a corresponding reduction in the acreage irrigated in this vicinity from this source, while the acreage irrigated in the San Luis Valley from the Rio Grande has greatly increased. The proposed project will restore and improve former conditions in the valleys to be reclaimed without damage to areas now being irrigated in San Luis Valley, though to insure its success large additional developments in the San Luis Valley are prevented. The board does not believe that the objections of the San Luis Valley people are of sufficient weight to warrant a change in the plans of the Rio Grande project.

33. *Summary.*—(1) The Rio Grande project involves the reclamation of 155,000 acres of land in the United States, of which 12,000 acres are public land, subject to the reclamation act.

(2) It provides for delivering water to Mexico in fulfillment of treaty obligations.

(3) It is interstate as well as international in character.

(4) The water supply is sufficient for the purpose.

(5) The estimated total cost is $9,665,000, of which $665,000 has been expended.

(6) It is feasible from an engineering and economic standpoint, and the land can bear the probable construction charge of $56.

(7) The water users' association should be required to increase the par value of its stock to not less than $56.

(8) Assuming such action by the water users' association, the project should be completed.

(9) The following allotments are recommended for the four years, 1911–1914, inclusive:

From the fund	$1,855,000
From the loan	4,500,000
Total	6,355,000

SECTION XIX.

MISSOURI RIVER PUMPING UNITS, NORTH DAKOTA.

1. The board visited these projects on August 17, 1910, inspecting the power station, the coal mine, the floating and secondary pumping plants, the settling basins, and a large part of the ditches and the irrigible lands. Public hearings were held on the same day at Buford and at Williston.

2. *Unity of projects.*—These projects are carried in the reclamation records as two separate projects under the names of the Buford-Trenton and the Williston, and the water users under each of these units are organized into a water users' association, with each of which the Reclamation Service has made a contract for the irrigation of lands

owned by the stockholders. Physically, however, these projects constitute two units of a single project, and in this report are so considered.

3. *Location.*—This project is located on the north bank of the Missouri River, just below the mouth of the Yellowstone, and lies entirely within Williams County, N. Dak. The Great Northern Railway runs through the project and gives it good transportation facilities, the principal stations being Williston, Buford, and Trenton.

4. *Description.*—This is a pumping project, the water being lifted by electrically operated pumps. For the generation of electricity there is a central power plant near Williston from which high-voltage transmission lines carry the current to the several pumping plants. The present power installation is sufficient only for such pumps as are now installed, but additions can readily be made to the power plant when required. The power house is located at the mine from which fuel is obtained. The fuel is lignite, which is burned in special furnaces. The United States owns the mine, the cost of the fuel to the project being only the cost of mining.

5. The Buford-Trenton unit in its present condition includes a pumping plant mounted on a barge in the Missouri River, forcing water through steel pipes into a settling basin located near Buford. On the barge are mounted four electrically driven pumps having a combined capacity of 120 second-feet for a 30-foot lift. At the settling basin there is located a secondary pumping plant in which are installed four electric pumps having a combined capacity of 64 second-feet. These force the water through a reenforced-concrete pipe into the high-line canal, having an elevation of 50 feet above the settling basin. This high-line canal has a capacity of 60 second-feet at its head, and is designated to supply water for the higher lands in this unit, including 4,0501 acres already within reach of water and 1,375 acres under the proposed extension of the canal. From the settling basin a low-line canal is projected, to have at its head a capacity of 80 second-feet, for the purpose of supplying water to about 6,600 acres on the Buford Flats. From the high-line and low-line canals laterals will distribute water to the farms. This unit, it is stated, is 36 per cent complete. As originally outlined, this unit included an area of about 3,000 acres on the Trenton Flat, which was to be supplied with water by a separate floating pumping outfit to be located near Trenton. Apparently, however, this area is no longer considered part of the unit.

6. The Williston unit in its present condition includes a pumping plant, mounted on a barge in the Missouri River, to force water through steel pipes into a large settling basin located near Williston. On the barge are mounted three electrically driven pumps, having a combined capacity of 90 second-feet for a 30-foot lift. From the settling basin the water flows to the power house through the main, or "A" canal, having an initial capacity of 100 second-feet. One mile from the river is pumping station No. 2, which supplies the "B" canal. It contains two electrically driven pumps with a combined capacity of 35 second-feet under a 28-foot lift. About 1 mile west on the "B" canal pumping station No. 4 is located, in which one electric pump lifts 20 second-feet into the "C" canal, an additional height of 28 feet. At the power house are two sets of steam-driven

pumps. One set has a lift of 56 feet and a capacity of 40 second-feet, discharging into the "E" canal, which extends about 7 miles up the Little Muddy Valley. The other set has a lift of 28 feet and a capacity of 15 second-feet and supplies the "D" canal. From the "A," "B," "C," and "D" canals water is supplied to the lands through laterals, the area now in reach of water being 8,047 acres. As at present outlined the Williston unit includes in addition the irrigation of the west and east bottoms, an aggregate area of 3,100 acres. The irrigation of these bottoms will require the installation of two more small floating pumping outfits, each of which will pump into a settling basin, from which laterals will carry water to the lands. The Williston unit is stated to be 64 per cent complete. This unit originally was intended to include other irrigable lands in the Little Muddy Valley, as well as lands west of Williston. Apparently, however, this work is no longer considered part of the unit.

7. The barges for the floating pump plants and the houses thereon are of wood. Some of the minor structures on the canals and laterals are of wood, others of concrete. Concrete enters largely into the construction of the power house and the pumping plants. The examination of this project by the board showed well-designed and well-constructed power plant, pumping plants, pressure pipes, and settling basins; and the canals and laterals, with the minor structures thereon, seem generally to be good.

8. *Water supply.*—The water supply for this project depends altogether on the capacity of the pumping plant, since there is always an ample supply in the river. Low water in the river, however, affects the capacity of the pumps by increasing the head against which the floating pumping units must operate. The average head is 28 feet. The pumping units were designed to supply 2 acre-feet of water per acre when working continuously for a period of 80 days. It appears, however, that the rated capacity of the pumping units as installed is somewhat short of this, and that to supply the proposed quantity of water the pumps must be operated practically continuously throughout the irrigation season of about 120 days. The supplying of water at this uniform rate makes necessary equal uniformity in its use. The board does not believe that this condition of uniform use, day and night, throughout the season can be fulfilled in practice, and that the margin for contingencies is small. The need for water on the irrigated land is not the same throughout the season, and while the irrigators can come much nearer to uniformity in use of water than they now think possible, it seems to be very probable that at certain times during the irrigation season some of the crops will suffer for lack of water. On the other hand, it should be stated that the lands of this project lie in the semiarid belt, the average annual rainfall being 15 inches, and that 1½ acre-feet of pumped water per acre will probably suffice except for extremely dry seasons. It will be during such very dry seasons, however, when the failure to supply water when actually needed will be most severely felt. Additional pumping capacity can readily be supplied, but only at an additional expense to the lands.

9. *Lands.*—The approved plans, as stated by the supervising engineer, provides for the irrigation of about 12,035 acres in the Buford-Trenton unit and about 11,147 acres in the Williston unit.

Of the total area of 23,182 acres, only about 2,400 acres are public land subject to the reclamation act.

10. Both subdivisons have been partially opened by public notice, the area opened in the Buford-Trenton unit being 4,060 and in the Williston unit being 8,047 acres. The farm unit for private lands is 160 acres and for public land 80 acres. The announced building cost is $38 per acre, with an operation and maintenance charge of $0.70 per acre per year and $0.50 additional for each acre-foot of water supplied to the lands, making a total of $1.70 for operation and maintenance for 2 acre-feet supplied. So far only 2,968 acres in the Buford-Trenton and 6,253 acres in the Williston have made application for water, while the area actually irrigated in 1910 was only 400 acres in the former and 2,000 acres in the latter.

11. The average elevation is 1,900 feet above sea level. This project is in the semiarid belt and in some years will produce good crops without irrigation. This is believed to be partly responsible for the small use made by the farmers of the irrigation water, the year 1909 being a wet year and the pumped water not being needed. The present year, however, has been very dry and the crops on the nonirrigated lands were, in general, failures. During normal years comparison between the crop returns on irrigated and nonirrigated lands shows a substantial increase in yield due to irrigation. The higher lands of the project do not require clearing before being put under cultivation, while on much of the bottom land considerable clearing is necessary. In the Williston unit some of the higher lands are rolling and, therefore, are difficult to prepare for irrigation.

12. The soil is generally of good quality, ranging from sandy loam to a heavy clay loam. The principal crops are the small grains, but alfalfa can be grown with success, as probably, also can sugar beets. Due to the high altitude the growing season is short, but two and often three cuttings of alfalfa can be obtained.

13. Owners of lands under the ditches who have not perfected their water-right applications nor made the required payments will, at the beginning of the irrigation season of 1911, be in arrears for four installments of the building charge and four annual assessments of the fixed charge for operation and maintenance, a total of $18 per acre. Under the terms of the reclamation act, these lands are subject to the cancellation of the water application for private land and of the entry of the land if it is public; but in the event that the land office does not enforce this cancellation these lands can obtain water for the season of 1911 only by the prior payment of $13.50 per acre. The farmers may be at fault for this condition, but it does not seem probable that many of them can make this payment.

14. There is general complaint that the annual charge per acre amounting to $5.50 (including $3.80 for construction costs, $0.70 fixed charge for operation and maintenance, and $1 for 2 acre-feet of water) is more than the land will bear. It appears, however, that, with good methods of farming, the difference in yield per acre on irrigated and nonirrigated land is, in an average year, in value considerably more than $5.50 per acre, while in very dry years like the present, it is a question of a crop or no crop. For this reason the board believes that, while a charge of $5.50 may in many cases be burdensome, the lands generally will bear this charge provided the farmer can start in anew without the handicap of a requirement for

an immediate payment of the accumulated back charges. There is also general complaint from the owners that the annual charges are more than twice what had been promised them; the statement being that they were promised that the annual charge per acre, inclusive of both construction and operation and maintenance, would not be over $2 to $2.50. The par value of the stock of the water users' association is $20 for the Buford-Trenton and $24 for the Williston.

15. The result of the dissatisfaction is that the farmers seem to have no disposition to apply for the water. They are insistent that some modification be made in their contract, either to extend to 20 years the period in which construction charges are to be paid, to arrange for graduated payments, or to waive temporarily the payment of all unpaid back charges and to arrange for collection of the first annual installment of the building charge after the end of the next crop year. The owners of private land within the proposed extensions very generally desire to be released from their agreement with the Government. The board believes that the conditions existing in this project make it desirable that some modification be made in the present requirements which would permit the farmers to obtain one irrigated crop prior to any demand for back charges, or which would provide for a system of graduated payments.

16. *Operation and maintenance.*—The cost of operation and maintenance is claimed by the farmers to be unnecessarily expensive; but since the plant is operated for such a small area, and that area requiring the highest pumping lifts, the operation is necessarily expensive. The shortness of the irrigation season also has a tendency to make cost of operation high, since the plant must be cared for during the nonirrigation season, and since, when the season opens, a large force of temporary employees has to be engaged not only for the power and pump plants but also for the coal mine and for the ditches. Such temporary employees must be paid at higher rates than would permanent employees, and they are not as efficient. The board does not see how the cost of operation and maintenance can be materially reduced, except from the natural result of more lands using the water, and especially from the farmers being educated to use the water in rotation, according to an arranged schedule, instead of all demanding water at one time and thus requiring the maximum output occasionally during the season with intervals between when little water is used.

17. *Costs.*—There has been allotted to this project to date $963,000, of which there was expended to June 30, 1910, $806,465.71 for construction and $98,098.89 for operation and maintenance. There was due the General Electric Co., as balance on a contract, $10,326. Since only $3,978.85 was collected for operation and maintenance, there was a deficit under that head of $94,120.04. The following table shows the probable financial condition of this project on December 31, 1910:

Construction cost to June 30, 1910	$806,465.71
Balance due on contract	10,326.00
Deficit on operation and maintenance to June 30, 1910	94,120.04
Probable deficit on operation and maintenance for remainder of 1910	14,088.25
Total cost to United States to Dec. 31, 1910	925,000.00
Returnable on building charge, 12.316 acres, at $38 per acre	468,000.00
Balance	457,000.00

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Therefore, if no extensions are made, the United States will have a loss on the project by the end of 1910 of about $457,000, even if the lien on the lands is considered of value sufficient to cover the amounts charged against them. The above estimated loss will probably be increased for several years to come by deficits for operation and maintenance.

18. *Completion and extension.*—The supervising engineer, under date of August 31, 1910, estimates that the project can be completed practically as outlined for the following costs:

Subdivisions.	Estimate for completion.	Irrigable acres added.
Buford-Trenton subdivision	$160,000	7,975
Williston subdivision	110,000	3,100
Total	270,000	11,075

Thus the completion would reduce the estimated loss on the project to about $300,000. Should conditions justify the opening of this additional area at a higher construction charge than $38 per acre, the loss to the reclamation fund would be further reduced. From this, it appears that it will be advisable to complete the system in case further experience with the irrigable areas already opened shows that the owners of the irrigated lands are securing satisfactory results and that there is a reasonable probability of the additional lands being taken up. In the meantime, however, the board does not deem the completion advisable.

19. Additional areas can be put under irrigation in this region by pumping if conditions warrant. The supply of water is ample and the lands are in easy reach of moderate pump lifts. At present, however, extensions of this project are not advisable.

20. *Summary.*—(1) This project is entirely within the State of North Dakota.

(2) Of the total area of 23,182 acres in the project only about 10 per cent is public land subject to the reclamation act.

(3) The power plant, pumping plant, and the distribution system are well designed and constructed.

(4) While the supply of water in the river is ample, the capacity of the pumping plant is based on a continuous, uniform use of the pumped water, a condition of use difficult to attain in practice, and there is therefore a probability that, with the small margin for contingencies in the pumping capacity, there will be an occasional injurious shortage of water.

(5) Some modification should be made in the terms of the contracts with the farmers on this project which will enable them to obtain one irrigated crop prior to any demand for back charges, or which will provide for a system of graduated payments.

(6) While the annual charge per acre of $5.50 may in many cases be burdensome, the lands generally, with good methods of farming, will bear this charge, provided the farmer can start anew without the handicap of a requirement of immediate payment of accumulated back charges.

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(7) The completion of the project as outlined is feasible from an engineering standpoint, but is not advisable until the area now in reach of water is being irrigated with success and is repaying to the reclamation fund the assessment made against it.

(8) In the event of successful results from the present works, the completion of the approved project is desirable, as the addition to the irrigable area will help reduce the loss to the reclamation fund, and will also tend to a reduction of the annual cost per acre of operation and maintenance.

(9) Whether or not the project is completed it appears to be inevitable that there will be a large loss to the reclamation fund.

(10) The estimated final cost of the project is about $1,195,000, of which approximately $911,000 had been expended prior to June 30, 1910.

(11) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the fund $270,000

SECTION XX.

UMATILLA PROJECT, OREGON.

1. The board visited the Umatilla project, near Hermiston, Oreg., September 7, and spent the day in examining the feeder canal, Cold Springs Reservoir and Dam, the distributing system, and the lands to be irrigated.

2. A public hearing was held on the evening of September 7, in Hermiston, at which those interested were given an opportunity to make statements and furnish information to the board. In general, they expressed their approval of the work under the project, both as to progress and cost.

3. *Location and description.*—The Umatilla project is located in eastern Oregon in the near vicinity of Hermiston and lies wholly within the limits of the State. Large areas of good land surround this town, which depends for its prosperity upon the neighboring agricultural areas now being irrigated. The project covers the irrigation of about 25,000 acres lying in the angle between the Umatilla and the Columbia Rivers on the east side of the Umatilla, from which river it takes its water supply at a point several miles upstream. The average elevation of the irrigated areas is 470 feet above sea level. The temperature ranges from 28° below zero to 115° F. The Oregon Railroad & Navigation Co. partly traverses this project and also follows its borders on two sides. The Spokane, Portland & Seattle Railway on the other side of the Columbia River affords a second line of transportation.

4. The project includes a diversion dam in the Umatilla River 2 miles above Echo. This dam produces the necessary head for the feeder canal which supplies water to the Cold Springs Reservoir, where 50,000 acre-feet may be stored.

5. The Cold Springs Reservoir lies in a natural depression, about 6 miles east of Hermiston, which is closed by an earth dam across its outlet. Its area is 1,500 acres. The stored water is discharged,

by means of a concrete conduit passing through the dam, into the main distributing canal and thence into the system of laterals.

6. Taking the project as a whole, the engineering structures are apparently satisfactorily designed and executed. The only important engineering structure is the earth dam closing the outlet to the Cold Springs Reservoir. This dam has already withstood almost the maximum head and appears stable, although its height of 98 feet makes it one of the high earth dams of the country. Leakage under the dam, amounting to about 1.3 second-feet, was observed. It is said that increase of head against the dam does not increase the flow materially. This is being watched and is not thought to be serious. It is assumed by the Reclamation Service that this leakage is through seams in the foundation under the dam and at its ends.

7. The main feeder canal, 24½ miles long, has a capacity of 300 second-feet at the reservoir. There are 62 miles of laterals having capacities less than 50 second-feet. The distribution system consists of a main distributing canal, called the "A" line, leading out from the reservoir through a concrete conduit supplied with valves. From this "A" line all the remainder of the system is supplied. Water is carried to the lower laterals through concrete pipes, the intention being to generate electricity at some of the drops and use the power for pumping for the irrigation of a small area lying above the gravity system. One concrete siphon is 9,831 feet long, 46 inches in diameter, and is under 110-foot head.

8. *Water supply.*—The water supply is taken from the Umatilla River and consists exclusively of flood flow. None of the low water discharge is available for the project as all of it has already been appropriated. The drainage area of this river is 1,600 square miles, and the watershed has an elevation of 2,000 feet above sea level. The average rainfall is 20 inches and the average normal run-off is 530,000 acre-feet per annum. Discharge measurements have been kept at Gibbon, Oreg., since 1897 and at Yoakim since 1903. The water rights appear to have never been adjudicated, but application has been made by the United States to the State board of control for a determination of the priority and amount of all claims. This determination is now in progress. The priorities as estimated by the Reclamation Service and the river discharge for 13 years are as follows:

	Area.	Maximum rate of diversion.	Acre-feet required for full supply.
Umatilla project:	*Acres.*	*Sec.-ft.*	
Maxwell Canal	25,000	114	100,000
Feed Canal		350	
Western Land & Irrigation Co	[1] 10,000	125	25,000
Inland Irrigation Co	[1] 8,000	100	[2] 20,000 [3] 6,000
Oregon Land & Water Co	[1] 5,000	60	12,000
Allen Ditch			
Mill Ditch			
Pioneer Ditch	2,400	30	6,000
Courtney Ditch			
Slusher Ditch			
Taylor Ditch			
Brownell Ditch	[1] 1,200	15	3,000
Total	51,600	794	172,000

[1] Estimated. [2] Flood. [3] Stored.

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The experience of this year (1910) indicates that the return flow to the river will be sufficient to supply the priorities of the Oregon Land & Water Co. and Brownell Ditch Co. This will reduce the total in the tabulation to 719 second-feet and 154,000 acre-feet, respectively. Moreover, since the Maxwell Canal will not be operated prior to March 15 it is not likely that the maximum rate of diversion of the Maxwell Canal and the feed canal will occur at the same time, so it appears that priorities for existing project may be considered as a total of 154,000 acre-feet, and a maximum rate of diversion not exceeding 670 second-feet.

Umatilla River, discharge since 1896 and assumed priorities.

Year.	Total discharge.	Assumed priorities.	Unappropriated.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
1897	572,000	154,000	418,000
1898	408,000	154,000	254,000
1899	770,000	154,000	616,000
1900	(1)	154,000	[2] 200,000
1901	616,000	154,000	462,000
1902	507,000	154,000	353,000
1903	534,000	154,000	380,000
1904	693,000	154,000	539,000
1905	250,000	154,000	96,000
1906	602,000	154,000	448,000
1907	567,000	154,000	413,000
1908	369,000	154,000	215,000
1909	439,000	154,000	285,000

[1] Incomplete. [2] Probably.

It thus appears that the present supply is sufficient to provide water for the proposed project, with considerable surplus.

9. The duty of water is assumed at 2½ acre-feet at the farm, requiring 62,500 acre-feet. If 33 per cent loss from evaporation and seepage be allowed in the laterals and 5 feet evaporation in the reservoir, the total amount required would be about 101,000 acre-feet to supply 2½ acre-feet on the land. The capacity of the reservoir is 50,000 acre-feet and it will be necessary, therefore, that 51,000 acre-feet to be supplied direct from the river. It is estimated by the Reclamation Service from hydrographs that the prolongation of the flood period into the irrigation season will be sufficient to supply this quantity.

10. *Lands.*—The total acreage under this project as above mentioned is 25,000. During the season of 1910, the area for which water was available was 15,319. This leaves 9,454 acres still to be furnished with water under the present proposed extensions. Of the total acreage there were only 4,120 acres of public land subject to entry under the reclamation act. The Northern Pacific Railway owned 1,980 acres, and other land under private ownership, or not subject to the reclamation act, amounted to 18,673 acres. Lands owned by the railroad are now being sold to settlers under contract to apply for water under the terms of the reclamation act. About one-half of the public land is embraced in the proposed continuation of the project which would therefore not receive water if present plans were interrupted.

11. The average rainfall on the project is about 9 inches annually, which is too little for crops without irrigation. The land in this project consists of sandy loam throughout, and is, in a large propor-

tion, volcanic ash. The top surface is underlaid with gravel which assists materially in drainage, so that but little attention has been paid to waste water in the upper portions. In the vicinity of Hermiston there are considerable areas now swamped which will require a more or less extensive drainage system before the project can be utilized to its fullest extent. This will not be difficult and provision therefor has been included in the estimates. The high winds often make necessary the replanting of grain crops when they are not protected by windbreaks. The farm units have been restricted to 10 acres in the close vicinity of Hermiston, to 20 acres in the more remote areas, and to 40 acres near the outer limits of the project. Although the irrigated land in the vicinity of Hermiston is still new, it is now being planted with orchards, both peach and apple, and alfalfa is also being seeded. Some vegetables are being grown and berry bushes have been set out. The hopes of the settlers are that this area will equal some of the Wenatchee and Yakima lands in fruit products, such as apples, peaches, and grapes, and already land has been sold for $200 per acre, exclusive of construction charges. Should this hope of productiveness be realized, it seems plain that a high construction cost can be supported without hardship. The charge already fixed by the Reclamation Service for this land is $60 per acre and applies to 18,200 acres. The cost of operation and maintenance, as fixed by the Reclamation Service, is $1.30 per acre.

12. *Cost of the project.*—The amount expended on this project up to June 30, 1910, has been $1,211,827.71, which includes maintenance and operation charges amounting to $61,624.91. The project is about 70 per cent completed. The cost of completion is estimated by the Reclamation Service at $330,000, in addition to present allotments, with which it is expected to irrigate new areas lying between the present completed portions of the system and the Columbia River, and, also, a new strip of land lying between the feeder canal and the permanent lateral of the distributing system known as the "A" line. It is also expected to drain some of the swamped areas.

13. *Returns to the reclamation fund.*—The amount set by the Reclamation Service as a building charge is $60 per acre. This was originally believed to be ample, but it was found later that increased charges would be necessary. The $60 charge applies to 18,200 acres. To cover the cost it is now expected to charge $75 per acre for one unit of 3,130 acres and $100 per acre for one unit of 3,300 acres. At these rates, if all the land is taken up, the return will be $1,656,750. As the total estimated cost is $1,650,000, there will be no loss unless the estimates for completion are exceeded. It is doubtful whether the higher-priced lands will be rapidly taken up. There is still a deficit on account of operation and maintenance of about $41,000, which it is believed by the Reclamation Service will be returned to the fund in 10 years by retaining the present charge of $1.30 per acre, which will, it is expected, exceed the actual cost when the entire area is irrigated. In this connection it is noticed that the par value of stock in the water users' association is $60. If the higher payments are not fully secured by a lien on the land under the present agreement with this association and its members, new agreements should be made covering the higher-priced land.

14. *West extension.*—The people of Hermiston and vicinity are very desirous that the Government extend this project to the west side of

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the Umatilla River, where the reclamation of from 40,000 to 60,000 acres of land by a gravity system is proposed. This extension was the main subject discussed at the public hearing. This development, while being properly an extension of the Umatilla project, inasmuch as it would receive its water from the same source and lie contiguous to the areas at present being irrigated, yet is in the nature of new work as its development bears in no way upon the completion of the present unit of the project. The extension would require the construction of a reservoir of a capacity of about 135,000 acre-feet by building a dam in the Umatilla River near the mouth of Butter Creek. The water surface would be raised about 70 feet, and the supply would then be distributed over the land by a gravity system. This gravity plan could be supplemented to cover about 30,000 acres more by electric pumping, should this further extension be deemed desirable. Reservations on the Des Chutes River for a dam site with which to develop power have been made, the power to be used in pumping water from the gravity canals or from the Columbia River to the areas not irrigable by any gravity system. If the water supply is sufficient, the total area of the proposed extension can be expanded to about 100,000 acres, including the pumping project.

15. Experience on the Umatilla project and on private projects at Irrigon and Kennewick indicates that the soil is abundantly able to produce fruits and alfalfa as well as vegetables and berries. The climate is suitable thereto, and although the areas are swept by strong winds throughout the spring of each year the soil can be protected by cultivating windbreaks. Of the area under the proposed gravity system there are but 17,000 acres of public land. The remaining land belongs either to the Northern Pacific Railroad or is now in private ownership through homestead and desert-land entries, or through purchase from the railroad. Hydrographs for 12 consecutive years indicate that there will be a surplus of over 200,000 acre-feet, making allowances for private rights and the requirements for the main Umatilla project.

16. Allowing 5 feet evaporation on the average area of the proposed reservoir—3,200 acres—and a loss of 5,000 acre-feet for a 6 per cent loss in the distribution, a total loss of 21,000 acre-feet of storage water is to be provided for. The use of concrete-lined distributaries is proposed by the Reclamation Service, which it is expected will reduce the losses from seepage to the low amount stated. By using flood water direct it is calculated from the records by the reclamation engineers that a surplus of 22 acre-inches only will need to be stored, which gives a total of 112,000 acre-feet necessary in a season, allowing 23,000 acre-feet of stored water to be carried over if the reservoir were filled. It thus appears from these assumptions that the water supply will be sufficient for 50,000 acres if the proposed reservoir be built.

17. The cost of this extension, exclusive of the pumping system, but including the dam across the Umatilla River with its accessories, estimated at about $1,000,000, amounts in all to nearly $4,000,000. This is approximately $80 per acre for an area of 50,000 acres.

18. *Summary.*—(1) The project is feasible and practicable from an engineering and economic standpoint.

(2) The project lies wholly within the limits of the State of Oregon.

(3) The total area of land to be irrigated is 25,000 acres, of which about 16 per cent is public land subject to the reclamation act.

(4) The water supply is sufficient for the area of the present project.

(5) The proposed west extension being entirely distinct should be postponed for the present on account of the large amount of money needed for the completion of other projects to which the United States is committed by the large expenditures already made.

(6) The total estimated cost of the work is $1,650,000, of which about $1,212,000 has already been expended.

(7) The land can bear the cost of construction estimated at $60, $70, and $100 per acre, although that subject to the higher charges may not be rapidly taken up.

(8) The project as now adopted is worthy of completion in view of the advanced condition of the work.

(9) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the loan $325,000

SECTION XXI.

KLAMATH PROJECT, OREGON AND CALIFORNIA.

1. The board visited this project on September 30 and October 1 and 2, 1910. A public hearing was held at Bonanza on September 30 and at Klamath Falls on the evening of October 1.

2. *Location.*—The lands of this project are located in Klamath County, Oreg., and in Siskiyou and Modoc Counties, Cal. Transportation facilities at the present time consist of a branch of the Southern Pacific Railway, called the California & Northeastern Railway. Upon completion, this branch will form a through line between Portland and San Francisco. Surveys for two other lines are reported as reaching the vicinity of Klamath Falls, one of which, if constructed, will give an outlet to the east.

3. *Historical.*—The original plans included what was known as the "upper" and "lower" projects. The "upper" project, according to preliminary surveys, comprised an area of 48,350 acres, and included Langells, Yonna, and Upper Poe Valleys. The "lower" project, from the preliminary surveys, comprised an area of 188,045 acres situated in Klamath and Lower Poe Valleys. This area included the marsh lands to be reclaimed around Lower Klamath Lake and those to be uncovered by the lowering of Tule Lake.

4. Before beginning work, the Reclamation Service purchased certain private rights and canals as follows:

(1) The property and rights of the Klamath Canal Co.

(2) The property and rights of the Little Klamath Water Ditch Co. (Adams Canal).

(3) The property and rights of the Klamath Falls Irrigating Co. (Ankeny Canal).

(4) The Keno Canal, belonging to Moore Bros.

5. The Klamath Canal Co. and the Ankeny Canal controlled the situation on the east side of the outlet of the Upper Lake, the main

source of the water supply. They owned certain essential rights of way and irrigated a small amount of land. The Adams Canal was a private canal taking water from White and Lower Klamath lakes and this interest prevented the lowering of the latter lake, a necessary preliminary to the reclamation of the Klamath marsh lands. This canal occupied rights of way and irrigated lands which it was desired to have in the project. The Keno Canal controlled the outlet on the west side of the Upper Lake and held certain riparian rights which it was thought desirable to obtain. As a part of the purchase price of this canal, the Reclamation Service agreed to deliver in perpetuity to the Moore Bros. at their power plant 205 second-feet for power purposes. A part of the original plan was the construction of a reservoir at Clear Lake, and for this purpose the Carr ranch was bought. This purchase also extinguished the riparian rights of the owners around Tule Lake, which was to be lowered.

6. The main canal for the project was located on the east side of the outlet of Upper Klamath Lake, and a capacity of 1,500 second-feet was required. Before any radical changes were made in the project this canal was constructed to its proposed length and dimensions. For irrigation and power purposes and to deliver to the Moore Bros. the 205 second-feet due them by contract, the Keno Canal was constructed to carry 650 second-feet. This canal terminates at the Moore Bros. power plant. Owing to changes in plans this canal has not been extended.

7. The project at the outset was further complicated by the fact that both Upper and Lower Klamath Lakes are navigable waters, together with a portion of Klamath River between Klamath Falls and Keno. Navigation can not be carried on between the lakes, but small craft can pass from Lower Klamath Lake to Klamath River. Upper Klamath Lake lies wholly in the State of Oregon, while Lower Klamath Lake lies partly in California and partly in Oregon. As the original plans of the Reclamation Service contemplated changes in the channel of Klamath River, a possible lowering of Upper Klamath Lake, and the lowering of the level of Lower Klamath Lake, acts of the legislatures of the States of California and Oregon were obtained, authorizing the United States to lower or change the levels of the lakes in question, and ceding to the United States any lands not previously disposed of which might be uncovered by the lowering. The Congress also passed an act (February 9, 1905) authorizing the Secretary of the Interior to make such changes in the levels of the lakes in question as might be deemed necessary in carrying out any irrigation project under the reclamation act. Under these acts the Secretary of the Interior entered into a contract with the California & Northeastern Railway Company by which the latter was to carry its railway across the upper portion of Lower Klamath Lake in a manner prescribed by the Reclamation Service. The United States is obligated under this contract to assume all responsibility for any interruption to navigation. The act of Congress, while authorizing the changing of the lake levels, does not expressly authorize the closing of the lakes to navigation. The embankments constructed by the railway under this contract interfered with navigation between the lake and Klamath River. The board is informed that action is now pending for damages on

account of the interference with navigation, in which the United States is made defendant on account of the obligation assumed in the contract with the railway.

8. Owing to the construction charges having proved higher than was expected by the citizens, much dissatisfaction was expressed and large areas of land subscribed to the project as above outlined were released. Other large areas of private land which it was expected would subscribe did not do so. The project has, therefore, been materially changed in its outlines.

9. *Description of present project.*—The project as now proposed has three approved subdivisions and two which have not yet received executive approval. All are described as follows:

(*a*) *Lower project uplands.*—This portion of the project, 37,000 acres in area, includes a strip of valley land extending northwesterly and southeasterly between Klamath and Tule Lakes, together with Poe Valley. This valley and the easterly portion of Klamath Valley are traversed by Lost River, a stream having its headwaters in Clear Lake and discharging into Tule Lake. This river has so little fall and is generally so far below the surface of the surrounding land as not to be available, except to a limited extent, for irrigating these two valleys. Water for this subdivision comes from Upper Klamath Lake through the main canal and distributing system, although 1,800 acres will be irrigated by water from Lost River diverted at the proposed Wilson's bridge dam.

(*b*) *Tule Lake subdivision.*—This includes 35,000 acres, all to be uncovered by lowering Tule Lake. This lake covers 96,000 acres. It is of fresh water and is fed by Lost River. It has no known outlet, but a small amount of water escapes at the southerly end into the crevices of the lava beds. By artificially enlarging some of the crevices the discharge was temporarily increased from 10 second-feet to 32 second-feet, but as the lake subsided the outflow decreased; and it seems probable, therefore, that no reliance can be placed on this method for lowering the lake. In 1888 the Klamath River broke through its banks at a point three miles south of Klamath Falls, diverting a considerable amount of water through Lost River Slough and Lost River to Tule Lake. This caused a rising of the lake until the settlers closed the break by a levee. After a comprehensive study of the situation it is proposed by the Reclamation Service to reclaim from thirty-five to forty thousand acres of land around the northern end of the lake by the following plan: First, the utilization of the reservoir at Clear Lake to regulate the discharge of Lost River. This also provides water which can be used for the irrigation of lands elsewhere. Second, construction of a diverting dam on Lost River at Wilson's bridge and a diversion channel of 250 second-feet capacity connecting Lost River with Klamath River. This capacity of 250 second-feet provides for a constant discharge from Lost River of 200 second-feet, and for 50 second-feet estimated return flow from lands along Lost River irrigated from Upper Klamath Lake. Third, a dike to be built across the northerly end of the bed of Tule Lake to prevent flooding of the lands after being reclaimed. Fourth, pumps at the dike to pump drainage water from behind the dike to irrigate a narrow strip of land along the easterly side of the lake. Fifth, a diversion dam near the present mouth of Lost River, together with a distributing system of canals and laterals, as well as

drains, in the reclaimed area. By these means it is proposed to keep all Lost River water out of Tule Lake except such flood flow as can not be controlled by the reservoirs. The main canal from the Upper Klamath Lake, now used only to water the first subdivision, was constructed with a capacity sufficient to irrigate these Tule Lake lands. Attention is called to the fact that the successful use of these tule lands after being reclaimed depends largely on the prevention of subirrigation from seepage from the higher irrigated lands around them and upon the success of the plan to control Lost River floods by means of Clear Lake Reservoir, the diversion channel, and the dike.

(*c*) *Marsh lands.*—It was proposed originally to irrigate the reclaimed marsh lands by means of the main canal which was given sufficient capacity for the purpose as far as constructed. The drainage was to be effected mainly by the construction of the Keno Cut and tunnel, involving excavation in the Klamath River to lower its level, the improved channel to lead to a tunnel cutting through the bend below. Power was to be developed at the lower end of the tunnel. As these plans proved, on more detailed investigations to be too costly, they were abandoned. The construction of the embankment and trestle of the California & Northeastern Railway across the marshes will, when the embankment is made continuous, divide the marshes and necessitate separate treatment of the two portions. Several plans for the reclamation of these marsh lands have been considered by the Reclamation Service. Inasmuch, however, as the efforts of the Agricultural Department at its experiment farm near Ady to cultivate these marsh lands after being drained have been unsuccessful, the board does not consider it advisable to expend further money on the reclamation of these lands until the agricultural possibilities are better known. In connection with the marsh land subproject, request was made by parties interested that the Government require the railway to close its embankment across the marshes and install the gates for the control of the inflow and outflow of Lower Klamath Lake in the concrete structures provided for the purpose; that the connection of the Adams and Van Bremmer canals with White and Lower Klamath lakes be severed and the lands under these canals receive water from the main canal as contemplated in the final completion of the project; and that the Government make a small amount of excavation, estimated to cost $50,000, in the upper part of Ankeny Falls, Klamath River. The parties then desire to be released from their subscriptions and be allowed to experiment with reclaiming their marsh lands which lie south and east of the railway embankment. In view of the conclusions of the board with regard to this subdivision, any work in connection with these lands involving additional expense to the United States is considered inadvisable. It is recommended that private lands in this subproject be released from their obligations.

(*d*) *Upper subproject.*—It is proposed to irrigate certain lands on the north side of Lost River, together with a small area to the south of that river, and lands in the Yonna Valley, by water stored in Horsefly Reservoir, located on the headwaters of Miller Creek, a tributary of Lost River. The lands at present included in it were originally subscribed to the main project in the belief that the construction charge would be about $20 an acre. As it was subsequently found that this cost would be much greater, the owners were released from their

agreement. Under the present plan and the estimated charge about 75 per cent of the landowners have again subscribed. This subproject has not received executive approval. The main features comprise the reservoir dam at the headwaters of Miller Creek, a diverting dam in the creek in the vicinity of the lands to be irrigated, and the necessary canals and laterals.

(*e*) *Modoc subproject.*—As Clear Lake Reservoir could not be used to irrigate lands in the lower Langell Valley, as originally contemplated, it became desirable to develop some other use for these waters, and a reconnoissance showed that this water might be diverted to lands in Modoc County, Cal., and also to the narrow strip of lands in Oregon on the east and north of Tule Lake, above the irrigating system under the first subdivision. It would appear from investigations now in progress that about 18,000 acres can be irrigated at a cost of about $64 per acre. If this plan is adopted the land should bear its proportion of the cost of Clear Lake Reservoir.

10. The main engineering features of the project comprise the storage dam at Clear Lake, the main canal leading from Upper Klamath Lake on the east side, the Keno Canal leading from Upper Klamath Lake on the west side, the diversion dam in Lost River, the diversion channel from Lost River to Klamath River, the dike in Tule Lake, the laterals and subsidiary distributing system, and a power plant and distribution of electrical power for sale and for pumping water for irrigation and drainage in Tule Lake subdivision. These features present nothing unusual or difficult in design or execution. Those that are constructed appear to have been well designed. The main canal will carry only 500 second-feet, but was constructed, as stated above, with a capacity of 1,500 second-feet. The Keno Canal will not now be used to supply water for irrigation, though originally designed to do so.

11. *Water supply.*—The water supply for the project as herein considered is to be obtained from three sources—Upper Klamath Lake, Clear Lake Reservoir, and Horsefly Reservoir on Miller Creek. Upper Klamath Lake has a drainage basin of 3,100 square miles, with an average annual rainfall of about 20 inches. It has an area of 66,000 acres. A storage of 200,000 acre-feet can be provided at small cost. This lake will supply all the water for the lower project uplands and for Tule Lake reclaimed lands except 100 second-feet, the total required for both subprojects being 720 second-feet. Lower Klamath Marshes, if reclaimed, will derive the necessary water from Link River, diverted at a point below the power plants on the Keno Canal. The upper subproject will receive its waters from Horsefly Reservoir and the Modoc subproject from Clear Lake Reservoir. There are certain undefined water rights claimed in Upper Langell Valley that will have to be satisfied, to the extent allowed, from Clear Lake Reservoir. These rights are now being adjudicated, but are not believed to be large enough, even if found valid, to affect the use of the reservoir for the Modoc subproject. The adjudication, however, should be completed before proceeding with this subproject. An analysis of the water supply for the whole project is included in the appendix to this section, and it is there shown that there will be sufficient supply for each of the subprojects, attention being called to the water rights claimed in the Langell Valley affecting the Modoc subproject.

12. Intimately connected with this question of water supply is the reclamation of the Tule Lake lands. This is to be accomplished mainly by evaporation, the supply of water being cut off except in times of floods, by the storage reservoirs, the diversion channel connecting Lost and Klamath Rivers, and the use for irrigation of 100 second-feet of Lost River flow which enters Lost River below the Clear Lake Reservoir. The rate at which Tule Lake would recede under the measures proposed is also discussed in the water-supply appendix. From this study it would appear that about nine years would be required to reduce Tule Lake so that 35,000 acres of land could be reclaimed. The studies of the Reclamation Service relative to this subject have been comprehensive, but there are many elements entering the problem, such as run-off from the surrounding drainage basin, future rainfall, seepage from lands now being placed under irrigation, that are more or less indeterminate, and time alone can decide whether the assumptions made are warranted. That 35,000 acres of these lands can eventually be reclaimed in the manner proposed seems probable.

13. *Lands.*—The average elevation of the irrigable area is 4,100 feet above sea level, and the average annual rainfall is 15 inches. Dry farming is possible, and in years of more than average rainfall is profitable. The irrigable land under the five subdivisions is shown in tabular form as follows:

Subdivision.	Private.	State.	Public.	Total.
Lower project uplands	36,300	.....	[1] 700	37,000
Tule Lake lands	3,100	.....	[1] 31,900	35,000
Lower Klamath Marshes	27,000	.....	[2] 27,000	54,000
Upper subproject	14,000	500	1,500	16,000
Modoc subproject	8,000	1,000	9,000	18,000
Total	88,400	1,500	70,100	160,000

[1] These lands were originally practically all State lands, but were deeded to the United States by States owning same for homesteads, under condition that the lands should revert to the State if not reclaimed.
[2] Fourteen thousand public and thirteen thousand State lands ceded under conditions in note 1.

Of the 160,000 acres, 70,100 are public lands subject to the reclamation act, 88,400 are private, and 1,500 acres State. Omitting the marsh lands, the total is 106,000 acres, of which 43,100 are public, 61,400 private, and 1,500 acres are State.

14. The soil in the first subdivision is generally decomposed basalt of good fertility. In the lower part near Tule Lake there is much fine sand, making it difficult to cultivate. The soil is fairly deep, but is underlaid with diatomaceous ash, more or less impervious, rendering drainage essential. The duty of water is 1.8 acre-feet per annum at the farm. Under this first subdivision the first unit of 27,776 acres of subscribed land and 1,771 acres of land to which water free of construction charges was to be furnished was opened November 18 and December 7, 1908. At the present time 24,860 have made application for water. Reports for 1910 are not available, but in 1909 18,471 acres were irrigated, the total value of the crops being reported as $327,220. There are two portions of this first unit which require drainage and this is to be provided by the Reclamation Service. An item of $10,000 is included in the estimate for this purpose.

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15. The land in the Tule Lake subdivision is largely public, but is wholly covered at present by the lake. The soil immediately around the lake seems fertile, and much land now covered, due to the rising of the lake in recent years, was formerly exposed and was then equally good. The indications are that the lands reclaimed will prove fertile.

16. The marsh lands around Lower Klamath Lake are about half public and half private. So far experiments with this land have not given favorable results. It appears to be very difficult to work, is very much like peat, and several years are necessary before the soil can be reduced to a cultivable state capable of growing any crop.

17. The upper subproject lands appear to be of good quality and are easily drained. The owners are desirous of having water brought to their lands.

18. The Modoc subproject lands likewise are of good quality and easily drained. The settlers are very desirous of having this subdivision irrigated, as the lands included are high and they think well suited to fruits.

19. The last two subdivisions are not as yet part of the approved project, and whether the waters of Clear Lake will be applied to the Modoc lands or to the lands north of Langell has not yet been decided. The Langell lands have not been included in any proposed subproject, as a large part of them are held in large tracts whose owners decline to subscribe.

20. *Costs.*—Expenditures to June 30, 1910, have been $1,905,715.37. The estimated cost of completion of the five subdivisions is shown in the following table:

(*a*) Lower project uplands:	
Expenditures made and charged to this account	$857,288
Estimated to complete	199,980
Total	1,057,268
Acreage, 37,000; approximate building cost, $28.57; announced charge, $30.	
(*b*) Tule Lake reclamation:	
Expenditures made and charged to this account	621,506
To complete	854,000
Total	1,475,506
Acreage, 35,000; approximate construction charge, $42.16.	
(*c*) Reclamation marsh lands:	
Expenditures made and charged to this account	377,420
To complete	1,432,242
Total	1,809,662
Acreage, 54,000; approximate construction charge, $33.51.	
(*d*) Upper subproject:	
Expenditures made and charged to this account	21,379
To complete	775,000
Total	796,379
Acreage, 16,000; approximate construction charge, $49.77.	
(*e*) Modoc subproject:	
Expenditures made and charged to this account	12,490
To complete	1,132,920
Total	1,145,410
Acreage, 18,000; approximate construction charge, $63.33.	
Total to complete the five subprojects	4,394,142.00
Total estimated cost	6,279,857.37

In this table the previous expenditures have been adjusted by the Reclamation Service among the five subprojects in as nearly equitable proportions as now practicable.

21. It is believed that the lands in all the subprojects, except the marsh lands, can bear the probable construction charges.

22. The par value of the stock of the water users' association has recently been increased from $20 to $30. This new value will cover the construction charges of the first subdivision. In the other four, the estimated construction charges range from $33.51 to $63.33. It is believed that these subdivisions should be dealt with independently through new associations or trustees, the lands to be bound to the full construction charges before large expenditures are made.

23. *Comments.*—Due apparently to insufficient information as to construction costs at the time this project was undertaken, radical changes in the plans and scope of the project have been necessary. The main canal and the Keno Canal were both constructed before these changes were made and are much larger than needed in the present proposed development, though the latter can be made of use in the development of power. The inclusion of the Klamath marsh lands within the project and the expenditure thereon of about $300.000 without knowing their agricultural possibilities was unwise.

24. *Summary.*—(1) This project is interstate in character, the irrigable area lying partly in Oregon and partly in California.

(2) Of the total lands, 106,000 acres, exclusive of the marsh lands, 43,100 acres, or 40.6 per cent, are public lands subject to the reclamation act, of which 700 acres are in the lower project uplands, 31,900 acres are Tule Lake lands. 1,500 are in upper subproject, and 9,000 in the Modoc subproject.

(3) Water supply is sufficient.

(4) The total estimated expenditures, exclusive of marsh lands, is $4,470,195.37, of which about $1,500,000 was expended to June 30, 1910, as follows:

Lower project uplands	$857,288
Tule Lake	621,506
Upper subproject	21,379
Modoc subproject	12,400

(5) The lands, exclusive of the marsh lands, will bear the construction charges estimated as follows:

	Per acre.
Lower project uplands (announced)	$30.00
Tule Lake lands	42.16
Upper subproject	49.77
Modoc subproject	63.33

(6) (*a*) The lower project uplands or first subdivision is feasible from an engineering and an economic standpoint and worthy of completion.

(*b*) The construction of the Tule Lake subdivision should be taken up tentatively to allow further study of the reclaimed lands and the efficiency of the proposed means of controlling the lake area.

(*c*) The upper subproject is an extension not yet approved. It is feasible from an economic and an engineering standpoint, but owing to the necessity of completing more important work elsewhere and to the small amount of public land involved, it is not advisable to prosecute it at the present time beyond such preliminary work as will enable definite plans to be made.

(*d*) The Modoc subproject is feasible from an economic and an engineering standpoint, but it has not yet received Executive approval. Owing to the large amount of public land in this subproject, and to the fact that the water supply therefor is already provided in Clear Lake Reservoir, it is regarded as worthy of completion as funds are available, subject to the adjudication of water rights in Upper Langell Valley.

(*e*) The development of the marsh land subdivision around Lower Klamath Lake should be postponed until it has been shown that the lands can be made productive when cultivated.

(7) Keno Canal power should be developed as needed by the project; the excess power should be developed in cooperation with the water users' association in such manner as to insure return of cost to the United States.

(8) The par value of the stock of the water users' association is sufficient to cover the construction charge on the first subdivision only. For the remaining subdivisions new arrangements should be made by which the land will be bound for the full building charge.

(9) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the loan $600,000

SECTION XXII.

BELLE FOURCHE PROJECT, SOUTH DAKOTA.

1. The board visited the Belle Fourche project on August 8 and 9, inspecting the headworks at the town of Belle Fourche, the dam, the reservoir site, and part of the distribution system on the 8th, and the lands under irrigation and those which it is proposed to irrigate on the 9th. An informal public hearing was held at the railroad station at Belle Fouche on August 9, at which time those interested were given an opportunity to express their views with regard to the work on the project.

2. The Chicago & Northwestern passes through the town of Belle Fourche, and the Belle Fourche Valley & Northwestern, a branch line, runs diagonally through the irrigated land. Good facilities for shipping products are thus provided.

3. *Location and description.*—The Belle Fourche project is located on both sides of the Belle Fourche River in the northwestern part of South Dakota, northeast of the Black Hills. The land and the water supply are all within the limits of that State. The general elevation of the land in the project is from 2,600 to 3,000 feet above sea level and the temperature ranges from 25° below zero to 100° F. The project consists essentially of a diversion dam in the Belle Fourche River about 2 miles below the town of Belle Fourche, S. Dak., which diverts the greater part of the flow of this stream into an inlet canal. This dam, at its northern end, is provided with headworks admitting water into the canal which supplies a large storage reservoir formed in the bed of a small stream, known as Owl Creek. This creek is closed by a high earth dam in which are placed

two concrete culverts with regulating gates, from each of which leads a distribution canal carrying water to the farms through minor laterals. The inlet canal for supplying the reservoir from the Belle Fourche River is a large one, having a capacity of 1,635 cubic feet per second. It has a length of 6½ miles. The reservoir has an area of 8,010 acres and a total storage capacity of 204,000 acre-feet. The north distribution canal has a capacity of 650 second-feet and will ultimately irrigate 60,000 acres; and the south distribution canal has a capacity of 300 second-feet and will irrigate 40,000 acres.

4. *Water supply.*—Owing to the fact that there are no prior filings below the diversion dam all of the water supply of the Belle Fourche River which reaches this dam is available for direct irrigation or storage. Above the dam there is considerable irrigation, particularly on Red Water and Spear Fish Creeks, tributaries of the Belle Fourche River, but no extension of this work can be made under State law if it interferes with the Government project. The present supply, therefore, seems to be amply protected.

5. A complete record of the flow of the Belle Fourche River at the diversion dam has been kept since June, 1903 (except during 1907, when the gaging station was destroyed), and an analysis of the results to and including 1909 shows that the total quantity and its distribution throughout the year were such as to have permitted the diversion through the present inlet canal of the amounts shown by the following table. These totals cover only nine months in each year, excluding December, January, and February, during which ice would probably obstruct the flow.

Run-off of the Belle Fourche River and Owl Creek.

Years.	Run-off of the Belle Fourche River.	Run-off of Owl Creek.	Total.
	Acre-feet.	*Acre-feet.*	*Acre-feet.*
1903	116,280	35,000	[1] 151,280
1904	261,470	38,000	299,470
1905	290,960	37,200	328,160
1906	252,310	34,700	287,010
1907	[2] 240,000	39,000	279,000
1908	218,710	18,400	237,110
1909	217,800	31,000	248,800
Mean of 1903 to 1909	246,875	33,050	279,925

[1] Part year only. [2] Estimated.

NOTE.—No record of run-off of Crow Creek. (Drainage area, 125 square miles.)

5. The run-off of the Belle Fourche River for the first part of 1910 was notably less than for the corresponding part of any previous year of recorded flow, the amount between March 1 and July 31 being only 40 per cent of that for the corresponding period of 1909.

6. The duty of water on this project is estimated at 2 acre-feet per acre per annum, measured at the farm, and the area included in the project is 100,000 acres.

7. Evaporation losses on the reservoir may be roughly estimated at 18,000 acre-feet and seepage and evaporation losses in the canals at 25 per cent, which would leave approximately 200,000 acre-feet for delivery to the farms. Some of the above losses will be offset by the

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inflow from Crow and Indian Creeks, so it is apparent that in normal years the water supply will be sufficient for the needs of the project. The partial measurements for 1910 indicate that there would have been a shortage of water had the entire area under the project been in cultivation, but an occasional shortage of this kind does not affect the feasibility of the project, as the cost of providing for such abnormal conditions would probably be greater than the resulting benefits.

8. *Land.*—The irrigable area is about 100,000 acres, of which 50,000 acres are private land, 20,000 withdrawn from entry, 21,600 acres entered subject to the reclamation act, 2,946 open to entry, and 5,515 acres State school land which will be sold to private owners. Practically all the public land thus far opened has been entered for settlement, there remaining but about 40 farms not taken up. The farm unit on public land is 80 acres, except within 2 miles of town sites, where it is reduced to 40 acres. On private land it is 160 acres.

There were 47,568 acres of land ready to be irrigated in 1910, leaving the remainder to be brought under irrigation by extensions of the lateral systems. There were 23,500 acres actually supplied with water. The soil on the north side of the Belle Fourche River is usually clay loam of the gumbo type and difficult to work, several years being necessary to subdue it, but it is productive when cultivated. The soil on the south side is lighter, and the lands on this side are more sought after. The rainfall is about 15 inches, and the region is therefore classed as semi-arid. Dry farming is practiced to some extent, but the crops are only one-fourth to one-half the crops on irrigated land, and are failures in some years. The crops are grain, corn, alfalfa, potatoes, and possibly fruit. Irrigated land sells at prices varying from $40 to $50 for raw land and from $75 to $100 when brought thoroughly under cultivation. The character of the land does not warrant high construction charges for irrigation, but it is believed that the charge of $30 already fixed for the first unit and the charge of $35 suggested by the Reclamation Service for the remainder can be easily borne, together with charges for operation and maintenance of about $0.50 per acre per year.

9. *Distribution system.*—The distribution system is in two units, one being served by the north side canal and the other by the south side canal. The north side canal has a capacity of 1,600 second-feet for a length of about a half mile, and from there on a capacity of 650 second-feet. It has been completed and is in use for a distance of 9 miles to Indian Creek. It is now being extended for an additional length of 36 miles. The south side canal is smaller, having a capacity of 350 second-feet, and has been completed to the Nine Mile Creek, a distance of 45 miles, nearly its full projected length. It crosses to the south side of Belle Fourche River in a concrete siphon 3,565 feet long and 5 feet in diameter. The distribution system now completed covers less than one-half of the whole project. The remaining areas are to be covered by the extensions now being made, and lie mainly under the north side canal. Some drainage will likely be necessary to prevent swamping.

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10. *Cost of the project.*—The total cost of the project up to June 30, 1910, has been $2,394,157.01. The estimated cost of completion is $755,863, as follows:

Belle Fourche Dam	$95, 839
North canal and laterals	630, 024
Nine-mile lateral	30, 000
	755, 863

11. *Returns to the reclamation fund.*—The price of $30 per acre to cover construction charges was set in 1907 considerably in advance of the completion of the later units. This figure is too small, but 11,293 acres were opened to settlement in June, 1907, under this charge, and about 35,000 acres more were reached by the ditches in 1910, and were officially opened in February, 1910, for the same building charge. For the remainder of the land it will be necessary to set a new and somewhat higher construction charge if the total cost is to be returned to the reclamation fund. The settlers who were on the ground when the project was started, many of whom were owners of patented land, applied for water under the reclamation act under the agreement that charges over the entire project were to be uniform. The price of $30 was set later, so that a higher charge can not apply to areas covered by the early applications without modification of the contract. It is expected by the Reclamation Service to charge $30 per acre for 70,000 acres and $35 per acre for 30,000 acres, the total of which amounts to $3,150,000. If all the lands under the project were to be finally disposed of at these charges and the present estimates for completion not exceeded, the expected returns would just cover the cost. The cost of operation and maintenance has exceeded the returns at the charge set of $0.40 per acre per annum, and a deficit of about $4,000 exists in consequence. This charge has now been raised to $0.50, which it is expected will refund the deficit in several years. Should drainage be found necessary, it is believed that this should be paid for by assessments against the land under operation and maintenance charges.

12. *Comments.*—In general the work seems well adapted to the purpose for which designed. The earth reservoir dam has been constructed with slopes somewhat steeper than is customary in dams of this type and height. Some flow is noticeable at the lower toe of the dam, although but little water was in the reservoir at the time when the dam was inspected. The board believes that the dimensions of the dam should be made the subject of further study, and that the leakage be kept under constant observation. A fuller description and discussion is appended. In general, the project appears to be feasible and practicable in an engineering and economical sense.

13. *Summary.*—(1) This project with its water supply lies wholly within the limits of the State of South Dakota.

(2) The area of the irrigable land in the project is 100,000 acres, of which the amount of public land subject to the reclamation act is about 45 per cent.

(3) The total estimated cost is $3,150,000, of which about $2,400,000 has been expended.

(4) The project is feasible from an engineering and economic standpoint and is worthy of being completed.

(5) The water supply is sufficient for the area now proposed for irrigation.

(6) The land is productive and can readily refund the construction charge of from $30 to $35.

(7) The advanced condition of the work, the promptness with which the land has been taken up by settlers, the relatively large areas of fairly productive land, and the comparatively low cost of irrigation render it desirable to continue the work at an economical rate of progress until completed.

(8) The following allotment is recommended for the four years, 1911–1914, inclusive: From the fund, $480,000.

SECTION XXIII.

STRAWBERRY VALLEY PROJECT, UTAH.

1. The board visited this project September 15, 16, and 17 and met the directors of the Strawberry Valley Water Users' Association, at Provo, on September 16.

2. *Location.*—The project lies wholly within the State of Utah, the irrigable area being on the southeast shore of Utah Lake, about 60 miles south of Salt Lake City and surrounding the towns of Payson, Spanish Fork, and Salem.

3. Excellent transportation facilities are afforded by the San Pedro Los Angeles & Salt Lake Railroad and by the Denver & Rio Grande Railroad, both of which traverse the project.

4. *Description.*—The project contemplates the irrigation of 60,000 acres of mesa and bottom land, all in private ownership, with certain possible extensions, which will be referred to hereafter. Much of the area under the project proper is now under cultivation, and has been for many years. About 30,000 acres are now being partially irrigated from Spanish Fork River and certain small creeks, and dry farming is practiced on part of the remainder.

5. Of the land irrigated, it is estimated that in normal years about 8,000 acres receive a full supply, and that occasionally there is a fair supply for approximately 20,000 acres during the entire season.

6. The object of the work undertaken by the Reclamation Service is to supplement the flow of the Spanish Fork River by bringing an additional supply through the rim of the Great Salt Lake Basin from the Colorado River drainage. This involves the construction of a reservoir in the valley of the Strawberry River, a tributary of the Duchesne River, and the diversion of the water thus stored by a tunnel nearly 20,000 feet long through the rim of the Great Basin. From the tunnel it will be discharged into the Sixth Water Creek and flow thence through Diamond Creek into Spanish Fork River.

7. The project includes the ultimate development of about 3,000 electric horsepower, to be obtained by dropping through penstocks to some of the lower distributing laterals part of the flow diverted at Spanish Fork Dam. The diversion dam and the power canal, which is 3¼ miles long, have been constructed, and 1,200 horsepower is

now being developed. This power development is primarily for use in driving the tunnel, but there is a surplus, part of which is being sold to the town of Spanish Fork.

8. Work on the tunnel is in progress, and about 9,000 feet have been excavated, nearly one-half of the total length. No work has been done upon the storage reservoir nor upon the distribution system.

9. *Engineering structures.*—The Strawberry Tunnel has an arched top. It is 8 feet 6 inches high at the crown, 6 feet 6 inches high at the spring line, and has a width of 7 feet. Its slope is 0.003 and its capacity about 600 second-feet. It is being driven from a single heading at a rate of 400 feet a month. No serious difficulties have been encountered and none are expected. Based upon work already done the cost, including lining, will be about $45 per lineal foot. The Spanish Fork Diversion Dam is of concrete, well constructed and substantial in character. The arrangements, however, for keeping heavy silt out of the canal seem unnecessarily complicated and expensive.

10. *Water supply.*—The run-off of Spanish Fork River at the mouth of the canyon has been measured since 1903, and the amount that could have been diverted to the irrigable area during the irrigation season through the diversion canals as planned is shown in the table below. There is also included in the table such information as is available concerning the run-off of Strawberry Creek (including Indian Creek, which is to be diverted into the storage reservoir):

Years.	Available supply.	
	Spanish Fork.	Strawberry.
	Acre-feet.	*Acre-feet.*
1903	42,000	.....
1904	51,000	54,820
1905	38,500	[1] 40,160
1906	89,500	[2] 84,300
1907	125,500	.....
1908	50,000	.....
1909	125,000	150,000
1910	[3] 72,600	.....
Average	74,262	.....

[1] April 13 to December 31. [2] January 1 to July 12. [3] To September 10.

11. The Reclamation Service has filed on the waters of Spanish Fork, but there are prior appropriations confirmed by court decree which aggregate 350 second-feet, or considerably more than the low-water flow. Under its contract with the Strawberry Valley Water Users' Association, however, these prior water rights will nearly all be merged with those of the United States. Therefore, the maximum amount that can be diverted will be available for the project.

12. On Strawberry Creek a filing was made for 100,000 acre-feet, though the capacity of the reservoir as now proposed is 175,000 acre-feet. This filing expires in January, 1911, and when renewed should, if practicable, be increased. There are no prior rights.

13. *Duty of water.*—The average rainfall on the project is 18 inches, and it is estimated by the Reclamation Service that 2.2 acre-feet per acre additional will be sufficient for agricultural purposes. This

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is believed to be reasonable, though less than the average amount now being used on a number of the irrigated farms.

14. The evaporation loss on the reservoir, owing to its position in the mountains, will be slight, and the losses between the reservoir and the diversion weir will also be small. Assuming an evaporation and seepage loss of 25 per cent in the distribution system, 33⅓ per cent will probably cover the total losses on stored water. On this basis, 3.3 acre-feet of reservoir water, or 3 acre-feet of Spanish Fork water, will be required for each acre irrigated.

15. The average run-off of the Spanish Fork River is approximately 75,000 acre-feet, sufficient for the irrigation of 25,000 acres, and the irrigation of the remainder of the outlined project will require 3.3 acre-feet on 35,000 acres, or 115,000 acre-feet from Strawberry Valley. The discharge measurements of Strawberry Creek are so meager that no definite conclusions can be reached as to its ability to furnish the required amount of water. Certainly the data is insufficient to justify the assumption that there will be any greater amount than 115,500 acre-feet.

16. The usable run-off of Spanish Fork Creek can be somewhat increased by the construction of auxiliary reservoirs on Diamond Fork, for which an item of $100,000 is included in the estimate. No surveys have yet been made of these sites, so that neither the amount nor the cost of this auxiliary storage is known. As Diamond Fork Canyon is relatively steep and narrow, the storage will probably be small and the cost per acre-foot relatively high.

17. Based upon the above, it seems probable that there will be sufficient water in ordinary years from the Spanish Fork River and Strawberry Creek for the projection as now outlined, but not sufficient for the irrigation from these sources of any of the proposed extensions.

18. *Lands.*—The irrigable area has an average elevation of 4,500 to 4,800 feet above sea level, and is of good quality, the soil being a sandy and gravelly loam, with deep black soil in the lowlands. Where sufficiently irrigated it produces abundant crops of alfalfa, sugar beets, hay, cereals, and vegetables. Much success has been attained with sugar beets, there being a factory and several slicing stations in the valley. The crop is usually worth from $70 to $75 per acre, with a net profit of from $35 to $40. Parts of the area are devoted to raising fruit and the success thus far attained indicates that a considerable percentage of the area under the project may be suitable for this purpose. Estimates by interested persons place this as high as 60 per cent. There is some trouble with frosts on the fruit lands, especially where there is no air drainage. Near the mouths of the canyons, where there is wind, frost is less likely to occur. In other places owners are compelled to smudge occasionally at a cost of from $8 to $10 per acre.

19. The land used for grain, alfalfa, etc., is worth from $60 to $150 per acre under irrigation. Fruit land with bearing trees has been sold at from $250 to $1,000 per acre, and is said to yield a profit of from $200 to $600 per acre. Land for dry framing is worth from $20 to $40 per acre. In purchasing nonirrigated land for the high-line canal, $40 to $45 per acre was paid.

20. A large part of the land is very low and flat, and the ground water in many places is within from 4 to 6 feet of the surface. Al-

though large areas are at the present time swamped, very little work has been done in the way of drainage.

21. *Cost.*—There has been expended to June 30, 1910, $909,000, and the estimated expenditures to December 31, 1910, are $1,130,000. The estimated additional cost for the completion of the project is as follows:

Storage Dam on Strawberry River, height above foundations, 77 feet	$262,000
Dike between Indian Creek Valley and Strawberry Valley, height above foundation, 35 feet	225,000
Indian Creek diversion. Diversion of all the small streams emptying into Indian Creek, into Strawberry Reservoir	60,000
Completion of Strawberry Tunnel, 10,000 feet of excavation, 15,000 feet of lining, and controlling works east portal of Strawberry Tunnel, gatekeeper's house, etc	695,000
Road to Strawberry Dam and maintenance of tunnel road	25,000
High-line canal, 26 miles long	650,000
Improvements around Spanish Fork diversion dam, and work along power canal	10,000
Siphon and small canal to supply high ground above East Bench Canal	50,000
Rebuilding old canal system, rebuilding old diversion dams, widening old canals, etc	100,000
Distribution system	100,000
Auxiliary reservoirs in Diamond Fork Canyon	100,000
	2,277,000

Making a total cost of $3,407,000, or a cost per acre of $56.80. This unit cost may be considerably reduced should the proposed extensions to be described hereafter prove feasible.

22. At the time the Strawberry Valley Water Users' Association was formed the par value of the shares was placed at $40, which was supposed to represent the building charge. As it now seems probable that the building charge will be considerably higher and as it is questionable whether the land owner can be held for an amount greater than the par value of his stock, unless in making his water-right application he voluntarily assumes the additional obligation, due consideration for the investment of the United States requires that the par value of the stock of the water user's association be increased as provided for in the by-laws. Furthermore, this increase should be made within a reasonable time and prior to any large additional expenditures on the project.

23. There are a number of private and State irrigation projects in the vicinity, the cost of which has varied from $20 to $75 per acre. Considering this fact and the quality of the land in the project, the board believes that, even if the cost amounts to $56.80 an acre, it will not be excessive for fruit land. For other land it will be burdensome but probably not prohibitive.

24. In furtherance of this project 43,000 acres of land, covering practically all of the Strawberry Valley drainage area above Strawberry Dam, was acquired by purchase from the Indian Bureau. This is now leased for grazing purposes at $0.20 an acre a year, and the returns from this source, together with the returns from the sale of surplus electric power, should make the net cost of operation and maintenance low.

25. *Proposed extensions.*—The project as outlined in the last annual report included only 60,000 acres, but recently consideration has been given to a dike and drainage project which would reclaim ap-

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proximately 36,500 acres additional. It consists in diking off two arms of Utah Lake, draining these areas by means of pumps, and, during the irrigating season, using the drainage water to irrigate the lands drained. While this extension adjoins the original project and would use power developed in connection with the original project, it is in other respects entirely distinct. The diking off of these two areas was considered by the Reclamation Service in 1904 in connection with what was then known as the Utah Lake projects, and in reference to these dikes a board of consulting engineers then reported:

Investigations indicate that the material in the bed of the lake is of such character that this plan is not feasible.

26. It is understood that no subsequent examination with a view to finding a suitable site for the dikes has been made. The character of the soil in the bed of the lake is not known. No tests have been made to determine the effect of pumping upon the ground-water levels nor is it definitely known that the drainage water will be suitable for irrigation. Doubt also exists as to whether the ownership of the bed of the lake is in the United States or in the State of Utah. No detailed plans of this extension have yet been prepared, so that the estimate submitted for it, $900,000, must be considered as a mere approximation. Pending the collection of more physical data no opinion can be expressed as to the feasibility of this extension.

27. There has also been under consideration an extension of the gravity system across Santaquin Ridge to include 6,500 acres of public land at the southern extermity of Utah Lake. This is contingent upon a water supply in Spanish Fork and Strawberry Creek more than sufficient for the 60,000 acres in the original project. As this is improbable, the extension does not require further consideration.

28. *Summary.*—(1) The discharge measurements of Strawberry Creek were not sufficient at the time the tunnel was started to warrant so costly an undertaking, and they are not even now sufficient to justify a definite conclusion as to the amount of water that will be available from this source.

(2) The entire area of 60,000 acres under the original project was in private ownership when work was started.

(3) No interstate or international features are involved, the irrigable area as well as the water supply lying within the State of Utah.

(4) Except for the uncertainty as to the water supply, the project is feasible from an engineering standpoint.

(5) Work has progressed so far that due regard for the investment already made requires that the project be completed.

(6) The land can probably bear the building charge, but before any large additional expenditures are made, the members of the water users' association should be required to demonstrate their faith in the project and at the same time guarantee the United States against possible loss by increasing the par value of the stock in their association from $40 to $60 an acre.

(7) Assuming such action by the water users' association, the board believes the project should be completed.

(8) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the loan---------- $2,272,000

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SECTION XXIV.

OKANOGAN PROJECT, WASHINGTON.

1. This project, except the reservoirs which were not visited, was examined by a committee of the board on September 7, 1910, and a public hearing held at Omak on the afternoon of that day.

2. *Location.*—The project, both as to the water supply and irrigable land, lies wholly within the State of Washington. Transportation facilities are poor, the nearest railroad being 50 miles away, and the nearest steamboat line 30 miles away, except for two months each year when the Okanogan River, which bounds the project on the east, is navigable for light-draft boats. The Great Northern Railway is, however, now building a line through the Okanogan Valley which, when completed, will furnish adequate transportation facilities.

3. *Description.*—The project covers 8,650 acres. Water is obtained from Salmon River, a stream which drains about 152 square miles in the eastern foothills of the Cascade Mountains. Flood waters are stored in two reservoirs adjacent to each other, one Salmon Lake with a capacity of 2,000 acre-feet, and the other Conconully Reservoir with a capacity of 13,000 acre-feet. In the latter the water is impounded by an earth dam, 60 feet high. The dam has just been completed and has not as yet been subjected to its full head. A spillway of 5,000 second-feet capacity is provided, which is about ten times the maximum recorded discharge. The outlet is through a reenforced concrete conduit controlled by a cast-iron gate. From the dam the water is discharged into the natural bed of Salmon River and flows thence 12 miles to a small diverting weir. There is a fall of over 800 feet from the outlet of the reservoir to the diverting weir. The canal leading from this weir has a capacity of 100 second-feet. At the end of the second mile it divides into two parts known as the upper main lateral and the lower main lateral, the latter diverting from the main canal through a drop of 105 feet. The upper main lateral also contains a drop of 58 feet at a point one and three-fourth miles beyond the junction. These two drops afford opportunities for the development of power in small quantities which have not yet been utilized. The structures examined were well built and suitable for the purpose intended.

4. *Water supply.*—The run-off of the Salmon River as measured since 1903 is—maximum 56,000 acre-feet, minimum 22,000 acre-feet. In 1908 and 1909 the run-off was less than 30,000 acre-feet and it is probable that the run-off for 1910 will also be less than 30,000 acre-feet. As prior rights on this stream covering 1,350 acres must be satisfied in addition to the 8,650 acres in the Government project, there is need for 30,000 acre-feet every year, the duty of water at the farm being placed at 2 acre-feet and the seepage and evaporation loss at 33 per cent. In 1909 seepage and evaporation losses in the distribution system alone averaged 40 per cent, but these losses will probably decrease with further use of the ditches. It is therefore evident that the capacity of the stream is fully utilized and there probably will be times when less than 2 acre-feet per acre can be delivered at the farms.

5. *Lands.*—The irrigable area within the project is 8,650 acres, of which approximately 1,100 acres were Government land subject to

the provisions of the reclamation act at the time the project was undertaken. The remainder was in private ownership. The average elevation above sea level is 1,000 feet. The average annual rainfall is 8 inches, and without irrigation no crops can be raised.

6. The character of the soil within the irrigable area is volcanic ash, sand, and gravel. It is nearly all suitable for fruit, particularly apples, and is valued at from $100 to $300 per acre. About 4,000 acres of the 8,650 in the project received water this year, and it is probable that 70 per cent of the total will be under irrigation in 1911.

7. *Cost.*—The cost of the project to June 30, 1910, was $573,000, and the estimated cost of completion at that date $17,000, a total of $590,000. The building charge was fixed in 1908 at $65 per acre, except as to 499 acres, which were allowed credits of from $6 to $10 per acre in consideration of the owners constructing their own ditches and carrying devices. The anticipated returns are $558,304, so there will be a loss to the reclamation fund on this project of about $32,000, nearly $4 per acre. The charge for operation and maintenance in 1909 was $1.50 per acre. There is also a deficit under this heading due to the small acreage under cultivation, but it is expected that this will be made up in subsequent years.

8. *Extensions.*—The project as outlined by the Reclamation Service has been practically completed, but request is made by the Okanogan Water Users' Association for an extension primarily for the purpose of increasing the size of the irrigable area and thereby reducing the cost of operation and maintenance per acre. Two extensions have been considered, one to utilize part of the power now going to waste between the storage dam and the diversion weir, or the power that can be developed at the two drops and transmit it electrically to a point on the Okanogan River, and there pump water from the Okanogan River to lands adjacent to the left bank of the river and within the Colville Indian Reservation. Another suggestion is to increase the size of the upper main lateral between the two drops and continue it at the high level beyond the 58-foot drop. To provide water for this purpose it is proposed to utilize part of the water now dropped into the lower main lateral and to substitute for the water so withdrawn water pumped from the Okanogan River, utilizing power to be developed either at the drops or in Salmon River above the diversion weir. The areas covered by the proposed extensions consist of good fruit land, equal and probably superior to the low-lying areas under the existing project.

9. The cost of the extension to the Indian lands on the left bank of the Okanogan has been approximately estimated by the Reclamation Service at somewhat less per acre than the cost of the existing project. No estimate has been made of the cost of irrigating the land between the upper main lateral and Johnsons Creek, but judging from the superficial examination made it would be in excess of $65.

10. Statements were made by interested persons that a building charge up to $100 per acre would not be prohibitive, so there is no doubt but that all of the land under the extensions will be able to carry the construction charge. The proposed extensions are also feasible from an engineering standpoint.

11. None of the land under consideration is public land subject to homestead entry, though that on the east bank is unallotted Indian land.

12. *Summary.*—(1) The Okanogan project lies wholly within the State of Washington.

(2) As constructed it is feasible from an engineering standpoint, is practically completed, and the land can readily pay the construction charge placed upon it.

(3) The total cost will be approximately $590,000.

(4) The announced building charge, $65 per acre, is not sufficient to insure full returns to the reclamation fund, the estimated loss being $32,000.

(5) The proposed extensions are feasible from an engineering standpoint, and the probable cost per acre will be well within what the land can stand.

(6) As there is no land under these extensions subject to homestead entry, it is not advisable to undertake either of them with reclamation funds.

(7) If the Okanogan Water Users' Association desires to do this work at its own expense it should be encouraged to do so.

(8) The following allotment is recommended for the four years, 1911–1914, inclusive:

From the fund $13,000

SECTION XXV.

YAKIMA PROJECT, WASHINGTON.

1. The board inspected this project from August 29 to September 1, inclusive, and held public hearings at Sunnyside, North Yakima, and Ellensburg. The examination included the proposed additional units, as well as those under construction. All the principal structures and the sites of those proposed were visited either by the board as a whole or by committees of its members.

2. *Location.*—The project both as to water supply and irrigable area lies wholly within the State of Washington. With the exception of the Benton unit, which lies in the Columbia Valley, all the irrigable area is in the valley of the Yakima River, upon which river with its tributaries it depends for the necessary supply of water. North Yakima is the principal city within the project. The main line of the Northern Pacific Railroad passes through the entire valley, affording with its branches adequate transportation facilities. These are supplemented by the Chicago, Milwaukee & Puget Sound Railroad, which passes through Ellensburg in the Kittitas unit, and by the North Coast Railroad, now under construction in the lower valley.

3. *Description.*—This project as outlined contemplates the irrigation of over 400,000 acres of land, divided into a number of distinct units. While these units are in a measure independent of each other, they are, with the exception of the Tieton unit, all dependent upon a common system of storage reservoirs and by formal order of the Secretary of the Interior, March 3, 1909, were consolidated into one project.

4. On two of the units, the Sunnyside and the Tieton, work is now in progress, the former being 60 per cent complete and the latter 80

per cent complete. No work has been done on the Kittitas and Wapato units beyond the preparation of preliminary plans and estimates of cost. On the Benton unit no work has been done except a preliminary reconnaissance in 1905.

5. A sixth unit, known as the High Line, has recently been proposed by private interests and has been made the subject of investigation by the Reclamation Service.

6. *Water supply.*—Before work on the Yakima project was undertaken by the Reclamation Service the low-water flow of the Yakima River was overappropriated and there were many conflicting claims. As a precedent to beginning work in the valley it was required that these conflicting claims be settled. This was done by limiting agreements entered into by the users of water whereby the aggregate amount of the claims was limited to approximately the low-water flow. These agreements do not have the binding force of a court decree, but will probably serve as the basis of an adjudication should one be made in the future. In addition the State legislature by enactment made it possible for the Reclamation Service to withdraw from further appropriation all the unappropriated waters of the watershed, thus permitting a maximum development. This control of the unappropriated run-off is dependent upon continuous progress of construction and upon beneficial use of water.

7. As the development of this project depends primarily upon the storage of flood water, five reservoir sites have been selected, the capacities of which are given in the following table. The first three of these are at the headwaters of the Yakima River and the last two at the headwaters of the Naches River, one of its tributaries:

Reservoir sites.	Capacity.	
	Present.	Ultimate
	Acre-feet.	*Acre-feet.*
Lake Cle Elum	23,000	426,000
Lake Keechelus	15,000	142,000
Lake Kachess	56,000	210,000
McAllister's meadow	.....	115,000
Bumping Lake	35,000	35,000
Total	129,000	928,000

8. The present capacity of the reservoirs is only sufficient to meet existing requirements on the Sunnyside and Tieton units. It will be gradually increased as further work on the irrigable areas is undertaken.

9. The water shed of the Yakima River has an area of 5,050 square miles and an average annual run-off of 3,000,000 acre-feet. A comprehensive study of the hydrographs of this river at different points during the period of 1904–1910 has been made by the Reclamation Service. Against the discharge curves has been plotted the demand curves for the different units and the storage requirement determined for each year, due allowance having first been made for prior rights. The results of this study are appended to this report and show the proposed storage in connection with flood flow to be sufficient for the irrigation of 417,000 acres. If to this be added the 64,000 acres in the Sunnyside and Wapato units, to which low-water rights attach,

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the total area capable of irrigation becomes 481,000 acres. In the following table are listed the acreages assumed in this study and the corresponding storage requirements:

Project.	Total acres under project.	Acreage requiring storage.	Storage charge (acre-feet).	Cost of storage, assuming full development and uniform distribution.
Kittitas	67,000	67,000	146,000	$654,000
Benton, or High Line	160,000	160,000	366,000	1,638,000
Tieton	34,000	34,000	59,000	264,000
Wapato	120,000	108,000	247,000	1,106,000
Sunnyside	100,000	48,000	110,000	493,000
Total	481,000	417,000	928,000	4,155,000

The assumptions upon which the analysis was made appear to be reasonable and the conclusions justifiable.

RESERVOIRS.

10. *Cle Elum Lake Reservoir* is on the Cle Elum River about 7 miles above its confluence with the Yakima. The average annual run-off at this point is 575,000 acre-feet. A temporary crib dam built in 1907 affords capacity for 23,000 acre-feet. It is proposed to develop an ultimate capacity of 426,000 acre-feet by the construction of an earth-fill dam at the outlet of the lake, with concrete outlet works and spillway. The foundations are suitable for such a dam, and satisfactory material for its construction can be obtained in the vicinity.

11. *Keechelus Lake Reservoir* is near the source of the Yakima River, the average annual run-off at this point being 200,000 acre-feet. A temporary crib dam built in 1907 affords capacity for 15,000 acre-feet. It is proposed to develop an ultimate capacity of 142,000 acre-feet by the construction of an earth-fill dam at the outlet of the lake, with a concrete outlet conduit and controlling works and concrete lined spillway. The foundations are suitable for such a dam and satisfactory material for its construction can be obtained in the vicinity. Final plans for this dam have not yet been made.

12. *Kachess Lake Reservoir.*—This lake lies between Keechelus Lake on the west and Cle Elum Lake on the east, the dam site being only 3 miles from the railroad. The lake has a drainage basin of only 63 square miles, but the average run-off since 1904 has been 208,000 acre-feet. A temporary crib dam, constructed by a private company, whose rights have since been acquired, provides storage for 16,000 acre-feet. During the past year this has been increased by the construction of a drainage channel, enabling the lake to be lowered and thereby increasing its capacity to 56,000 acre-feet. It is proposed to develop an ultimate capacity of 210,000 acre-feet partly by increasing the depth of the drainage channel and partly by the construction of a permanent earth dam of greater height than the existing crib dam. The plans include a spillway with a capacity equal to the greatest flood of record—7,200 second-feet—but as the reservoir provides for storing the maximum run-off, and as maximum

floods usually occur when the reservoir is at its low stage, the spillway will, probably, not often be required.

13. *McAllister's Meadow Reservoir.*—The site of this reservoir is on the headwaters of the Tieton River and has an estimated capacity of 115,000 acre-feet, about one-third of the average annual run-off at this point. This site was examined by a committee of the board and its report thereon is appended. The dam site is suitable for the character of dam proposed and the general plan as outlined is feasible, though probably at greater cost than is given in the estimates.

14. *Bumping Lake Reservoir.*—This reservoir is situated at the headwaters of the Bumping River, a tributary of the Naches River, about 46 miles from Naches. The reservoir has a capacity of 35,000 acre-feet and the run-off above it is more than sufficient to fill it each year. The reservoir is formed by an earth-fill dam now under construction and nearing completion. The report of a committee of the board which examined it is appended. In this report attention is invited to inferior concrete in the spillway, and to the material used and slopes adopted. It is believed that additional work on the dam may be necessary.

15. The ultimate capacity, estimated total cost, and cost per acre-foot of the different reservoirs are tabulated below:

Sites.	Ultimate capacity (acre-feet).	Already expended or allotted.	Additional allotment required.	Estimated total cost.	Ultimate cost per acre-foot.
Lake Cle Elum	426,000	$48,834	$1,050,000	$1,100,000	$2.58
Lake Keechelus	142,000	44,955	850,000	895,000	6.30
Lake Kachess	210,000	138,000	574,000	703,000	3.35
McAllister's Meadow	115,000	32,654	900,000	932,000	8.10
Bumping Lake	35,000	525,000	.....	525,000	15.44
Total	928,000	789,443	3,374,000	4,155,000	.....

SUNNYSIDE UNIT.

16. *Location and description.*—This unit lies in Yakima and Benton Counties and is based upon a private canal known as the Sunnyside, which possessed one of the oldest and largest water rights in the valley, amounting to 1,050 second-feet. Only 650 second-feet was being beneficially used at the time of its acquisition, and in the limiting agreements as to prior water rights, referred to above, the Sunnyside Canal is accorded this amount. This canal with its appurtenances was purchased in 1906 for $250,000. Water is diverted from the Yakima River just below Union Gap by a concrete diversion dam built by the Reclamation Service to replace an old crib dam. It is 7 feet high and rests on a rock foundation. The main canal, which is to be about 60 miles long, is now being enlarged to a maximum capacity of 1,076 second-feet. Other improvements undertaken by the Reclamation Service were:

(*a*) The construction of concrete drops in the main canal, the original slope being too steep to admit of enlargement without danger of excessive erosion.

(*b*) The construction of additional culverts for the better protection of the main canal against storm waters.

(*c*) Reconstruction of turnouts, substituting concrete for wood.

(*d*) The construction of three wasteways, which also serve as main drains for low-lying areas. The most important of these is the Sulphur Creek wasteway, 37 miles from the headworks, designed to carry the full flow of the canal at that point—515 second-feet.

(*e*) The construction of the Mabton siphon across the Yakima River designed to water about 10,000 acres on the right bank of the Yakima River in the vicinity of Mabton.

17. *Water supply.*—The water rights acquired in the purchase of the Sunnyside Canal are insufficient for more than 5,200 acres and must be supplemented by storage. From the hydrographs of the river the storage required has been determined at 110,000 acre-feet.

18. *Lands.*—The irrigable area is about 100,000 acres, of which 1,346 is public and the remainder private land. The average elevation of the irrigable area is 700 feet above sea level, and the average rainfall 7 inches.

19. The soil is deep volcanic ash and gravel. Without irrigation farming is not possible. When irrigated the soil is very productive, the principal crops being forage, hops, vegetables, and fruits. About one-half of the area under the project is now being irrigated and water will be available for 12,400 acres additional by December 31, 1910. Of the area under cultivation the largest part is used for raising hay and alfalfa. The higher lands are devoted to fruit and yield abundant crops of peaches and apples.

20. The average value of lands under irrigation varies from $200 for alfalfa lands to $500 for fruit lands. The average returns from irrigated land, as stated by the residents in this unit, are large, and it can readily bear the construction charge. Considerable areas under this unit have been rendered temporarily useless by alkali, due to subirrigation. The first step to remedy this condition has been taken in the construction of the Sulphur Creek wasteway, which is to serve also as the main drain for the Sunnyside Basin. The cost of this main drain is charged against the unit as a whole. The cross drains leading to it, which will be necessary to fully reclaim the alkali lands, are to be constructed by the owners of the land directly benefited. The Granger Basin in this vicinity is also in need of drainage, and preparatory surveys have been made.

21. *Cost.*—The expenditures on this unit to June 30, 1910, including storage, were $1,443,000, and the estimated cost of completion, exclusive of storage, is $1,205,000. This cost of completion includes $388,000 for pumping plants, the cost of which is to be repaid by the lands to which the water is pumped in addition to the regular construction charge. The estimated cost of storage is $500,000, making the total cost $3,148,000.

22. *Returns to the reclamation fund.*—Under the terms of agreement by which the Sunnyside Canal was acquired, 3,080 acres was to be provided with water free of charge and the remainder of the land under the canal was to bear no construction charge but an annual operation and maintenance charge of $1 per acre. These lands, however, had no right to stored water and to put them on a parity with new lands irrigated under this unit, the owners of the old lands were permitted to purchase a supplementary water right at cost of $10 per acre. This not only entitled them to share in the benefits of the storage system but entitled them to operation and maintenance at actual cost instead of at a fixed sum of $1 per acre. This unit also includes

1,108 acres of land at Prosser, which, owing to prior partial development, is to bear a construction charge of $31 per acre. The remainder of the irrigable area, 52,913 acres, is to bear a construction charge of $52 per acre. The estimated returns slightly exceed the estimated expenditures.

23. *Comments.*—Less than 2 per cent of the land under this unit is public land subject to homestead entry, but the expenditures already made are so largely in excess of the returns that would be received from the areas now irrigated that a continuation of the work is desirable at least to an extent sufficient to insure the return of the investment.

24. The proposed extensions of the Sunnyside unit include four pumping plants to be operated electrically, power being developed at a number of different drops in the distribution system. These pumping plants are designed to cover 14,310 acres of land, the water being pumped from laterals supplied through the main canal. The cost of these pumping plants is to be borne by the land irrigated by them, and in addition these lands must pay the regular construction charge for this unit of $52. As 85 per cent of the land to be thus irrigated is in private ownership, it would seem to be advisable to leave the installation of the pumping plants to the owners, the United States merely delivering water to the pumps and receiving therefor the regular construction charge. Such an arrangement while desirable is contingent upon the passage of a law providing for the sale of surplus water.

TIETON UNIT.

25. *Location.*—This unit, containing 34,500 acres, lies on the right bank of the Yakima River between the Naches River and Atanum Creek. It is all within 20 miles of North Yakima and is served by the North Yakima and Valley Railroad and by an electric line.

26. *Description.*—Water for this unit is taken from the Tieton River about 15 miles above its confluence with the Naches River. The system consists of a concrete overflow diversion dam founded on rock and rock-filled cribs, concrete headworks, a concrete lined main canal 12 miles long with a capacity of 330 second-feet, and a system of distributing laterals diverting from the North Fork of Cowiche Creek, into which the main canal empties.

27. The main canal is lined with concrete throughout the entire length of 12 miles, except for a short distance below the intake. It is built through a rough country and 2 miles of it are in tunnel. Concrete wasteways, approximately 2 miles apart, are provided and are intended to operate automatically. Each is capable of discharging the entire flow of the canal, a condition deemed necessary owing to the danger of stoppage or breakage by rocks rolling down the canyon side.

28. The distributing system for the first subdivision of 11,000 acres has been completed and that for the second subdivision of 9,000 acres is under construction. No work has been done upon the third subdivision, covering the remainder of the area, except the preparation of plans and specifications.

29. The distribution system in the Tieton unit provides for delivering water to each 40-acre tract, and since much of the area is broken or undulating, flumes and pipe lines have been freely used. On the

main laterals the flumes are of steel (Maginis type) with timber substructures, and on the sublaterals all timber. The pipe line sublaterals are of cement and wood stave pipe 6 inches to 24 inches in diameter. Eleven miles of flumes and 53 miles of pipe line are constructed or contemplated.

30. All the structures on this unit are well built and suitable for the purpose intended. All are of a permanent character except the wooden flumes. The latter, were estimated to cost less, including repairs and renewals, than if built of more durable material.

31. *Water supply.*—Pending the construction of McAllisters Meadow reservoir, this unit will be dependent upon the unregulated flow of the Tieton River. Measurements since 1900 indicate that the Tieton low water will be taxed to its capacity to supply water for the Tieton project and that full development may require some storage on this river.

32. To satisfy prior water rights below the diversion dam, all of which, except 5 second-feet, are in the Lower Naches and Yakima valleys, the water diverted from the Tieton during the low water flow will be replaced in the Naches River from the Bumping Lake Reservoir. If McAllisters Meadow reservoir is constructed the Tieton unit will draw on this reservoir, leaving the appropriated water of the Tieton undisturbed, and Bumping Lake reservoir a part of the general storage system.

33. *Lands.*—The average elevation of the irrigable area is 1,700 feet above sea level and the average rainfall 9 inches. Dry farming is impossible. The irrigable area is 34,500 acres of which less than 6 per cent is public land subject to the reclamation act.

34. The soil is volcanic ash, in places underlaid with hard pan, and much of the first subdivision is rough and broken. Nearly all of the land in this unit is suitable for fruit. Based on the character of the soil and on the crops that will probably be raised, the duty of water is assumed at 2.17 acre-feet per acre on the land, while on the Sunnyside unit 3 acre-feet per acre are provided for. This duty of water will require economic use. One thousand six hundred acres of land in the first subdivision were partially irrigated from flood flow this season.

35. The land in private ownership has been divided into tracts ranging from 10 to 80 acres and is being sold at prices varying from $125 to $175 per acre, the purchaser paying the construction charge in addition thereto. Before the Government took up this project the land was practically valueless.

36. *Cost.*—The total expenditures, including liabilities, to June 30, 1910, and exclusive of storage, amounted to $1,720,000, and the expected expenditures to December 31, 1910, will bring this total up to $2,000,000. Approximately $660,000 will be required after that date to complete the unit.

37. If to this amount is added the cost of the Bumping Lake storage—$525,000—the total estimated cost will be $3,185,000, or about $93 an acre. This may be somewhat reduced, if the entire project, as outlined, is constructed and the total cost of the common storage system divided among the different units in proportion to their needs of stored water.

38. The land in the Tieton unit is not all equally good nor all suitable for fruit. Fruit land can readily bear the construction charge. For other land, the charge will be high, but probably not prohibitive.

39. The par value of the stock in the Water Users' Association is $60 a share. As it is questionable whether the land can be held for any greater amount, unless in making their water applications the owners voluntarily assume the added obligation, due regard for the investment already made requires that the par value of said stock be increased, as provided in the by-laws of the association, to not less than $93 a share.

40. The project is feasible from an engineering and economic standpoint, and though the direct interest of the United States is small, due to the limited amount of public land, early completion is desirable in order that the investment already made may be returned to the reclamation fund.

KITTITAS UNIT.

41. *Location.*—The proposed Kittitas unit lies in the Upper Yakima Valley in the vicinity of Ellensburg and partially surrounds an area now under irrigation by private canals. Some of these canals receive water from the Yakima River and some from small creeks.

42. *Description.*—This unit was first investigated in 1905, and because of the relatively high cost and the relatively low value of irrigated land at that time, its feasibility was considered doubtful. In 1909 careful preliminary surveys were made and estimates prepared based on the following general plan:

43. A diversion dam is to be built on the Yakima River above Easton with a 500 second-foot canal heading on the right bank and running down the valley 32 miles. At this point the flow is to be divided, the greater part being carried over the river and railroads in a wood stave pipe supported on truss bridges. From the crossing to the irrigable lands the canal is to follow the left bank of the river.

44. *Water supply.*—Water is to be obtained partly from the flood flow of the river and partly from storage taken from the general reservoir system. The storage charge for this unit is 146,000 acre-feet.

45. *Lands.*—There are 67,890 acres in this unit, of which less than 7 per cent is public land subject to the reclamation act. One-third of this area now has a partial water right from creeks estimated at 25 per cent of a full water right. If these lands pay only 75 per cent of the construction charges the returns to the reclamation fund will be equivalent to full returns on 62,000 acres.

46. The average elevation of the irrigable area is 1,600 feet above sea level, and the average rainfall 10 inches.

47. The higher lands under this unit are volcanic ash underlaid with hardpan. The lower lands have more gravel.

48. The duty of water is placed at 25 inches. This seems to be low and will require economical use.

49. The main produce of the area now irrigated is hay, with some fruit and vegetables. Much of the land in the proposed unit lies higher than that now irrigated, and 40 per cent of it is considered good fruit land, while the remainder seems better adapted to hay or alfalfa.

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50. Hay land is said to be worth $200 an acre. Fruit land will be worth much more.

51. *Cost.*—The estimated cost of this unit is $4,525,000, which includes $527,000 for storage. This is equivalent to $73 an acre. As the cost of storage is likely to be greater than that assumed above, the unit cost may be $75 an acre.

52. This cost is nearly 50 per cent greater than on the Sunnyside unit, but from statements made to the board by interested persons, it is believed that the land can bear the charge.

53. The project does not involve any unusual engineering difficulties, though the main canal is expensive and for part of the distance passes through difficult country. While this unit has by Executive order been made a part of the Yakima project it is essentially a new project. It contains less than 7 per cent of public land and large expenditures will be necessary before any part of the unit can be irrigated. For these reasons, together with the need of available funds for the completion of projects in which the Federal interests are larger, it does not seem advisable to undertake the irrigation of this unit except to create and furnish the necessary stored water, should the sale of surplus water be authorized by law.

WAPATO UNIT.

54. *Location.*—The proposed Wapato unit lies on the right bank of the Yakima River, just below Union Gap, and consists of land at one time allotted to members of the Yakima Tribe of Indians. Of the 114,000 acres in the project, about 7,000 acres are now owned by white settlers and about 24,000 acres additional is under lease to white settlers. About 32,000 acres are now partially irrigated, 27,000 being Indian allotment land and 5,000 acres being in white ownership. The existing canals were largely built by the Indian Service, which began work in 1903, though several small ditches had been constructed prior to that date.

55. *Description.*—A preliminary allotment for this unit was made in 1906, but no construction work has yet been undertaken. Two plans for irrigating this area have been considered. One provides for an enlargement of the existing New Reservation Canal sufficient to carry all the water needed, and the construction of a diversion dam at its head; the other provides for partial diversion at this point without the aid of a dam and the diversion of the remainder and larger part at the Sunnyside Dam. The first permits of a larger power development. Estimates based on existing information show little difference in cost. Under either plan 100,000 acres will be irrigated by gravity and 14,000 acres by pumping. The main laterals are designed to follow the contours on proper grade, with sublaterals on each section line and sufficient branches to reach each 80-acre tract. An adequate system of drains is also provided for.

56. *Water supply.*—At the time the water rights in this valley were settled by limiting agreements, 147 second-feet were being beneficially used on this reservation, and the Secretary of the Interior at that time limited the rights of the Yakima Indians to that amount. As the total amount of water that will be required for full development is 1,425 second-feet, approximately 1,278 second-feet must be furnished from storage during the season of low water. This

amount with an allowance for losses in transmission is provided for in the study of the water supply of the valley.

57. *Lands.*—The average elevation of the irrigable area is 850 feet above sea level and the average rainfall 7 inches. On the higher lands the soil is volcanic ash and on the lower lands a sandy loam with loose gravel subsoil. The duty of water is placed at 3.6 acre-feet per acre and is made higher than on the Sunnyside unit because of the loose gravel subsoil over the greater part of the area. The high lands will be valuable for fruit raising, while the low lands are better adapted to raising hay and potatoes, though good fruit has been raised on limited areas of low land.

58. Unimproved land has been sold at from $100 to $165 an acre, and land with fruit trees 4 years old as high as $500 an acre.

59. In constructing the existing ditches sufficient care was not taken to keep them above the underlying stratum of gravel. As a result the lower end of the irrigated area is now badly swamped and in need of drainage. An appropriation to do this work was recently made by Congress, and preliminary steps have already been taken.

60. *Cost.*—The estimated cost, exclusive of storage, is $3,100,000, and the storage charge about $1,105,000, making the cost per acre nearly $37. It is understood that this includes payment to the Yakima Indian fund for the irrigation works heretofore constructed.

61. *Comments.*—The irrigation of this unit is practicable from an engineering standpoint, and the land is of such character that it can bear the construction cost.

62. Under the Jones Act of March 8, 1906, the Indian allottees are permitted to dispose of all land in excess of 20 acres, the proceeds to pay for the irrigation of the area retained. The same act also authorizing the homesteading of any irrigable surplus or unallotted lands, but it is understood that there are no such lands in this unit.

63. While all the land involved is in private ownership, most of the present owners are Indians who are still the wards of the nation. As long as this condition exists the irrigation of this area in a comprehensive manner by private enterprise is impossible. For this reason it is believed to be advisable for the United States to undertake this work when funds become available.

BENTON UNIT.

64. This proposed unit includes from 120,000 to 150,000 acres of land on both sides of the Yakima River near its junction with the Columbia. This unit has never been surveyed, and while a reconnoissance made five or six years ago showed in a general way its possibilities, the cost of irrigation per acre can not be definitely stated. Adjoining lands both on the north and south sides of the Yakima River are now being irrigated from private ditches, and excellent results are being obtained. Lands under these private ditches near Kennewick are held at from $300 to $500 per acre, including water right. As the lands under the proposed Benton unit are as good or better than those now being irrigated, it is believed that they can bear any reasonable construction charge. Included in this unit are approximately 50,000 acres of Government land subject to entry under the reclamation act, a larger percentage of Government land than in any other unit under the Yakima project.

65. The original plan for irrigating the Benton unit was to divert water from the Yakima River near Prosser, carry it down the valley to a point some 32 miles below, and there divide the canal into two branches, the larger leading to the lands in the Columbia River Valley above the mouth of the Yakima, and the smaller by siphon across the Yakima River to the lands near Kennewick. A second method is included in the plans of the Valley of the Yakima Water Users' Association, which recently submitted a proposition looking to the purchase from the United States of stored water, to be used in the reclamation of 200,000 acres on the left bank of the Yakima River above existing canals. This request is made contingent upon the passage by Congress of an act authorizing the sale of stored water.

66. If this proposition is accepted, the reclamation of the Benton unit by water from the Yakima River would have to be abandoned, as the supply would not be sufficient for both the Benton unit and the area named in the application of the Valley of the Yakima Water Users' Association. To meet this objection, it is proposed to utilize the power developed at certain drops in the proposed high line to pump water from the Columbia River on to 100,000 acres of the Benton unit lying north of the Yakima River. The proposed high line provides for the use in the Yakima Valley proper of all the storable water of the Yakima River, leaving the Benton project, which geographically belongs in the valley of the Columbia, to be watered from the Columbia River.

67. This plan interferes somewhat with the proposed Kittitas unit in that the acreage under it will have to be reduced. The Benton unit will also have to be reduced, and the cost of placing it under irrigation, as well as the subsequent cost of operation and maintenance, will be largely increased.

68. The high-line plan was advocated generally by the residents of the upper valley and opposed by those in the vicinity of Kennewick, who claim that in the adjustment of low-water rights concessions were made on the assumption that the Benton project as originally outlined would be carried out.

69. The data available are not sufficient upon which to base a definite opinion as to the feasibility of the high line either from an engineering or economic standpoint.

70. Even if found to be feasibile, its advisability is questionable, as it will probably add 75 per cent to the cost of irrigating the public land in the Benton unit and probably double the cost of operation and maintenance. As the primary object of the reclamation act is the irrigation of public lands, the interests of the Government would seem to lie in irrigating the Benton unit in the cheapest possible manner, though, on the other hand, it may be advantageous to sacrifice the interests of the United States in its own lands for the good that may result to the Yakima Valley as a whole.

SUMMARY.

1. The entire project, both water supply and irrigable land, lies within the State of Washington.

2. As outlined, it covers 481,000 acres of land, of which 13 per cent is public land subject to the reclamation act. All but 13,000 acres of this public land lies in the proposed Benton unit.

3. The water supply as regulated by the proposed reservoir system is sufficient for the above acreage if the assumed duty of water on the different units proves to be sufficient. There is an assured supply for the Sunnyside, Tieton, and Wapato units herein recommended.

4. The Sunnyside unit contains 100,000 acres, of which 1,346 acres are public land subject to the reclamation act. It is feasible from an engineering and economic standpoint. The estimated total cost is $3,150,000, the unit cost being $52 an acre. Sixty per cent of the work has been done and due regard for the investment already made renders its completion advisable, except possibly the pumping plants. If authority is granted by Congress for the sale of surplus water it may be advantageous to leave the installation of the pumping plants to private enterprise, as only 15 per cent of the land involved is public land.

5. The Tieton unit contains 34,500 acres, of which 2,034 acres are public land. It is feasible from an engineering and economic standpoint. The estimated total cost is $3,185,000, the unit cost being $93 an acre. Eighty per cent of the work has been done. In order that the investment already made may be returned to the reclamation fund its completion is advisable. Such action, however, should be contingent upon the water users' association first increasing the par value of its stock to not less than $93 an acre.

6. The proposed Kittitas unit contains 67,000 acres, of which less than 7 per cent is public land. It is feasible from an engineering and economic standpoint. The estimated cost is $4,600,000, the unit cost being $75 an acre. Owing to the limited amount of public land and the large amount of uncompleted work on other projects where the Federal interests are larger, it is not advisable to undertake the Kittitas unit except to supply the necessary stored water should this course be authorized by law.

7. The Wapato unit contains 114,000 acres of land all in private ownership. Most of the owners, however, are Indians whose lands can not be disposed of without the consent of the United States. It is feasible from an engineering and economic standpoint. The estimated cost is $4,205,000, the unit cost being $37 an acre. While there is no public land in the strict sense of that term, most of the private owners are wards of the nation, and for this reason it is advisable to undertake the irrigation of this area when funds become available.

8. Information concerning the Benton unit is too meager to warrant a definite opinion as to its feasibility. Even if found to be feasible, its development can advantageously be postponed pending the completion of work on the Sunnyside, Tieton, and Wapato units. Surveys, however, should be made to determine the probable cost of irrigating it by gravity from the Yakima River.

9. The proposed High Line as a private enterprise is dependent upon the United States furnishing stored water for which there is no present authority of law. The estimated cost of the High Line is $26,000,000, and it is extremely doubtful whether the necessary capital can be raised for an irrigation enterprise of this magnitude; nor with the great demand for funds on other projects, involving public

land, is it advisable for the United States to undertake this work with reclamation funds. Further, until the cost of irrigating the Benton unit, in accordance with the original plans, is ascertained, it is recommended that no action be taken that will obligate the Reclamation Service to furnish stored water for the High Line project.

10. A general system of storage in this valley should be developed and controlled by some central power, even though the delivery of water to the land in some of the units is left to private capital. Due to the large interests of the United States in this valley, both by reason of expenditures already made, as well as those herein recommended, a storage system as now planned should be developed with reclamation funds at a rate that will keep pace with the demand.

11. The following allotments are recommended for the four years 1911–1914, inclusive:

For Sunnyside unit (from the loan)	$1,250,000
For Tieton unit (from the loan)	665,000
Total	1,915,000

Section XXVI.

SHOSHONE PROJECT, WYOMING.

1. On August 10 the board inspected the Shoshone Dam and water-storage system; on August 11 the lands under the high line and Garland-Frannie Canals, the Oregon Basin, diverting dam, tunnel, reservoir, canals, laterals, and other constructions. A public hearing was held at Cody, Wyo., on the evening of August 10.

2. *Location.*—The lands to be irrigated lie on both sides of the Shoshone River in northern Wyoming, east of Yellowstone Park. The water is taken from the Shoshone River, a branch of the Big Horn River, just below the junction of the north and south forks. The land and water supply are entirely within the State of Wyoming. The general elevation is about 4,500 feet. A branch of the Chicago, Burlington & Quincy Railroad passes through the north-side lands.

3. *Description.*—The project as proposed and partially constructed consists of a large dam and storage reservoir in the Shoshone Canyon and of the diverting systems, tunnels, main canals, and laterals.

4. The dam is practically completed. It is 328.4 feet above the lowest point of foundation, the width at bottom 108 feet, at top 10 feet, length at top 200 feet, radius of center line at top 150 feet. There is a spillway 300 feet long, discharging through a tunnel 20 feet square and 400 feet long, excavated in granite; and the discharge is regulated by tunnels and pipes at different elevations. The dam is constructed of concrete in which large bowlders are embedded. In case additional storage or additional head proves desirable, it is proposed by the Reclamation Service to increase the height of the dam. The cost of the dam to June 30, 1910, was $978,466.01, at which time the dam was almost completed. These items do not include cost of lands overflowed, amounting to $184,458.23, nor the cost of the canyon road, $105,191.51, necessary to the construction of the dam.

5. The distributing system, as projected, consists of three main canals, as follows:

(*a*) The high-line canal starting at the reservoir, irrigating lands lying north of the river in the general vicinity of the towns of Cody, Corbett, and Eagle Nest. No work has been done on this canal.

(*b*) The Garland-Frannie Canal, irrigating land on the north side of the river from the town of Ralston to Frannie. Water for the Garland-Frannie unit is diverted at a point on the river 15 miles below the reservoir by the Corbett Dam, a concrete structure 400 feet long and 18.1 feet high. The water is then carried in a concrete-lined tunnel, 17,355 feet long with a capacity of 1,000 second-feet, and emptied into a basin formed by closing a natural depression with an earth dam. At this point begins the main Garland-Frannie Canal, which has a capacity of 1,000 second-feet and is completed for a distance of 18 miles. At about 7 miles from its head it passes through the Ralston reservoir, which serves to equalize the flow and will probably also serve as a source of water supply for the town of Ralston. It is expected that about 1,000 horsepower may be developed on this canal. This unit is about 75 per cent completed.

(*c*) The Willwood Canal, irrigating lands south of the river, will take water by a diversion dam or other means at a point about 21 miles below the reservoir. No work has been done on this canal.

6. *Water supply.*—The run-off of the Shoshone River above the dam is relatively uniform as far as records go, and varies from 975,000 to 1,506,000 acre-feet per annum. The storage reservoir will impound 456,000 acre-feet. As the irrigation season includes the times of maximum run-off, practically the entire flow can be used for irrigation. On the basis of a duty of 3 acre-feet at the reservoir and 2 acre-feet at the farm, 344,000 acres could be irrigated, including private irrigation projects. There are a number of private filings on the unregulated flow of this river, some antedating and some subsequent to those of the United States. There are no private filings on the storage water and practically none on the North Fork, which carries double the water of the South Fork. It seems assured that there is sufficient water to irrigate the 164,000 acres of land included in this project. A discussion of the water rights and filings is appended. The duty of water is taken as 2 feet at the farm. This is thought to be sufficient.

7. *Land.*—The total amount of irrigable land included in the project is given in the annual reports at 132,000 acres, of which 123,000 acres are public, 7,680 acres State and school, and 1,220 acres private land. The public land will not be opened to settlement until water is available. The land has not been completely surveyed, and the assumed amount of irrigable land is therefore approximate. In a recent statement of the supervising engineer, based on later surveys and relocation of some of the canals, he estimates the total amount of irrigable land in the project at 164,000 acres, including 7,500 acres to be supplied by pumping from the high-line canal. The proportion of public land is about the same.

8. In 1899 Col. W. F. Cody and Mr. Nate Salisbury prepared for the irrigation, under the Carey Act, of land lying on the north bank of the river immediately below the canyon, and applied for water to irrigate 120,000 acres. This was subsequently limited by the State

engineer to about 65,000 acres. No constructions were made, and in 1904 all water rights were transferred to the United States.

9. Under the high-line unit there are 36,500 acres to 40,000 acres, under the Garland-Frannie unit 73,000 acres to 86,622 acres, and under the Willwood unit 22,500 acres to 30,000 acres. Under the completed part of the Garland-Frannie Canal 30,989 acres have been opened to settlement and about 3,200 acres near Ralston can be thrown open within a few months. Of this area, about 15,000 acres have been filed on and were under cultivation this year, leaving about 16,000 acres, or 200 farm units, not yet taken up. The rate of filing has been about 100 farm units a year. The Government farm unit is 40 to 80 acres, dependent on location.

10. The soil is gravelly and sandy loam, and is generally shallow. In the low, flat parts drainage is necessary. Results from the farms cultivated in the Government project, and also under a private ditch in the vicinity of Cody on the south side of the river, indicate that good crops can be raised. The main crops are oats, wheat, potatoes, alfalfa, etc., with a tendency toward the greater cultivation of alfalfa. Good prices have been obtained, and the settlers appear well satisfied with conditions this year. These crops are not of a nature to warrant a high construction or operating cost. Dry farming is not successful. The rainfall on the irrigable area is from 6 to 10 inches. There are several Government town sites on the project. Powell is the principal town at the present time.

11. In addition to the irrigable lands in the valley of the Shoshone River, there lies some five or six miles to the south of the valley a large area of good land known as the Oregon Basin, which can be irrigated from the Shoshone and which has water rights on the South Fork of that river. It is estimated to comprise about 125,000 acres of irrigable land held under the Carey Act. Some work has been done in ditch construction by private parties, but the water supply has never been sufficient or satisfactory, no water having as yet been obtained from the South Fork. Water can be brought by tunnel from the Shoshone Reservoir. To do this work economically the height of the Shoshone Dam should be increased. It has been suggested that there be obtained from Congress the necessary authority to sell water to irrigate this basin, if detailed surveys show this plan to be feasible. This will reduce the cost of construction and operation in the Shoshone Valley project.

12. *Engineering structures.*—The constructions on the Shoshone project are well designed and built, and of a permanent nature. For the high dam special study by an expert engineer employed for the purpose was made of the temperature and other strains, and based on his conclusions its design was made by a board composed of engineers of the Reclamation Service and consulting engineers. All the usual precautions seem to have been taken to secure a stable and enduring structure both in design and construction.

13. *Cost.*—The total amount allotted to December 30, 1910, is $3,828,000. The estimated cost of completion, as submitted to the board by the Reclamation Service, is $3,411,000, making a total cost for the project of $7,239,000. The estimate of completion is divided as follows:

Garland-Frannie unit	$650,000
Willwood unit	1,000,000
High-line unit	1,500,000
Contingencies, maintenance, etc	261,000
Total	3,411,000

14. The Garland-Frannie unit estimate, including simply extensions of ditches and laterals, may be taken as reasonably accurate. Test pits have been dug along the high-line canal but the structures necessary to bring water out of the canyon and the structures for the Willwood unit have not been designed, and these estimates must be considered approximate. The chief engineer of the Reclamation Service has submitted a revised estimate of completion of $4,000,000. In view of certain changes in the plan so as to include more land within the project, it seems safe to adopt this increase, making the total estimated cost of the project $7,828,000.

15. On this assumption and of a land area of 132,000 acres under the project, the cost per acre would be $59.23. If a total area of 164,000 acres can be irrigated, the cost would be $47.70. The announced cost of construction on farm lands already thrown open is $45 for 15,237 acres and $46 for 15,662 acres, a total amount of $1,406,117, leaving a remainder of $6,421,883 to be borne by new units. On the basis of a total of 132,000 acres of irrigable land in the whole project, this would bring the cost of construction of each remaining acre to $63.51. If the total amount of land is 164,000 acres it would be $48.20 per acre. It may prove possible to sell surplus water to private companies, if allowable under the law, thus reducing the cost per acre.

16. Having in view the nature of the soil and climate, and the kind of crops raised, a cost of construction of over $50 per acre it is thought would not lead to the rapid settling of this country. It would therefore be desirable to include as much land as possible in the project to reduce the cost per acre.

17. The cost of maintenance and operation has been $1 per acre. It is expected when more land is opened to reduce this to about 75 cents. This is thought to be reasonable and within what the land can bear. The present annual cost of maintenance and operation is not now returned because of the small number of units opened; and the deficit, it is understood, will be charged against new units. The estimated returns to December, 1910, are about $225,000.

18. The cost of construction is in excess of the first estimates, due to increase in price of material and labor, unforeseen difficulties, damage by floods, etc. The high dam, the necessary length of tunnels and supply canals make the cost per acre high.

19. *Comments.*—The completion of the Garland-Frannie unit will open from 42,101 to 55,700 additional acres. The estimated additional cost, including the proportion of maintenance and contingencies, is from $700,000 to $800,000. As this relatively small additional cost will bring a large area under irrigation, it is thought desirable to do the work necessary to open the complete unit as rapidly as land is taken up.

20. The construction of the high-line canal will irrigate, it is estimated, 36,500 acres to 40,000 acres, and the pumping unit an addi-

tional 7,500 acres. The estimated cost is $1,620,000 to $2,000,000. The land to be irrigated by the canal lies on the benches above the river, extending from the canyon down. It appears to be of the same general character as the remainder of the project. The irrigable land lies well and can be readily drained. There will be, however, considerable waste land. A reason for the early construction of this canal lies in the fact of its being largely part of the Cody-Salisbury tract turned over to the United States with a valuable water right. Part of the Cody-Salisbury tract is now irrigated under the Garland Canal, but much can be irrigated only by the high-line canal.

21. The Willwood Canal, when constructed, will irrigate 22,500 to 30,000 acres, at an estimated cost of $1,100,000 to $1,300,000. The estimates are still indefinite. The character of the soil is similar to other tracts and the land lies well for irrigation and drainage.

22. The estimates both of area of land irrigated and cost of construction under the high line and Willwood Canals are not sufficiently definite for satisfactory comparisons of cost per acre. It appears from the estimates of the Reclamation Service that the Willwood extension will be slightly more costly per acre than the land served by the high line. It lies somewhat better and has less waste land.

23. It is thought that the high-line canal should be constructed before the Willwood on account of the conditions under which a large part of the water rights were acquired by the United States, the better existing railroad facilities, the approximate equal cost per acre, and the fact that the seepage water from the upper unit that returns to the river can be used on the lower lands.

24. While the cost of the project per acre will be larger than at first estimated, and while, in order to recover the full amount, the cost reaches an amount per acre which, it is thought, will but slowly attract settlers, the board is of the opinion that the work should be completed. It is considered that this completion should be gradual, based on the rapidity with which the lands are taken up. That all of the lands will be ultimately entered appears probable.

25. *Summary.*—(1) The completion of the project is feasible from an engineering and an economic standpoint.

(2) The lands and water supply are all within the State of Wyoming.

(3 The water supply is sufficient for the whole project.

(4) The total amount of land is about 164,00 acres. One per cent of this is private land and 10 per cent State or school land. The remainder is subject to the reclamation act.

(5) Of the total estimated cost of $7,828,000, about one-half has been expended.

(6) The storage system for the whole amount of land is practically completed.

(7) Further expenditures will be used to extend the distribution system.

(8) Only about 35,000 acres can be irrigated without further extensions.

(9) The land can bear the cost of construction, estimated at about $50 per acre.

(10) The board believes the project to be worthy, and recommends that the completion of the Garland-Frannie Canal system be first

undertaken, followed by the high line and then the Willwood Canals, and that the rate of work should depend on the rapidity with which lands are taken up. As the cost will reach so closely what it is thought the land can stand for construction charges, and as the water supply is indicated as sufficient, the full amount of 164,000 acres should, if practicable, be brought into the project.

(11) The following allotment is recommended for the four years 1911–1914, inclusive:

From the fund **$2,000,000**

APPENDIXES.

APPENDIX TO SECTION V.

GRAND VALLEY PROJECT.

WATER SUPPLY.

[By the project engineer.]

1. The Central Colorado Power Co. contemplates the construction of storage reservoirs to maintain the flow through their power plant near Glenwood Springs at 1,250 second-feet. The dotted line on the hydrograph shows the estimated effect on the Palisade flow due to such use of stored water in 1902. This shows that 1,600 second-feet may be expected as a minimum when such storage is developed.

2. There is now pending in the Mesa County courts the first adjudication of the water rights of the irrigation ditches in this water district. No decrees have been entered and only a few of the ditches have as yet filed their statements of claim. No report is expected from the referee before March, 1911. From the records of the water filings and data concerning the flow in the various ditches, and the acreage irrigated, the following liberal estimate of the different priorities which will probably be decreed has been formulated.

3. The ditches are listed in the order in which their head gates are located along the river.

	Priority No.	Power water.	Irrigation water.
		Sec.-ft.	*Sec.-ft.*
Orchard Mesa irrigation district	7	325	125
Government high line	6	120	[1] 710
Mesa County irrigation district	4	377	[2] 31
Palisades irrigation district	4	500	[2] 90
East Palisades irrigation district	[3] 5	.....	10
Grand Valley Irrigation Co	1	.....	521
Rose Point filing	3	100	[4] 6
Orchard Mesa power	2	214	10
Totals	.....	1,636	1,453

[1] Fifty second-feet seepage returns to river above next head gate.
[2] Power water based on 40 per cent total efficiency of turbines and pumps.
[3] Doubtful.
[4] Abandoned to the United States.

4. The Orchard Mesa irrigation district power water is returned to the river at the Grand Valley head gates, and the high line power water will be returned a short distance below the East Palisades intake. No other power water is carried by the canal past any canal intake.

5. With priorities as above the supply of water lawfully available for the high line is estimated as follows for different conditions:

6. First, assuming that the United States depends on its own filings and acquires no additional priorities, then the high line would draw a full head until the flow in the river fell to 1,798 second-feet. As the river continued to

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fall the head in the canal would decrease and be shut off entirely when the river flow was less than 1,018 second-feet.

7. This use of the river necessitates the wasting of 577 second-feet past the last canal intake when all canals are running full capacity.

8. Second, either of the two locations proposed for the high line can supply water by gravity to the canal of the Palisades irrigation district, and it is generally believed that the courts will allow the United States to condemn and use their power water for irrigation if the flow in their ditch is maintained. On this basis the high line would draw a full head until the river fell to 1,536 second-feet, and would be reduced to 90 second-feet when the river fell below 876 second-feet. It would be entitled to draw water for the Palisades district lands with the river running between 866 and 776 second-feet. Under this arrangement 1,788 second-feet would have to flow to supply all priorities and 341 feet would be wasted.

9. Third, if the United States acquired the power water of the Smith Bros.' Orchard Mesa power canal in addition to that of the Palisades district, the high line would draw its full head with the river carrying 1,322 second-feet and cease to draw except for the Palisades district and Smith Bros. when the supply fell below 662 second-feet; 301 feet of power water would be wasted past the Grand Valley head gate in this case.

10. Fourth, in case the Government acquired the Mesa County district's filing for power as well as those of the Palisades district and Smith Bros.', the high line would still draw water at the same times as noted in the third case, but no water would be wasted, and the Orchard Mesa district could get a full head when there was 301 feet less water in the river.

11. Some anxiety has been felt by the people interested in the Grand Valley that eastern slope users might get a valid right to the use of some of the Grand River waters which are required on the western slope during times of low flow. The four appropriations that have been filed to divert water from the Grand River to the eastern slope amount to 3,876 second-feet. One claimant has built capacity to divert 48 second-feet and is diverting 12. So far as known, the remaining three appropriators have done no work. Investigation of available data relating to the watershed and run-off from the drainage basins concerned would indicate that it is impossible for these claimants to divert in excess of 6 per cent of the low flow of the Grand River at Palisades. It is believed that the feasibility of the Grand Valley project will be recognized, and that the project will be completed and in operation, and an adequate water right perfected before the demand for land and water on the eastern slope will justify the cost of building the necessary diversion tunnels to carry water from the Grand River across the Continental Divide.

12. It is apparent that if the rights of the Palisades and Mesa County districts and of the Smith Bros. are turned over to the Government, that the available water supply will be adequate to fully supply all canals at all times except during July and August of exceptionally dry years. During those months less water is demanded by the crops than earlier in the season, and part of this demand is in normal years supplied by rainfall.

13. It is estimated that about 70,000 acres are under cultivation in the Grand River watershed above Palisades. As a rule further development of irrigable lands in this territory will necessitate the storing of water, and in consequence a probable increase in the low-water flow in the river.

DUTY OF WATER.

14. The duty of water used in estimating the project's requirements has been figured at 100 acres per second-foot at the lateral head gate, or (allowing 20 per cent seepage and evaporation) 80 acres per second-foot at the controlling works above Palisades.

15. Records of the daily flow in the Grand Valley, Price, and Stub ditches have been kept by the Reclamation Service for the last two years. At no time has the duty been less than 80 acres per second-foot.

APPENDIX TO SECTION VI.

UNCOMPAHGRE PROJECT.

WATER SUPPLY.

1. The water supply for this project is obtained from the Uncompahgre and Gunnison rivers, part of the flow of the latter being diverted through a tunnel of 1,300 second-feet capacity.

2. Discharge measurements of the Uncompahgre at the southern boundary of the project during the irrigating season are available for the period July, 1895, to September, 1899, and show a flow varying from 3,375 second-feet in May, 1896, to a minimum of 4 second-feet in September, 1899, with mean discharges, in second-feet, for the irrigating months as follows: April, 330; May, 670; June, 725; July, 360; August, 140; September, 103; October, 109.

3. Similar measurements for the period 1903–1910 are also available, and show a maximum flow of 1,870 second-feet in July, 1907, and a minimum of 67 second-feet in April, 1904, with mean discharges, in second-feet, for the irrigating months as follows: April, 250; May, 500; June, 890; July, 516; August, 340; September, 206; October, 155.

4. For 1902 one reading only is available, and this shows a flow of 63 second-feet on July 17, which probably decreased to nothing during August.

5. Discharge measurements of the Gunnison River were made at Iola, Colo., 1900 to 1903, at Whitewater, 1902, at Cimarron and Cory, 1903–1905, and at the river portal of the Gunnison Tunnel, 1905–1910.

6. Iola is above the river portal and above two important tributaries, the Lake Fork and the Cimarron River. Cimarron is at the junction of the Gunnison and Cimarron rivers, below any considerable tributaries and above the tunnel entrance.

7. Whitewater is over 100 miles below the intake of the tunnel, and Cory is 30 odd miles below the tunnel intake.

8. During the period 1905–1910 the flow varied from a maximum of 14,660 second-feet in June, 1905, to a minimum of 470 second-feet in September of the same year, with mean discharges, in second-feet, for the irrigating months, as follows: April, 2,174; May, 5,145; June, 7,704; July, 3,107; August, 1,562; September, 940; October, 917.

9. There are numerous appropriations of the waters of these rivers that antedate those of the Reclamation Service. On the upper Gunnison, above the tunnel portal, they aggregate 1,815 second-feet. It is not known whether this amount is being beneficially used, but owing to high altitudes (7,400 feet to 8,000 feet), which largely limit the crops to wild and timothy hay and to restricted irrigable areas, no increased use of water above the tunnel is probable even though authorized by decreed priorities.

10. On the Gunnison below the tunnel the prior appropriations aggregate 1,835 second-feet. Part of this amount will be supplied by return waters from the project and the remainder, about 100 second-feet, will have to be passed by the tunnel entrance, unless it can be supplied from tributaries entering below this point.

11. On the Uncompahgre, the appropriations below the point at which discharge measurements were taken aggregate 1,589 second-feet, but it is the expectation that before completion of the project all of these filings, together with the lands to which they pertain, will be absorbed and become a part of the project.

DUTY OF WATER.

12. The average rainfall at Montrose is about 9 inches, and the project is based upon supplying from the ditches 3 acre-feet of water per acre, which, with a seepage and evaporation loss in the distribution systems of 30 per cent, corresponds to a diversion duty of 4.2 acre-feet per acre.

13. The assumed, in acre-feet, demand for water measured at points of diversion and based on an irrigable area of 140,000 acres, is as follows: April, 83,000; May, 105,000; June, 106,000; July, 107,000; August, 88,000; September, 57,000; October, 41,000.

14. Such a demand requires a minimum flow of nearly 1,800 second-feet, and can only be supplied when the tunnel is running full and when the flow in the Uncompahgre aggregates 500 second-feet.

15. As the July flow of the Uncompahgre frequently falls below 500 second-feet, it will be necessary at such times to reduce the deliveries below that assumed. This, however, will not occasion a serious shortage, as, in the opinion of the board, a duty of 2.5 acre-feet per acre at the farm will fulfill all reasonable requirements.

16. By plotting the combined supply curves of the two rivers against the assumed demand curve, it is found that during the period 1903–1910, the following shortage would have occurred:

Years.	If all water is available for diversion.	If 100 second-feet are passed to satisfy priorities.
1903	32,000	41,000
1904	18,000	24,000
1905	18,000	35,000
1908	10,000	16,000
1910 [1]	7,000	16,000

[1] To September 1, 1910.

17. These shortages are not serious, and if they represented the worst conditions it is questionable whether the expense of providing storage to overcome them would be warranted.

18. It appears, however, that in 1902 the flow of both the Gunnison and the Uncompahgre Rivers was much less than in any year since. Unfortunately, complete hydrographic data for 1902 are not available, but based upon the measured run-off of the Gunnison at Whitewater, 100 miles below the tunnel intake, storage to the extent of 125,000 acre-feet would have been required to maintain a constant flow of 1,300 second-feet up to September 25, and considerably more would have been required to maintain such a flow at the tunnel.

19. Present plans contemplate the storage of 105,000 acre-feet in a reservoir to be built at Taylor Park, in the headwaters of the Gunnison. This storage will provide a full supply for all but years of abnormally low run-off. such as 1902, and a reasonable supply for even very low years.

20. No suitable storage reservoirs have been found on the Uncompahgre.

Appendix No. 1 to Section VII.

MINIDAKO PROJECT.

1. *Minidoka Diverting and Reservoir Dam.*—The dam, which occupies the main channel of the Snake River, is rock and earth fill, with concrete cut-off wall of varying height extending from abutment to abutment. The crest of the dam is straight in plan, with a maximum height as modified of 86 feet above the foundation and a length of 650 feet. The rock fill forming the lower or downstream portion of the dam is 10 feet wide on top, with upstream side slopes of 1 on 1 and downstream side slopes of 1½ to 1. The earth fill forming the upstream portion of the dam is 10 feet wide on top, giving a total width of the crest of 20 feet, the side slope of the reservoir side being 3 on 1. The foundation is solid rock, and all loose bowlders, etc., were removed. This dam is in process of completion and so far has shown but little leakage, which apparently comes through a seam in the foundation rock.

2. The left abutment of the dam, of concrete, forms the beginning of the concrete spillway, and the right abutment forms the left end of the regulating works, 180 feet in length. These regulating works consist of five sluiceways, each controlled by 8 by 12 feet sliding gates, the sills being 48 feet below the spillway crest, the sluiceways being excavated in the rock. Above the sluiceways in this section are the penstock openings for the power development. To the right of the regulating works are the headworks of the main canal for the north side unit, while the head gates and regulating works for the south side main canal are at the left end of the spillway. They are both controlled

by sliding cast-iron gates of the usual pattern. There are 9 gates on the north side, each 5 by 7 feet, with sills 9.5 feet below spillway crest. On the south side there are 12 gate openings, each 5 by 6 feet, with sills 6 feet below the original elevation of the spillway crest.

3. The spillway, lying between the main dam and the headworks of the south-side canal, is 2,400 feet in total development. It consisted originally of a concrete wier varying in height from 0 to 14 feet, following the high part of the rock bottom of the river, and was designed to pass 50,000 second-feet, with a maximum depth of water of 5 feet, over it. Owing to the fact that the main storage of this project is to be at Jackson Lake, some 275 miles by river above this dam, and to the fact that a large portion of the storage water released from the storage dam at Jackson Lake might be diverted by private users between the two points if their canals were staked too early in the season, it became desirable to divide the storage between the two points, thus enabling the river between the two points to obtain its natural flow and the private canals to be staked at low state of river before it becomes necessary to draw water from the upper reservoir. To accomplish this the diverting dam was converted into a storage dam of about 52,000 acre-feet capacity by raising the main dam, and by constructing on the crest of the spillway piers 2 feet thick, 8 feet high, 7 feet from center to center, their tops being connected by a bridge, and having arrangements by which flashboards may be placed on the crest, enabling the water surface to be raised 5 feet. The cost of this work was $29,000. When the additional head of water was brought upon the main dam, the material of which had been hydraulicked into place, additional material and height had to be added to the dam. This work was in progress at the time of the board's inspection, and its estimated cost is $22,000. On the south side, the relatively low ground of the bank at the shore end of the regulating works was raised by an embankment about 1,000 feet long, having a maximum height of 16 feet. It is 20 feet wide on top, and constructed of earth and rock fill in the same manner as the main dam. Both the dam and this embankment have a riprap protection on water slope where exposed to wave action.

4. The plan for this project now contemplates pumping by electricity to three different levels to supply high lands, the water to be supplied by the main south side canal, the pumping plants to be located near its extremity. The power for the pumping plants is to be supplied by a generating station at the Minidoka dam. This power plant has been constructed in part and will be completed during the ensuing year. It consists essentially of the following:

5. A hydro-electric power development having a capacity of 10,000 horsepower; 31 miles of 33,000-volt, three-phase transmission line, and 3 pumping stations, where the power is used in raising water for the irrigation of approximately 50,000 acres of land. Power for general purposes will also be supplied to the towns on the project some time before November 1, 1910.

6. *Power house.*—The power house is of reenforced concrete, 150 feet long and 50 feet wide, and is built against the downstream side of the concrete structure or dam containing the regulating works across the diversion channel. Extension to nearly double the present capacity of the plant can be easily made.

7. The buttresses of this concrete dam are built on 18-foot centers, forming bays, in each of which is a 10-foot penstock opening. Five of these bays will be utilized for the installation of the five 2,000 horsepower units of the present equipment; another bay contains the two exciter units; and the remaining bays included in the power house will be required in case of future extension.

8. *Main units.*—Each of the main units consists of a 2,000 horsepower vertical turbine, direct connected to a 1,490 kilovolt-ampere, three-phase alternator. The turbines are placed on the lowest floor of the power house, the center lines of the runners being 16 feet above mean tail water surface.

9. The generators are located on the main or generator floor of the plant. They generate three-phase current at 2,300 volts, 60 cycles, and have a rated capacity of 1,490 kilovolt-amperes.

10. *Exciters.*—Two 120 kilowatt exciters direct connected to 180 horsepower turbines furnish 125-volt exciting current for the main generators. Each exciter has its individual governor system, but all of the governors of the main units get their oil pressure from a central oil system, which is provided with a duplicate outfit of motor-driven gear oil pumps and pressure tanks.

11. *Transformers.*—Each generator is provided with a 1,490 kilovolt-ampere, 2,300 to 33,000 volt, three-phase air-blast transformer, connected to the generator

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terminals by disconnecting switches so that each generator and its transformer form a unit delivering 33,000-volt, three-phase current to the high-tension bus.

12. *Switchboard.*—The plant is controlled from a switchboard located on an extension of the transformer gallery across the north end of the plant. This switchboard contains a panel for each generating unit and line and one panel for the two exciters. The highest voltage brought to this board is that of the exciters, which is 110.

13. *Transmission line.*—The present transmission line consists of a single circuit of copper wire run on wooden poles spaced approximately 150 feet apart. The line runs southwest from the dam, following the general direction of the main north side gravity canal and the Minidoka & Southwestern Railroad, to the Heyburn substation, a distance of 19 miles. From a point 10 miles from the dam a branch runs due south to pumping station No. 1, crossing the Snake River by a span 150 feet in length supported by steel towers. The poles on this part of the line are spaced 250 feet apart. The second transmission line will be built early in 1911. This line will cross the river near the dam and run directly to the pumping stations.

14. *Pumping stations.*—At the lower end of the south side gravity canal, is located the first pumping plant, having under the present plan a capacity of 500 second-feet. A portion of this 500 second-feet is diverted for use in the "G" canal, which supplies an area of 10,982 acres, while the remainder is elevated a second time at station No. 2. This station has a capacity of 375 second-feet. A portion of this water is diverted for use under the "H" canal, irrigating 15,922 acres, while the remainder is again lifted at a pumping station No. 3. This plant has a capacity of 200 second-feet and delivers water to the "J" canal, which supplies 23,414 acres of land. The lift at each station is 30 feet.

15. The three pumping plants follow very closely the same general design so that a description of one will suffice for all three. All of the buildings are of reenforced concrete with reenforced concrete roofs.

16. *Station No. 1.*—Pumping station No. 1 has a total length of 121 feet, the pump end of the building being 18 by 71 feet, and the part which covers the electrical apparatus being 30 by 50 feet in plan. The pump end will contain four 125 second-feet, double-suction, vertical, centrifugal pumps, each one of which is mounted in a separate compartment or pit at such an elevation that the top suction is normally submerged. Each pump is direct connected to a 600-horsepower vertical, 3-phase, 2,200-volt, synchronous motor operating at 300 revolutions per minute. In each station space is provided for one additional pump of 75 second-foot capacity, this space to be utilized should such additional capacity prove desirable or necessary.

17. Current is supplied to the motors by air-blast transformers, one 590 kilovolt-ampere transformer being provided for each pump. These transformers receive current at 30,000 volts from the high-tension bus, and deliver it to the low-tension bus at 2,200 volts. The wiring is so arranged that any one or all the transformers may be used with any motor. Two induction motor-driven exciters, either of which is of sufficient capacity to excite all of the motors, are conveniently located close to the switchboard. The switchboard contains one panel for each motor and one for the two exciters, besides panels for the auxiliary apparatus.

18. *Commercial-power substations.*—Provision has been made for supplying power to distributing companies in Rupert, Heyburn, and Burley. A transformer station at Rupert will supply that town, and one on the Snake River near Heyburn will supply both Heyburn and Burley. These two substations are identical in design and are of reenforced concrete structure, approximately 20 by 30 feet in plan. The stations are designed to receive power at 30,000 volts and deliver it to local distributing circuits at 2,200 volts. Each station contains three 75-kilowatt, oil-cooled transformers protected by expulsion fuses. A switchboard panel controls the circuit for each town, and lightning arresters are provided for both high and low tension circuits.

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APPENDIX No. 2 TO SECTION VII.

MINIDOKA PROJECT.

1. *Water supply.*—The water supply for the project is taken from the Snake River, having a watershed area above the diversion dam of about 22,600 square miles. The average elevation of the water shed is about 6,000 feet above sea level, and the estimated average rainfall is about 21 inches.

2. The duty of water for the project is estimated at 3 acre-feet per acre measured on the land.

3. The mean annual run-off of the Snake River at the Minidoka Dam is about 6,000,000 acre-feet, the maximum being about 7,500,000, and the minimum about 3,800,000.

4. Below is given a table showing the mean discharge in second-feet of the Snake River at the Minidoka Dam during the irrigation season for several years prior to the time when stored water was turned down the river:

Mean discharge, in second-feet, Snake River, below American Falls.

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1896	5,241	9,357	39,551	13,341	5,450	4,972	4,975
1897	7,678	32,863	30,399	10,740	5,223	4,982	.....
1898	8,629	17,658	20,936	9,142	4,498	4,383	4,818
1899	6,028	12,187	29,142	26,270	8,477	5,813	5,598
1901	.....	23,020	15,700	4,511	2,115	2,568	4,600
1902	5,800	10,300	18,200	10,400	3,300	3,900	5,550
1903	7,023	10,170	19,813	9,674	3,228	3,897	5,553
1904	7,790	24,520	28,200	12,970	4,881	5,576	5,778
1905	5,780	8,925	10,910	4,545	1,976	1,955	3,415
1906	7,000	14,400	21,300	9,000	3,000	3,700	5,300
1907	.....	21,800	29,300	22,500	7,600	6,200	7,100

Total run-off in acre-feet.

Mean for eight years	5,900,000
Maximum	7,300,000
Minimum	3,800,000

5. Of these amounts the South Side Twin Falls project is entitled to 30/34 up to 3,000 second-feet, and the North Side Twin Falls project to 4/34 up to 400 second-feet, after which the Minidoka project is entitled to 1,726 second-feet under State engineer's permit dated January 6, 1909 (date of priority, Mar. 26, 1903). Other filings made for the Minidoka project on which no proof has yet been made are as follows:

August 6, 1908, 3,000 second-feet for irrigation and domestic use; January 30, 1909, 2,500 second-feet for power; March 10, 1910, 75,000 acre-feet for storage; March 10, 1910, 400,000 acre-feet for storage, all in Idaho, and on August 23, 1906, 300,000 acre-feet for storage in Wyoming, at Jackson Lake.

6. The natural flow of the river is not sufficient to supply the needs of the project for the entire irrigation season during the low years, and this deficiency is supplied by storage at Lake Walcott and at Jackson Lake. At Lake Walcott storage works for 52,000 acre-feet are now constructed. This reservoir, located just above the diversion dam, also serves as an equalizing basin for the control of the water turned down from Jackson Lake. At Jackson Lake a temporary dam has been in use to store the necessary water for the last three years. Permanent works for the storage of 380,000 acre-feet are now being built at that point.

7. The low-water flow of the Snake River up to 3,400 second-feet must pass over the Minidoka Dam to supply the rights of the Twin Falls projects, which are located farther down the river. This amply protects the power filings for the Minidoka project for all time.

8. In determining the storage required the following assumptions were made by the Reclamation Service and the result computed in the manner indicated:

(1) That the minimum flow in the Snake River occurred in 1905.

(2) That at any time during the delivery of stored water the natural flow of the river can not be lawfully determined within 500 second-feet.

(3) That 25 per cent of the stored water will cover the loss due to seepage, evaporation, and misappropriation of water by the Idaho Falls irrigation district.

(NOTE.—This assumption is based upon actual measurements taken during summer of 1909.)

(4) That 132,000 acres of land are to be irrigated by the Government.

(5) That 1 second-foot per 80 acres of land must be delivered at the head gates of the Minidoka project (a total of 1,650 second-feet).

(6) That the South Side Twin Falls Co. have prior rights up to 3,000 second-feet of natural river flow and that the North Side Twin Falls Co. have prior rights up to 400 second-feet of natural river flow.

(7) That the reservoir at Lake Walcott will store 52,000 acre-feet of the total storage required by the project.

(8) That 700 second-feet of water is returned to the river flow by seepage from the Minidoka project, according to measurements made in 1909.

(9) That, though the legal irrigation season in Idaho extends from April 1 to November 1, no stored water will be needed after October 10.

9. *Methods of computing.*—The following lines were placed on the "Hydrograph" of the Snake River at Montgomerys Ferry, which is located about 6 miles below Minidoka diversion and storage dam:

(1) A line representing the minimum flow at the Milner Dam—that is, 700 second-feet greater than the minimum flow at Montgomerys Ferry—and extending over the time that the river flow is less than 3,400 second-feet. Milner Dam is the diversion dam of the South Side Twin Falls project (private), and is located about 5 miles below the lower limits of the project.

(2) The 3,400 second-foot line which represents the lawfully natural river flow due the Twin Falls companies.

(3) The 2,900 second-foot line covering errors in stream measurements under second assumption (3,400—500=2,900).

(4) The 5,050 second-foot line which represents the flow required in the river to supply the necessary 1,650 second-feet of water for the Minidoka project and the 3,400 second-feet for the Twin Falls projects.

10. The 5050 line shows that stored water must be delivered to the Minidoka project from July 11 to October 10, making 91 days. This shows a total of 353,600 acre-feet, 52,000 acre-feet in Lake Walcott. Therefore, 301,600 plus 25 per cent represents storage required in Jackson Lake Reservoir and equals 376,000 acre-feet, say, 380,000.

11. It will be noted—

(1) That the assumed acreage exceeds that in the project by 7,500;

(2) That the diversion of 1,650 second-feet for 193 days, April 1 to October 10, means the diversion of 636,900 acre-feet, or sufficient to provide 3 acre-feet per acre for 132,000 acres after deducting 37½ per cent for seepage and evaporation losses in the distribution system; and

(3) That provision is made for a loss of 500 second-feet during the delivery of stored water in addition to a 25 per cent loss for seepage, evaporation, and misappropriation.

12. In the opinion of the board these assumptions are very liberal. In most projects no effort is made to fully provide for the year of lowest measured run-off, but rather for a mean of the years of low run-off on the assumption that a slight shortage in supply at infrequent intervals would be less objectionable than the cost of providing storage for years of extreme low run-off.

13. While the storage provided on this project seems somewhat larger than necessary, it will probably prove to be a good investment if the project is extended or if congressional authority is eventually obtained for the sale of surplus water.

14. Attention is invited to the fact that storage filing in Wyoming is for 300,000 acre-feet, while the capacity of Jackson Lake Dam is 380,000 acre-feet. It is suggested that an additional filing for 80,000 acre-feet be made.

APPENDIX No. 1 TO SECTION VIII.

BOISE PROJECT.

1. *Deer Flat Reservoir embankments, upper and lower.*—These embankments were visited by a committee of the board on September 9, 1910. By their construction a natural depression in the surface is converted into a reservoir with a total capacity of 186,000 acre-feet and an available capacity of 170,000 acre-feet. These embankments are both earth fill, the upper containing 932,200 cubic yards and the lower 936,600 cubic yards. The earth-fill type was adopted because no other suitable material was available and the foundations were not suitable for masonry construction.

2. The general dimensions are as follows:

		Upper embankment.	Lower embankment.
Height	feet	70	40
Length of crest	do	4,000	7,200
Width of crest	do	20	20
Side slopes:			
Reservoir side		3:1	3:1
Outer slope		2:1	1½:1

3. The subsoil in the upper embankment is composed of about 4 feet of ordinary soil, then 3 or 4 feet of hardpan, after which sand and gravel were found to an indefinite depth.

4. At the site of the lower embankment the soil is about 6 feet in depth with a somewhat thicker layer of hardpan, followed by sand and gravel. In each case a cut-off trench was constructed and filled with puddled earth, the remaining original surface being plowed in order to make good bond with the fill. The only arrangement for draining the reservoir is through the headworks of the canals forming the distribution system. These dams are both straight in plan; and the puddled ditch was carried up into the end slopes forming the abutments. There is no spillway, as it is proposed to control the water entering the reservoir through the main supply canal. This reservoir is filled by the main supply canal, called the "New York Canal," leading from the diversion dam in the Boise River to where it discharges into Indian Creek. After following Indian Creek about 9 miles the water is again diverted into a supply canal leading to the reservoir. The inlet works at the reservoir end of this supply canal is a concrete structure of the usual form, controlled by sliding gates, riprap protection being placed around the discharge to prevent scour. The outlet works to the distributing canals are located in both embankments. The upper dam has two sets of outlet gates, one set near each end. In one of these sets, a conduit is placed under the embankment and has the usual gate tower at the inner end. The capacity of the sliding cast-iron gates, of which there are four, is 650 second-feet. The outlet at the other end of the upper embankment is a simple conduit running under the embankment, controlled by a gate at the lower end, approximately 6 by 8 feet, with a capacity of 80 second-feet. In the lower embankment the discharge conduit lies under the embankment and is of concrete with the usual tower, etc., in the reservoir. It is controlled by sliding cast-iron gates of the ordinary type, and the delivery is about 650 second-feet.

5. In both embankments the earth fill was placed in layers, dampened and rolled. It is the purpose to place on the reservoir side of each embankment riprap protection, at present lacking. There will be needed to complete the reservoir another small embankment, not yet constructed, for closing a low place in the rim of the reservoir.

6. The cost of the upper embankment was $302,777.51, and of the lower $288,590.09. In both cases this is exclusive of the general expense charges. In order to aid in irrigating lands during the season of 1910 water was diverted to the reservoir to a depth of 7 feet. As a result of this head no leakage was observed under the lower embankment, but leakage amounting to at least 1½ second-feet occurred under the upper embankment. To correct this leakage, which seemed to come through the subsoil, a blanket of gravel, 200 feet wide, 12 feet thick at the toe of the dam and 4 feet thick at the outer edge, was

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placed below the embankment. At the outer edge of this blanket a row of sheet piling was driven 16 feet into the ground. Tile drains were then laid each way under this edge of the blanket to connect with the central drain, led out below. In addition tile drains were laid approximately at right angles to these collecting side drains, up to the drains previously laid under the toe of the dam. The total cost of this work was $21,025. While it appears that the leakage at the upper embankment comes through the subsoil beneath, it is believed that the leakage should be kept under constant observation. Experience with a small reservoir in the neighborhood, in which the bottom proved to be porous, indicates that large seepage losses may be expected in the reservoir and its usefulness correspondingly reduced.

Appendix No. 2 to Section VIII.

REPORT OF COMMITTEE THAT EXAMINED SITE FOR BOISE RIVER STORAGE RESERVOIR.

1. The committee visited both of the possible dam sites for the proposed Hell Gate Reservoir, i. e., at Hell Gate and at Arrow Rock. It appears from examination of data collected by the United States Reclamation Service that a masonry dam can be constructed at either site to store 150,000 acre-feet (the capacity proposed); but that the lower (Arrow Rock) site has some points of superiority. The estimated cost of dams at the two sites are practically the same, and each provides for storage of 150,000 acre-feet. The Hell Gate Dam would have a maximum height of 303 feet, raising water 212 feet, and the Arrow Rock Dam would have a maximum height of 318 feet, raising water 212 feet. The chief points of superiority of the Arrow Rock over the Hell Gate site are the better quality of the granite on which dam is to be founded; the lesser average thickness of overlying materials in bed of stream; the lesser extent of volcanic capping; the somewhat more accessible site and the slightly lesser cost.

2. The cost of storage on the Boise River will be high, but the examinations of the Reclamation Service indicate that it will be less for the Hell Gate Reservoir (with dam at Arrow Rock) than for any other site or sites on the river. Even this site requires a high masonry dam, which must be constructed of gravity section. On account of the depth of rock in the bed of the stream much difficulty may be expected in the construction of that portion of the dam below low-water level.

The following estimates are submitted by the United States Reclamation Service:

Rough estimate cost Hell Gate Dam.

One hundred and fifty thousand acre-feet; rubble masonry, type A; raising water 212 feet; dam, 303 feet high; crest elevation, 3,212; flooding, 1,920 acres; watershed area, 2,207 square miles.

Railroad, Barberton to Hell Gate, 20 miles, at $20,000		$400,000
Plant		200,000
Freight, exclusive of cement, sand, and gravel		25,000
Tunnel, 900 linear feet, at $80		72,000
Gates		100,000
Cofferdam		150,000
Excavation in cofferdam:		
20,000 cubic yards rock, at $3	$60,000	
186,000 cubic yards bowlders, gravel, and sand at $2	372,000	
		432,000
Excavation above water for dam:		
33,100 cubic yards rock, at $1.10	36,100	
27,000 cubic yards earth and loose rock, at 60 cents	16,200	
		52,300
Rubble masonry in dam, 412,200 cubic yards, at $6.25		2,576,300
Spillway		330,000
Incidentals, 10 per cent of above items		433,700
Engineering and administration		433,700
Total cost		5,205,000

Cost per acre-foot for 150,000 acre-feet, $34.70.

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Rough estimate cost Arrow Rock Dam.

One hundred and fifty thousand acre-feet storage; rubble masonry dam, type A; raising water 212 feet; dam, 318 feet high; crest elevation, 3,180; flooding, 2,050 acres; watershed area, 2,207 square miles.

Railroad, Barberton to Arrow Rock, 17 miles, at $20,000		$340,000
Plant		200,000
Freight, exclusive of cement, sand, and gravel		25,000
Tunnel, 900 linear feet, at $80		72,000
Gates, $100,000; cofferdam, $150,000		250,000
Excavation in cofferdam:		
21,000 cubic yards solid rock, at $3	$63,000	
143,000 cubic yards gravel and bowlders, at $2	286,000	
		349,000
Excavation above water for dam foundation:		
52,000 cubic yards solid rock, at $1.10	57,000	
10,000 cubic yards earth and loose rock, at 60 cents	6,000	
		63,000
Rubble masonry in dam, 432,000 cubic yards, at $6.25		2,700,000
Spillway		300,000
Incidentals, 10 per cent of above items		430,000
Engineering and administration		430,000
Total cost		5,159,000

Cost per acre-foot for 150,000 acre-feet, $34.39.

Appendix to Section XI.

MILK RIVER PROJECT.

WATER SUPPLY.

1. The flow of the Milk River is not in itself sufficient for the irrigation of the areas included within this project, and recourse is had to St. Marys River which rises in the United States and flows north through Canada into Hudson Bay. The Milk River also rises in the United States and flows for about 200 miles of its length through Canadian territory before returning to the United States.

2. The diversion of part of the flow of St. Marys River into the Milk River has been under consideration for the last 20 years, but recently, since the execution of a treaty between the United States and Canada, has this diversion been equitably possible. The treaty, which was signed in 1909 and proclaimed May 13, 1910, provides that these two rivers, the St. Marys and Milk, shall be treated as one stream for the purposes of irrigation and power, and the waters thereof apportioned equally between the two countries. It is also provided that more than one-half may be taken from one river with a corresponding reduction in the amount used from the other river. A further condition provides that during the irrigation season, from April 1 to October 31, inclusive, the United States shall be entitled to prior appropriation of 500 cubic feet per second of the waters of the Milk River, or so much of such amount as constitutes three-fourths of its natural flow, and that Canada shall have a similar prior right to the flow of the St. Marys River.

3. Gaugings of the St. Marys River have been made annually since 1902. Most of them were made at Cardston, Alberta, just north of the International Line. Others were made at Kimball, Alberta, and near Babb, Mont., while still others were made near St. Marys, the site of the proposed storage dam. From these gaugings the average run-off of the St. Marys River is found to be approximately 740,000 acre-feet, varying from a maximum of 1,108,000 acre-feet to a minimum of 516,000 acre-feet. A study of the hydrographs made by the Reclamation Service also shows that it is possible by means of storage to satisfy Canada's prior right and still divert 850 second-feet during the irrigation season, April 1 to October 31, inclusive. The storage that would have been required to furnish such a supply during the period 1903 to 1909, inclusive, varies from a minimum

of 74,800 acre-feet to a maximum of 174,700 acre-feet. As storage to the amount of 218,000 acre-feet can be provided in St. Marys Lakes at reasonable cost a continuous diversion of 850 second-feet for 7 months, or a total of 360,000 acre-feet, is assured without trespassing upon Canada's prior rights.

4. Discharge measurements on Milk River have been made at Havre, Mont., 60 miles below the international boundary, since 1898, at Malta since 1902, and Hinsdale since 1908. The discharge as measured at Havre is much less uniform than that of the St. Mary River, showing an average discharge of 230,000 acre-feet, with a maximum of 750,000 acre-feet and a minimum of 30,000 acre-feet, with two successive years of low run-off, namely, 1905, 30,000, and 1906, 70,000.

5. Storage on the river is to be provided in Nelson Reservoir for 142,000 acre-feet.

6. Prior water rights in Milk River and its tributaries amount to approximately 500 second-feet, part of which will be merged with and become a part of the project, and the filings of the United States cover the remainder of the flow. Filings have also been made by the United States on all of the unappropriated waters of the creeks and coulees entering Milk River above the lowest diversion dam.

7. The average rainfall at Havre since 1881 has been 13.6 inches, with a minimum in 1905 of less than 7 inches. Nearly 50 per cent of the annual precipitation occurs in May, June, and July. This fact, together with past experience in this valley, leads to the conclusion that 1½ acre-feet per acre per annum on the land will be a sufficient allowance, if it can be delivered during the growing season.

8. To determine the amount of water that could have been delivered to the land during the period 1902–1910, had the system as now planned been completed, a comprehensive analysis of the data available has been made by the Reclamation Service. In making this analysis such portion of the daily flow of the Milk River at Havre as is secured by treaty to the United States, supplemented by the proposed diversion of St. Mary River water, has been compiled, together with the daily quantities that could have been diverted through the Chinook diversion canals. The capacity of these canals is assumed as 500 second-feet, the irrigable area under them being 100,000 acres.

9. To determine the daily amount available for diversion at Dodson Dam, the second diversion point, there was added to the daily quantities remaining after the Chinook diversion the daily accretions to the stream flow between Havre and Malta, the latter being for practical purposes coincident with the Dodson Dam. These daily accretions were determined by subtracting from the daily discharge at Malta the discharge at Havre of two days previous. It will be noted that these accretions are net accretions and exclude from consideration the amount that was being used for irrigation between Havre and Dodson Dam. The Dodson canals are to have a combined capacity of 1,100 second-feet, and the amount that could have been diverted daily through them from the available supply has been tabulated for each day of the nine-year period for which discharge measurements are available.

10. In a similar manner the daily quantities remaining in the river after the Dodson diversion were tabulated and to them added the daily accretions between Dodson Dam and Vandalia Dam, the latter being determined by subtracting from the discharge at Vandalia (Hinsdale) the discharge at Dodson Dam (Malta) of one day previous. From the daily quantities thus available at Vandalia Dam the daily amounts that could have been diverted through a canal of 200 second-feet capacity were determined.

11. In the following tabulated statement, prepared by the Reclamation Service, is presented a summary of the results that could have been obtained during the years 1902 to 1910, inclusive, for the Dodson and Nelson Reservoir divisions, after furnishing the canals in the Chinook division with 500 second-feet continuous flow. From this table it appears that for all the years in the period, including the extremely dry years—1905 and 1910—all lands in the project could have been furnished with 1½ acre-feet per acre per annum on the land, delivery being made through a period of seven months. In the estimates allowance is made for a 25 per cent seepage and evaporation loss in the canals, including the St. Mary diversion canal, and for an annual evaporation loss in Nelson Reservoir of 5 feet depth of water, equivalent to 20,000 acre-feet. No allowance is made for evaporation from that portion of Milk River used in conducting St. Mary water, as the additional supply will but slightly increase the water surface exposed to evaporation.

Supply available for Dodson and Nelson Reservoir divisions.

[Acre-feet.]

Years.	1	2	3	4	5	6	7	8
1902	271,945	149,945	129,945	.....	28,000	101,945	21,945	21,945
1903	321,237	199,237	179,237	13,199	14,801	164,436	84,436	106,381
1904	244,224	122,224	102,224	14,519	13,481	88,743	8,743	115,124
1905	165,472	43,472	23,472	.....	28,000	− 4,528	− 84,528	30,596
1906	231,710	109,710	89,710	14,175	13,825	75,885	− 4,115	26,481
1907	336,318	214,318	194,318	33,312	.....	194,318	114,318	140,799
1908	262,157	140,157	120,157	9,985	18,015	102,142	22,142	[2] 142,000
1909	317,024	195,024	175,024	46,778	.....	175,024	95,024	[2] 142,000
1910	172,623	50,623	30,623	10,783	17,217	13,406	− 66,594	75,406

[1] Accretions from drainage basin between Malta and Hinsdale not included for years 1902 to 1907, inclusive.
[2] Proposed maximum capacity of Nelson Reservoir.

(1) Amount which could have been diverted at Dodson Dam after the diversion of a continuous flow of 500 second-feet into canals in the Chinook division.

(2) Amount which could have been stored in Nelson Reservoir, 122,000 acre-feet having been used in the irrigation of the 61,000 acres in the Dodson division.

(3) Amount which could have been delivered from Nelson Reservoir, deducting 20,000 acre-feet for evaporation from the reservoir.

(4) Amount which could have been delivered into Vandalia Canal by direct diversion from Milk River after all diversions into canals above.

(5) Amounts which would have been required from Nelson Reservoir to have given the Vandalia Unit its full supply of 28,000 acre-feet.

(6) Balance remaining in Nelson Reservoir for Nelson Reservoir North and South Canals, and for storage for use in subsequent years.

(7) Amount which could have been carried over in Nelson Reservoir for use in subsequent years after giving to lands under Nelson Reservoir North and South.

(8) Amount stored in Nelson Reservoir at end of season.

12. In making these estimates the supervising engineer in his analysis states: "All water supply where not shown by records has been disregarded. The flow has been considered from April 1 to October 31 only, whereas a considerable quantity of water may be obtained frequently during other months. In a number of instances records are lacking for parts of the period April 1 to October 31, and in such cases the flow has been disregarded for such times as records are not available. The return seepage, which will undoubtedly be considerable and will augment the supply for lower diversions, has been disregarded. The quantity of water assumed to be available from the flow of the upper Milk River has been limited to such part of the flow as is assured by treaty, whereas any surplus above this quantity at any time not required by Canada will enter the United States and be available for diversion. In determining the accretions to Milk River between Havre and Malta, the difference in discharges of the river at the two points has been taken. This disregards all diversions that were being made at that time between Havre and Malta and the full supply of 2 acre-feet per acre per annum was allotted the lands that were using this water for irrigation. In fact, in all instances an effort has been made to estimate not the probable supply, but the assured supply."

13. This analysis has been reviewed by the board, and with the following exceptions it concurs in the assumptions made and in the conclusions reached:

(1) It is believed that specific allowance should have been made for seepage and evaporation loss in the 26 miles of diversion canal between St. Mary and Milk River, in addition to allowing a 25 per cent loss from this source in the distribution system. If the loss in this main diversion canal is placed at 10 per cent, which is less than one-half of 1 per cent per mile, it would be equivalent to 36,000 acre-feet in a year.

(2) Attention is called to the disproportion in the assumed capacity of the Chinook Canals, 500 second-feet for 100,000 acres, and that of the Vandalia Canal, 200 second-feet for 14,000 acres. The necessary changes in the capacities would not, however, have unfavorably altered the result.

(3) It is questionable whether the delivery of 1½ acre-feet per acre at a more or less uniform rate during seven months of the year will meet irrigation

requirements in a region where the growing season is only five months. While the storage provided in Nelson Reservoir will serve in a measure to adjust the annual supply to the demand it must also serve to equalize the variable supply of different years. Whether it is large enough to fulfill both functions is a matter about which there is reasonable doubt.

14. As additional storage can if necessary be provided in Milk River, the above comments do not alter the conclusion that in normal years there will be a sufficient water supply for the 215,000 acres under the project.

15. The only other point to be considered is whether the amount to which the United States is entitled from the Milk River flow added to the amount which it is proposed to divert from St. Mary River will exceed one-half of the total flow of these streams. One-half of the combined average annual discharge of these streams is 480,000 acre-feet.

	Acre-feet.
Proposed to be used by the United States, 215,000 acres, at 2 feet	430,0000
Evaporation loss, Nelson Reservoir	20,000
Total	450,000

16. Seepage from the main diversion canal is not included in the above, as it will all drain into the St. Mary Basin and be available for use in Canada. There will be added to the above, however, the amount to which the Belknap Indians are entitled under court decree—125 second-feet—and also part of the amount now being used by other prior appropriators on Milk River, as all of them will not, probably, come in under the project. Assuming 75,000 acre-feet as the amount necessary to satisfy prior rights, the total use of Milk River water in the United States will aggregate 525,000 second-feet.

17. A comparison of the discharge measurements at Havre, Malta, and Hinsdale shows an average annual accretion between Havre and Malta of 40,000 acre-feet, and between Malta and Hinsdale of 35,000 acre-feet, a total of 75,000 acre-feet, or sufficient to satisfy the prior rights above referred to. In other words, the proposed use of these two streams is about 30,000 acre-feet less than the amount to which the United States would be entitled under the treaty.

Appendix No. 1 to Section XII.

SUN RIVER PROJECT.

DAMS AND RESERVOIRS.

1. *Warm springs reservoir and dam.*—The Reclamation Service has furnished the following description of this dam with proposed methods of construction:

"This is located on the North Fork of the North Fork of Sun River some 12 miles within the mountains, about a mile above the confluence of the North and South Forks. At this point the dam was planned to be constructed of loose rock fill, backed by earth placed by hydraulic process. About three-quarters of a mile below the dam site is a large talus of diorite, composed of rock from 1 to 30 or more cubic yards in size, and a good portion will be from 1 to 6 cubic yards. This material can be cheaply transported by gravity tramway to the dam site and placed therein by cableway. Test pits were dug from 1 to 25 feet deep upon the hill sides above the dam site, and ample supply of materials for making hydraulic fill was developed within 2,000 feet of this point of use. These consist of clay, coarse and fine gravel, and some bowlders. By placing the material in this manner it can be sorted by the water so that the interstices between the stones of the rock fill will be filled with impervious material, making that portion solid and water tight, as well as the backing. Also the sorting can further be carried out to place the coarser material upon the upstream face so that a paving will not have to be resorted to other than the selection of stones during construction to act as baffle rock to hold the hydraulic material in place. Water can be delivered for this purpose by building a ditch of some 20 second-feet capacity about 4 miles long from Bear Creek. Almost any desired head can be secured to give pressure at the nozzle. If the supply of Bear Creek should not prove sufficient for sluicing purposes as well as disintegration purposes, ample supply can be secured from South

Fork by a ditch about 7 miles long, which will catch the flow of Elk, Goat, and Bear Creeks en route. This could afterwards be used to supply an additional amount of water back of the dam if needed. The economical height of the dam is controlled by the occurrence of bed rock in the spillway, which is about 2,000 feet from the dam and behind the butte several hundred feet high. The crest of the dam was made 10 feet higher than for the spillway, so that it need not be overtopped, but floods will pass around the butte into the river. Top of dam was placed at contour 4,980 and flood line at 4,970, which will make a dam 190 feet above stream bed with a capacity of 156,868 acre-feet. At the dam site the foundation is of hard diorite where North Fork has cut through Sheep Reef. Bed rock shows across the river, and diamond drill borings have been made at three points to develop its continuity. The greatest depth of bed rock below stream bed is 25 feet, which gives a total height of dam from stream bed to crest of 215 feet.

"The outlet work will consist of a tunnel approximately 900 feet long, 10 feet in size, with a slight arch, passing through the left abutment, being in the solid diorite. The outlet gates will be controlled through a shaft rising from this tunnel which would be through solid rock, but more economic construction would probably necessitate the upper portion of the shaft to be of concrete in order to shorten the length of tunnel. A tunnel of this size with a slope of 0.01 will discharge 2,200 second-feet. When construction is begun on this feature, it will be necessary to construct the tunnel, shaft, and set the gates the first season in order to take care of the spring floods and provide a by-pass around the dam. The first season the dam will be built some 80 feet above stream bed in order to amply discharge the maximum flood, which probably does not exceed 4,000 second-feet.

"The completion of the Great Northern Railway to Augusta will materially assist in this work, and if the line is completed through the mountains it will run within a mile of the dam site."

2. While the board believes the cross section of a rock-fill dam here of the unusual height, 215 feet from the lowest point of prepared river bed, is feasible and practicable, it believes that should the railway be completed to the point near the site as suggested in the preceding paragraph it may be found that with the transportation facilities thus afforded the cost of a masonry dam will be but relatively little greater, and therefore that careful comparative studies and estimates of the two types should be made before the adoption of either type. As it will be several years before this structure is commenced, time is available. The estimate of cost of the Warm Springs Reservoir is as follows:

Dam:		
Rock fill, 380,000 cubic yards, at 75 cents	$285,000	
Earth fill, 1,031,000 cubic yards, at 5 cents	51,550	
Riprap, 38,500 square yards, 18 inches deep, at $1.25	48,150	
Outlet tunnel, 900 by 10 by 10 feet, at $80 per linear foot	72,000	
Gates, shaft, and gate house	50,000	
		$506,700
Gate tender's house and barn		2,000
Telephone line to canyon, 10 miles, at $200		2,000
Canyon road, 10 miles, at $2,000		20,000
Highway Bridge at Forks, 63-foot span		1,500
Bear Creek hydraulic-pressure ditch		2,000
South Fork hydraulic-supply ditch		43,300
Engineering and contingencies, 15 per cent		86,600
		664,100

3. If the slope of the rock fill is increased as proposed to one and one-half to one, instead of one to one, the amount of rock will be increased about one-third, necessitating an increase of estimated cost for work of $95,000, making the cost of dam $601,700, and the total cost of reservoir $759,000.

4. *Willow Creek Dam and Reservoir.*—This reservoir will when completed to full height serve two purposes:

(1) To store the flood waters of Willow Creek to supplement the flow of Sun River available for Fort Shaw Unit in dry years; and

(2) To store flood waters of Sun River by means of canal connecting it with the Sun River above the Canyon Diversion Dam.

5. For the first purpose the dam need be only 70 feet high, while to accomplish both ends the height is to be 110 feet. It is the present intention of the Recla-

mation Service to complete the dam for the first purpose only, leaving the additional height for the larger storage to be added later when required for new areas. This additional storage will be used by private users below the Fort Shaw Unit in exchange for which Sun River water can be diverted to the Pishkun Reservoir system and thus increase the irrigable acreage under it and which otherwise would not receive water.

6. The earth-fill type is the most suitable for the locality. The dam is designed to be 20 feet wide on top with side slopes of three on one on the reservoir side and two on one on the outer slope. The subsoil is compact glacial drift on top of sandstone and shale. The thickness of the material overlying this rock is 15 feet at the bottom of the creek and less on the hillsides. Four cut-off trenches are excavated to the underlying rock and filled with selected puddled material.

7. The reservoir slope is to be faced with a layer of selected glacial bowlders, 2 feet thick, hand placed. An outlet tunnel 584 feet in length passes around one end of the dam. It is circular in cross section, 4 feet 6 inches in diameter. Its capacity under 10-foot head is 400 second-feet. It is controlled by a sliding gate operated through a shaft, concrete lined, extending up to crest of dam.

8. The storage for Willow Creek is 16,700 acre-feet. The storage for the higher dam will be 84,000 acre-feet, the difference to be supplied from the North Fork of Sun River, as noted above.

9. The spillway for the lower dam is through a sag in the surrounding hills, which will, for the high dam, be closed by a small embankment. Another higher sag will form a spillway, if ever needed, for the higher dam. In each case the overflow discharges into a small creek about one mile away. The estimated cost of the dam, complete, is as follows:

Outlet tunnel and shaft to elevation 4,140 completed and gate set. Camp established, equipment and supplies assembled. Cut-off trenches practically done and embankment begun. Paving rock on hand for face to elevation, 4,140.

Dam:		
Earth fill, 460,000 cubic yards, at 28 cents	$128,800	
Supplying and placing 6,000 cubic yards paving, at $2.50	15,000	
	15,000	
Placing 4,000 cubic yards paving, at $1	4,000	
		$147,800
Dike, 210,000 cubic yards, at 35 cents		73,500
Raising gate-control shaft 40 feet, 100 cubic yards concrete, at $12		1,200
Gate house		500
Measuring weir in Willow Creek about 1 mile below dam, with diversion box for Floweree Canal to measure 400 second-feet (no design)		5,000
One mile, 200 second-feet canal, measuring weir to head Floweree Canal, 21,000 yards earth, at 18 cents		3,800
Engineering and contingencies, 15 per cent		34,800
		266,600

Appendix No 2 to Section XII.

SUN RIVER PROJECT.

WATER SUPPLY.

[Study of supervising engineer, H. N. Savage.]

The irrigation plan of the Sun River project contemplates the construction of a storage reservoir on the North Fork of Sun River controlled by the Warm Springs Dam, storing the flow of this branch of the Sun River; a diversion dam on the South Fork of the North Fork of Sun River diverting water into a supply canal discharging into the Warm Springs Reservoir; a diversion dam on the Sun River about 12 miles below the Warm Springs Reservoir diverting water into two canals, one on the north side of the river, serving as the supply canal to the Pishkun Reservoir, the other on the south side of the river, serving as a supply canal for the Willow Creek Reservoir; and the construction of the Pishkun and Willow Creek Reservoirs, with their subsidiary-canal systems. The water supplied to the Pishkun Reservoir will be taken out into a canal to

be constructed so as to cover the high lands to the north of Sun River. A portion of the water of this same reservoir is to be discharged into Deep Creek, a tributary of the Teton River, on which a diversion dam is to be constructed diverting water into a canal and irrigating lands on the southern slope of the Teton River basin. The water stored in Willow Creek Reservoir will be discharged into Sun River and will furnish partial supply for the Fort Shaw unit and for prior private water rights on Sun River below the mouth of Willow Creek, thus permitting a larger part of the low-water flow of the North Fork to be utilized in the irrigation of lands on the north side of the river.

A reservoir may be constructed at the site of Benton Lake, about 8 miles north of Great Falls, to which surplus water from the Teton Slope Canal may be conducted by means of a supply canal some 4 miles in length, and stored for the irrigation of some 21,000 acres lying on the north side of the Missouri River opposite Great Falls.

It is proposed to divert Bowl Creek, a tributary of Flathead River, into the head of Sun River. Bowl Creek, above the point of diversion, has a drainage area of about 9 square miles situated very near the continental divide.

The area of land to be furnished with water is limited by the available water supply and not by the area to which water can be delivered. The project could be increased to include double the irrigable area at present proposed, were a sufficient water supply available.

The flood stage of the Sun River occurs during the period when there will be large requirement for water for irrigation, the maximum flood usually occurring in June. Storage reservoirs are available for conserving the greater part of the winter flow and for regulating the summer discharge by the storage of the surplus waters during times of maximum floods.

The annual run-off of the Sun River ranges from 500,000 to 1,000,000 acre-feet, with an average of about 700,000 acre-feet. It is believed that this will be sufficient for the irrigation of from 300,000 to 350,000 acres. On this basis lands have been selected aggregating 322,000 acres, situated as shown in the following table:

	Acres.
Fort Shaw unit	16,000
North Side high-line unit	15,000
Greenfields unit	75,000
Teton Canal lands	195,000
Benton Lake unit	21,000
Total	322,000

STORAGE RESERVOIRS.

The areas and capacities of the principal storage reservoirs are given in the following table:

Reservoir.	Area.	Capacity.
	Acres.	*Acre-feet.*
Warm Springs	1,976	156,800
Willow Creek	2,285	84,320
Pishkun	1,542	45,747
Benton Lake	9,130	140,200

RECORDS OF RAINFALL AND RUN-OFF.

Records are available of the precipitation at Fort Shaw, Mont., from 1867 to 1886, inclusive, and from 1907 to date, also of that at Great Falls, Mont., from 1892 to date.

Records are available of the run-off of Sun River from 1906 to date, of the South Fork of Sun River from 1905 to date, of the North Fork of Sun River from 1905 to date, of Willow Creek from 1906 to date, and of Smith Creek, and of Ford Creek, tributaries of the South Fork, from 1906 to date.

Tabulated statements of precipitation, and hydrographs showing the flow of the several streams accompany the report on the Sun River project, submitted under date of August 10, 1910.

DUTY OF WATER.

A consideration of the records of precipitation and of its monthly distribution, as well as of the results of irrigation as practiced in the vicinity of the project, leads to the conclusion that 1½ acre-feet per acre per annum delivered on the land, will be an ample allowance. Losses from seepage in canals will be returned to a great extent to the river and will be available for diversions below, reducing to such extent the quantity to be turned down the river for supplying such diversions. It is believed that an allowance of 25 per cent will be sufficient to cover final losses from evaporation and seepage in canals, and that 2 acre-feet per acre per annum delivered at the head of canals will be ample to supply the total requirement. No allowance need be made for losses from evaporation from the river, the records of stream flow used to determine the available supply showing net supply after such losses have occurred.

PRIVATE WATER RIGHTS.

Appropriations of water prior to filings by the United States, stated in terms of the acreages to be irrigated and classified according to the various streams from which diversions are made, are given in the following tabulated statement:

Stream.	Irrigated.	Susceptible of irrigation.	Total.
	Acres.	*Acres.*	*Acres.*
North Fork of Sun River	1,522	21,360	22,882
Willow Creek and tributaries:			
Willow Creek and Little Willow Creek	1,691	725	2,416
Barr Creek	288	242	530
South Fork and tributaries:			
South Fork	4,659	3,471	8,130
Goss Creek	313	101	414
Blubber Creek	19	.....	19
Elk Creek	121	235	356
Dubray Creek	689	1,456	2,145
Ford Creek	194	.....	194
Smith Creek	207	478	685
Sun River below mouth of South Fork and its tributaries:			
Sun River	6,661	7,844	14,505
Dry Creek	424	415	839
Simms Creek	15	38	53
Total	16,803	36,365	53,168

In addition to the above, C. H. Campbell has a water filing of 468 second-feet on the waters of Sun River for power purposes, the power to be utilized in pumping water for the irrigation of his lands. The location of the power site is below all diversions by the United States and below practically all diversions by other appropriators. However, the appropriator is willing to relinquish this water right to the United States and receive in lieu thereof water right under the Government canal.

The adjudication of the Sun River water rights is now pending before the State court, and the tabulated statement of probable acreages is based upon defendant's answers and the referee's report.

In the following discussion, the quantities which will be used by private appropriators has been estimated on the basis of 2 acre-feet per acre per annum delivered at the head of canals, it being believed that any quantities in excess of these, if actually delivered to the land, will run off as surface drainage, or will be by seepage eventually returned to the river and will be available for diversion below.

AVAILABLE WATER SUPPLY.

The irrigation period may be assumed to extend from April 1 to October 31 of each year. The winter flow of the North Fork of the North Fork of Sun River will be stored in Warm Springs Reservoir. A diversion canal will be constructed of size sufficient to convey to this reservoir the flow of the South Fork of the North Fork, with the exception of the peak of floods. It is expected that ordinarily this canal can be operated during one-half of the winter period.

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In the following discussion it has been assumed that the winter flow of the South Fork of the North Fork, except during the months of December and January, can be delivered into the Warm Springs Reservoir, and that that of the North Fork below the Warm Springs Reservoir during the same period can be diverted into the south or north supply canals and stored in Willow Creek or Pishkun Reservoir.

Stream measurements for the North Fork of Sun River have been made at a gaging station situated at a point about 9 miles below the proposed diversion dam for the north and south supply canals. In order that the quantities which may be stored in Warm Springs Reservoir may be estimated, it has been necessary to estimate what portions of the stream flow at the gaging station are derived from the North Fork of the North Fork, the South Fork of the North Fork and of the North Fork below the reservoir site. The areas of these drainage areas are approximately 208, 211, and 135 square miles respectively. The drainage area of the North Fork of the North Fork having a greater elevation, the relative quantities of run-off per square mile from the three areas are assumed to be in the proportion of 4, 3, and 3. On this basis the percentages of the total run-off for the three drainage areas are 45 per cent, 35 per cent, and twenty per cent, respectively.

Several appropriations of the waters of the North Fork have been made prior to filings by the United States. The total irrigable area covered by these prior appropriations is approximately 23,000 acres, of which approximately 1,500 acres have been irrigated. All of these filings are situated below the gaging station and the records of stream measurement show the stream flow before the diversion of any water for supplying the lands irrigated. Table 1 shows, for the years for which records are available, the estimated quantities of water which would have been available from the three drainage areas tributary to the North Fork and the balance available for use by the United States after deducting 46,000 acre-feet for supplying the prior rights for approximately 23,000 acres.

The total area of irrigable land for which appropriations of water have been made from the South Fork of Sun River prior to filings by the United States is approximately 11,950 acres, of which approximately 6,200 acres have been irrigated. All of these appropriations are above the South Fork gauging station, and records of stream measurement show the flow after the diversion of water for the lands irrigated. For supplying prior rights it is necessary, therefore, to deduct from the flow as shown by the gaugings only 11,500 acre-feet per annum for supplying the 5,750 acres of land not irrigated. Table 2 shows, for the years for which records are available, the estimated run-off of the South Fork of Sun River during the irrigation period and the amounts that would have been available for use by the United States after deducting 11,500 acre-feet for supplying prior rights.

The total area of irrigable land for which appropriations of water have been made from Willow Creek prior to filings by the United States is approximately 3,000 acres, of which approximately 2,000 acres have been irrigated. All of these appropriations are above the Willow Creek gauging station, and records of stream measurement show the flow after the diversion of water for the lands irrigated. For supplying prior rights it is necessary, therefore, to deduct from the flow as shown by the gaugings only 2,000 acre-feet per annum for supplying the 1,000 acres of land not irrigated. The remainder of the run-off for the entire year can be stored in Willow Creek Reservoir and sufficient additional water diverted from the North Fork and delivered through the North Supply Canal to fill the reservoir. Table 3 shows, for the years for which records are available, the estimated annual run-off of Willow Creek, the amounts which would have been available for storage and use by the United States after deducting 2,000 acre-feet for supplying prior rights and the amounts which it would have been necessary to divert from the North Fork to fill Willow Creek Reservoir to its full capacity of 84,300 acre-feet.

Appropriations of water from Sun River below the mouth of Willow Creek prior to filings by the United States embrace a total of approximately 14,500 acres, of which amount about 6,700 acres have been irrigated. The Fort Shaw unit has an irrigable area of about 16,000 acres. There will be then a total irrigable area below the mouth of Willow Creek of about 30,500 acres, for the irrigation of which there will be required approximately 61,000 acre-feet of water.

Table 4 gives, for the years for which records are available, the estimated amounts of water which would have been available from the South Fork of Sun River and from Willow Creek, after deducting sufficient quantities for supplying

prior rights on these streams, and the estimated balance which would have been required from the North Fork of Sun River in order to supply the 61,000 acre-feet required for the irrigation of lands on Sun River below the mouth of Willow Creek.

Table 5 gives, for the years for which records are available, the estimated supply from the North Fork of Sun River available for lands on the north side of the river after deducting such quantities as would have been required to give lower diversions a full supply.

As heretofore stated, it is proposed to divert Bowl Creek into the head of Sun River. The drainage basin of Bowl Creek above the point of diversion has an area of about 9 square miles ranging in elevation from 6,500 feet to 8,000 feet above sea level. It is estimated that the average run-off per square mile of this area will be 25 per cent greater than the average run-off per square mile of the basin of the north fork of the North Fork. On this assumption, the probable run-off for the years 1905 to 1910, inclusive, would have been as given in Table 6. The high altitude of the Bowl Creek drainage basin will bring its maximum run-off considerably later than the maximum flood period of the North and South Forks of the North Fork, and will facilitate the storage of the run-off in the Warm Springs Reservoir.

The winter flow of the North Fork of the North Fork and of the South Fork of the North Fork will be stored in the Warm Springs Reservoir. It is assumed that the irrigation period will begin about April 1 and continue until about October 31, with maximum requirement in June, July, and August. Records of stream flow of the North Fork show that, ordinarily, the natural flow continues comparatively low during April. If conditions indicate a large run-off, the winter flow may be returned to the river for diversion into the several canals before the beginning of the flood period, thus leaving the reservoir in condition to retain the maximum quantity during the period of greatest discharge.

The proposed capacity of the north supply canal is 2,000 second-feet and that of the south supply canal 1,100 second-feet. After April 1, then, the entire flow of the North Fork can be diverted into these canals except during such periods as the discharge exceeds 3,100 second-feet and, in case no water is required for the Willow Creek Reservoir, the entire flow can be diverted into the north supply canal except during such periods as the discharge exceeds 2,000 second-feet. A comparison of the last columns in Tables 3 and 4 shows that a larger quantity of water from the North Fork could have been stored each year in Willow Creek Reservoir than would have been necessary to supply the requirement. Any water furnished from the North Fork to Willow Creek Reservoir will be delivered either during the winter season from accretions below the Warm Springs Reservoir or during periods of maximum flood when Warm Springs Reservoir is full and the North Supply Canal unable to handle the flow of the stream remaining after allowing sufficient water to pass to supply the rights of canals below. The inability to utilize any part of the available water can result only from the Warm Springs Reservoir being full at such time as the normal flow of the stream at the diversion works of the supply canals, after deducting water required for canals diverting below, exceeds the capacity of the supply canals, or at such time as Willow Creek Reservoir is full and the flow exceeds the capacity of the North Supply Canal after providing for lower diversions.

In Table 7 are given, for the years for which records are available, the quantities from the flow of the North Fork available for north-side lands, the quantities which could have been diverted into the North Supply Canal or stored in the Warm Springs Reservoir, and the estimated surplus above storage and diversion capacities which would necessarily have had to be diverted into the South Supply Canal or would have passed on downstream.

The water supply from Bowl Creek will also be available for north-side lands. However, during ordinary years the supply from this stream during the flood period can not be so utilized as the storage and diversion capacities will be exceeded by the flood discharge of the North Fork. It will be in years of comparatively low flow that the Bowl Creek flood supply can be best utilized and will be most useful. In 1905, 1906, and 1910, the entire estimated annual run-off of Bowl Creek could have been stored in the Warm Springs Reservoir for use at such times as required. In 1907 to 1909, inclusive, it is probable that but a small part of the flow could have been utilized, as the flow of the North Fork was in excess of the storage and diversion capacities. The estimated annual run-off for the years 1905, 1906, and 1910 is shown as supplied to north-side

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lands, while the estimated run-off for the years 1907, 1908, and 1909 is omitted for reasons stated above.

In addition to the water diverted through the North Supply Canal for north side lands, there will be available for lands under the Teton Canal and the Benton Lake unit, the run-off of Deep Creek and its tributary, Willow Creek, both of which are tributary to the Teton River.

As no discharge measurements have been made of the flow of Deep Creek and Willow Creek, an estimate of the probable run-off has been made by a comparison of these streams with the South Fork of Sun River. Willow and Deep Creeks resemble the South Fork as regards the situation, elevation, and topographic features. It would seem that their run-off would be approximately proportional to their drainage areas. The total drainage area of Willow Creek and Deep Creek is approximately 240 square miles, while that of the South Fork is approximately 87 per cent of this area. On this basis. the probable run-off of Willow and Deep Creeks has been estimated for the years 1905 to 1910, inclusive, and the estimated quantities are given in Table 8.

In Table 8 are given, for the years for which records are available, the quantities from the North Fork which could have been delivered to the north side lands either by direct diversion of the normal flow or by storage in Warm Springs Reservoir and subsequent diversion, the quantities from Bowl Creek which could have been delivered to north side lands, the quantities available from Deep and Willow Creeks for lands under the Teton Canal or the Benton Lake unit, and the total quantities which could have been delivered to north side lands from all of these sources. From this table it will be seen that north side lands could have been furnished with an abundant supply during the years 1907, 1908, and 1909, and with practically a full supply in 1910. Considerable additional supply could have been obtained in the spring of 1910 from cross drainage tributary to the long one-bank main canals. This amount is difficult to estimate, but it is certain that it would have materially increased the available supply.

The years 1905 and 1906 were years of extraordinarily low run-off. Measurements of stream flow have not been made for a sufficient number of years to show the probable recurrence of such years of low flow. During such years there would not have been a sufficient supply, after providing water for the Fort Shaw unit and for appropriations prior to those of the United States, to have furnished a full supply to the 306,000 acres on the north side of Sun River. It will be a number of years, however, before works can be constructed to cover the entire area proposed for irrigation. In the meantime, measurements of stream flow can be continued and the lands for which works are constructed can be limited to such area as may be decided most practicable. The minimum year should not be taken as determining the amount of land to be irrigated unless such minimum flow is of frequent recurrence. It is believed that years having flow similar to 1905 and 1906 are of very infrequent occurrence and that further stream measurement will show that the irrigation of approximately 300,000 acres on the north side of the river is feasible.

TABLE 1.—*Estimated supply in acre-feet from the North Fork of Sun River.*

	1905	1906	1907	1908	1909	1910
Estimated run-off of the North Fork of the North Fork for the years [1]	164,000	166,000	359,000	354,000	330,000	283,000
Estimated run-off of the South Fork of the North Fork, February to November, inclusive [2]	122,000	111,000	269,000	266,000	246,000	210,000
Estimated run-off of the North Fork below Warm Springs Reservoir, February to November, inclusive [3]	70,000	64,000	134,000	152,000	141,000	120,000
Water available for use by the United States after deducting 46,000 acre-feet for supplying prior rights	310,000	295,000	716,000	726,000	655,000	567,000

[1] 45 per cent of the flow at the gauging station for like period.
[2] 35 per cent of the flow at the gauging station for like period.
[3] 20 per cent of the flow at the gauging station for like period.

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TABLE 2.—*Estimated supply in acre-feet from the South Fork of Sun River, Apr. 1 to Oct. 31.*

	1905	1906	1907	1908	1909	1910
Estimated run-off	32,200	32,000	78,000	106,000	130,000	11,000
Water available for use by the United States after deducting 11,500 acre-feet for supplying prior rights	20,700	20,500	66,500	94,500	118,500	.....

TABLE 3.—*Estimated supply in acre-feet from Willow Creek and amount in acre-feet required from the North Fork of Sun River to fill Willow Creek Reservoir to its full capacity of 84,300 acre-feet.*

	1905	1906	1907	1908	1909	1910
Estimated run-off for the year	10,000	8,000	25,000	25,000	35,000	11,000
Water available for storage and use by the United States after deducting 2,000 acre-feet for supplying prior rights	8,000	6,000	23,000	23,000	33,000	9,000
Balance of Willow Creek Reservoir capacity which would have been available for the storage of water from the North Fork, assuming all Willow Creek flow to be stored	76,300	78,300	61,300	61,300	51,300	75,300

TABLE 4.—*Estimated available supply from South Fork and Willow Creek and estimated balance required from the North Fork to supply 61,000 acre-feet for lands for which water will be taken from Sun River below the mouth of Willow Creek.*

Year.	Estimated supply from South Fork (from Table 2).	Estimated supply from Willow Creek (from Table 3).	Balance required from the North Fork.
1905	20,700	8,000	32,300
1906	20,500	6,000	34,500
1907	66,500	23,000	.....
1908	94,500	23,000	.....
1909	118,500	33,000	.....
1910	.....	9,000	52,700

TABLE 5.—*Estimated supply, in acre-feet, from the North Fork of Sun River available for lands on the north side of Sun River.*

	1905	1906	1907	1908	1909	1910
Total estimated available supply from the North Fork after deducting water required for prior rights on North Fork (from Table 1)	310,000	295,000	716,000	726,000	655,000	567,000
Required for lands on Sun River below the mouth of Willow Creek (Table 4)	32,300	34,500	.....	.....	.....	52,000
Balance available for lands on north side of Sun River	277,700	260,500	716,000	726,000	655,000	515,000

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TABLE 6.—*Estimated supply in acre-feet from the North Fork of the Sun River and from Bowl Creek available for lands on the north side of the Sun River.*

	1905	1906	1907	1908	1909	1910
Estimated supply from the North Fork available for north-side lands (from Table 5)	277,700	260,500	716,000	726,000	655,000	515,000
Estimated run-off from Bowl Creek	8,000	8,000	19,000	19,000	15,500	12,500
Total	285,700	268,000	735,000	745,000	670,000	527,500

TABLE 7.—*Estimated supply in acre-feet from the North Fork of the Sun River available for north-side lands, estimated quantities which could have been diverted into the north supply canal or stored in Warm Springs Reservoir for subsequent diversion, and estimated quantities which could not have been so diverted nor stored owing to the limited capacity of reservoir and supply canal.*

	1905	1906	1907	1908	1909	1910
Estimated supply available from North Fork for north-side lands (from Table 9)	277,700	260,500	716,000	726,000	655,000	515,000
Estimated quantities which could have been diverted into north supply canal or stored in Warm Springs Reservoir	277,700	260,500	650,000	627,000	632,000	515,000
Quantities which could not have been so diverted or stored	.....	.....	66,000	99,000	23,000	.....

TABLE 8.—*Total available supply for north-side lands.*

	1905	1906	1907	1908	1909	1910
Quantities from the North Fork which could have been diverted into the north supply canal or stored in Warm Springs Reservoir for subsequent diversion (from Table 7)	277,700	260,500	650,000	627,000	632,000	515,000
Quantities from Bowl Creek which could have been diverted into north supply canal or stored in Warm Springs Reservoir for subsequent diversion	8,000	8,000	.....	.....	.....	12,500
Quantities from Deep Creek and Willow Creek available for lands under the Teton Canal	37,000	37,000	90,000	130,000	152,000	13,000
Total for north-side lands	322,700	305,500	740,000	757,000	784,000	540,000

APPENDIX TO SECTION XIII.

LOWER YELLOWSTONE DIVERSION DAM.

1. *Description.*—This dam is a rock-filled, timber and pile, overfall dam with concrete abutments, one of which forms the head gates of the canal. The crest is straight, measuring 700 feet between abutments; the width of base is 50 feet 4 inches; the maximum elevation of crest above the original river bed is about 12 feet, and above the low-water surface (of 1904) 3.5 feet. The abutment on the right bank is a straight buttressed wall of reenforced concrete. From this abutment a small earth dike with rock-paved slopes, was constructed to connect the abutment with a hillock which is never under water, the object of the dike being to prevent the scouring of a channel around the abutment during ice jams. The ordinary floods will pass over the dam with a maximum depth on the crest of about 8 feet, but at times, due to the formation of ice gorges below, there may be a depth on the crest of 25 feet.

2. The dam consists of seven rows of round piles and an upstream and a downstream row of triple-lap sheet piling. The piling is well tied together with longitudinal and transverse timbers, and the space between the piles is filled with rock. The upstream face is sloping and has a decking of 12 by 12 inch transverse timbers laid in contact. The top and front face of the dam form an ogee section, the decking on this part of the dam being formed of 12 by 12 inch longitudinal timbers laid in contact. To the decking on this face of the dam 1 by 4 inch iron straps, spaced 2 feet between centers measured longitudinally, are secured. The decking of the apron is of 8 by 12 inch timbers laid in contact and perpendicular to the axis of the dam. The toe of the apron is higher than its intersection with the lower face of the dam, the object of this arrangement being to retain a pool of water on the apron when the flow over the dam has ceased. Timber was selected as the material for the superstructure of this dam, because of its being the cheapest and because it was known that the dam would be constantly wet, for several years at least, and therefore the timber would not be liable to decay, it being expected that when, by an increased use of water higher up the river, the dam becomes exposed, the timber decking must be replaced, which can be done with concrete slabs at a relatively small cost.

3. *Headworks.*—The combined headworks and abutment is a massive concrete structure with a height of 45 feet 6 inches, a width at base of 31 feet 6 inches, and a width at crest of 11 feet. The work consists of a straight wall, 163 feet 4 inches long, and two return walls connecting with the high bank. These walls have lengths respectively of 83 feet 9 inches, and 80 feet. There are 11 circular culverts in the wall, each 5 feet in diameter, closed by sliding cast-iron gates. The combined capacity of these openings with the water surface at the crest of the dam is considerably greater than the capacity of the main canal, but the supervising engineer stated that "the area provided is only sufficient to insure the filling of the canal during the probable future low-water discharge of the Yellowstone River, which will, in a few years, at the present rate of appropriations, be materially less than at present. It is likely that within 10 years the openings in this structure may not be much in excess of the actual requirements."

4. *Pile driving.*—The subsoil of the dam is shale and sandstone, with some gravel, and it proved to be a very difficult material into which to drive timber piles. An average penetration of 20 feet was, however, secured. On account of the difficulty encountered in driving the triple-lap sheet piling and the small penetrations obtained in some places, the timber piling at these places was reinforced by steel sheet piling driven in contact with it. During the construction of the dam a large number of round piles had to be pulled on account of drift collecting against them during a flood in the river, causing considerable scour in the bed of the river and endangering the work. After the flood subsided these piles were redriven and the dam finished.

5. *Costs.*—The following is a statement of the costs of this work, as furnished by the local office:

Headworks, total cost	$66,131.33
Dam	333,105.03
Total	399,236.36

6. Based on experience elsewhere this cost appears very high. It is thought that a dam equally secure and equally suitable could have been built following some cheaper type for a much more reasonable expenditure. Possibly, also, a location could have been selected that would have obviated the construction of the dam, taking the water direct from the river by suitable headworks as in the Huntley project.

7. It is stated by the supervising engineer that the fact that they were under necessity of prosecuting the work in midwinter at temperatures of 45 degrees at times, added perhaps 100 per cent to the cost, and that the combination design was adopted as giving almost absolute certainty against being carried away. He states also that the possibility of dispensing with the dam was considered but rejected mainly on account of the lower level at which the headworks would have to be placed, necessitating a much longer useless length of main canal and much heavier excavation, as well as a reduction in the acreage which could be reached by the canal.

APPENDIX TO SECTION XIV.

NORTH PLATTE PROJECT.

[Duty of Pathfinder Reservoir, by A. P. Davis, Chief Engineer.]

The available water supply for the North Platte Valley is indicated by existing records of stream flow as follows:

Orin Junction, Wyo., 1896 to 1899, inclusive.

Guernsey, Wyo., from June, 1900, to 1908, inclusive.

Whalen, Wyo., for 1909 and 1910.

The above observations can be reduced to discharge at a common point with small error.

Alcova, Wyo., 1904 and 1905.

Pathfinder, Wyo., 1905 to 1910 inclusive.

The observations for Alcova and Pathfinder may be taken as practically the same point as there is little difference in drainage area.

An effort has been made to reach a comparison of percentages among these various stations in order to complete unfilled portions of the record from 1896 to date.

Most of the observations of stream flow omit the winter months, but as these are months of low flow and little fluctuation the observations may be supplied without important error by inspection of the tables, and this has been done.

Rainfall observations have been compiled for Saratoga and South Pass City, in the basin of the North Platte, and Waterdale, Laramie, Fort Laramie, and Lander, outside of the basin but sufficiently close and representative to be of some value as indicating the precipitation in the basin itself. The stations of Laramie and Fort Laramie are in the basin of the Laramie River, which empties into the North Platte below the lowest diversion of this river by the Reclamation Service. Lander is to the north in the Big Horn Basin, and Waterdale is in the basin of the South Platte. The records for Saratoga and South Pass City are so badly broken that their utility is greatly impaired. The rainfall observations have been tabulated by years, ending September 30, as precipitation after that date affects the discharge of its own calendar year much less than the year following.

In the years 1905 to 1908 coincident odservations of stream flow were made at Pathfinder and at Guernsey.

During 1909 and 1910 coincident observations were made at Pathfinder and Whalen, and as the discharge was practically the same at Guernsey and at Whalen the years 1905 to 1910 can be taken as indicating the relative percentage of run-off at Pathfinder and at Guernsey.

The mean of these percentages by months is as follows, taking Guernsey as 100 per cent:

TABLE I.—*Comparative discharge at Pathfinder and Guernsey.*

Months.	Pathfinder.	Guernsey.	Percentage Pathfinder of Guernsey.
	Acre-feet.	*Acre-feet.*	
January, 1910	37,796	40,474	94
February, 1910	20,564	34,506	59
March (3 years)	90,038	115,933	78
April (4 years)	137,364	178,112	77
May (6 years)	308,976	331,427	93
June (6 years)	511,858	559,295	91
July (6 years)	195,976	270,392	73
August (6 years)	59,582	138,318	43
September (5 years)	38,482	67,410	57
October (5 years)	37,353	75,454	49
November, 1909	44,688	60,114	74
December, 1909	33,572	47,268	71
Total	1,446,249	1,918,703	76

Using the above percentages the discharge for Pathfinder is extrapolated for the years 1896 to 1903, inclusive, and the observations at Alcova are taken for 1904 as showing the flow at Pathfinder.

We thereby have discharge values from 1906 to 1910, inclusive, for Pathfinder and Guernsey as shown in the following table, which also shows for four successive years the flow of the Laramie River at Uva, near its mouth, for the months of May and June. This flow represents only a small fraction of the flow of the Laramie River, the major part being diverted above Uva.

The flow given would be available for the satisfaction of prior rights below the interstate canal.

The table also gives for the five years of actual synchronous observations, the difference for May and June, showing the run-off for those months of the area between Pathfinder and Guernsey.

This will be used later.

In each case the year ending September 30 is taken:

TABLE II.—*Observed and estimated discharge of North Platte River.*

Year ending Sept. 30—	Pathfinder.	Orin.	Difference.	Summer flow, Laramie, at Uva, May and June.	Rain.[1]	Rain.[2]
1896	[3] 966,000	1,200,000	234,000	30,000	14.85	.....
1897	[3] 1,895,000	2,239,000	345,000	139,000	12.55	.....
1898	[3] 982,000	1,184,000	202,000	64,000	13.43	.....
1899	[3] 3,022,000	3,851,000	829,000	233,000	12.34	.....
1900	[3] 917,000	[4] 1,099,000	182,000	.....	16.15	12.95
1901	[3] 1,333,000	[4] 1,561,000	228,000	.....	12.61	24.56
1902	[3] 942,000	[4] 1,110,000	168,000	.....	11.22	10.22
1903	[3] 1,228,000	[4] 1,494,000	266,000	.....	12.52	14.31
1904	[5] 1,266,000	[4] 1,620,000	354,000	[6] 163,000	12.79	.....
1905	[5] 1,175,000	[4] 1,694,000	519,000	[6] 230,000	14.25	.....
1906	1,410,000	[4] 1,725,000	315,000	[6] 120,000	16.41	18.31
1907	1,787,000	[4] 2,408,000	621,000	[6] 261,000	13.97	16.21
1908	959,000	[4] 1,565,000	606,000	[6] 494,000	14.45	.....
1909	2,257,000	[7] 2,512,000	255,000	.....	15.33	.....
1910	929,000	[7] 1,194,000	265,000	.....	10.69	19.26
Mean	1,411,000	1,764,000	352,000	.....	.....	.....

[1] Mean of Lander, Waterdale, Laramie and Fort Laramie.
[2] Mean of Saratoga and South Pass City.
[3] 76 per cent of observed discharge at Orin or Guernsey.
[4] At Guernsey.
[5] Measured discharge at Alcova.
[6] Between Pathfinder and Guernsey, May and June only.
[7] At Whalen.

It will be noted that six years in the record show less than 1,100,000 acre-feet run-off at Pathfinder and that the low years contained in this record never occur consecutively. This condition is favorable for utilizing the surplus storage capacity of the Pathfinder Reservoir. The last year in the record, 929,000 acre-feet, is the year 1910, which is pronounced by settlers the driest year ever known, and it seems to consider this near the minimum, although the record indicates an estimated flow for 1900 slightly lower, and the record at Saratoga indicates a lower rainfall in 1902.

There are many claims to the waters of the North Platte that antedate Government filings, but only a portion of these have been actually applied to beneficial use.

An adjudication of these has recently been made by the State engineers of Wyoming and Nebraska, amounting to 463 cubic feet per second in Wyoming and 4.618 feet in Nebraska. The adjudication for Wyoming may be fairly reasonable, but that for Nebraska is evidently excessive and sheds little light upon the amount that must be allowed to pass the Government diversion dam. For example, 1801 second-feet were adjudicated to the region east of Bridgeport, while only 100 second-feet were demanded there last year, the driest for many years. Of the adjudicated areas, both above and below Bridgeport, a large portion is swamp land in the North Platte Bottoms, and part of the necessary water is furnished by return seepage from the old irrigated lands. From an intimate knowledge of the valley the project engineer expresses the

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opinion that 2,000 second-feet will cover all existing valid prior rights. The Nebraska adjudication is of no force in Wyoming where the proposed diversions are located, and the adjudication made would not stand in a Federal court. Nevertheless, it would hardly be safe to ignore it at the present time.

Of the total adjudication it is believed to be very conservative to assume that no more than 3,000 cubic feet per second will be actually demanded, and this, of course, only during the time when the natural flow of the river is furnishing this amount. When it falls below this amount the later rights must go short unless they arrange for stored water from the Government reservoirs.

The following table shows the dates at which the river declined to specified discharges in the period of record:

Flow of Platte at Guernsey on dates mentioned.

Year.	5,000 second-feet.	3,000 second-feet.	2,000 second-feet.
1902	June 22	June 22	July 1.
1903	June 29	July 11	July 16.
1904	June 27	July 13	July 18.
1905	June 30	July 11	July 22.
1906	June 26	July 25	July 26.
1907	July 12	July 26	Aug. 7.
1908	June 26	July 10	July 13.
1909	July 14	July 20	Aug. 5.
1910	May 18	June 10	June 20.

On the above assumption the Reclamation Service may store at Pathfinder only such amounts as are in excess of the needs of the canals using 3,000 second-feet in the height of the season. After the river discharge declines below 3,000 cubic feet per second, which usually occurs in July, the entire flow of the river must be allowed to flow through the reservoir in addition to the draft for reclamation uses. The irrigation season usually closes about October 1, and the little water needed after that date may be obtained from the run-off and seepage below Guernsey. The amounts that would, under these assumptions, have been released from storage as the river declined is given for five years in the following table:

TABLE III.—*Water to release from reservoir to satisfy prior rights after July 1.*

	1904	1905	1906	1907	1908	1909
July	110,000	108,000	137,000	180,000	122,000	150,000
August	36,000	37,000	41,000	84,000	75,000	80,000
September	23,000	16,000	39,000	35,000	33,000	70,000
Total	169,000	161,000	217,000	299,000	230,000	300,000
Less excess flow above Guernsey	.....	.....	70,000	90,000	10,000	.....
Net amount	169,000	161,000	147,000	209,000	220,000	300,000

The item "Less excess flow above Guernsey" refers to the inflow between Pathfinder and Guernsey while the flow at Guernsey is above 3,000 second-feet.

The region furnishing water to the North Platte Valley above Gering may be considered in four parts:

1. The region above Pathfinder tributary thereto; drainage area 12,000 square miles. Observations of stream flow at or near this point cover seven years, from 1904 to 1910, given in Table II.

2. The region below Pathfinder and above Guernsey, with an area of 4,240 square miles, from which the runoff can be obtained by comparing the measurements at Pathfinder with those at Guernsey. By means of regulation at Guernsey this can be made available. (See Table II.)

3. The drainage basin on Laramie River above Uva, with an area of 3,180 square miles, for which we have observations of the flow at Uva for four years, 1896 to 1899, inclusive. Most of the run-off of Laramie River is diverted above Uva for irrigation, and the measured discharge is the residue and return

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seepage at that point, and is available for the satisfaction of water rights below the mouth of the Laramie. (See Table II.)

4. The portion of the basin below Guernsey and above Gering, exclusive of the Laramie above Uva. This area is 4,920 square miles. In this stretch of the river most of the ditches having prior rights divert water. The best available data for the run-off of this region is by comparison with the discharge from the region between Pathfinder and Guernsey. The measurements at the latter points show by comparison the run-off of this part of the basin in excess of diversions. The region between Guernsey and Gering is similar in topography, but lower in altitude, with a lighter rainfall, but is known to contribute an important supply in the irrigation season. As the drainage area is larger, it is believed, to be conservative, to estimate its drainage to be equal to that between Pathfinder and Guernsey less the diversions in that region, and this estimate is here used.

During the month of June it is expected that for prior rights the maximum quantity would be required throughout the month, 3,000 second-feet for 30 days, or about 180,000 acre-feet. In May a less amount is required, say 160,000 acre-feet, making a total of 340,000 acre-feet required to satisfy prior rights to June 30. This could be supplied from the following sources:

Water for prior rights in May and June:	
From Laramie River, value for 1896 (Table II)	30,000
Other drainage below Guernsey (estimated)	120,000
Run-off between Pathfinder and Guernsey (Table II, 1906)	120,000
Balance from reservoir	70,000
Total supply for May and June priorities	340,000

The draft of 70,000 added to the 220,000 (see Table III) passing through the reservoir after July 1 gives a total of 290,000 acre-feet to be deducted from the supply above Pathfinder to satisfy prior rights.

From the above we may assume that the amount of water that must pass the Pathfinder Reservoir, which cannot on account of prior rights be held there, is 300,000 acre-feet per annum.

The large required amount indicated in Table III for the year 1909 is due to the excessive flow of that year, and would have been wasted in any event, because of a full reservoir. It may, therefore, be disregarded. Aside from this, the highest year is 1908, in which 220,000 acre-feet would have passed through the reservoir after July 1. Little irrigation is done in April, and this in the latter part. This period is one of rather large run-off from the low country, and there would always be plenty of water for all prior rights in April from the run-off below Pathfinder.

The contracts on the North Platte project allow a water supply limited to beneficial use of not to exceed 2½ feet in depth. As not all land with water right is under cultivation at any one time, and as much grain and other crops of short season will always be grown, it seems safe to assume that the actual average consumption of water will be considerably less than 2½ feet measured on the land. To furnish this we may assume that it will be necessary to provide 3 acre-feet in the reservoir for every acre holding full water right.

In addition to prior rights above mentioned, it is desirable to provide a full water supply to the following lands:

	Acres.
Interstate Canal	115,000
Goshen Park high line	150,000
Fort Laramie Canal	50,000
Total	315,000

In addition to the above there is an indefinite area of land in private ownership above Guernsey and under the Tristate Canal aggregating over 100,000 acres, which may or may not apply for reservoir rights in the future under the terms of the reclamation act. The purpose of this discussion is to determine as approximately as possible what acreage we can safely undertake to water in order to proceed along a rational plan.

Of the above area under the Interstate Canal, 30,000 acres is to be watered from small reservoirs to be constructed on the project which will be filled partly by waste water from that canal, but mainly from the run-off of the area below Pathfinder in the fall and early spring. It is believed to be safe, there-

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fore, to eliminate this area from that to be supplied from the Pathfinder Reservoir.

In the ultimate development there will be considerable return seepage from the upper lands available for the Interstate Canal and for the prior rights below, and though no data on this point is available, it seems conservative to estimate that this will be sufficient for the irrigation of about 30,000 acres. The deduction of this area leaves a total of 255,000 acres to be supplied with irrigation water from the contemplated Government works.

The year ending September 30, 1900, as given in Table II, is the lowest in the record, and is followed by a year of less than average supply, and this in turn by one of the lowest in the record. This constitutes the most severe combination in the record.

The heavy discharge in the year 1899 insures a full reservoir June 30, 1900. According to our assumptions, prior rights would have required after that date 220,000 acre-feet of water, and 315,000 acres in the Government projects would have required 60 per cent of a full supply, or 567,000 acre-feet. This would have left 313,000 acre-feet in the reservoir. We would have had—

Remaining in reservoir Sept. 30, 1900		313,000
Run-off for 1901		1,333,000
		1,646,000
Evaporation	45,000	
Prior rights	300,000	
Irrigation draft	945,000	
		1,290,000
Remaining in reservoir Sept. 30, 1901		356,000
Run-off for 1902		942,000
		1,298,000
Evaporation	50,000	
Prior rights	300,000	
Irrigation draft	945,000	
		1,295,000
Balance		3,000

According to the above we may safely construct both the Goshen Park line and the Fort Laramie Canal and have sufficient water to supply 30,000 acres of private land and as much more as may be supplied from the return seepage water from the above systems. The demand for this is developed only to a very small extent as yet.

If two or more years in succession should occur with discharge as low as that of 1900, there would still be more than a 70 per cent supply, which would not be disastrous, but is such a shortage as we should expect at long intervals under a proper development. Also, the same acreage may be served if the minimum year should furnish a supply much smaller than any now of record, provided it does not occur two years in succession.

In case of a large private demand for stored water, or that some of the above assumptions are more favorable than facts will justify, it may be found desirable to omit the Fort Laramie Canal, or to build it of smaller dimensions than now contemplated. In this there is such a margin that there can be no doubt of the water supply being sufficient for the Goshen Park project if desirable to use it there.

It is believed, however, that the greatest error in the above assumptions is the large amount set aside for prior rights, namely, 3,000 cubic feet per second. If this can be held down to 2,000 second-feet, according to the estimate of the project engineer, it will add about 80,000 acres to the above duty.

APPENDIX TO SECTION XV.

TRUCKEE-CARSON PROJECT.

WATER SUPPLY.

1. The water supply for this project is obtained from the Carson and Truckee Rivers, a canal with a capacity of 1,200 second-feet, diverting the flow from the latter to the Carson.

2. The project provided for the regulation of the flow of the Truckee River by means of storage at Lake Tahoe, and the construction of storage reservoirs on the Lower Carson River, known as the Carson Reservoir, with a capacity of 290,000 acre-feet, and Alkali Flat Reservoir, the capacity of which is at the present time undetermined, but will be approximately 228,000 acre-feet.

3. The following condensed statement of the available supply and irrigation requirements for the Truckee-Carson project has been prepared for the board by the supervising engineer:

"The average flow of the Truckee River at Vista, Nev., a gauging station a few miles above the Derby Dam but below the irrigated lands at Reno, is 880,000 acre-feet per annum during the period 1900 to 1907, inclusive. Excepting about 30 second-feet during the irrigation season, all of this flow is available for diversion for the Truckee-Carson project.

"The average flow of the Carson River at Empire, Nev., a point a few miles above the proposed Carson Dam, is 364,000 acre-feet per annum after making deduction for all vested rights on the river. This amount is, therefore, all available for use on the Truckee-Carson project.

"By regulating the flow of the Truckee River by means of storage at Lake Tahoe it will be possible to deliver water through the main Truckee Canal into the proposed Carson Reservoir to an annual amount of 710,000 acre-feet, This is the net amount after making appropriate deductions for vested rights along the Truckee River and the irrigation supply for lands under the Truckee-Carson project between the Derby Dam and the Carson Dam.

"There will therefore be available in the Carson Reservoir an average annual supply of 1,070,000 acre-feet, made up of 360,000 acre-feet from the Carson and 710,000 acre-feet from the Truckee.

"In order to irrigate 172,000 acres below the Carson Dam there will be required 602,000 acre-feet of water, allowing 3.5 acre-feet per acre. Of this amount 312,000 acre-feet can be turned directly from the Truckee main canal into the Carson River and thence onto the irrigable lands without utilizing any storage. The balance of 290,000 acre-feet will have to be supplied from storage on the Carson River.

"The 290,000 acre-feet of storage water can be derived from deliveries from the Truckee main canal into the Carson Reservoir during the nonirrigating season, or from the natural flow of the Carson River into the Carson Reservoir, or both. In practical operation it will probably be found advantageous to use Carson River water as far as it will go, making up the deficiency by deliveries from the Truckee main canal during the nonirrigating season. This will permit the service of the main canal to be discontinued during a considerable portion of the nonirrigating season.

"Hydrographic studies show that at no time during a nine-year period over which records extend would the Carson River Reservoir have been seriously depleted or reduced below a storage of 100,000 acre-feet.

"The ultimate construction of a reservoir at Alkali Flat will utilize much of the surplus flow of the Carson River for irrigating lands in Churchill Valley.

"It will be noted that apparently a considerable excess supply of the Truckee and Carson Rivers exists. The period over which records extend apparently includes a cycle of excessive precipitation. The California records show that during the seventies a prolonged period of excessive drouth occurred much in excess of anything that had previously or has since been experienced. The apparent margin of safety in the supply works for the Truckee-Carson project as at present designed need not, therefore, be considered as being in any way excessive, as there is a distinct possibility that should a prolonged period of drouth, as before mentioned, recur the supply will not prove more than adequate.

"Accompanying this statement is a tabulation entitled 'Table of requirements and available supply for irrigating various areas of land below Carson Dam.' The land below Carson Dam includes 172.000 acres made up of the first unit,

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districts 3, 4, and 5, and Carson Lake extension. The two remaining branches of the project, viz, Pyramid Lake extension and Churchill Valley, would be watered directly from the Truckee main canal or from the Alkali Flat Reservoir on the Carson River."

4. The above statement assumes a regulated flow in the Truckee River. About a year ago an agreement between the power company controlling the outlet to Lake Tahoe and the Reclamation Service was drafted, under the provisions of which the desired regulation of the Truckee River was to be secured at a very nominal cost to the project, approximately $20,000. This agreement has been before the Secretary of the Interior for some time, but has not received his approval. The regulation of the Truckee River could probably be accomplished by storage elsewhere than in Lake Tahoe, but at a largely increased cost. Some agreement with this company, even at a greater cost to the Truckee-Carson project, is desirable.

5. An examination of the hydrographs of the Truckee and Carson Rivers shows 1908 as a year of minimum flow, and the following table, based upon conditions that year, indicates that, excluding Alkali Flat Reservoir and the land that can be irrigated directly from it in Churchill Valley, only 150,000 acres could have been irrigated in that year had the flow of the Truckee River not been regulated:

Months.	Mean monthly flow.			Monthly demand for 150,000 acres.	Balance required from Carson Reservoir.
	Truckee River less 20 per cent loss in canal.	Carson River.	Combined flow.		
	Second-feet.	*Second-feet.*	*Second-feet.*	*Second-feet.*	*Second-feet.*
April	920	450	1,370	882	.....
May	536	570	1,106	1,537	431
June	496	410	906	1,941	1,035
July	272	150	420	1,878	1,458
August	248	50	298	1,708	1,410
September	216	50	266	529	263
October	336	70	406	171	.....

Being equal to 275,820 acre-feet.

6. As approximately 13,000 acres below Carson Dam has prior vested rights in the unregulated flow of the Carson River, the area under the project that could have been irrigated in this year of low run-off would not have exceeded 140,000 to 145,000 acres, exclusive of Churchill Valley, as against 192,000 acres if the Truckee River had been regulated.

7. By increasing the capacity of Alkali Flat Reservoir above that required for Churchill Valley it may be possible to secure sufficient water for the needs of this project without regulating the flow of the Truckee River, but at greater expense and with less certainty, particularly in view of the probability of a prolonged period of drought such as is said to have occurred in the seventies.

8. The regulation of the flow of the Truckee by means of storage at Lake Tahoe may not be an essential part of this project, but it is a desirable one, as it will reduce the cost per acre and insure an ample supply of water under all conditions.

Table of requirements and available supply for irrigating various areas of land below Carson Dam.

Months.	Available supply delivered from main Truckee Canal.	Monthly demand for 85,000 acres.	Balance required from Carson River.	Monthly demand for 100,000 acres.	Balance required from Carson River.	Monthly demand for 125,000 acres.	Balance required from Carson River.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
January	1,080	.....	.....	.....	.....	.....	.....
February	1,080	.....	.....	.....	.....	.....	.....
March	1,080	.....	.....	.....	.....	.....	.....
April	968	500	.....	588	.....	735	.....
May	902	871	.....	1,025	123	1,281	379
June	826	1,100	274	1,294	468	1,681	792
July	840	1,064	224	1,252	412	1,566	726
August	849	968	119	1,138	289	1,423	574
September	1,003	300	.....	353	.....	441	.....
October	1,039	97	.....	114	.....	142	.....
November	1,080	.....	.....	.....	.....	.....	.....
December	1,080	.....	.....	.....	.....	.....	.....
Total .....acre-feet..	710,000	294,000	37,000	352,000	77,500	436,000	148,000

Months.	Monthly demand for 135,000 acres.	Balance required from Carson River.	Monthly demand for 150,000 acres.	Balance required from Carson River.	Monthly demand for 175,000 acres.	Balance required from Carson River.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
January	.....	.....	.....	.....	.....	.....
February	.....	.....	.....	.....	.....	.....
March	.....	.....	.....	.....	.....	.....
April	794	.....	882	.....	1,029	61
May	1,383	481	1,537	635	1,793	891
June	1,747	921	1,941	1,115	2,264	1,438
July	1,691	851	1.878	1,038	2,191	1,351
August	1,537	688	1,708	859	1,992	1,143
September	476	.....	529	.....	617	.....
October	153	.....	171	.....	199	.....
November	.....	.....	.....	.....	.....	.....
December	.....	.....	.....	.....	.....	.....
Total.....acre-feet..	467,000	176,000	525,000	219.000	612,000	293,000

APPENDIX TO SECTION XXI.

WATER SUPPLY.

1. Water is obtained for this project from Link River and Lost River. Link River, which is the outlet of Upper Klamath Lake, has a drainage area of 3,100 square miles, with an average rainfall on the drainage area of about 20 inches.

2. Discharge measurements have been made continuously since August, 1904, and the results show an average annual run-off of 1,700,000 acre-feet. The mean monthly discharge for this period varies from 3,839 second-feet in April to a minimum of 1,185 second-feet in September. The lowest average daily discharge for any one month was 900 second-feet in September, 1908.

3. Upper Klamath Lake, with an area of 66,000 acres, constitutes a good natural reservoir, and at slight cost additional storage to the extent of 200,000 acre-feet can be provided.

4. An examination of the discharge measurements since 1904 indicates that with such storage no difficulty would have been had in maintaining a constant flow during the irrigating season of not less than 1,400 second-feet. There are prior rights on this river amounting to 325 second-feet, all of which is used in development of power. The requirements of the project are analyzed as follows:

Area to be irrigated.

	Acres.
Lower project uplands	37,000
Tule Lake lands	35,000
	72,000

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5. On the basis of 1 second-foot for each 100 acres, 720 second-feet will be required for this area. Of this amount 100 second-feet will be furnished from Lost River, as described hereafter, and the remainder, 620 second-feet, from Link River through the main canal. For the development of power by the Reclamation Service there will be required 445 second-feet delivered through the Keno Canal, making a total diversion from Link River for the project of 1,065 second-feet. This added to the amount to which prior appropriators are entitled equals 1,390 second-feet, or practically the amount obtainable from Link River after its flow has been regulated as above described.

6. Lower Klamath marshes, if drained in accordance with the present plans, will also be irrigated with water discharging from Link River. As the point of diversion will be below the power plants there will be an abundance of water for this purpose.

7. Discharge measurements of Lost River have been made since 1904 and show an average annual run-off of 118,960 acre-feet below Clear Lake Dam, the drainage area above this point being 600 square miles. To regulate the flow of this river, Clear Lake Reservoir has been built. It has an area of 25,000 acres and an available capacity of 462,000 acre-feet. The primary purpose of this reservoir was to store the flood waters of Lost River and increase the evaporation loss therefrom so as to permit the reclamation of part of Tule Lake by evaporation, but it also serves to store water that can subsequently be used in irrigation.

8. A study of the history of this reservoir, assuming it to have been built in 1904, and assuming that commencing with the season of 1906 an annual irrigation draft had been made upon it of 75,000 acre-feet (sufficient for watering 30,000 acres) shows that during the entire period covered by the records the reservoir would have been full at no time, and that during the past four years there would, probably, not have been sufficient water for the full irrigation of the 30,000 acres. As to the effect of this reservoir upon Tule Lake, an analysis made by the Reclamation Service indicates that with a yearly evaporation of 4.65 feet the surface level of Tule Lake would have been reduced about 6 feet in a little over five years, a rate of recession that would delay for an unreasonable length of time the reclamation of submerged Tule Lake lands. To hasten this result, a diversion channel has been planned leading from Lost River to Klamath River. As to the size of this channel the following is quoted from a report by the project engineer:

"The diversion of water from Lost River through a 200 second-feet capacity channel would have lowered the surface of Tule Lake an additional 5 feet, or to a total of 11 feet in the period under consideration. Additional diversion through a 400 second-feet channel, instead of one of 200 second-feet, would have lowered the lake surface but an additional 2 feet during the same time.

"These computations may be considered as showing the most favorable conditions, as no correction has been made for the inevitable increase of discharge of Lost River due to return water from irrigation on the lower project, and from a similar source on the upper project in case the latter, eventually, should be irrigated. It is considered, however, that the fact of this return water could be offset by making the actual capacity of the drainage canal about 50 second-feet greater than the figures used for purposes of computing diversion. Some further corrections would have to be made if the computations of amount diverted through the Lost River diversion channel should be computed from daily discharge measurements, rather than from monthly totals. Such computations have been made in part, but are found to have an inappreciable effect on the general result."

9. The analysis as to what might have been accomplished during the past five years has been continued by the Reclamation Service up to and including 1913 under the assumption that the rainfall conditions for the years 1906–1909 could be applied to the succeeding four years, from which it appears that at the end of 1913 the surface of Tule Lake would have been at elevation 4,038, equivalent to a total lowering of 18 feet and to the reclamation of about 35,000 acres. Under the assumptions made this work would have required nine years from the completion of Clear Lake Dam and the Lost River diversion.

10. The studies of the Reclamation Service relative to the reclamation of Tule Lake lands contain many elements entering into the problem, such as run-off from the surrounding drainage basin, rainfall in the future, seepage from lands now being placed under irrigation, that are more or less indeterminate, and time alone can decide whether the assumptions made are warranted. That

35,000 acres of these lands can, eventually, be reclaimed in the manner proposed seems probable.

11. Water for irrigating Tule Lake lands may be obtained from Link River, or from Lost River. If the Modoc subproject is built the bulk of it will be obtained from Link River. In considering above the draft upon Link River, it was assumed that only 100 second-feet of the amount required for the Tule Lake lands would be obtained from Lost River, this amount being available in the lower reaches without trespassing upon Clear Lake storage.

12. The Modoc subproject, if constructed, will be watered from Clear Lake Reservoir. It is estimated that there will be sufficient water in this reservoir for the irrigation of from 25,000 to 30,000 acres, and as the Modoc subproject covers only 18,000 acres, there will be a balance probably sufficient to satisfy certain undetermined prior rights in Upper Langell Valley that are now in the process of adjudication.

13. The upper subproject, if constructed, will depend for its supply upon Miller Creek, the annual run-off of which averages 70,000 acre-feet, varying from a maximum of 125,000 acre-feet in 1907 to a minimum of 19,000 acre-feet in 1908. With the proposed Horsefly Reservoir, having a capacity of 55,000 acre-feet, it is reasonable to assume that there will be available not less than 40,000 acre-feet each year. Only 1½ acre-feet per acre are deemed necessary on the land. Seepage and evaporation losses are assumed by the Reclamation Service at 40 per cent, thus requiring a reservoir allowance of 2½ acre-feet per acre. At this rate there will be sufficient for 16,000 acres. These allowances are liberal and it may be found possible to subsequently increase the acreage under this subproject.

Appendix to Section XXII.

BELLE FOURCHE PROJECT.

1. *Reservoir Dam.*—This is of earth fill, without core wall, which type was adopted mainly on account of the character of subsoil and the material available for the fill. The general dimensions are: Length on top, 6,200 feet; width on top, 19 feet; maximum height, 115 feet above stream bed; side slope, 2 to 1 on the inside, except that below the concrete toe wall the slope is 5 to 1, and for the uppermost 15 feet is 1¼ to 1. On the outside the slope is 2 to 1 except for the uppermost 30 feet where it is 1.65 to 1. The downstream slope is strengthened by two berms, 8 feet wide, provided with concrete drainage gutters. The dam will contain, when completed, 1,600,000 cubic yards of earth and 45,000 cubic yards of gravel. A cut-off trench was excavated the full length of the dam along its center line, and filled with selected material. The earth fill was deposited in 6-inch layers, wetted, and rolled with a steam roller. A drawing showing the cross section of the dam is appended hereto.

2. There is considerable gypsum in the vicinity, and efforts were made to exclude it from the material used in the body of the dam, borrow pits being selected with this end in view. In the fourth annual report of the Reclamation Service it was stated that the "material of which it will be built is heavy clay and gumbo, which weighs in some places 120 pounds per cubic foot." and "a number of open borrow pits were sunk to bedrock under the proposed dam, and it was found that the distance to shale under the body of the dam was 40 feet. No continuous gravel or water-bearing strata were encountered, and the base under the dam will therefore be impervious. All borrow pits at which earth or gravel is to be obtained were carefully investigated by open test wells and borings. An examination and analysis of the earth to be used in the dam was made by H. Means, and his report showed only a small amount of soluble matter in the material from most of the borrow pits, but in two pits there was a large percentage of gypsum, and this material will not be used."

3. The methods followed in preparing the site and in depositing the fill are those used in good engineering practice. The concrete block facing on the waterside is especially substantial. It is made of slabs, 6 feet by 4 feet, and 8 inches thick, molded in a yard and later placed on a 24-inch layer of screened gravel. The facing is held in place at the foot by a concrete toe wall. The two concrete gutters on the upper and lower berms on the downstream side are well suited to their purpose. An ample spillway is provided to take care of floods,

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the crest being 15 feet below the top of the dam. This spillway is semicircular in plan and 314 feet in length. The fall of the water over the crest is broken by two concrete steps, after which the water flows in a concrete-lined channel on a 4 per cent grade to the foot of the slope, and there is discharged into the river bed, which is protected against undue erosion by concrete work.

4. The capacity of the reservoir is 204,000 acre-feet. Two outlets are provided, one for the north and one for the south main canal, with capacities of 650 and 300 second-feet, respectively. The gates in each are in duplicate, those nearest the reservoir being of the piston type, while those in the rear are of the sliding type. The clear opening of the gates is 4 feet by 6 feet. The proportions used in concrete were 1 cement, 2¼ sand, and 4½ gravel.

5. *Comment.* The board deems it prudent to call attention to the relative steepness of the side slopes for the dam. Usually these slopes, especially on the upstream side, in dams of this height and character without core wall, are not steeper than 3 on 1, to avoid sloughing when the reservoir is drawn down and when under full head to keep the hydraulic grade line through the dam and subsoil from coming to the surface on the downstream slope or too near the toe. This may be accomplished with the steeper downstream slopes, but to assume that it is satisfactorily done in any particular case necessarily places great reliance on the results of the methods of construction followed and material used to obtain water-tightness in the dam, a reliance not always justified. The best practice, therefore, while using every precaution in construction, also usually adopts the flatter side slopes.

6. In the present instance, the dam has not been exposed to the full head; in fact, the water has risen to less than half the projected height. While there has been no appearance of seepage through the dam itself, there has appeared some seepage apparently through the subsoil at a point about 100 feet to one side of the maximum section and a short distance below the toe.

7. This indicates that there is some leakage through the dam or that the subsoil is more permeable than as stated in the quotation above.

8. In view of this and of the great damage the failure of the dam would occasion, it is thought that it should be carefully watched for several years to detect any signs of weakness.

9. The total cost to date has been $950,231.46, and the estimated additional cost to complete it is $166,000, or a total of $1,116,000 in round numbers. These figures include all overhead charges.

Appendix No. 1 to Section XXV.

WATER SUPPLY.

Summary of data and conclusions, final development Yakima project.

I. CAPACITY OF RESERVOIRS.

Name of reservoir.	Capacity (acre-feet).	Remarks.
Keechelus	142,000	Upper lakes, 778,000 acre-feet.
Kachess	210,000	
Clealum	426,000	
Bumping	35,000	
McAllister	115,000	Naches, 150,000 acre-feet.
Total	928,000	

Summary of data and conclusions, final development of Yakima project—Continued.

II. ACREAGE AND ESTIMATED STORAGE REQUIREMENTS.

[Based upon an irrigation season from April to October 15, inclusive, and high line acreage of 160,000. Storage movement by years given below.]

Project.	Point of diversion.	Total acres under project.	Acreage requiring storage.[1]	Mean August requirement.		Storage charge (acre-feet).[2]	Duty of storage water (acre-feet per acre).[3]
				Duty (second-feet per acre).	Diversion (second-feet).		
Kittitas	Easton	67,000	67,000	1.84	800	146,000	2.18
High Line	Teanaway	160,000	160,000	1.80	2,000	366,000	2.28
Tieton	Tieton River	34,000	34,000	1.106	320	59,000	1.73
Wapato	Union Gap	120,000	108,000	1.80	1,350	247,000	2.28
Sunnyside	do	100,000	48,000	1.80	600	110,000	2.28
Total		481,000	417,000		5,070	928,000	2.22

[1] The Sunnyside project has 650 second-feet of natural river flow. This is considered as serving 650 by 80, or 52,000 acres without storage. Also Wapato has 150 second-feet, considered as serving 12,000 acres without storage.

[2] This storage charge is computed on a basis of the acreage under each project which will require storage and the diversion per acre for the project.

[3] This may be termed the storage charge per acre.

III. PRIVATE CANALS.

All private canals above Union Gap are provided for on basis of past usage. The private canals in the lower valley will receive a sufficient quantity for their needs from return flow.

IV. PLEDGED STORAGE.

Cascade County: An allowance of 17,000 acre-feet is provided from storage as follows: July 20–31, 113 second-feet; August, 115 second-feet; September, 92 second-feet; October, 1–15, 58 second-feet.

Union Gay Irrigation Co.: The small quantity of storage due this company is considered as coming from Kittitas return flow.

V. HOLDOVER.

As the two Naches reservoirs will always have a considerable excess run-off available, no holdover should be stored in them. For the following summary the holdover has been considered as stored as follows: Keechelus, 10 per cent; Kachess, 40 per cent; Clealum, 50 per cent.

VI. KACHESS FEED CANAL.

For this scheme of development, no necessity for a feed canal from Keechelus to Kachess has arisen during the past seven years of record. Conditions might arise that would make such a canal operative; for example, if a year like 1908 had followed the year 1906. It would seem, however, that the probability of such necessity is not very great.

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Summary of storage movement, by years, final development Yakima project.

[Basis of summary: Reservoir capacity and project acreage as noted on sheet 1; provision for private canals (sheet 2). Irrigation season April 1 to October 15. Storage season starts November 1. **Summary from hydrographs.**]

Season and reservoir.	Storable run-off.	Hold over from year previous.	Total quantity stored for season.	Storable water lost for lack of reservoir. capacity.	Project.	Acreage to required storage.	Total storage (from hydrography).
1904:							
Keechelus	151,000		142,000		Kittitas	67,000	71,000
Kachess	199,000		210,000		Sunnyside	48,000	
Clealum	534,000		426,000		Wapato	108,000	306,000
Naches			150,000		Tieton	34,000	
					High line	160,000	253,000
Total			928,000		Cascade County		17,000
Next season hold over			261,000		Pass S. S. Dam		20,000
Total used			667,000		Total	417,000	667,000
1905:							
Keechelus	130,000	26,000	142,000	14,000	Kittitas	67,000	76,000
Kachess	155,000	104,000	210,000	49,000	Sunnyside	48,000	
Clealum	270,000	131,000	426,000		Wapato	108,000	368,000
Naches			150,000		Tieton	34,000	
					High line	160,000	288,000
Total		261,000	928,000	38,000	Cascade County		17,000
Next season hold over			159,000		Pass S. S. Dam		20,000
Total used			769,000		Total	417,000	769,000
1906:							
Keechelus	132,000	16,000	142,000	6,000	Kittitas	67,000	94,000
Kachess	141,000	64,000	210,000		Sunnyside	48,000	
Clealum	346,000	79,000	426,000		Wapato	108,000	450,000
Naches			150,000		Tieton	34,000	
					High line	160,000	333,000
Total		159,000	928,000		Cascade County		17,000
Next season hold over			14,000		Pass S. S. Dam		20,000
Total used			914,000		Total	417,000	914,000
1907:							
Keechelus	220,000	1,000	142,000	79,000	Kittitas	67,000	98,000
Kachess	209,000	6,000	210,000	5,000	Sunnyside	48,000	
Clealum	527,000	7,000	426,000	108,000	Wapato	108,000	360,000
Naches			150,000		Tieton	34,000	
					High line	160,000	320,000
Total		14,000	928,000	192,000	Cascade County		17,000
Next season hold over			113,000		Pass S. S. Dam		20,000
Total used			815,000		Total	417,000	815,000
1908:							
Keechelus	170,000	11,000	142,000	39,000	Kittitas	67,000	66,000
Kachess	188,000	45,000	210,000	23,000	Sunnyside	48,000	
Clealum	447,000	57,000	426,000	78,000	Wapato	108,000	258,000
Naches			150,000		Tieton	34,000	
					High line	160,000	240,000
Total		113,000	928,000	140,000	Cascade County		17,000
Next season hold over			327,000		Pass S. S. Dam		20,000
Total used			601,000		Total	417,000	601,000
1909:							
Keechelus	120,000	33,000	142,000	11,000	Kittitas	67,000	77,000
Kachess	146,000	131,000	210,000	67,000	Sunnyside	48,000	
Clealum	307,000	163,000	426,000	44,000	Wapato	108,000	361,000
Naches			150,000		Tieton	34,000	
					High line	160,000	293,000
Total		327,000	928,000	122,000	Cascade County		17,000
Next season hold over			160,000		Pass S. S. Dam		20,000
Total used			768,000		Total	417,000	768,000
1910:							
Keechelus	227,000	16,000	142,000	101,000	Kittitas	67,000	102,000
Kachess	228,000	64,000	210,000	82,000	Sunnyside	48,000	
Clealum	590,000	80,000	426,000	244,000	Wapato	108,000	416,000
Naches			150,000		Tieton	34,000	
					High line	160,000	360,000
Total		160,000	928,000	427,000	Cascade County		17,000
Next season hold over			13,000		Pass S. S. Dam		20,000
Total used			915,000		Total	417,000	915,000

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APPENDIX No. 2 TO SECTION XXV.

M'ALLISTER MEADOWS RESERVOIR SITE.

1. The McAllister Meadows Storage Reservoir site was visited by a committee of the board on August 30, 1910.

2. This reservoir site is located on the headwaters of the Tieton River. At the present time there is no water stored in this locality, the site consisting of meadow land which it is proposed to flood by the construction of a high dam in the Tieton River, backing water up into the North and South Forks. It is expected that a spillway can be placed in a low portion of the rim of this reservoir, now occupied by Milk River, a small stream flowing into the Tieton. This site, however, has not been explored, and the construction of a spillway may involve many engineering difficulties, increasing the cost above what is now estimated. If the present plans are carried out, McAllister Meadows will be developed into the fourth reservoir, in point of size, in the Yakima project.

3. The dam site is in a narrow gorge of the Tieton River, where the width is not over 300 yards between the high rock headlands on both sides of the canyon, furnishing what appears to be excellent abutments for dam construction. Borings have been made in the dam site and drifts have been dug to develop the underlying material. It appears from these, as far as now completed, that the rock faces of the canyon on either side continue at about the present slope to great depths. The intervening space across the bottom of the canyon is filled with bowlders, broken rocks, and disintegrated material. Some borings as deep as 80 feet were made without striking any more solid material.

4. As this site is impracticable for a masonry dam, some sort of earth or rock fill dam will be necessary. This construction, and the estimates of the Reclamation Service have been based upon a structure of this type, is contingent on adequate spillway facilities, as no overflow can be permitted to take place over a dam of the character suggested.

5. This estimate the committee believes to be somewhat low, and it may be desirable to revise these figures after further examinations are made of the possible spillway sites.

6. The capacity of the McAllister Meadows Reservoir is to be 115,000 acre-feet. The maximum height of proposed dam is 150 feet, length on crest 900 feet, and the estimated cubical contents about 450,000 cubic yards.

APPENDIX No. 3 TO SECTION XXV.

BUMPING LAKE RESERVOIR.

1. Bumping Lake is located in Washington, about 46 miles from Naches, the nearest railway point. The object of this reservoir is to store the flood waters of the lake for use in the Yakima project. It was visited on August 30 and 31 by a committee of the board.

2. The capacity of the reservoir is 34,000 acre-feet and the variation of water level 35 feet. The work consists in the construction of a dam across the Bumping River about one-half of a mile below the lake, the spillway, and the discharge conduit and accessories. At the time of the inspection the work was approximately 75 per cent completed and it is proposed to finish it this season.

3. The dam is of the earth-fill type, 45 feet in total height and 3,500 feet in length. The width on top is 20 feet. The side slopes are 3 to 1 on the reservoir side and 2 to 1 on the downstream side. This latter slope flattens out to 4 to 1 near the toe. In plan the dam is slightly curved to follow the high ground and reduce the embankment.

4. The materials for the fill are excavated from a borrow pit by steam shovel, loaded on small dump cars and hauled by horses on a railway to the dam site. The line from the borrow pit branches at the end of the dam into two lines, one of which follows each slope of the dam. The cars are dumped toward the center of the dam, forming two parallel embankments. The fine material is then washed down toward the center by water from pressure nozzles, thus forming a sluice-fill core, leaving the heavier gravel and bowlders to form the outside portions of the dam. The tracks are shifted as the dam rises and the core thus becomes progressively thinner and the proper slope is given to

the faces. The reservoir face is being paved with a 2-foot layer of bowlders of more or less rounded shape and of varying sizes. These bowlders are obtained in part by selection of the larger ones exposed in sluicing down the finer materials, but mainly from the spillway excavation. The subsoil is gravel, bowlders, and volcanic earth in varying proportions. Undisturbed it seems fairly compact, but is thought to be somewhat porous. The earthy part is easily eroded when exposed to water currents. Originally it was the intention to put in a core wall of puddle, but on account of the difficulty in obtaining suitable materials, the sluicing method was adopted. In addition to the excavation for the core wall, all vegetable matter was removed from the site of the dam. The right abutment is the natural soil stripped as above described. The left abutment of the dam forms part of the spillway.

5. While it was designed to have the sluice-fill core throughout the whole length of dam, owing to failure of water supply last year a portion of the dam was constructed without a sluice core. This portion, however, lies near the right end and forms the part of the dam with least height. The material as a whole is not of the best for the purpose. The earthy part, being volcanic ash, is very fine, while the remainder, forming only a small proportion, is composed of more or less rounded bowlders, none of which are very small. The water tightness of the dam depends entirely on the sluice-filled core. The embankments may be expected to wash more or less badly from rains and melting snows, where not protected. Drift and ice may also damage the interior slope. On account of the lightness of the material, seepage and erosion must be carefully watched and a protecting covering on crest and downstream slope may be necessary.

6. The outlet is through a concrete conduit under the dam near its center. It is controlled by four gates, two of which are emergency and two for regular operation. The maximum capacity of the outlet works is 1,000 cubic feet per second, while the normal discharge is to be 400 cubic-feet per second. The gates are operated by hand and are set in a concrete gate tower surmounted by a wooden gatehouse, connected with dam crest by small foot bridge. The opening given by each gate is 5 feet square.

7. The spillway is 235 feet clear length, and is designed to pass 6,000 second-feet with a crest depth of 4 feet. The cross section shows a vertical back and ogee front face, the fall being 6 feet. The fore bay is paved for some distance, and is level with the crest of the spillway, which is 10 feet below the crest of the dam. The abutments are of the buttressed reenforced concrete type. The walls are carried downstream to join the concrete lining of the discharge channel. This channel narrows to 42 feet width, where it joins a wooden flume 115 feet long discharging into the river. The bed of the river where the water falls will be protected by large bowlders. The flume as designed is of very heavy construction and is to be supported by three sets of piers, three piers in each set.

8. The concrete of the gate tower seems excellent in every way, but that of the spillway is poor. Both were made from the same brand of cement. The proportions used were 1, 2½, and 4½ of cement, sand, and gravel. The paving of the spillway floor showed effects of spring water coming up from beneath, and much of the floor is to be relaid.

9. The total estimated cost is $525,000.

Appendix to Section XXVI.

SHOSHONE PROJECT.

WATER SUPPLY.

1. The water supply for the Shoshone irrigation project, Wyoming, is derived from the Shoshone River, the flood discharge being regulated by the Shoshone Reservoir which, as now completed, has a capacity of 456,570 acre-feet.

2. The drainage basin above the reservoir contains approximately 1,250 square miles. The rainfall records at one point in the basin are available for a period of 20 years, and show an average precipitation of 18.8 inches. The precipitation on the higher portions of the drainage basin is probably much larger.

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3. Gaugings of the discharge of the Shoshone River have been made at different periods and at different places, but the only continuous series of readings was made at Cody during the years 1903 to 1909, inclusive, and the results are shown in the following table:

Discharge.

	Acre-feet.
1903	975,100
1904	1,305,100
1905	977,500
1906	1,064,700
1907	1,596,500
1908	1,202,600
1909	1,413,300
Average	1,219,000

4. An examination of the hydrographs shows the following average percentage of discharge during each month of the year:

	Per cent.		Per cent.
January	2	July	27
February	1	August	9
March	2	September	4
April	4	October	3
May	15	November	2
June	29	December	2

5. It will be noted from the above that the period of maximum discharge closely coincides with the period of maximum use, so that the storage provided makes available for irrigation purposes practically the entire discharge of the river, except during the periods of abnormally high run-off.

6. Experience during the past three years indicates that an average of 2 acre-feet per acre per annum at the farm will be sufficient and probably more than is necessary for the best results. Allowing a loss of 33 per cent for seepage and evaporation in canals and reservoirs, a gross quantity of 3 acre-feet per annum will be required. The project contemplates the irrigation of approximately 164,000 acres, consequently 492,000 acre-feet, as measured in the reservoir, will be required.

7. *Prior rights.*—The State engineer of Wyoming, under date of October 1, 1910, prepared a statement showing all appropriations of water, ditches, and enlargements from the Shoshone River, and from this statement the following table has been prepared:

Appropriations.	Above reservoir.		Below reservoir.		Total area appropriated for which water must be supplied.
	Completed.	Time.	Completed.	Time.	
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*
1. To May 22, 1899	2,192		24,711		24,711
2. Permit 2111, Cody & Salisbury, U. S. Reclamation Service				65,803	65,803
3. From May 22, 1899, to Mar. 5, 1904	1,746	125,789	15,909	13,112	154,810
4. Reservoir permit No. 492, res. Mar. 5, 1904		[1] 159,500			
5. Permit No. 1189, enl. Mar. 29, 1904				30,745	30,745
6. Permit No. 1191, enl				8,159	8,159
7. From May 2, 1904, to Sept. 7, 1905	80	303	103		406
8. Permit No. 751, enl		[1] 456,570			[2] 59,415
Total	4,018	126,029	40,723	117,819	344,049

[1] Acre-feet.
[2] Filings of U. S. Reclamation Service secondary permit No. 10138 and supplemental permits under No. 492 resolution and No. 751, res. enl. Irrigates 59,415 additional acres, making approximately a total of 164,000 acres to be irrigated by the U. S. Reclamation Service.

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8. The first item represents filings which antedate all rights of the United States; second, a filing acquired by the United States; third, filings between the date of the Cody-Salisbury filing and the first reservoir permit; fourth, fifth, and eighth represent permits for the storage of water and for enlargements from time to time, while the sixth represents a filing acquired from the Willwood Irrigation Co.

9. From this table it appears that the full development of the project to a total of 164,000 acres can only be made if water in sufficient quantity is assured for 344,000 acres, though a large percentage of private prior rights can not be fully availed of without resort to storage either in conjunction with the United States or separately. Even assuming all prior rights to be perfected, it is found that there will be a sufficient supply of water for the project. Three hundred and forty-four thousand acres at 3 acre-feet per acre aggregate 1,032,000 acre-feet. This is only 57,000 acre-feet more than the minimum discharge of the river during the last seven years, and can readily be cared for by carrying over this, or even a greater amount, in years of maximum discharge.

10. This statement, also, takes no account of waste water or return seepage. Out of 164,000 acres of irrigable land on the Shoshone project, 100,000 acres will drain toward the Shoshone River and discharge into it above where the several canals take out, so that this return water will be available for use. The amount of this return water is indefinite, but it is believed that it will be sufficient to insure against a shortage should the run-off in future be less than that heretofore measured.

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DEPARTMENT OF THE INTERIOR

OFFICE OF THE SECRETARY

File No. 8 3

(Part 4)

- RECLAMATION SERVICE.

-ooo-

- RIO GRANDE PROJECT -
--New Mexico.-

--o--

- RIO GRANDE RIVER -

- DISTRIBUTION OF WATERS.-

--o--

Nov. 21, 1912

Apr. 17, 1914.

8-3

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DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
WASHINGTON, D. C. April 17, 1913.

OFFICE OF THE DIRECTOR

8-3 Rio Grande Irrigation Projects

Memorandum for Secretary Lane.

Attached hereto is a brief discussion of the water supply of the Rio Grande with reference to the development of the Elephant Butte project in Southern New Mexico.

Particular attention is called to the fact that the present policy was instituted six years before the passage of the Reclamation Act at the instance of the Department of State; also to the showing on page 5 that this policy is necessary.

Very respectfully,

A. P. Davis
Chief Engineer.

enc.

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8-3
Rio Grande
Distribution Waters

WATER SUPPLY OF RIO GRANDE

FROM OFFICIAL RECORDS

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WATER SUPPLY OF THE RIO GRANDE.

Historical Review of the Controversy.

In order to gather data for adjustment of the international questions on the Rio Grande, the United States Government entered into a convention with the Republic of Mexico on March 1, 1889, which was duly ratified and proclaimed December 26, 1890 (26 Stat., 1512). This convention provided for a commission known as the International (Water) Boundary Commission, and from its organization was diligently engaged in carrying on investigations of the water supply and other international questions, involving the Rio Grande.

Under the act of October 2, 1888 (25 Stat., 526) surveys and investigations were made along the Rio Grande with a view to reserving reservoir sites that would provide for the proper utilization of the waters of the river. As a result of these surveys four large reservoir sites along the river were withdrawn from entry by the Secretary of the Interior upon the recommendation of the Director of the Geological Survey, February 27, 1891, namely, Reservoir Sites Nos. 12, 29, 38, and 39.

On December 5, 1896, in pursuance of a request by the Department of State, through the Department of Justice, the Secretary of the Interior, D. R. Francis, directed the Commissioner of the General Land Office to suspend action on applications for rights of way through the public lands for the purpose of irrigation by the use of the waters of the Rio

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Grande or any of its tributaries in the State of Colorado or in the Territory of New Mexico until further instructions.

On January 13, 1897, the order was modified by limiting its application to those tributaries of the Rio Grande which empty into that river above the point where it becomes the boundary between the United States and Mexico.

This request of the Department of Justice was made in connection with the suit pending for the cancellation of the right of way of the Rio Grande Dam and Irrigation Company and because of pending negotiations between the United States and Mexico concerning large claims filed by Mexico, based upon the allegation that the diversion of the waters of the Rio Grande had seriously injured a number of its citizens who for many years had been using these waters for irrigation.

These orders were issued more than five years prior to the passage of the Reclamation Act of June 17, 1902, and were continued in force for several years thereafter.

On March 1, 1903, the Reclamation Service, acting largely in accordance with suggestions from the Department of State, took up and continued investigations on the Rio Grande with a view to the largest and most complete utilization of its waters. These investigations developed the fact that a high dam constructed on the Rio Grande near Elephant Butte, New Mexico, would impound all the available water of the Rio Grande, and would furnish sufficient supply to irrigate a large area of arid lands in New Mexico in addition to those lands in Texas and in Mexico which had claims to water rights dating back many years prior to the settlement of the Upper Rio Grande in Colorado and New Mexico.

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The total area irrigable from the reservoir was estimated at 180,000 acres, assuming that all the flood waters of ordinary years were stored.

These investigations also showed that the plans for a large reservoir on the Rio Grande near El Paso which had been a subject of investigation of the International (Water) Boundary Commission would not solve the problem so completely or satisfactorily as the proposed Elephant Butte Reservoir.

A report of this investigation will be found in the Third Annual Report of the Reclamation Service of operations in the years 1903 and 1904 at page 395.

By an Act approved February 25, 1905 (33 Stat., 814), Congress extended the Reclamation Act to include the portion of Texas bordering upon the Rio Grande, which would be irrigable from the Elephant Butte Dam.

Agreement with Mexico: On January 16, 1907, the President proclaimed a Treaty between the United States and Mexico, providing for the furnishing of 60,000 acre feet annually from the Elephant Butte Reservoir to Mexico upon its construction, said water supply to be in full settlement of claims on account of the diversion of the waters of the Rio Grande within the United States, which claim aggregated a very large sum.

March 4, 1907, Congress appropriated $1,000,000 towards the construction of the Elephant Butte dam for carrying out the said treaty, (34 Stat., 1357), as covering the share of the United States in this project on account of the delivery of 60,000 acre feet of water to Mexico.

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The Act of February 25, 1905, extending the Reclamation Act to include Texas for the purpose of the Rio Grande project was regarded as in effect a legislative approval of the project and accordingly by letter of December 2, 1905, the Secretary of the Interior made an allotment of $200,000 for the construction of the Leasburg diversion dam and canal forming part of the project upon condition that the Elephant Butte and El Paso Valley Water Users Associations make appropriate agreements guaranteeing the repayment of the amounts expended on this part of the project within two years.

Promptly thereafter on January 23, 1906, formal notice was filed with the Territorial Engineer of New Mexico in pursuance of the law of New Mexico, claiming all the unappropriated waters of the Rio Grande for storage in the Elephant Butte Reservoir.

Contract with Water Users: Under date of June 27, 1906, the Secretary of the Interior entered into contract with these Water Users Associations in which they agreed to repay the cost of the Leasburg Diversion Dam and canal and also their proportionate share of the entire Rio Grande project.

By these contracts the United States is under obligation to complete the construction of the entire project involving the necessity of storing in the Elephant Butte Reservoir all the available water supply.

In the irrigation development of a large river system, such as the Rio Grande, it is undoubtedly wise to use a considerable proportion of the water in the upper valleys soon after it leaves the mountains and before it has had much opportunity to evaporate.

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As more tributaries reach the river, the additional water supply justifies other diversions lower down, which can also utilize return seepage from the upper valleys.

As development progresses, storage becomes necessary in order that the winter waters and the spring freshets may be held until needed, but for irrigation purposes, such storage requires favorable natural reservoir sites, which are usually of rare occurrence. It will not be possible to find such sites on all the important tributaries of such a stream as the Rio Grande. In addition, there is a multitude of small tributaries, each insignificant in itself but aggregating a vast drainage area, which cannot be used except by storage on the lower part of the main stream.

To utilize entirely the water supply of a large basin with a varied climate, it is necessary, therefore, to have at least one large storage reservoir well down stream, and, to make such a reservoir financially feasible, sufficient water supply must be reserved for its use to justify its construction. Otherwise, a large percentage of the drainage from the basin must forever run to waste.

As a matter of fact, considerable acreages in Mexico, Texas, and New Mexico, were irrigated from the Rio Grande before any irrigation development in Colorado and were deprived of their water supply by diversion in Colorado. If the rule of prior appropriation were given full effect, considerable areas in Colorado would be deprived of their water supply in order that the water might flow down to prior appropriators on the lower river.

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No attempt has been made to do this, but the United States has undertaken to increase the available supply by storage in order to restore the supply to lands formerly irrigated and to furnish a supply to a large additional acreage, without which a feasible storage project would not be possible.

This is being done partly by the direct appropriation of $1,000,000, and partly by the use of the Reclamation Fund, under the terms of the Reclamation Act, the entire legality and feasibility of which has been affirmatively passed upon by Congress, requiring the construction of this storage reservoir.

The lower Rio Grande has in recent years frequently been entirely dry for months at a time at points where formerly large irrigation diversions were made, and it has, on its lower reaches, large and important tributaries with little or no perennial flow, but which yield, in the aggregate, a large amount of torrential floods which can be made available for irrigation only by very large storage works which will hold water from one year to another.

The following table is the result of measurements of the river flow during the past 17 years and careful study of the same, from which it will be seen that the annual flow fluctuates from about 200,000 acre feet in 1902 to more than 12 times this amount in 1905:

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Summary of Runoff of Rio Grande at Elephant Butte, New Mexico, Reservoir capacity 2,640,000 acre feet.

Year	Inflow	Irrigation Use	Evaporation	Surplus	Deficiency
1895	1,259,234	0	125,305		
1896	554,855	590,076	148,910		
1897	2,215,953	750,000	188,227		
1898	960,981	750,000	260,430		
1899	239,434	750,000	220,915		
1900	467,703	750,000	165,780		
1901	656,252	750,000	125,262		
1902	200,729	750,000	77,573		
1903	1,272,069	724,330	76,264		25,670
1904	709,796	609,108	52,733		140,892
1905	2,422,008	750,000	205,862		
1906	1,563,917	750,000	268,677	41,187	
1907	2,157,529	750,000	285,277	1,122,252	
1908	774,109	750,000	273,446	62,886	
1909	1,279,934	750,000	268,999		
1910	852,692	750,000	273,487	213,793	
1911	1,799,733	750,000	267,365	346,492	
Totals	19,386,928	11,673,514	3,284,512	1,786,610	166,562

The above table shows that with a normal draft of 750,000 acre feet per annum, there would have been a deficit amounting to less than 4 percent in 1903, and another to about 19 percent in 1904, neither of which is very serious. It also shows that with this reservoir there would have been a surplus of flow over the spillway only five years out of seventeen, and that in only two years out of seventeen did the overflow exceed the evaporation. This surplus could not be utilized unless a reservoir of larger capacity were provided and illustrates the necessity of the large capacity which has been planned.

The act making appropriations for the sundry civil expenses of the Government for the fiscal year ending June 30, 1908, contains the following provision in pursuance of a convention between

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the United States and Mexico proclaimed January 16, 1907:

> Convention with Mexico: Toward the construction of a dam for storing and delivering sixty thousand acre-feet of water annually, in the bed of the Rio Grande at the point where the head works of the Acequia Madre now exists, above the city of Juarez, Mexico, as provided by a convention between the United States and Mexico, proclaimed January sixteenth, nineteen hundred and seven, one million dollars, to be available as needed and to be expended under the direction of the Secretary of the Interior in connection with the irrigation project on the Rio Grande: Provided, that the balance of the cost of said irrigation project over and above the amount herein appropriated shall be allotted by the Secretary of the Interior, as may be needed and as may be available from time to time, from the reclamation fund and collected from the settlers and owners of the land benefited under the provisions of the reclamation act approved June seventeenth, nineteen hundred and two, and acts supplemental thereto or amendatory thereof, (34 Stat. L., 1357).

Thus the United States undertakes to restore to Mexico, Texas, and New Mexico, the water supply diverted in Colorado, without charging any portion of the cost to any Colorado interest. It is believed that this policy on the part of the general Government is one of liberality and generosity to the irrigation interests of Colorado and not oppression, as sometimes alleged.

During 1910, an investigation was made of the irrigation conditions in the Rio Grande basin in Colorado, including the sinking stream area in the northern San Luis valley. The investigations covered 638 canals having decreed water rights diverting water directly from the Rio Grande and its tributaries, and of 126 canals without decreed water rights diverting water from this river and its tributaries, that were constructed or about to be constructed, and of 452 other canals in the northern San Luis valley in the sinking stream area. At the same time, storage possibilities, seepage conditions and the irrigable lands, in this territory were given careful study.

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The 638 canals with decreed water rights diverting water from the Rio Grande and its tributaries had a carrying capacity of 12,200 second feet and had decreed to them 14,550.3 second feet of water. The 126 additional canals without decreed water rights obtaining their water supply from the same source had a carrying capacity of 1,100 second feet. These two groups of canals with a total capacity of 13,300 second feet were used at that time for the irrigation of 425,000 acres of land within the drainage area of the Rio Grande and also irrigated some additional lands in the territory of the sinking streams of northern San Luis valley.

It is estimated that there were irrigated in 1910 in the Rio Grande basin in Colorado 523,000 acres, that there were approximately 318,000 additional acres that, sometime within the past 20 or 30 years had been irrigated, but have become so water-logged or alkalied from the application of water that their cultivation is no longer profitable; and that there were over 100,000 additional acres of uncultivated irrigable land that have been ruined by seepage, making 941,000 acres of land, either irrigated or waterlogged. This is about five times the area that we proposed to irrigate from the Elephant Butte Dam.

The records show that the water supply of San Luis valley is such that no further development can be carried out without producing a water shortage in the valley in some years. The effect of such development, therefore, would be to injure lands already irrigated, and deplete the supply of the New Mexico project, without furnishing an adequate supply to the new area.

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TWELFTH ANNUAL REPORT

OF THE

RECLAMATION SERVICE

1912-1913

F. H. NEWELL, DIRECTOR

WASHINGTON
GOVERNMENT PRINTING OFFICE
1914

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ANNUAL REPORTS OF THE RECLAMATION SERVICE.

[Reports may be purchased from Superintendent of Documents, Government Printing Office, at the price given.]

I. June 17 to Dec. 1, 1902; 317 pages, 46 plates, 65 figures, case of drawings. Out of print.

II. Through the field season of 1903; 550 pages, 49 plates, 56 figures. Cloth, 85 cents.

III. Through the field season of 1904; 653 pages, 59 plates, case of drawings. Cloth, $1.25.

IV. Through the field season of 1905; 374 pages, 63 plates. Paper, 80 cents.

V. Fiscal year 1905–6; 312 pages, 101 plates, 2 figures. Cloth, $1.25.

VI. Fiscal year 1906–7; 287 pages. Paper, 25 cents.

VII. Fiscal year 1907–8; 219 pages. Paper, 25 cents.

VIII. Fiscal year 1908–9; 222 pages. Cloth, 40 cents; paper, 20 cents.

IX. Fiscal year 1909–10; 329 pages. (Includes history of construction to date.) Cloth, 40 cents; paper, 25 cents.

X. Fiscal year 1910–11; 290 pages. (Includes index Vols. I–X.) Cloth, 40 cents; paper, 25 cents.

XI. Fiscal year 1911–12; 310 pages, map. Cloth, 40 cents; paper, 25 cents.

XII. Fiscal year 1912–13; 382 pages. Cloth, 40 cents; paper, 25 cents.

A price list of publications issued by the Reclamation Service can be obtained by application to the Director, Washington, D. C.

The monthly bulletin of the service, the "Reclamation Record," is printed about the middle of each month. It contains 16 or more pages of general construction news and notes of interest about the projects. The subscription price is 50 cents per year.

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LETTERS OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
Washington, December 1, 1913.

SIR: In compliance with the provisions of section 2 of the act approved June 17, 1902, entitled "An act appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands," I have the honor to transmit the accompanying Twelfth Annual Report of the Reclamation Service.

Very respectfully,

FRANKLIN K. LANE.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEPARTMENT OF THE INTERIOR,
UNITED STATES RECLAMATION SERVICE,
Washington, October 4, 1913.

SIR: Transmitted herewith is the Twelfth Annual Report of the Reclamation Service. This report relates in particular to work completed and in progress during the fiscal year ended June 30, 1913, but contains also information in regard to previous operations in order that the methods, progress, and results of reclamation work may be more readily understood.

Very respectfully, A. P. DAVIS, *Acting Director.*

The SECRETARY OF THE INTERIOR.

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Operation and maintenance:		
Operation as a whole	$18,118.58	
Maintenance of inlet canal	1,161.34	
Maintenance of outlet canal	60.92	
Maintenance of reservoir	873.37	
Maintenance of distributing system	5,696.99	
		$25,911.20
Total building and operation and maintenance cost during construction		364,163.80

Estimated cost of contemplated work.—During the fiscal year 1912–13 a survey was made looking toward the construction of a ditch from near the Diamond A ranch to the head of the lateral system for the purpose of conducting water from a point near the Diamond A ranch and delivering it to the distributing system of the Hondo project.

NEW MEXICO-TEXAS, RIO GRANDE PROJECT.

(For *Results to June 30, 1913*, and *Data for Complete Projects*, see Appendix, pp. 322 and 337.)

LOCATION.

Counties: Socorro, Sierra, Dona Ana, N. Mex.; El Paso, Tex.
Townships: 8 to 29 S., Rs. 3 E. to 5 W., New Mexico meridian.
Railroads: Atchison, Topeka & Santa Fe, El Paso & Southwestern, Southern Pacific, and Texas & Pacific.
Railroad stations and estimated population, January 1, 1913: Elephant Butte, 1,500; Engle, 50; Rincon, 230; Selden; Leasburg; Dona Ana, 600; Las Cruces, 4,000; Mesilla Park, 150; Mesquite, 25; Vado; Berino, New Mexico. La Tuna; El Paso, 50,000; and Ysleta, Texas, 500.

WATER SUPPLY.

Source of water supply: Rio Grande.
Area of drainage basin: 37,000 square miles.
Annual run-off in acre-feet of Rio Grande: At San Marcial (30,000 square miles), 1895 to 1912—maximum, 2,420,000; minimum, 201,000; mean, 1,160,000. At El Paso, Tex. (38,600 square miles), 1889 to 1912—maximum, 2,010,000; minimum, 50,700; mean, 947,000.

AGRICULTURAL AND CLIMATIC CONDITIONS.

Area for which the service is prepared to supply water, season of 1913: Leasburg unit, 25,000 acres; El Paso Valley, 10,000.
Area under rental contracts, season of 1913: 35,000 acres.
Length of irrigating season: From February 15 to November 15—274 days.
Average elevation of irrigable area: 3,700 feet above sea level.
Average annual rainfall on irrigable area: 9½ inches; 1912, 10.14 inches.
Range of temperature on irrigable area: 0° to 100° F.
Character of soil of irrigable area: Fertile alluvium and sandy loam.
Principal products: Alfalfa, corn, wheat, melons, fruit, and vegetables.
Principal markets: Towns in Texas, New Mexico, Louisiana, and eastern cities.

LANDS OPENED FOR IRRIGATION.

No lands have been opened for irrigation by public notice. All lands of Leasburg unit and in El Paso Valley are being irrigated under rental contracts.

CHRONOLOGICAL SUMMARY.

Reconnoisance and preliminary surveys begun in March, 1903.
Construction of Leasburg unit recommended November 29, 1905.
Construction of Leasburg unit authorized December 2, 1905.

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Reclamation act extended to Texas June 12, 1906 (34 Stat., 259).
Treaty with Mexico providing for distribution of waters of the Rio Grande proclaimed January 16, 1907.
Construction of Elephant Butte Dam authorized by Congress and $1,000,000 appropriated March 4, 1907 (34 Stat., 1357).
Leasburg unit completed July, 1908.
First irrigation by Reclamation Service (Leasburg unit), season of 1908.
Construction of Elephant Butte Dam authorized by Secretary May 23, 1910.
Construction plans of Elephant Butte Dam approved by board of engineers June 6, 1910, January 22, 1911, August 12, 1912, January 30, 1913.
Construction plans approved by Secretary October 26, 1910.
Franklin Canal purchased October, 1912.
Elephant Butte Dam 43 per cent completed June 30, 1913.

IRRIGATION PLAN.

The irrigation plan of the Rio Grande project provides for the storage of flood waters of the Rio Grande in a reservoir controlled by Elephant Butte Dam, about 12 miles west of Engle, N. Mex., and the diversion of water from the Rio Grande, about 6 miles below the storage dam, for the irrigation of lands in Las Palomas Valley; about 24 miles below for watering lands in Rincon Valley; about 60 miles below for the irrigation of 90,000 acres in Mesilla Valley, of which 25,000 acres comprise the Leasburg unit, and about 120 miles below for supplying water to lands in El Paso Valley and furnishing 60,000 acre-feet of water per annum for use on land in El Paso Valley on the Mexican side of the Rio Grande. The United States claims all waste, seepage, spring, and percolating water arising within the project, and proposes to use such water in connection therewith.

All the irrigation works required for Las Palomas and Rincon Valleys will be new; those for the Leasburg unit include a diversion dam, 6½ miles of canal, and an extension of the existing 25,000-acre canal system to cover all the lands in the Mesilla Valley, and those required for El Paso Valley will supplement and improve present canal systems.

The only features of the above irrigation plan that have been constructed are the diversion dam, headworks, and main canal of the Leasburg unit.

Construction work is in progress on the Elephant Butte Dam and the features remaining for future construction are the canal systems for the Palomas, Rincon, and El Paso Valleys and the extension of the Leasburg unit.

CONSTRUCTION DURING FISCAL YEAR.

Elephant Butte Dam.—All preliminary work, except in connection with the earth embankment, has been finished, and camp buildings have been completed. It has been decided to increase the capacity of the sand-cement grinding plant by the addition of a fourth tube mill. With this exception, all plants are complete that are to be used in connection with the main dam. Studies are being made at the site of the earth embankment to determine the proper character of core wall to be adopted. No further work has been done on the spillway during the year. The flume has been completed and the river was diverted through it on November 6, 1912. Both the upper and lower cofferdams have been closed and brought to safe heights. On November 8, 1912, excavation for the main dam was started with the cableways and grab buckets, working three shifts, and has continued without delay. Until April, 1913, the bulk of the excavation was done by the above means. In April the grab buckets were removed and skips substituted, as all efforts were being directed toward preparing a portion of the foundation for concreting. Concreting was started with one shift on June 3, 1913, and continued until June 30, while excavation has been carried on with three shifts as usual. The channeler was started cutting out the cut-off trench

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at the heel of the dam on June 23 and is working two shifts with good progress. The sand-cement plant made a trial run during March and short runs have been made since to test out the plant. It is expected that all plants will be operated; concreting will be carried on with two shifts daily and excavation will be resumed by grab buckets on and after July 1, 1913.

Surveys.—Farm unit and topographic surveys were continued in the Rincon and Mesilla Valleys during 1912. Canal location surveys were made for various routes for high-line and valley canals in these districts, and office work on estimates for the several routes and studies of the drainage and river crossing structures continued in the El Paso and Las Cruces offices.

OPERATION AND MAINTENANCE.

The diversion dam and main canal on the Leasburg unit were operated during the year 1912, supplying water to the three principal community ditches in the Mesilla Valley. The contract between the Government and the Elephant Butte Water Users' Association for the delivery of water through its canal to the intakes of the Las Cruces, Dona Ana, and Mesilla Canals was renewed in February, 1912. Approximately 6 acre-feet of water per acre were supplied to the 25,000 acres receiving water from Leesburg diversion dam.

The Franklin Canal was purchased for $120,000 from the Franklin Irrigation Co. in October, 1912, a valuable right of way being obtained through the city of El Paso and in the valley which would otherwise have been difficult and expensive to secure. The canal from head gate to end is approximately 31 miles. It has 61 check gates, 6 of which are concrete, and 200 turnouts. The capacity is approximately 175 second-feet, and 14,000 acres can be served when the river stage is sufficient. Future plans consider widening the canal with necessary enlargement of the head gates and structures to irrigate approximately 40,000 acres. Operation of the canal was begun in February, 1913, after some cleaning and repairs to structures had been accomplished, and approximately 10,000 acres are being irrigated from this source.

For "Summary of operation and maintenance results," see Appendix, p. 334.

Historical review, Rio Grande project.

Item.	1909	1910	1911	1912	1913, to June 30.
Acreage for which service was prepared to supply water	25,000	25,000	26,000	25,000	35,000
Acreage irrigated	22,000	22,600	25,980	23,115	[2] 34,799
Number of farms irrigated	975	885	885	890	1,488
Miles of canal operated	6	6	6	6	36
Water diverted (acre-feet)	[1] 145,892	[1] 99,789.6	[1] 152,685	[1] 125,000	[3] 124,520
Water delivered to land per acre of land irrigated (acre-feet)	[1] 6.6	[1] 4.4	[1] 6	[1] 5.4	.....

[1] At lateral head gates; service does not distribute water. Does not include scouring and silting water furnished free of charge.
[2] Exclusive of 203 city lots.
[3] Includes water delivered to lateral headgates Leasburg unit and total water diverted Franklin Canal.

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SETTLEMENT.

Little extension of the area under cultivation has been made, on account of the limitations of the water supply. The farmers and prospective settlers realize that little dependence can be placed on the supply from the river until the storage dam is completed and the flow regulated. It is expected that stored water will be available in 1915 and the dam completed a year later. While the farming area under cultivation on the entire project has not increased, the principal city and towns have grown considerably in population.

PRINCIPAL CROPS.

About 60 per cent of the irrigated land is planted to alfalfa, 20 per cent to corn, 9 per cent to small grain, and 11 per cent to orchards, vineyards, gardens, and miscellaneous crops. Alfalfa is generally the most successful crop grown and gives the best net returns, although the yield for 1912 was slightly below normal because of river conditions. Considerable fruit was planted, and the crop was remarkably good.

Crop statistics Rio Grande project calendar year 1912 under Leasburg diversion dam.

Crop.	Acreage irrigated or cropped.	Unit of yield.	Total yield.	Total value.
Alfalfa	16,740	Ton	54,405	$544,050.00
Corn	3,767	Bushel	90,408	63,285.60
Wheat	1,020	do	30,600	22,950.00
Oats	262	do	14,410	7,637.30
Barley	28	do	1,260	1,323.00
Beans	234	Pound	210,600	6,318.00
Sorghum	161	Ton	564	5,640.00
Orchard	445	Pound	1,335,000	33,750.00
Grapes	30	do	144,000	4,320.00
Miscellaneous	428			21,400.00
Total cropped	23,115			710,673.90

In addition to the above acreage there were approximately 57,000 acres irrigated under the project from community canals having temporary river headings.

FINANCIAL STATEMENTS.

Assets and liabilities Elephant Butte storage project, June 30, 1913.

ASSETS.

Cash in special fiscal agent's possession awaiting remittance			$2,775.39
Accounts receivable, miscellaneous			954.01
Inventories:			
Mercantile stores		$29,300.00	
Equipment in use—			
Animals	$7,762.98		
Mechanical and other	168,088.77		
		175,851.75	
Materials, supplies, etc., in storehouse		48,468.98	
Cement		506.48	
Lumber		9,519.68	

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Inventories—Continued.			
Explosives		$5,750.16	
Forage		2,445.20	
Fuel		841.49	
Products of local operations		16,370.92	
Goods in transit		1,873.00	
Unadjusted transfer between projects		24,637.57	
Undistributed cost (freight and handling on inventory property)		6,153.99	
			$321,719.22
Improvements to land:			
Gross cost		2,151,737.19	
Less credits from incidental operations—			
Rentals of cottages	[1] $3,235.90		
Power and lights	855.64		
Revenues, miscellaneous	840.72		
Profits on mess operations	988.95		
Profits on mercantile store	25,534.93		
Loss on hospital	[1] 803.95		
Contractor's freight refunds	2,034.09		
Forfeitures by defaulting bidders and contractors	1,463.43		
		27,677.91	
			2,124,059.28
Total assets			2,449,507.90

LIABILITIES.

Accounts payable:			
Labor		14,937.54	
Purchases		13,779.08	
Contract estimates		249.53	
Freight and express		17,348.95	
Passenger fares		555.73	
Land agreements		12,612.00	
Coupons		373.65	
Miscellaneous		113.60	
			59,970.08
Reserves, for depreciation on plant and equipment			180,139.98
Unadjusted credits, net earnings of Government animals			1,443.15
Net investment:			
Reclamation fund—			
Disbursement vouchers		1,207,981.24	
Transfer vouchers received		113,390.71	
		1,321,371.95	
Less—			
Collection vouchers	97,830.02		
Transfer vouchers issued	14,086.24		
		111,916.26	
			1,209,455.69
Rio Grande Dam appropriation—			
Disbursement vouchers		998,590.78	
Less collection vouchers		91.78	
			998,499.00
Total liabilities			2,449,507.90

Feature costs, Elephant Butte storage unit, to June 30, 1913.

Preliminary:		
Surveys, examinations, and borings	$29,267.27	
Real estate (rights and property), lands submerged	312,871.97	
		$342,139.24

[1] Debit balance.

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Preparatory:			
Roads and bridges		$43,091.42	
Buildings		141,128.13	
Plant		778,149.78	
			$962,369.33
Elephant Butte Dam:			
Flume and cofferdams		220,500.13	
Excavation for foundation		361,732.02	
Masonry		205,528.23	
Gates and sluiceways		9,679.77	
			797,440.15
Earth dike			2,194.19
Spillway			22,466.73
Inventory of cost ledger supplies			25,127.55
Total building cost			2,151,737.19

Assets and liabilities, Rio Grande (including Leasburg project), June 30, 1913.

ASSETS.

Inventories:			
Equipment in use—			
Animals	$2,853.05		
Mechanical and other	16,495.30		
		$19,348.35	
Materials, supplies, etc., in storehouse		1,557.72	
Cement		16.00	
			$20,922.07
Improvements to land:			
Gross cost		542,841.65	
Less credits from incidental operations—			
Rentals of cottages	10.00		
Rentals, irrigation water	72,698.90		
Profits on mess operations	[1] 1,729.65		
Adjustments, contractors' freight refunds	2,114.34		
		73,093.59	
			469,748.06
Total assets			490,670.13

LIABILITIES.

Accounts payable:			
Labor		4,593.84	
Purchases		1,315.26	
Freight and express		415.06	
Passenger fares		42.70	
			6,366.86
Reserves for depreciation on plant and equipment			2,026.96
Unadjusted credits, net earnings of Government animals			1,127.22
Net investment:			
Disbursement vouchers	565,989.82		
Transfers received	23,876.20		
		589,866.02	
Less—			
Collection vouchers	90,874.68		
Transfers issued	17,842.25		
		108,716.93	
			481,149.09
Total liabilities			490,670.13

[1] Deduct.

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Feature costs Rio Grande project to June 30, 1913.

Preliminary examination:			
Hydrographic survey		$16,939.36	
Topographic surveys and investigations—			
General	$55,477.13		
Soil and cement	1,686.50		
		57,163.63	
Canal surveys—			
Mesilla Valley	59,322.90		
El Paso Valley	9,260.19		
Rincon Valley	19,313.22		
Palomas Valley	3,528.92		
		91,425.23	
			$165,528.22
Franklin Canal:			
Surveys		3,767.56	
Purchase price		125,976.06	
Improvements		2,941.85	
Operation and maintenance		13,685.98	
			146,371.45
LEASBURG UNIT.			
Preliminary examination:			
Surveys		5,776.78	
Real estate (rights and property)		1,556.67	
Irrigable lands, farm units, and subdivision		5,994.62	
			13,328.07
Diversion dam:			
Sluiceway and headworks		8,065.95	
Concrete weir and abutments		73,827.41	
Embankment at west end		4,495.91	
			86,389.27
Main canal:			
Excavation station 0–59		31,030.46	
Excavation and structure station 60–309		43,847.98	
Sand sluiceway		6,749.38	
Change in river channel		13,809.33	
			95,437.15
Buildings and plants:			
Concrete house		3,031.66	
Tool house, stable, corral, bunk house, water tower, fencing, tents, and windmill		2,028.80	
			5,060.46
Telephone system		893.44	
Roads		234.13	
Bridges		398.08	
			1,525.65
Inventory of cost ledger supplies			232.49
Operation and maintenance (during construction):			
Operation			23,266.67
Maintenance—			
Main canal and sluiceway		2,483.23	
Change in river channel		87.00	
Dam, sluice, and head gates		314.00	
Canal structures		313.04	
Flood protection		201.75	
Buildings and plants		2,142.95	
Headquarters grounds		160.25	
			5,702.22
Total building and operation maintenance (during construction)			542,841.65

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Estimated cost of contemplated works, Rio Grande project.

Wagon roads	$9,000
Flume and cofferdams	3,000
Excavation for foundation of dam	347,000
Masonry for dam	1,129,000
Gates and sluice gates	82,000
Spillway	3,000
Earth dam at reservoir	155,000
Real estate	37,000
Construction plants	14,000
Camp buildings and grounds	2,000
Total	1,781,000

NORTH DAKOTA, NORTH DAKOTA PUMPING PROJECT.

(For *Results to June 30, 1913*, and *Data for Complete Projects*, see Appendix, pp. 322 and 337.)

LOCATION.

County: Williams.

Townships: 152 to 155 N., Rs. 100 to 104 W., fifth principal meridian.

Railroad: Great Northern.

Railroad stations and estimated population, January 1, 1913: Buford, Trenton, and Marley, on Buford-Trenton unit, are small unincorporated villages. population not available. Williston, on the Williston unit, is an incorporated city of about 4,000 population.

WATER SUPPLY.

Source of water supply: Missouri River.

Area of drainage basin: 155,000 square miles.

Mean run-off of Missouri River, near Williston, May to October, 1905 to 1907: 15,000,000 acre-feet.

AGRICULTURAL AND CLIMATIC CONDITIONS.

Area for which the service is prepared to supply water, season of 1913: Buford-Trenton unit, 4,049 acres; Williston unit, 8,189 acres.

Area irrigated, season of 1912: 323 acres on Williston unit. No part of the Buford-Trenton unit was irrigated. Area irrigated in 1913, to June 30, 1,386 acres.

Length of irrigation season: June 15 to September 3, 80 days. Actual irrigation occurred in 1912 only during a period from July 21 to August 31.

Average elevation of irrigable area: 1,900 feet above sea level.

Average annual rainfall on irrigable area (past 10 years), 13.10 inches; at Williston, 1912, 16.33 inches.

Range of temperature on irrigable area: —49° to 107° F.

Character of irrigable area ranges from sandy loam to heavy clay gumbo.

Principal products: Alfalfa, grain, and vegetables.

Principal markets: Local, St. Paul, Minneapolis, Duluth, and Chicago.

LANDS OPENED FOR IRRIGATION.

Dates of public notices and orders: Buford-Trenton unit, April 8, 1908; March 9, 1911; May 13, 1911; and June 25, 1912. Williston unit, April 27 and November 30, 1908; April 30, 1909; March 9 and April 14, 1911; June 25, 1912; March 11, 1913; June 23, 1913; and July 21, 1913.

Location of lands opened: Buford-Trenton unit, Ts. 152 and 153 N., Rs. 103 and 104 W., fifth principal meridian; Williston unit, Ts. 154 and 155 N., Rs. 100 and 101 W., fifth principal meridian.

Present status of irrigable lands: Buford-Trenton unit—288 acres entered subject to reclamation act; 251 acres open to entry; 91 acres of State lands; 3,420 acres in private ownership. Williston unit—54 acres entered subject to the recla-

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ENGINEERING DATA FOR COMPLETE PROJECTS.

TABLE 1.—*Reservoirs.*

Projects.	Name.	Area.	Capacity.	Spillways.	
				Length.	Elevation above stream bed.
		Acres.	*Acre-feet.*	*Feet.*	*Feet.*
Arizona: Salt River	Roosevelt	16,329	1,284,000	400	220
Arizona-California: Yuma	Laguna diversion	6,400			
California: Orland	East Park	1,800	45,600	415	85
Colorado: Uncompahgre Valley	Taylor Park	2,260	106,000	125	150
Idaho:					
Boise	Deer Flat	9,835	177,640	None.	
Do	Arrowrock	2,780	230,000	400	256
Minidoka	Lake Walcott	11,350	150,000	2,385	42
Do	Jackson Lake	22,600	380,000	160	24
Montana:					
Blackfeet	Two Medicine Lake	854	16,000	56	25½
Do	Spring Lake	1,400	29,000	50	45
Do	Four Horns	1,867	60,640	50	57
Flathead	Big Draw	901	9,330	100	25
Do	Dog Lake	160	3,200		30
Do	Dry Fork	250	1,918	100	25
Do	Flathead Lake	107,000	1,800,000	1,000	180
Do	Hubbart	480	20,000	50	108
Do	Kickinghorse	675	6,800		23
Do	Little Bitter Root Lake.	3,000	6,000	20	3
Do	Lower Crow Creek	300	9,485	100	82
Do	McConnell	100	2,000		40
Do	McDonald Lake	220	10,600	200	51
Do	Mission	300	8,300	100	74
Do	Ninepipe	1,630	15,100		30
Do	Pablo	2,100	29,600		36
Do	Polson	70	1,700		80
Do	St. Marys Lake	300	25,000	50	52
Do	Twin	70	937		25
Fort Peck	Little Porcupine	390	3,900		
Do	Wolf Creek	4,550			
Do	Smoke Creek	5,300			
Huntley	Highline		853		
Milk River	St. Marys Lakes	6,910	218,000	500	40
Do	Sherburne Lakes	2,000	100,000		
Do	Red Eagle Lakes		5,000		
Do	Nelson Reservoir	6,380	141,815	None.	None.
Sun River	Willow Creek	2,696	86,000	200	100
Do	Sun River storage	3,540	269,000	580	321
Do	Pishkun	1,542	45,700		
Do	Muddy Creek	1,828	33,000		
Do	Benton Lake	9,300	144,000		
Nebraska-Wyoming:					
North Platte	Pathfinder	22,700	1,070,000	660	184
Do	Reservoir No. 1, Lake Alice.	900	11,400	100	18
Do	Lake Minitare	2,240	67,025	100	55
Nevada:					
Truckee-Carson	Lake Tahoe	125,000	750,000	85	6
Do	Alkali Flat	8,500	88,000		
Do	Lahontan	11,000	290,000	500	112
New Mexico:					
Carlsbad	Avalon	970	7,000	1,000	21
Do	McMillan	6,250	70,000	2,700	23 to 26
Hondo	Hondo	1,910	40,000	None.	
N. Mex.-Tex.: Rio Grande	Elephant Butte	40,080	2,627,700	300	193
Oregon: Umatilla	Cold Springs	1,500	50,000	330	90
Oregon-California:					
Klamath	Upper Klamath Lake.	60,000	200,000		
Do	Clear Lake	25,000	462,000	357	24
South Dakota: Belle Fourche	Belle Fourche	8,010	203,770	314	100
Utah: Strawberry Valley	Strawberry Valley	8,200	278,000	60	60
Washington:					
Okanogan	Salmon Lake	200	2,600	None.	
Do	Conconully	460	13,000	180	56
Yakima	Bumping Lake	1,350	34,000	235	40
Do	Lake Clealum	4,680	490,000	660	116
Do	Lake Kachess	4,800	210,000	250	53
Do	McAllister Meadow	1,800	183,000	225	180
Do	Lake Keechelus	2,550	174,000	300	60
Wyoming:					
Shoshone	Shoshone	6,600	456,000	300	233
Do	Ralston	200	2,100	None.	
Total		584,367	13,255,713		

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ENGINEERING DATA FOR COMPLETE PROJECTS—Continued.

TABLE 2.—*Storage dams.*

Projects.	Name.	Type.	Maximum height.	Crest length.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
Arizona: Salt River	Roosevelt [1]	Rubble masonry, arch gravity.	280	1,125	342,000
California: Orland	East Park [1]	Concrete, arch gravity	139	250	12,200
Colorado:					
Uncompahgre Valley.	Taylor Park	Undetermined	200	(2)	(2)
Idaho:					
Boise	Upper Deer Flat [1]	Earth fill	70	4,000	1,170,200
Do	Lower Deer Flat [1]	do	40	7,200	1,130,800
Do	Deer Flat Forest [1]	do	16	950	22,500
Do	Arrowrock	Rubble, concrete arch	350	1,075	530,000
Minidoka	Minidoka [1]	Rockfill, concrete core	86	937	242,500
Do	Jackson Lake	Reinforced concrete piers and radial gates and earth fill.	40	3,256	66,994
Montana:					
Blackfeet	Two Medicine	Earth, embankment	36	900	
Do	Spring Lake	do	50	1,500	75,000
Do	Four Horns	do	62	2,225	149,000
Flathead	Big Draw	Earth	35	3,600	137,000
Do	Dog Lake	Loose rock and earth	35	2,250	67,000
Do	Dry Fork	Earth	33	1,860	130,000
Do	Newell	Concrete	170	850	100,000
Do	Hubbart	Loose rock and earth	118	450	302,000
Do	Kickinghorse	Earth	31	3,700	181,000
Do	Little Bitter Root Lake.	do	10	300	4,000
Do	Little Crow Creek	do	92	860	330,000
Do	McConnell	do	45	1,130	71,000
Do	McDonald Lake	Loose rock and earth	57	1,500	214,000
Do	Mission	do	80	2,500	346,000
Do	Ninepipe [1]	Earth	38	2,180	162,000
Do	Pablo	do	46	14,000	1,028,000
Do	Polson	do	85	1,100	170,000
Do	St. Marys Lake	Loose rock and earth	58	2,200	140,000
Do	Twin	Earth	30	1,600	46,000
Fort Peck	Little Porcupine [1]	Earth and brush mattress			43,400
Do	Wolf Creek	Earth fill			85,300
Do	Smoke Creek	do			75,600
Huntley	Highline	do	53	1,330	151,350
Milk River	St. Mary Lakes	Earth embankment	45	2,600	135,000
Do	Sherburne Lakes	do	95	900	300,000
Do	Red Eagle Lake	Rubble masonry	(2)	(2)	(2)
Do	Nelson Reservoir	Earth embankment	33	15,135	911,540
Do	Willow Creek [1]	Earth fill	110	1,045	452,000
Do	Sun River storage	Masonry	329	989	296,500
Sun River	Pishkun	Earth fill	48	3,500	444,000
Do	Benton Lake	do	35	120	12,000
Nebraska-Wyoming:					
North Platte	Pathfinder [1]	Broken range masonry arch	218	432	60,210
Do	Pathfinder Dike [1]	Earth fill	40	1,650	152,000
Do	Dam No. 1 [1]	do	30	3,100	240,000
Do	Dam No. 1½ [1]	do	23	2,550	119,000
Do	Minitare	do	65	3,600	570,000
Nevada:					
Truckee-Carson	Lake Tahoe	Concrete sluiceway regulator	14	109	425
Do	Alkali Flat	Not designed			
Do	Lahontan	Earth and gravel fill	124	1,600	770,000
New Mexico:					
Carlsbad	Avalon [1]	Earth and rock fill, concrete core.	50	1,380	175,073
Do	McMillan [1]	Earth and rock fill	55	1,686	149,600
Hondo	Hondo [1]	6-earth embankments	25	16,200	421,350
New Mexico-Texas:					
Rio Grande	Elephant Butte	Rubble concrete, gravity structure, straight.	290	1,200	500,000
Do	Elephant Butte Dike	Earth fill	42	1,875	
Oregon: Umatilla	Cold Springs [1]	do	98	3,800	789,500
Oregon-California: Klamath.	Clear Lake [1]	Rock fill	33	790	56,600
South Dakota: Belle Fourche.	Belle Fourche	Earth fill	115	6,200	1,600,000
Utah: Strawberry Valley.	Strawberry	Earth fill, reinforced concrete core.	72	488	108,415

[1] Completed. [2] Not designed.

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ENGINEERING DATA FOR COMPLETE PROJECTS—Continued.

TABLE 2.—*Storage dams*—Continued.

Projects.	Name.	Type.	Maximum height.	Crest length.	Volume.
Washington:			*Feet.*	*Feet.*	*Cubic yds.*
Okanogan	Salmon Lake[1]	Concrete headworks			
Do	Conconully[1]	Hydraulic earth fill	64	1,000	336,000
Yakima	Bumping Lake[1]	Earth fill	45	3,425	233,852
Do	Lake Clealum	do	125	1,150	617,000
Do	Lake Kachess[1]	Earth and gravel fill	60	1,400	182,150
Do	McAllister	Earth and rock fill	200	950	1,200,000
Do	Lake Keechelus	Earth fill	68	6,400	550,000
Wyoming:					
Shoshone	Shoshone[1]	Rubble, concrete arch	328	200	75,576
Do	Rolston	Earth fill	50	150	24,740
Total					19,007,375

[1] Completed. [2] Not designed.

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ENGINEERING DATA FOR COMPLETE PROJECTS—Continued.

TABLE 3.—*Diversion dams.*

Projects.	Name.	Type.	Maximum height.	Length, weir.	Volume
			Feet.	*Feet.*	*Cu. yds.*
Arizona:					
Salt River	Granite Reef [1]	Rubble concrete weir	38	1,000	40,000
Do	Power Canal [1]	do	12¾	400	4,800
Do	Joint Head	Concrete weir	10	600	1,450
Arizona-California: Yuma	Laguna [1]	Indian weir, concrete and rock fill.	40	4,780	441,732
California:					
Orland	Miller Buttes [1]	Concrete on sheet piling	20	900	550
Do	North Side diversion	Concrete weir, with removable timber crest.	8	360	250
Colorado:					
Grand Valley	Diversion	Masonry ogee weir with rolling crest 10 feet high.	22	420	18,000
Uncompahgre Valley	Gunnison [1]	Crib and rock fill			3,200
Do	Uncompahgre [1]	6-pile and timber weirs			
Idaho:					
Boise	Boise River [1]	Rubble concrete weir	45	246	21,750
Minidoka	Minidoka [1]	Combined diversion and storage dam.			
Montana:					
Blackfeet	Two Medicine	Brush and rock	4	165	
Do	Badger, Birch, and Cut Bank.	Birch and Cut Bank dams not designed.			
Flathead	Jocko River	Log crib, rock filled (not designed).			
Do	Little Bitter Root River.				
Do	Mud Creek				
Do	Crow Creek				
Do	Post Creek				
Do	Mission Creek				
Do	Dry Creek				
Do	Finley Creek				
Do	Agency Creek				
Do	Big Knife Creek				
Do	Valley Creek and others.				
Fort Peck	Little Porcupine	Concrete weir on timber crib	4	150	
Do	Poplar River	do	4	300	
Do	Big Porcupine	Not determined			
Milk River	Swift Current	Earth and timber crib	13	2,800	
Do	Chinook	Timber crib, rock filled			
Do	Dodson	do	25	319	
Do	Vandalia	Reinforced concrete	34	370	
Sun River	Sun River	Concrete masonry	1[illegible]0	190	3,300
Do	Deep Creek	Reinforced concrete weir	12	100	500
Montana-North Dakota: Lower Yellowstone.	Lower Yellowstone	Rock filled, timber weir	12	700	14,000
Nebraska-Wyoming: North Platte.	Whalan	Concrete weir	29	300	80,740
Nevada:					
Truckee Carson	Truckee River [1]	Concrete sluiceways	22	171	
Do	Carson River [1]	do	21	240	
Do		Others not designed			
New Mexico:					
Carlsbad	Avalon [1]	Combined storage and diversion dam			
Hondo	Hondo River [1]	Earth fill	20	100	3,700
New Mexico-Texas: Rio Grande.	Leasburg [1]	Rubble, concrete weir	9	600	
Oregon: Umatilla	Diversion [1]	Concrete weir	2½	400	296
Oregon-California: Klamath.	Lost River [1]	Hollow reinforced concrete	40	290	5,550
South Dakota: Belle Fourche.	Diversion	Concrete weir	23	400	12,149
Utah: Strawberry Valley	Spanish Fork	Reinforced concrete weir	16	70	1,261
Washington:					
Okanogan	Salmon Creek [1]	Concrete weir	4	50	131
Yakima	Sunnyside [1]	Concrete ogee weir	8½	500	
Do	Tieton [1]	Concrete and rock fill crib	3	110	
Wyoming: Shoshone	Corbett [1]	Reinforced concrete weir	18	400	4,951
Total					658,310

[1] Completed.

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ENGINEERING DATA FOR COMPLETE PROJECTS—Continued.

TABLE 4.—*Canals.*

Projects.	Principal canal.		Mileage, with capacity in second-feet.				
	Name.	Maximum capacity.	Over 800.	301–800.	50–300.	Less than 50.	Total.
Arizona:		*Sec. ft.*					
Salt River	Power[1]	225					
Do	Arizona[1]	2,000	32	70	108	531	741
Do	South[1]	1,600					
Arizona-California: Yuma	Main[1]	1,700	17	17	110	260	404
California:							
Orland	South Side[1]						
Do	North Side				24	75	99
Colorado:							
Grand Valley	Main	1,425	5	38	21	5	69
Uncompahgre Valley	South[1]	1,300					
Do	Montrose & Delta	450	12	28	100	200	340
Do	Loutsenhizer	290					
Idaho:							
Boise	Main[1]	2,500	40	57	165	766	1,028
Minidoka	North Side[1]	1,400	12	32	106	650	800
Do	South Side[1]	650					
Kansas: Garden City	Main	115			2	2	4
Montana:							
Blackfeet				40	144	600	784
Flathead				14	82	800	896
Fort Peck—							
Little Porcupine Unit					1	13	14
Poplar River Unit	"B" and "C" canals				29	70	99
Big Porcupine Unit					7		7
Big Muddy Unit							
Missouri River Unit		627		10	30	60	100
Galpin Bottom Pumping Unit.							
Milk River Pumping Unit							
Huntley	Main	500		10	19	274	303
Milk River	St. Mary	850	29				29
Do	Dodson South	900	44		110	190	344
Do	Dodson North				41	60	101
Do	Glasgow Division						
Sun River	Fort Shaw	175		240	110	140	490
Montana-North Dakota: Lower Yellowstone.	Main[1]	830		49	19	190	258
Nebraska-Wyoming: North Platte	Interstate[1]	1,400	90	10	89	586	775
Nevada: Truckee-Carson	Truckee[1]	1,500	42	62	80	509	693
New Mexico:							
Carlsbad	Main[1]	450		13	12	120	145
Hondo	Main Inlet[1]	2,900		3	2	45	50
New Mexico-Texas:							
Rio Grande	Leasburg[1]	520		6			6
Do	Franklin	175			50		50
North Dakota:							
North Dakota Pumping	Buford-Trenton				6	39	45
Do	Williston				3	58	61
Oregon: Umatilla	Feed[1]	300		25	25	70	120
Oregon-California:							
Klamath	Main[1]	1,500	9	1	58	214	282
Do	Keno[1]	635					
South Dakota: Belle Fourche	Inlet[1]	1,600	7	55	105	460	627
Utah: Strawberry Valley	Power[1]	500		5	40	100	145
Washington:							
Okanogan	Main[1]	100			10	38	48
Yakima	Sunnyside[1]	1,075	31	19	33	451	534
Do	Tieton[1]	300		12	32	194	238
Wyoming: Shoshone	Garland[1]	1,000	10	33	77	397	517
Total			380	849	1,850	8,167	11,246

[1] Completed.

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ENGINEERING DATA FOR COMPLETE PROJECTS—Continued.

TABLE 5.—*Tunnels.*

Project.	Name.	Length.
		Feet.
Arizona: Salt River.	Power Canal:	
	Intake	1,695
	Lee	122
	Wehri cut-off, 1	428
	Wehri cut-off, 2	129
	Wehri cut-off, 3	271
	Wehri	151
	Pinto	999
	Chilton	1,027
	Robinson	152
	Gray	761
	Moffet	214
	Grapevine	872
	No. 6	206
	No. 7	342
	No. 8	553
	No. 9	320
	No. 10	489
	No. 11	625
	No. 12	70
	No. 13	110
	Roosevelt:	
	Sluicing	480
	Outlet	167
	Penstock	620
Arizona-California: Yuma.	Colorado River siphon.	930
Colorado:		
Grand Valley	Main Canal, No. 1.	3,723
	Main Canal, No. 2.	1,655
	Main Canal, No. 3.	7,280
Uncompahgre	Gunnison	30,645
	South Canal, No. 1.	482
	South Canal, No. 2.	395
	South Canal, No. 3.	1,000
	South Canal, No. 4.	400
	South Canal, No. 5.	390
	West Canal	1,750
	West Canal Exten.	800
	Selig Extension, No. 1.	160
	Selig Extension, No. 2.	360
	Selig Extension, No. 3.	100
	Selig Extension, No. 4.	310
Idaho: Boise	Arrowrock	487
Montana:		
Flathead	Newell	1,800
	St. Mary Lake outlet.	1,620
Huntley	Main Canal, No. 1.	724
	Main Canal, No. 2.	1,545
	Main Canal, No. 3.	385
Sun River	Willow Creek	584
	Sun River Storage Reservation.	200
	Pishkun Canal No. 1.	690
	Pishkun Canal No. 2.	980
	Pishkun Canal No. 3.	2,235
	Muddy Creek Reservoir.	700
Nebraska-Wyoming: North Platte.	Pathfinder, North.	480
	Pathfinder, South.	360
	Pathfinder, Drainage.	155
	Pathfinder, Auxiliary.	209
	Pathfinder, Cross-cut.	55
Nevada: Truckee-Carson.	Main Canal, No. 1.	901
	Main Canal, No. 2.	309
	Main Canal, No. 3.	1,515
	Gilpin Spillway	115
New Mexico: Carlsbad.	Spillway, No. 1	97
	Spillway, No. 2	103
Oregon: Umatilla	Reservoir outlet	34
Oregon-California: Klamath.	Main Canal	3,300
South Dakota: Belle Fourche.	South Canal	1,307
Utah: Strawberry Valley.	Strawberry Valley	19,897
	Strawberry Dam	532
	Power Canal, No. 1	800
	Power Canal, No. 2	705
	Aqueduct	750
Washington:		
Okanogan	Conconully outlet.	395
North Yakima, Tieton.	Steeple, No. 1	55
	Steeple, No. 2	48
	Trail Creek	3,120
	Columnar	1,200
	Tieton	2,729
	North Fork	3,811
Wyoming-Shoshone.	Dam: Lower outlet	498
	Spillway	405
	Upper outlet	315
	Corbett	17,355
	Ralston reservoir	245
	Shoshone Road, No. 1.	39
	Shoshone Road, No. 2.	45
	Shoshone Road, No. 3.	14
	Shoshone Road, No. 4.	28
	Shoshone Road, No. 5.	136
	Shoshone Road, No. 6.	166
	High Line Canal, No. 1.	4,915
	High Line Canal, No. 2.	2,100
	High Line Canal, No. 3.	1,275
	High Line Canal, No. 4.	2,116
	High Line Canal, No. 5.	350
	High Line Canal, No. 6.	310
	High Line Canal, No. 7.	300
	High Line Canal, No. 8.	533
	High Line Canal, No. 9.	285
	High Line Canal, No. 10.	120
	High Line Canal, No. 11.	1,050
	Willwood, No. 1	560
	Willwood, No. 2	365
Total		[1] 149,640

[1] Total completed and prepared.

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TABLE 6.—*Power development.*[1]

(Water power unless otherwise stated.)

Projects.	Name of plant.	Maximum head.	Brief description as built.	Horsepower. Developed June 30, 1913.[2]	Horsepower. Total proposed.
Arizona, Salt River	Roosevelt	226	Three 1,260-horsepower and two 1,800-horsepower turbines; five 900-kilowatt generators.	[3] 8,040	14,700
	South Consolidated	30	Two 1,500-horsepower turbines direct connected; two 1,000-kilowatt generators.	[3] 2,680	2,680
	Arizona Falls	18	Two 825-horsepower turbines direct connected; two 525-kilowatt generators.	[3] 1,340	1,400
	Cross-cut	117	Six 1,000-horsepower vertical tangential wheels; six 875-kilowatt generators.		7,040
Arizona-California, Yuma	Drop in main canal				1,000
California, Orland					600
Colorado, Grand Valley					2,000
Colorado, Uncompahgre Valley					10,000
Idaho:					
Boise	Boise Dam	30	Three 850-horsepower turbines, direct connected, three 500-kilowatt generators.	3,220	3,220
Minidoka	Minidoka Dam	46	Five 2,000-horsepower turbines, direct connected to five 1,200 kilowatt generators.	9,380	9,380
Kansas, Garden City	Deerfield (steam)		Two 350-horsepower steam turbines and two 225-kilowatt generators	600	600
Montana:					
Flathead			Possible development from mountain streams		300,000
Huntley	Main canal drop	34	Two vertical turbines, direct connected to two 20-inch centrifugal pumps, capacity each 28 second-feet.	286	600
Montana-North Dakota: Lower Yellowstone.	Lateral K K drop				290
Nevada, Truckee-Carson	Lahontan Dam, etc.	115	Two 500-kilowatt generators	[3] 1,730	8,000
New Mexico-Texas: Rio Grande	Elephant Butte (steam)		Three 500-kilowatt steam turbine units	2,000	2,000
North Dakota-North Dakota: Pumping	Williston (steam)		Two 300-kilowatt and one 500-kilowatt generators	[3] 2,050	3,000
Oregon: Umatilla	Drainage outfall				75
Utah, Strawberry Valley	Spanish Fork	125	Two horizontal 30-inch turbines and two 425-kilowatt generators	[3] 1,140	3,500
Washington, Yakima:					
Sunnyside Unit					2,000
Tieton Unit					3,250
Wapato					9,000
Total				32,466	384,335

[1] Power may be developed on other projects but data not completed.
[2] Maximum safe observed output of plant.
[3] Slight change from previous reports which gave rated instead of actually measured output.

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TABLE 7.—*Irrigable area.*

Projects.	Units.		
	Name.	Area.	Total.
		Acres.	*Acres.*
Arizona: Salt River	Gravity system	190,000	230,000
	Pumping system	40,000	
Arizona-California: Yuma	All units	131,000	131,000
California: Orland	do	14,307	14,307
Colorado: Grand Valley	do	53,000	53,000
Colorado: Uncompahgre	do	140,000	140,000
Idaho:			
Boise	do	207,000	207,000
Minidoka	Gravity system	70,025	118,025
	Pumping system	48,000	
Kansas: Garden City	All units	10,677	10,677
Montana: Blackfeet	Two Medicine unit	48,000	122,500
	Badger	33,000	
	Cut Bank and Carlow	38,000	
	Birch	3,500	
Montana: Flathead	Jocko division	16,000	152,000
	Mission division	23,000	
	Post	30,000	
	Crow	14,000	
	Pablo	40,000	
	Polson	6,000	
	Big Arm	3,000	
	Camas	20,000	
Montana: Fort Peck	Little Porcupine	2,000	152,000
	Poplar River	28,000	
	Big Porcupine	4,000	
	Big Muddy	16,000	
	Missouri River	84,000	
	Galpin Bottom pump	10,000	
	Milk River	8,000	
Montana:			
Huntley	All units	32,405	32,405
Milk River	Malta division	12,800	219,557
	Other divisions	206,757	
Sun River	Fort Shaw unit	16,346	216,346
	Other units	200,000	
Montana-North Dakota: Lower Yellowstone.	First unit	40,914	60,116
	Extensions	19,202	
Nebraska-Wyoming: North Platte	North Platte C. & C. Co.	17,837	129,270
	First lateral district	36,760	
	Second lateral district	34,100	
	Third lateral district	38,000	
	Miscellaneous tracts	2,573	
Nevada: Truckee-Carson	First unit	96,573	206,000
	Other units	109,427	
New Mexico:			
Carlsbad	All units	20,277	20,277
Hondo	do	10,000	10,000
New Mexico-Texas: Rio Grande	Leasburg unit	25,000	155,000
	Other units	130,000	
North Dakota: North Dakota Pumping	Buford-Trenton unit:		15,025
	First division	4,050	
	Extensions	1,375	
	Upper Bottom division	2,600	
	Lower Bottom division	4,000	
	Trenton Flat	3,000	
	Williston unit:		11,289
	First division	8,189	
	West Bottom division	1,900	
	East Bottom division	1,200	
Oregon: Umatilla	Hermiston unit	6,968	25,000
	Second unit	4,350	
	Third unit	3,957	
	Fourth unit	1,976	
	Umatilla unit	1,150	
	Other units	6,599	
Oregon-California: Klamath	First unit	29,700	70,700
	Second unit	6,000	
	Tule Lake unit	35,000	
South Dakota: Belle Fourche	All units	100,000	100,000
Utah: Strawberry Valley	do	60,000	60,000
Washington: Okanogan	First unit	2,018	10,071
	Second unit	6,085	
	Third unit	464	
	Old water rights	1,353	
	Town of Okanogan	151	

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TABLE 7.—*Irrigable area.*

Present status.						
Public land.			State land.	Indian land.	Private land.	Total.
Entered.	Open.	Withdrawn.				
Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
16,000	.....	.....	14,000	.....	200,000	230,000
30,000	.....	44,000	.....	.....	57,000	131,000
.....	.....	4	.....	.....	14,303	14,307
13,670	.....	16,400	.....	.....	22,930	53,000
15,000	.....	19,000	.....	.....	106,000	140,000
67,219	.....	492	19,040	.....	120,249	207,000
95,100	925	.....	19,900	.....	2,100	118,025
.....	.....	.....	.....	.....	10,677	10,677
.....	.....	.....	.....	122,500	.....	122,500
70,000	2,000	.....	5,000	75,000	.....	152,000
.....	.....	.....	.....	152,000	.....	152,000
23,644	1,969	3,600	.....	.....	3,192	32,405
43,700	.....	28,300	8,700	30,000	108,857	219,557
110,477	2,405	54,108	14,680	.....	34,676	216,346
14,068	3,845	.....	1,644	.....	40,559	60,116
76,061	6,653	644	11,048	.....	34,864	129,270
21,259	328	118,864	102	.....	65,447	206,000
.....	.....	.....	.....	.....	20,277	20,277
240	.....	.....	.....	.....	9,760	10,000
1,423	.....	11,616	.....	.....	141,961	155,000
288	251	1,640	411	.....	12,435	15,025
54	289	.....	67	.....	10,879	11,289
10,794	156	1,746	38	.....	12,266	25,000
44	23	31,933	.....	.....	38,700	70,700
24,710	3,921	16,000	5,500	.....	49,869	100,000
.....	.....	.....	.....	.....	60,000	60,000
1,234	.....	.....	.....	.....	8,837	10,071

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TABLE 7.—*Irrigable area*—Continued.

Projects.	Units.		
	Name.	Area.	Total.
Washington, Yakima:		*Acres.*	*Acres.*
Sunnyside unit		102,824	137,361
Tieton unit		34,537	
Wyoming: Shoshone	First unit	15,246	164,122
	Second unit	15,954	
	Third unit	3,731	
	Fourth unit	6,378	
	Subsequent units	122,813	
Total, all projects		2,973,048	2,973,048
Per cent		100	100

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TABLE 7.—*Irrigable area*—Continued.

Present status.						
Public land.			State land.	Indian land.	Private land.	Total.
Entered.	Open.	Withdrawn.				
Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
1,269	142	1,154	2,880	.....	97,379	102,824
1,563	612	.....	2,274	.....	30,088	34,537
23,105	15,248	117,116	6,430	.....	2,223	164,122
660,922	38,767	466,617	111,714	379,500	1,315,528	2,973,048
22.2	1.3	15.8	3.7	12.7	44.3	100

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RECLAMATION ORGANIZATION.

(November, 1913.)

GENERAL OFFICES.

Hon. Franklin Knight Lane, Secretary of the Interior.

Brig. Gen. William L. Marshall, U. S. A., retired, consulting engineer to the Secretary of the Interior.

Frederick Haynes Newell, Director of the Reclamation Service, Washington, D. C.

Arthur Powell Davis, chief engineer, Washington, D. C.

Will R. King, chief counsel, Washington, D. C.

W. A. Ryan, comptroller, Washington, D. C.

I. D. O'Donnell, supervisor of irrigation, Billings, Mont.

Morris Bien, supervising engineer, in charge land and legal division, Washington, D. C.

F. W. Hanna, engineer, in charge engineering division, Washington, D. C.

O. H. Ensign, chief electrical engineer, 605 Federal Building, Los Angeles, Cal.; J. M. Gaylord and C. E. Hogle, engineers.

D. W. Murphy, engineer in charge of drainage, 602 Federal Building, Los Angeles, Cal.

D. C. Henny, consulting engineer, 1005 Spalding Building, Portland, Oreg.

A. J. Wiley, consulting engineer, Boise, Idaho.

W. H. Sanders, consulting engineer, 915 Grand View avenue, Los Angeles, Cal.

J. H. Quinton, consulting engineer, 605 Wright and Callender Building, Los Angeles, Cal.

W. W. Follett, consulting engineer, International (Water) Boundary Commission, consultation on Rio Grande, El Paso, Tex.

S. W. Dick, transportation agent, 777 Federal Building, Chicago, Ill.

C. J. Blanchard, statistician, Washington, D. C.

E. C. Bebb and E. A. Moritz, engineers, Washington, D. C.

J. Y. Jewett, cement expert, 408 Commonwealth Building, Denver, Colo.

E. G. Paul, chief clerk, Washington, D. C.

V. G. Croissant, accountant, Washington, D. C.

H. P. Seidemann, fiscal inspector, Washington, D. C.

C. G. Duganne, fiscal agent, Washington, D. C.

SOUTHERN DIVISION.

ARIZONA, NEW MEXICO, TEXAS, UTAH, CALIFORNIA.

L. C. Hill, supervising engineer, 307 Wright and Callender Building, Los Angeles, Cal.; C. S. Witbeck, examiner; S. B. Taggart, chief clerk.

Salt River project.—C. H. Fitch, project manager, Phoenix, Ariz.; W. A. Farish, engineer; I. C. Harris, engineer, power division; W. P. Marine, chief clerk; H. E. Edington and D. K. Clint, fiscal agents.

Yuma project.—F. L. Sellew, project engineer, Yuma, Ariz.; A. N. Kelley, irrigation manager; J. R. Stilson, chief clerk and fiscal agent.

Rio Grande project.—L. M. Lawson, project engineer, El Paso, Tex.; F. Teichman, engineer; J. D. Stannard, engineer; P. W. Dent, examiner; F. S. Cundiff, chief clerk; E. G. McCoy, fiscal agent; H. J. Gault, engineer, Las Cruces, N. Mex.; Earl Patterson, junior engineer, Selden, N. Mex.

Elephant Butte Dam.—E. H. Baldwin, construction engineer, Elephant Butte, N. Mex.; L. J. Charles, assistant engineer; J. L. Segall, chief clerk; J. C. Gawler, fiscal agent.

Carlsbad project.—L. E. Foster, assistant engineer, in charge of operation and maintenance, Carlsbad, N. Mex.; V. L. Minter, fiscal agent.

Hondo project.—C. A. May, clerk, in charge of operation and maintenance, Carlsbad, N. Mex.

Strawberry Valley project.—J. L. Lytel, project engineer, Provo, Utah; A. J. Hughes, chief clerk.

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PACIFIC DIVISION.

CALIFORNIA, OREGON, NEVADA.

E. G. Hopson, supervising engineer, 202 Central Building, Portland, Oreg.; O. P. Morton and E. S. Taylor, examiners.

Orland project.—A. N. Burch, irrigation manager, Orland, Cal.; C. H. Lillingston, chief clerk and fiscal agent.

Truckee-Carson project.—D. W. Cole, project engineer, Fallon, Nev.; Augustus Griffin, superintendent of irrigation; F. G. Hough, chief clerk; J. R. Post and G. W. Brown, fiscal agents.

Lahontan Dam.—F. H. Tillinghast engineer, Lahonton Nev.; L. G. Maney, superintendent of construction; H. N. Bickel, principal clerk.

Umatilla project.—H. D. Newell, project engineer, Hermiston, Oreg.; J. M. Griffin, superintendent of irrigation; C. W. Kellogg, chief clerk and fiscal agent.

Klamath project.—W. W. Patch, project engineer, Klamath Falls, Oreg.; Wm. Sargent, engineer; B. E. Hayden, assistant engineer, operation and maintenance; C. C. Hogue, chief clerk and fiscal agent.

Central Oregon investigations.—John T. Whistler, engineer in charge, 202 Central Building, Portland, Oreg.

NORTHERN DIVISION.

MONTANA, NORTH DAKOTA, WYOMING.

H. N. Savage, supervising engineer, Great Falls, Mont.; W. J. Egleston, examiner; C. P. Williams, engineer; G. O. Sanford, inspector of operation and maintenance.

Blackfeet project.—C. J. Moody, project engineer, Browning, Mont.; C. E. Frisbee, chief clerk; A. L. Erickson, fiscal agent.

Flathead project.—E. F. Tabor, project engineer, St. Ignatius, Mont.; E. D. Covell, assistant engineer; W. H. Meglasson, principal clerk; R. C. Elting, fiscal agent.

Fort Peck project.—R. M. Connor, project engineer, Poplar, Mont.; Frank Nivens, chief clerk and fiscal agent.

Huntley project.—R. H. Fifield, project manager, Huntley, Mont.; E. B. Le Claire, chief clerk and fiscal agent.

Milk River project.—R. M. Snell, project engineer; E. E. Roddis, assistant examiner, Malta, Mont.; W. W. Schlect, engineer, Vandalia, Mont.; G. E. Stratton, engineer, Glasgow, Mont.; H. W. Bruen, chief clerk; C. B. Mauser, fiscal agent, Malta, Mont.

St. Mary storage unit.—Joseph Wright, engineer, Babb, Mont.; C. E. Frisbee, chief clerk, Browning, Mont.; A. L. Erickson, fiscal agent, Browning, Mont. Erickson, fiscal agent, Browning, Mont.

Sun River project.—J. B. Bond, project engineer, Fort Shaw, Mont.; C. A. Peavey, chief clerk; H. T. Caldwell, fiscal agent.

North Dakota Pumping project.—W. S. Arthur, chief clerk and fiscal agent, Williston, N. Dak.

Lower Yellowstone project.—L. H. Mitchell, project manager, Savage, Mont.; C. H. Young, chief clerk; R. M. Reid, fiscal agent.

Shoshone project.—W. A. Stebbins, project manager, Powell, Wyo.; C. M. Jump, superintendent of irrigation; C. E. Piatt, chief clerk; T. W. Hause, fiscal agent.

CENTRAL DIVISION.

COLORADO, KANSAS, OKLAHOMA, SOUTH DAKOTA, NEBRASKA, WYOMING.

R. F. Walter, supervising engineer, 519 Commonwealth Building, Denver, Colo.; A. R. Honnold, examiner; J. A. Dolphin, chief clerk and fiscal agent.

Grand Valley project.—J. H. Miner, project engineer, Grand Junction, Colo.; O. T. Reedy, engineer; E. R. Mills, chief clerk; A. L. Collins, fiscal agent.

Uncompahgre Valley project.—Fred D. Pyle, manager, Montrose, Colo.; J. H. Fertig, assistant engineer; J. R. Alexander, examiner; J. M. Luney, chief clerk; E. R. Furstenfeld, fiscal agent.

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North Platte project.—Andrew Weiss, project engineer, Mitchell, Nebr.; Paul Rothi, irrigation manager; O. P. Burrows, chief clerk; M. T. Murray and J. R. Ummel, fiscal agent.

Pathfinder Dam.—H. D. Comstock, assistant engineer, Alcova, Wyo.

Belle Fourche project.—F. C. Magruder, project engineer, Newell, S. Dak.; R. B. Smith, chief clerk; T. E. Jones, fiscal agent.

IDAHO DIVISION.

IDAHO, OREGON, WYOMING.

F. E. Weymouth, supervising engineer, Boise, Idaho; B. E. Stoutemyer, examiner; F. L. Cavis, chief clerk; S. F. Hedden, fiscal agent.

Boise project (distribution unit).—G. H. Bliss, project manager, Boise, Idaho.

Boise River storage unit.—C. H. Paul, construction engineer, Arrowrock, Idaho; F. T. Crowe, contracting engineer, in charge of work in Pioneer Irrigation District; James Munn, superintendent of construction; A. B. Mayhew, engineer; R. R. Clawson, principal clerk.

Minidoka project.—P. M. Fogg, project manager, Rupert, Idaho; F. N. Cronholm, superintendent of construction; C. A. Lyman, chief clerk; N. K. Jensen, fiscal agent.

Minidoka power and pumping stations.—Barry Dibble, engineer, Minidoka, Idaho.

Snake River storage unit (Jackson Lake Dam enlargement).—F. A. Banks, Boise, Idaho; R. W. Miller, fiscal agent.

WASHINGTON DIVISION.

WASHINGTON.

C. H. Swigart, supervising engineer, North Yakima, Wash.; E. W. Burr, examiner; R. K. Cunningham, fiscal agent.

Okanogan project.—Calvin Casteel, project manager, Okanogan, Wash.; H. A. Yates, chief clerk and fiscal agent.

Yakima project:

Storage unit.—C. E. Crownover, project engineer, Meadow Creek, Wash.; T. E. Brick, chief clerk; W. W. Davis, fiscal agent.

Sunnyside unit.—R. K. Tiffany, project manager, Sunnyside, Wash.; J. G. Heinz, assistant manager; J. S. Moore, assistant engineer; E. M. Philebaum, chief clerk and fiscal agent.

Tieton unit.—R. K. Tiffany, project manager, Sunnyside, Wash.; G. C. Finley, assistant manager, Naches, Wash.; Floyd Foster, chief clerk.

EMPLOYEES.

Force employed June, 1913.

Where employed.	Government employees.				Contractors' force.	Grand total.	
	Secretary's appointees.	Registered.	Others.	Total.		Projects.	Division.
General administration:							
Washington office	90		8	98		98	
Chicago offices	14			14		14	
Denver office (cement)	2	2		4		4	
Los Angeles offices	14			14		14	
Southern division:							130
Division office	4			4		4	
Salt River project	18	93	458	569	95	664	
Yuma project	10	65	293	368		368	
Carlsbad project	3	9	39	51	6	57	
Hondo project		1	5	6		6	
Rio Grande project—							
Leasburg unit	18	28	56	102		102	
Elephant Butte unit	12	29	485	526		526	
Strawberry Valley	10	27	155	192		192	
							1,919

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An electrically operated shovel, illus., H. Hertz, The Excavating Engineer, Mar., 1913, vol. 9, p. 203.

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New Mexico, Carlsbad project.—Failures of Lake Avalon Dam, illus., E. C. Murphy, Eng. News, July 6, 1905, vol. 54, p. 9.

Reinforced concrete diaphragms for earth dams (section of Avalon Dam), illus., B. M. Hall, Eng. News, Feb. 6, 1908, vol. 59, p. 145.

New Mexico-Texas, Rio Grande project.—Pumping plants and wells in the valley of the Rio Grande, C. S. Slichter, Eng. News, Dec. 29, 1904, vol. 52, p. 580.

A Government railroad (short), Eng. Record, June 26, 1909, vol. 59, p. 819.

Engle Dam and Reservoir, illus., Eng. News, Aug. 18, 1910, vol. 64, p. 167.

Elephant Butte Dam (Engle), progress on (short), Eng. News, Oct. 19, 1911, vol. 66, p. 481.

Motion pictures of work, Engle Dam (short), Eng. News, June 20, 1912, vol. 67, p. 1190.

Construction of Engle Dam, illus. (short), The Contractor, Aug. 15, 1912, p. 35.

Construction features of the Elephant Butte Dam, illus. (incl. extracts from specifications), Eng. News, Jan. 16, 1913, vol. 69, p. 120.

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U. S. Bureau of reclamation

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, Secretary

FOURTEENTH ANNUAL REPORT

OF THE

RECLAMATION SERVICE

1914-1915

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WASHINGTON
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LETTERS OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
Washington, December 6, 1915.

SIR: In compliance with the provisions of section 2 of the act approved June 17, 1902, entitled "An act appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands," I have the honor to transmit the Fourteenth Annual Report of the Reclamation Service.

Very respectfully,

FRANKLIN K. LANE.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEPARTMENT OF THE INTERIOR,
UNITED STATES RECLAMATION SERVICE,
Washington, September 1, 1915.

SIR: Transmitted herewith is the Fourteenth Annual Report of the Reclamation Service. This report relates in particular to the work completed and in progress during the fiscal year ended June 30, 1915, but contains also information in regard to previous operations, in order that the methods, progress, and results of reclamation work may be more readily understood.

Very respectfully,

A. P. DAVIS,
Director and Chief Engineer.

The SECRETARY OF THE INTERIOR.

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NEW MEXICO-TEXAS, RIO GRANDE PROJECT.

R. F. WALTER, project manager, El Paso, Tex.

LOCATION.

Counties: Socorro, Sierra, Dona Ana, N. Mex.; El Paso, Tex.
Townships: 8 to 29 S., Rs. 3 E. to 5 W., New Mexico meridian.
Railroads: Atchison, Topeka & Santa Fe, El Paso & Southwestern, Southern Pacific, and Texas & Pacific.

WATER SUPPLY.

Source of water supply: Rio Grande.
Area of drainage basin: 37,000 square miles.
Annual run-off in acre-feet of Rio Grande: At San Marcial (30,000 square miles), 1895 to 1914, inclusive, maximum, 2,422,000; minimum, 200,700; mean, 1,129,400. At El Paso, Tex. (38,600 square miles), 1889 to 1914, inclusive, maximum, 2,010,000; minimum, 50,700; mean, 925,400.

AGRICULTURAL AND CLIMATIC CONDITIONS.

Area for which the service is prepared to supply water, season of 1915: 47,160 acres.
Area under rental contracts, season of 1915: 47,160 acres.
Length of irrigating season: From February 15 to November 15—274 days.
Average elevation of irrigable area: 3,700 feet above sea level.
Average annual rainfall on irrigable area: 30-year average, 10.07 inches; 1914, 17.02 inches.
Range of temperature on irrigable area: 0° to 100° F.
Character of soil of irrigable area: Fertile alluvium and sandy loam.
Principal products: Alfalfa, corn, wheat, melons, fruit, and vegetables.
Principal markets: Towns in Texas, New Mexico, Louisiana, and eastern cities.

LANDS OPENED FOR IRRIGATION.

No lands have been opened for irrigation by public notice.
All lands of Leasburg unit and in El Paso Valley are being irrigated under rental contracts.

CHRONOLOGICAL SUMMARY.

Reconnoissance and preliminary surveys begun in March, 1903.
Construction of Leasburg unit recommended November 29, 1905.
Construction of Leasburg unit authorized December 2, 1905.
Reclamation act extended to Texas June 12, 1906 (34 Stat. 259).
Treaty with Mexico providing for distribution of waters of the Rio Grande proclaimed January 16, 1907.
Construction of Elephant Butte Dam authorized by Congress and $1,000,000 appropriated March 4, 1907 (34 Stat., 1357).
Leasburg unit completed July, 1908.
First irrigation by Reclamation Service (Leasburg unit), season of 1908.
Construction of Elephant Butte Dam authorized by Secretary May 23, 1910.
Construction plans of Elephant Butte Dam approved by board of engineers June 6, 1910, January 22, 1911, August 12, 1912, January 30, 1913.
Construction plans approved by Secretary October 26, 1910.
Franklin Canal purchased October, 1912.
First 11 miles of Franklin Canal reconstructed March, 1914.
Second section (8 miles) reconstructed 1915.
Construction work begun on Mesilla Diversion Dam and East and West Side Canals, Mesilla Valley, 1915.
Elephant Butte Dam 92.7 per cent completed June 30, 1915.
Project, exclusive of storage, 19.7 per cent completed June 30, 1915.
Project, including storage, 50 per cent completed June 30, 1915.

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IRRIGATION PLAN.

The irrigation plan of the Rio Grande project provides for the storage of flood waters of the Rio Grande in a reservoir controlled by Elephant Butte Dam, about 12 miles west of Engle, N. Mex., and the diversion of water from the Rio Grande, about 6 miles below the storage dam, for the irrigation of lands in Las Palomas Valley; about 24 miles below for watering lands in Rincon Valley; about 60 miles below for the irrigation of 28,000 acres in the upper Mesilla Valley under the Leasburg Diversion Dam; about 80 miles below for the irrigation of 57,000 acres in the lower Mesilla Valley under the Mesilla Dam; and about 120 miles below for supplying water to lands in El Paso Valley and furnishing 60,000 acre-feet per annum for use on land in El Paso Valley on the Mexican side of the Rio Grande. The United States claims all waste, seepage, spring, and percolating water arising within the project and proposes to use such water in connection therewith. All the irrigation works required for Las Palomas and Rincon Valleys will be new; those for the Mesilla Valley include a diversion dam and 6½ miles of canal now constructed, as well as a diversion dam to be built 5½ miles southwest of Las Cruces to divert water for the lower end of the Mesilla Valley; and those required for El Paso Valley will supplement and improve present canal systems.

The features of the above irrigation plan that have been constructed are the diversion dam, headworks, and main canal for the 28,000 acres in the upper Mesilla Valley unit, and the reconstruction of a portion of the Franklin Canal in the El Paso Valley. Construction work was begun on the Mesilla Diversion Dam and East and West Side Canals.

CONSTRUCTION DURING FISCAL YEAR.

Elephant Butte Dam.—Concreting continued throughout the year, three shifts operating until April 1, 1915, and one shift after that time. The mass masonry placed during the year amounted to 313,950 cubic yards. The maximum amount placed during a month was 38,400 cubic yards in January, 1915; the maximum amount during one day, 2,651 cubic yards, January 25, 1915.

All gates and sluiceways, consisting of 16 slide gates and 4 balanced valves, were placed between September 1, 1914, and February 1, 1915.

The embankment, consisting of 165,000 cubic yards of material, was started in December, 1914, and completed June 30, 1915.

Final plans for the spillway, contemplating an arch bridge and four cylinder gates in connection with an ogee crest, were adopted and work was well under way on June 30. The required excavation at that time was approximately 60 per cent complete, including the open cuts for the gate discharges. The concrete placing system had been erected, and the bulk of the forms required had been constructed in the shop.

On April 1 concreting had advanced to such a point that the continuance of four placing crews on concrete was inadvisable. The force was reduced to one crew working one shift, and the number of employees dropped from 1,300 to 370.

Plans for the architectural treatment of the top of the dam have been adopted and detail drawings completed for this feature.

On June 30, 1915, the trash rack and straining tower had been completed to elevation 4,342. The lowest block in the dam was at elevation 4,335, the highest at 4,380, and work was in progress from station 2+25 to 11+09.

The dam, including spillway, embankment, and all other auxiliary features, was 92.7 per cent completed on June 30, 1915.

Franklin Canal.—On the Franklin Canal, El Paso Valley, reconstruction was begun in January on the section between Ysleta and Clint, 76,176 cubic yards of material being moved in enlarging the

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section. Several new structures were completed and some old ones repaired. An iron fence was erected along the populated section of canal on Eighth Street in the city of El Paso, as called for by the city ordinance. An important structure called the Ascarate Wasteway was completed during the year. This wasteway is located 6 miles below El Paso and permits the discharge of the entire capacity of the canal to the Rio Grande in case of necessity.

Preparations were begun in December for the construction of the Mesilla Diversion Dam near Las Cruces and the East Side and West Side Canals. Plant was assembled at the dam site and the work well started in February. Considerable difficulty was experienced in holding the cofferdam during the high-water period, on account of the rapid filling of all reservoir capacity at the storage dam. At the end of the fiscal year the floor and piers had been placed on the east side. Work on the East Side and West Side Canals was begun the latter part of December, 1914. The first mile of each canal was excavated by machine, 31,500 cubic yards being excavated by this means on the West Side Canal and 42,600 cubic yards on the East Side Canal. Approximately 450,000 cubic yards of earth were excavated by Government teams on the West Side Canal and 206,600 cubic yards on the East Side Canal. A number of concrete structures were also constructed.

SURVEYS.

The survey of farm properties continued and was nearly completed by the end of the fiscal year. These plats show approximately 12,000 separate tracts. Community ditch surveys also were in progress during the year and covered the ditches in the Mesilla and El Paso Valleys. In the Palomas and Rincon Valleys one survey crew located the two diversion dams and main canals, completing the preliminary field work and making possible the working up of final estimates and plans. Under the direction of the drainage engineer several main drains have been located in the Mesilla and El Paso Valleys, using data acquired from test wells bored during a portion of this and the previous year.

OPERATION AND MAINTENANCE.

The Leasburg Dam and the Leasburg Main Canal were operated, supplying water to the three principal community ditches in the upper Mesilla Valley. During the calendar year 1914 water was delivered through this system under contract between the United States and the Elephant Butte Water Users' Association.

The Franklin Canal was operated for its full length of 31 miles. Water was delivered through this canal under individual rental contracts, the basis of charge in 1914 being the area irrigated and in 1915 the acre-foot of water used.

During the calendar year 1914 there was irrigated under both systems an area of 28,442 acres. In the Mesilla Valley the amount of water delivered was 6.68 acre-feet per acre, while in the El Paso Valley the amount was 3.67 acre-feet per acre. The average duty of water for the entire project was 5.68 acre-feet per acre.

The season of 1914 was characterized by an excessive amount of rainfall, which was well distributed throughout the growing period. Although no reservoir water was available, good crop yields were made on the irrigated lands of the project.

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The season of 1915 has started with excellent growing weather, and at the end of June there was a plentiful supply of reservoir water available, which assures constant irrigation water throughout the season.

Historical review, Rio Grande project.

Item.	1910	1911	1912	1913	1914	[1] 1915
Acreage for which the Service was prepared to supply water	25,000	26,000	25,000	35,000	40,000	47,160
Acreage irrigated	22,600	25,980	23,115	27,723	28,442	32,000
Miles of canal operated	6	6	6	37	37	37
Water diverted (acre-feet)	[2] 99,790	[2] 152,685	[2] 125,000	[2] 149,610	[2] 179,964	[2] 217,800
Water delivered to land (acre-feet)	[2] 4.4	[2] 6	[2] 5.4	[2] 4.34	[2] 5.68	[2] 5.4

[1] Data for 1915 are estimated.
[2] At lateral headgates. Does not include scouring and silting water, furnished free of charge.

SETTLEMENT DATA.

On account of the availability of reservoir water during the season of 1915, a considerable amount of new land has been put in cultivation, especially in the El Paso Valley, under the Franklin Canal. A number of farms have been subdivided into small tracts in the vicinity of El Paso.

The towns of the project have grown steadily during the season. This is especially true of El Paso, where numerous building operations are constantly going on and the population steadily increasing.

Settlement data, Rio Grande project.

Items.	1913	1914	1915
Total number of farms on project	1,784	1,536	[1] 1,700
Population of farms	6,947	6,642	[1] 7,000
Number irrigated farms	1,784	1,536	[1] 1,700
Operated by owners	1,089	932	[1] 1,000
Operated by tenants	695	604	[1] 700
Population of	6,947	6,642	[1] 7,000
Number of towns	27	25	25
Population of	74,918	78,135	[1] 80,000
Total population in towns and farms	81,865	84,777	[1] 87,000
Number public schools	47	47	[1] 50
Number churches	76	81	[1] 85
Number of banks	14	14	19
Total amount capital stock	$2,580,000	$2,645,000	$3,251,000
Total amount deposits	$10,398,000	$11,653,000	$19,916,380
Total number depositors	40,000	45,784	48,090

[1] Estimated.

PRINCIPAL CROPS.

The crop returns per acre for the season of 1914 were considerably in excess of those for 1913, due probably to the fact that there was no water shortage in 1914. This advantage was somewhat offset, however, by damage to crops caused by heavy rains during the harvesting. In general, there was very little change in the amount and variety of the crops grown. Alfalfa was the principal crop, but no alfalfa seed was reported, as the season was too rainy for this crop. Excellent returns were received from pears, but the cantaloupe crop was almost a failure financially, due to inability to secure a market. Good results are expected from irrigation during 1915, as there is an abundance of stored water at Elephant Butte.

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Crop report of irrigated lands, Rio Grande project, Mesilla Valley, Leasburg unit (Reclamation Service operation), year of 1914.

Irrigated crop.	Area (acres).	Unit of yield.	Yields.		Values.		
			Total.	Average per acre.	Per unit of yield.	Total.	Per acre.
Alfalfa	12,648	Tons	44,268	3.5	$10.50	$464,814	$36.75
Barley	33	Bushels	990	30.0	.75	742	22.50
Beans	240	...do	1,320	5.5	1.80	2,376	9.90
Cantaloupes	81	Crates	16,200	200.0	1.25	20,250	250.00
Corn	3,205	Bushels	57,690	18.0	.84	48,460	15.12
Garden	533					31,980	60.00
Grapes	68	Pounds	136,000	2,000.0	.03	4,080	60.00
Milo maize	287	Bushels	5,740	20.0	.75	4,305	15.00
Oats	639	...do	28,755	45.0	.54	15,528	24.30
Orchard	363	Pounds	3,630	10,000.0	.02½	90,750	250.00
Pasture	274				13.00	3,562	13.00
Wheat	1,250	Bushels	43,750	35.0	.90	39,375	31.50
	19,621						
Less duplicated areas	1,066						
Total acreage cropped under irrigation.	18,555	Total and average				726,222	39.14
Irrigated, not cropped:							
Nonbearing orchard	420						
Miscellaneous	21						
Grand total irrigated	18,996						

Areas.	Acres.
Total irrigable area farms reported	[1] 19,500
Total irrigated area farms reported	18,996
Total cropped area farms reported	18,555

[1] 543 farms.

Crop report of irrigated lands, Rio Grande project, El Paso Valley (Reclamation Service operation), year of 1914.

Irrigated crop.	Area (acres).	Unit of yield.	Yields.		Values.		
			Total.	Average per acre.	Per unit of yield.	Total.	Per acre.
Alfalfa	5,772	Ton	21,760	3.8	$10.00	$217,600	$37.70
Apples	4	Pound	42,080	10,520	.02	842	210.40
Barley	29	Bushel	975	33.6	.67	653	22.53
Beans	80	...do	640	8	1.80	1,152	14.40
Cantaloupes	175	Crate	(1)				
Chili	40	Pound	240,000	6,000	.03	7,200	180.00
Corn	567	Bushel	11,119	19.6	.78	8,673	15.30
Garden tracts	1,048				150.00	157,200	150.00
Oats	38		1,088	28.6	.54	582	15.66
Onions	35	Pound	483,000	13,800	.01	4,830	138.00
Pastures	145				10.00	1,450	10.00
Pears	75	Pound	492,168	6,562	.025	12,304	164.06
Peaches	5	...do	133,720	26,744	.03	4,012	802.32
Sorghum (grain)	54	Bushel	1,890	35	.70	1,323	24.50
Sorghum (hay)	152	Ton	304	2	7.00	2,128	14.00
Sweet potatoes	60	...do	180	3	20.00	3,600	60.00
Vineyards	8	Pound	64,000	8,000	.03	1,920	240.00
Watermelons	60	...do	604,000	10,066	.006	3,624	60.40
Wheat	400	Bushel	6,000	15	.90	5,400	13.50
Total acreage cropped under irrigation.	8,747	Total and average				434,498	49.67
Irrigated, not cropped:							
Young orchard	555						
Miscellaneous	144						
Grand total irrigated	9,446						

Areas.	Acres.
Total irrigable area farms reported	[2] 11,300
Total irrigated area farms reported	9,446
Under rental contracts	9,446
Total cropped area farms reported	8,747

[1] No market.

[2] 230 farms.

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FINANCIAL STATEMENTS.

Assets, liabilities, reserves, and capital, Rio Grande project, to June 30, 1915 (exclusive of Elephant Butte storage).

ASSETS.

Cash in employees' hands awaiting transfer to fiscal agent			$2.75
Accounts receivable:			
Uncollected water rentals		$572.21	
Uncollected miscellaneous items		21.80	
Total			594.01
Inventories:			
Mercantile stores stock on hand		483.15	
Animals		2,615.97	
Mechanical and other equipment		35,560.26	
Materials and supplies on hand in storehouse		28,680.81	
Undistributed cost (freight and handling)		2,174.11	
Total			69,514.30
Construction work in process:			
Gross expenditure for construction of project to date		$1,434,133.40	
Less revenue earned during construction, as follows:			
Rental of cottages	$510.69		
Rentals of irrigation water	136,504.13		
Contractors' freight refunds	2,114.34		
Loss on mess houses	[1] 1,718.47		
Profits on mercantile stores	179.76		
Profits on hospital	6,662.68		
Total deductions		144,253.13	
Net expenditures for construction of project to date			1,289,880.27
Total assets			1,359,991.33

LIABILITIES, RESERVE, AND CAPITAL.

Accounts payable:			
Unpaid labor		$14,080.07	
Unpaid purchases		7,715.07	
Unpaid freight and express charges		17,076.09	
Unpaid passenger fares		379.25	
Unpaid agreements to purchase real estate		20,222.15	
Unredeemed coupons		14.85	
Unredeemed meal tickets		249.10	
Total			$59,736.58
Net investment:			
Disbursements	$1,401,787.91		
Transfers received from other projects	72,665.74		
		1,474,453.65	
Less—			
Collections	141,666.17		
Transfers issued to other projects	32,532.73		
		174,198.90	
Total			1,300,254.75
Total liabilities, reserves, and capital investment of the Government			1,359,991.33

[1] Deduct.

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Functional feature costs of Rio Grande project to June 30, 1915 (exclusive of Elephant Butte storage).

Examination and surveys	$142,635.25
Canal system	1,011,728.82
Lateral system	16,577.90
Drainage system	12,835.14
Flood protection	1,348.54
Farm units	120,396.84
Permanent improvements and land	12,784.59
Telephone system	6,089.45
Operation and maintenance during construction	109,736.87
Total	1,434,133.40

Estimated cost of contemplated work, Rio Grande project (exclusive of Elephant Butte storage), during fiscal year 1916.

Examination and surveys	$2,491.00
Canal system	268,090.00
Lateral system	10,000.00
Drainage system	5,000.00
Flood protection	5,000.00
Farm units	1,000.00
Permanent improvements and lands	1,291.00
Telephone system	7,474.00
Operation and maintenance	62,288.00
Stores and other operations (reimbursable accounts)	15,000.00
Unallotted to features	26,966.00
Total	404,600.00

Assets, liabilities, reserves, and capital, Elephant Butte storage, June 30, 1915.

ASSETS.

Accounts receivable, uncollected miscellaneous items			$60.25
Inventories:			
Mercantile stores stock on hand		$26,023.34	
Mechanical and other equipment		207,811.47	
Animals		6,070.38	
Material and supplies on hand in storehouse		85,019.30	
Goods in transit		23.00	
Unadjusted transfers between projects		1,168.86	
Undistributed cost (freight and handling on inventory property)		[1] 19,522.55	
			306,593.80
Construction work in progress:			
Gross expenditures for construction of project to date		5,115,591.53	
Less revenues earned during construction as follows:			
Rentals of cottages	[1] $21,009.16		
Rentals of power and light	2,243.33		
Miscellaneous revenues	5,068.54		
Contractors' freight refunds	2,189.34		
Forfeitures by defaulting bidders and contractors	5,243.43		
Profits on mess houses	7,359.53		
Profits on mercantile stores	82,260.15		
Profits on hospital	1,040.89		
Adjustments—			
Depreciation on plant and equipment	822,676.22		
Total deductions		907,072.27	
Net expenditures for construction of project to date			4,208,519.26
Total assets			4,515,173.31

[1] Deduct.

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LIABILITIES, RESERVES, AND CAPITAL.

Accounts payable:			
Unpaid progress earnings under construction contracts		$2,760.00	
Unpaid labor		18,942.61	
Unpaid purchases		12,519.39	
Unpaid contract holdbacks		1,200.00	
Unpaid freight and express charges		87,152.86	
Unpaid passenger fares		133.30	
Unpaid agreements to purchase real estate		11,662.55	
Unredeemed coupon books		563.60	
Unpaid miscellaneous		992.00	
			$135,926.31
Net investment:			
Disbursements	$4,437,258.09		
Transfers received from other projects	205,626.22		
		4,642,884.31	
Less—			
Collections	212,473.15		
Transfers issued to other projects	51,164.16		
		263,637.31	
Total			4,379,247.00
Total liabilities, reserves, and capital investment of the Government			4,515,173.31

Functional feature costs of Elephant Butte storage to June 30, 1915.

Storage system	$5,055,486.68
Permanent improvements and land	36,084.92
Stores and other operations (reimbursable accounts)	24,019.93
Total	5,115,591.53

Estimated cost of contemplated work, Elephant Butte storage, during fiscal year 1916.

Storage system	$521,531.60
Permanent improvements and lands	5,868.40
Stores and other operations (reimbursable accounts)	80,000.00
Total	607,400.00

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NEW MEXICO, HONDO PROJECT.

United States v. *El Paso and Rock Island Railway Co.*—Adjudication of the waters of Hondo River. Case still pending.

NEW MEXICO-TEXAS, RIO GRANDE PROJECT.

Oscar C. Snow v. *Francisco Abalos et al.*—Suit for the adjudication of water rights of the Rio Grande in New Mexico. Case still pending.

El Paso Water Users' Association v. *W. H. Austin et al.*—Suit for the adjudication of water rights of the Rio Grande in Texas. Case still pending.

United States v. *Lauteria Birner et al.*—Condemnation of land, Elephant Butte Reservoir, Socorro County. Report of commissioners of appraisement confirmed June 30, 1915.

United States v. *Jose Antonio Anaya et al.*—Condemnation of land for Engle Reservoir, Sierra County. Report by commissioners of appraisement pending.

**Elephant Butte Water Users' Association et al.* v. *L. M. Lawson et al.*—Suit filed in the district court for the third judicial district, N. Mex., May 4, 1915, praying for mandatory injunction requiring officials of the Reclamation Service to deliver, through Leasburg Dam and Canal, to certain community ditches and owners of rights thereunder, the normal flow of the Rio Grande to which the plaintiffs asserted a vested right, delivery of water having been discontinued on account of the refusal of the parties affected to execute water-rental contracts. A temporary restraining order was issued, but subsequently an agreement was reached and the case was dismissed at the cost of the plaintiffs.

OREGON, UMATILLA PROJECT.

Determination of water rights, Umatilla project.—Case still pending. Argument set for September 16, 1915.

OREGON-CALIFORNIA, KLAMATH PROJECT.

Klamath Lake Navigation Co. v. *California, Northeastern Railway Co. and Southern Pacific Co.*—Case still pending.

Adjudication proceedings Lost River water rights before State Water board.—Case still pending, United States appearing by suggestion.

United States v. *Robert A. Miller.*—Condemnation of land. Case settled by contract of December 1, 1914.

SOUTH DAKOTA, BELLE FOURCHE PROJECT.

Widell-Finley Co. et al v. *United States.*—No. 31436 Court of Claims. Damages on account of contract for construction of main supply canal. Case still pending.

Belle Fourche Valley Water Users' Association v. *Magruder et al.*—Suit in regard to various matters of controversy as to operation and maintenance, betterments, etc. Appeal from interlocutory orders decided by Circuit Court of Appeals, court sustaining the orders. Case now pending in United States District Court.

Samuel H. R. Robinson v. *United States.*—Court of Claims, No. 32678, for damages in connection with construction of main supply canal, Belle Fourche Project. Case still pending.

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ENGINEERING DATA FOR PROJECTS ON COMPLETION.

Engineering data for projects when completed.

RESERVOIRS.

Projects.	Name.	Area.	Capacity.	Spillways.	
				Length.	Elevation above stream bed.
		Acres.	*Acre-feet.*	*Feet.*	*Feet.*
Arizona: Salt River	Roosevelt	16,832	1,367,300	400	225
California: Orland	East Park	1,850	51,000	415	88
Colorado: Uncompahgre Valley	Taylor Park	2,260	106,000	125	150
Idaho:					
Boise	Deer Flat	9,835	177,640	None.	.....
Do	Arrowrock	2,860	244,300	402	247
Minidoka	Lake Walcott	11,350	[1] 150,000	2,385	42
Do	Jackson Lake	25,530	789,000	160	41
Montana:					
Blackfeet (Indian)	Two Medicine Lake	854	16,000	66	25½
Do	Spring Lake	1,400	29,000	50	45
Do	Four Horns	1,867	60,640	50	57
Flathead (Indian)	Big Draw	901	9,330	100	25
Do	Dog Lake	160	3,200	.....	30
Do	Dry Fork	250	1,918	100	25
Do	Flathead Lake	107,000	1,800,000	1,000	180
Do	Hubbart	480	20,000	50	108
Do	Kickinghorse	675	6,800	.....	23
Do	Little Bitter Root Lake	3,000	6,000	20	3
Do	Lower Crow Creek	300	9,485	100	82
Do	McConnell	100	2,000	.....	40
Do	McDonald Lake	220	10,600	200	51
Do	Mission	300	8,300	100	74
Do	Nine Pipe	1,630	15,100	(2)	[2] 30
Do	Pablo	2,100	29,600	(2)	[2] 36
Do	Polson	70	1,700	.....	80
Do	St. Marys Lake	300	25,000	50	52
Do	Twin	70	937	.....	25
Fort Peck (Indian)	Little Porcupine	390	3,900	.....	.....
Do	Big Porcupine	750	9,400	.....	.....
Do	Poplar River	2,600	31,000	.....	.....
Do	Wolf Creek	350	4,550	.....	.....
Do	Smoke Creek	300	5,300	.....	.....
Milk River	St. Mary Lakes	6,910	124,000	500	20
Do	Sherburne Lakes	2,000	78,000	200	70
Do	Nelson Reservoir	6,021	132,670	None.	.....
Do	Point of Rocks	.....	830	.....	.....
Sun River	Willow Creek	2,696	86,000	200	100
Do	Sun River Storage	3,540	269,000	580	321
Do	Pishkun Reservoir	1,542	45,700	Under control.	
Do	Muddy Creek	1,828	33,000	.....	80
Do	Benton Lake	9,300	144,000	Under control.	
Nebraska-Wyoming:					
North Platte	Pathfinder	22,700	1,070,000	660	184
Do	Reservoir No. 1, Lake Alice.	900	11,400	100	18
Do	Lake Minatare	2,240	67,025	100	55
Nevada:					
Truckee-Carson	Lake Tahoe	125,000	750,000	85	6
Do	Alkali Flat	8,500	88,000	.....	.....
Do	Lahontan	12,000	290,000	500	112
New Mexico:					
Carlsbad	Avalon	970	7,000	1,000	21
Do	McMillan	6,250	70,000	2,700	23-26
Hondo	Hondo	1,910	40,000	None.	.....
New Mexico-Texas: Rio Grande	Elephant Butte	40,080	2,627,700	300	193
Oklahoma: Lawton	Lake Lawtonka	1,080	14,000	257	50
Oregon: Umatilla	Cold Springs	1,500	50,000	330	90
Oregon-California:					
Klamath	Upper Klamath Lake	60,000	264,000	None.	.....
Do	Clear Lake	25,000	462,000	357	24
South Dakota: Belle Fourche	Belle Fourche	8,010	203,770	314	100
Do	Nine Mile	150	2,500	20	20
Utah: Strawberry Valley	Strawberry Valley	8,200	278,000	60	60
Washington:					
Okanogan	Salmon Lake	200	2,600	None.	.....
Do	Conconully	460	13,000	180	55

[1] 53,500 acre-feet only available; above fixed crest of spillway.
[2] No spillways; drainage limited; elevation is that of water surface.

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Engineering data for projects when completed—Continued.

RESERVOIRS—Continued.

Projects.	Name.	Area.	Capacity.	Spillways.	
				Length.	Elevation above stream bed.
Washington—Continued.		*Acres.*	*Acre-feet.*	*Feet.*	*Feet.*
Yakima	Bumping Lake	1,350	34,000	235	36
Do	Lake Clealum	4,680	501,000	660	112
Do	Lake Kachess	4,800	210,000	250	53
Do	McAllister Meadow	1,800	185,000	315	183
Do	Lake Keechelus	2,550	152,000	300	60
Do	Clear Creek	126	1,700	210	35
Wyoming:					
Shoshone	Shoshone [1]	6,600	470,000	300	233
Do	Ralston	200	2,100		
Total		577,803	13,774,995		

STORAGE DAMS.

Projects.	Name.	Type.	Maximum height.	Crest length.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
Arizona: Salt River	Roosevelt [2]	Rubble masonry arch, gravity.	280	1,125	342,325
California: Orland	East Park [2]	Concrete arch, gravity	139	250	12,200
Colorado:					
Uncompahgre Valley.	Taylor Park	Undetermined	200	([3])	([3])
Idaho:					
Boise	Upper Deer Flat [2]	Earth fill	70	4,000	1,190,275
Do	Lower Deer Flat [2]	do	40	7,200	1,207,606
Do	Deer Flat Forest [2]	do	16	950	22,500
Do	Arrowrock [4]	Rubble concrete arch, gravity.	349	1,100	585,130
Minidoka	Minidoka [2]	Rockfill, concrete core	86	937	242,500
Do	Jackson Lake [4]	Massive concrete gate section and earth fill.	67	5,000	320,000
Montana:					
Blackfeet (Ind.)	Two Medicine [2]	Earth embankment	36	900	28,600
Do	Spring Lake	do	50	1,500	75,000
Do	Four Horns	do	62	2,225	149,000
Flathead (Ind.)	Big Draw	Earth	35	3,600	137,000
Do	Dog Lake	Loose rock and earth	35	2,250	67,000
Do	Dry Fork	Earth	33	1,860	130,000
Do	Newell	Concrete	170	850	100,000
Do	Hubbart	Loose rock and earth	118	450	302,000
Do	Kickinghorse	Earth	31	3,700	181,000
Do	Little Bitter Root	do	10	300	4,000
Do	Lower Crow Creek	do	92	860	330,000
Do	McConnell	do	45	1,130	71,000
Do	McDonald Lake	Loose rock and earth	57	1,500	214,000
Do	Mission	do	80	2,500	346,000
Do	Ninepipe [5]	Earth	38	2,180	162,000
Do	Pablo [5]	do	46	14,000	1,028,000
Do	Polson	do	85	1,100	170,000
Do	St. Marys Lake	Loose rock and earth	58	2,200	140,000
Do	Twin	Earth	30	1,600	46,000
Fort Peck (Ind.)	Little Porcupine [2]	Earth and brush mattress			43,400
Do	Big Porcupine	Earth fill			227,000
Do	Poplar River	do			830,000
Do	Wolf Creek	do			85,300
Do	Smoke Creek	do			75,600

[1] Capacity to top fixed concrete crest, 456,000 acre-feet; flash boards, 2 feet; increased storage, about 14,000 acre-feet.
[2] Completed.
[3] Not designed.
[4] Under construction.
[5] First development, 64,191; completed for 5,000 acre-feet.
[6] First development, 153,750; completed for 5,000 acre-feet when paved; now paved for 3,000 acre-feet.

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Engineering data for projects when completed—Continued.

STORAGE DAMS—Continued.

Projects.	Name.	Type.	Maximum height.	Crest length.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
Montana—Contd.					
Milk River	St. Mary Lakes	Earth embankment	30	2,000	135,000
Do	Sherburne Lakes	do	78	850	215,000
Do	Nelson Reservoir	do	38	20,730	1,016,000
Do	Point of Rocks				
Sun River	Willow Creek [1]	Earth fill	110	1,045	452,000
Do	Sun River Storage	Masonry	329	989	296,050
Do	Pishkun	Earth fill	48	8,600	444,000
Do	Muddy Creek	do	90	800	440,000
Do	Benton Lake	do	40	240	12,000
Nebraska-Wyoming:					
North Platte	Pathfinder [2]	Broken range masonry arch	218	432	60,210
Do	Pathfinder Dike [2]	Earth fill	40	1,650	152,000
Do	Dam No. 1 [2]	do	30	3,100	240,000
Do	Dam No. 1½ [2]	do	23	2,550	119,000
Do	Minatare [2]	do	65	3,700	570,000
Nevada:					
Truckee-Carson	Lake Tahoe [2]	Concrete sluiceway regulator	14	109	425
Do	Alkali Flat	Not designed			
Do	Lahontan [2]	Earth and gravel fill with concrete spillways.	124	1,400	770,000
New Mexico:					
Carlsbad	Avalon [2]	Earth and rock fill, concrete core.	50	1,380	168,773
Do	McMillan [2]	Earth and rock fill	55	1,686	150,744
Hondo	Hondo [2]	6-earth embankments	25	17,371	639,993
New Mexico-Texas:					
Rio Grande	Elephant Butte [3]	Rubble concrete gravity, straight structure.	300	1,250	610,000
Do	Elephant Butte Dike [4]	Earth fill	42	1,900	164,650
Oklahoma: Lawton	Medicine Bluff [2]	Rubble masonry	55	357	9,500
Oregon: Umatilla	Cold Springs [2]	Earth fill	98	3,800	789,500
Oregon - California: Klamath.	Clear Lake [2]	Rock fill	33	790	56,600
South Dakota:					
Belle Fourche	Belle Fourche [2]	Earth fill	115	6,200	1,600,000
Do	Nine Mile	do	28	1,400	50,800
Utah:					
Strawberry Valley.	Indian Creek Dike [2]	Earth fill and reinforced concrete core.	37	1,311	101,107
Do	Strawberry [2]	do	72	488	108,415
Washington:					
Okanogan	Salmon Lake [2]	Concrete headworks			
Do	Conconully [2]	Hydraulic earth fill	64	1,000	336,000
Yakima	Bumping Lake [2]	Earth fill	45	3,425	233,852
Do	Lake Clealum	do	125	1,150	617,000
Do	Lake Kachess [5]	Earth and gravel fill	63	1,400	182,150
Do	McAllister Meadow	Earth and rock fill	200	950	1,200,000
Do	Lake Keechelus [6]	Earth and gravel fill	70	6,500	522,000
Do	Clear Creek [2]	Single concrete arch	63	210	2,516
Wyoming:					
Shoshone	Shoshone [2]	Rubble concrete arch	328	200	78,576
Do	Ralston [2]	Earth fill	50	150	24,740
Total					21,441,437

DIVERSION DAMS.

Projects.	Name.	Type.	Maximum height.	Length, weir.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
Arizona:					
Salt River	Granite Reef [2]	Rubble concrete weir	38	1,000	40,000
Do	Power Canal [2]	do	12½	400	4,800
Do	Joint Head [2]	Concrete weir	10	600	1,740
Arizona-California: Yuma	Laguna [2]	Indian weir, concrete and rock fill [7]	40	4,780	441,732

[1] Completed to height of 70 feet.
[2] Completed.
[3] Elephant Butte Dam 92.7 per cent completed June 30, 1915.
[4] Under construction.
[5] Lake Kachess Dam 98 per cent completed June 30, 1915.
[6] Lake Keechelus Dam 60.5 per cent completed June 30, 1915.
[7] Area formed by Laguna diversion dam, 6,400 acres.

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Engineering data for projects when completed—Continued.

DIVERSION DAMS—Continued.

Projects.	Name.	Type.	Maximum height.	Length, weir.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
California:					
Orland	Miller Buttes [1]	Concrete on piling	20	900	900
Do	North Side [1]	Concrete weir, with removable timber crest.	8	360	270
Do	East Park Feed Canal.[1]	Concrete arch	44	154	1,371
Colorado:					
Grand Valley	Diversion [1]	Masonry ogee weir with roller crest 10 to 15 feet high.	24	546	17,195
Uncompahgre Valley.	Gunnison [2]	Crib and rock fill and movable flashboards.	11½	237	3,200
Do	Montrose and Delta[1]	Movable flashboard weir	6.8	68½	
Do	Loutsenhizer [1]	Pile and timber weir		100	
Do	Selig [1]	Movable flashboard weir	6	95½	
Do	Ironstone	Not designed			
Do	East Canal [1]	Movable flashboard weir	([3])	72	
Do	Garnet	Not designed			
Idaho:					
Boise	Boise River [1]	Rubble concrete weir	45	[4] 246	21,750
Minidoka	Minidoka [1]	Combined diversion and storage dam. (See Storage.)			
Montana:					
Blackfeet (Indian)	Two Medicine [1]	Brush and rock	4	165	175
Do	Blacktail [1]	Concrete	14	54	290
Do	Badger Birch and Cut Bank.	Not yet designed			
Flathead (Indian)	Jocko River	Log crib, rock filled [5]			
Do	Little Bitter Root	do			
Do	Mud Creek [1]	Concrete	12	18	116
Do	Crow Creek [1]	do	13	82	330
Do	Post Creek—Kickinghorse.[1]	Log crib, rock filled	7	110	1,500
Do	Post Creek—Pablo Feeder.	do.[5]			
Do	Mission Creek [1]	Log apron	3	80	
Do	Dry Creek	Log crib, rock filled [5]			
Do	Finley Creek	do			
Do	Agency Creek	do			
Do	Big Knife Creek [1]	Concrete	5	6	25
Do	Valley Creek	Log crib, rock filled [5]			
Do	Other small creeks	do			
Fort Peck (Indian)	Little Porcupine	Concrete weir on timber crib.	4	150	
Do	Poplar River	do	4	300	
Do	Big Porcupine	do	6	150	
Milk River	Swift Current	Earth and timber crib	13	2,800	86,700
Do	St. Mary	Concrete	6.5	198	480
Do	Chinook	Reinforced concrete	20	250	3,400
Do	Dodson [1]	Timber crib, rock filled	25	319	12,000
Do	Vandalia [6]	Reinforced concrete	34	1,500	11,000
Sun River	Sun River [1]	Concrete masonry	132	220	6,200
Do	Deep Creek	Reinforced-concrete weir	12	100	500
Montana-North Dakota:					
Lower Yellowstone	Lower Yellowstone [1]	Rock-filled, timber weir	12	700	14,500
Nebraska - Wyoming: North Platte.	Whalen [1]	Concrete weir	29	300	80,740
Nevada:					
Truckee-Carson	Truckee River [1]	16 concrete sluiceways	22	171	3,322
Do	Carson River [1]	23 concrete sluiceways	21	240	2,707
New Mexico:					
Carlsbad	Avalon [1]	Combined storage and diversion. (See Storage.)			
Hondo	Hondo River [1]	Earth fill	20	100	3,700
New Mexico-Texas: Rio Grande.	Leasburg [1]	Rubble concrete weir	9	600	2,318
Do	Mesilla [6]	do	11.7	303	2,650
Do	Mexican [7]	Rubble masonry	4.7	320	
Do	Palomas	Not designed			
Do	Percha	do			
Oklahoma: Lawton	Medicine Bluff	Concrete weir	15	350	400

[1] Completed.
[2] Completed except for installation of movable flashboards.
[3] 6 feet and 6 feet 10 inches.
[4] Length, including logway.
[5] Not yet designed.
[6] Under construction.
[7] Constructed by Mexican authorities and used jointly.

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Engineering data for projects when completed—Continued.

DIVERSION DAMS—Continued.

Projects.	Name.	Type.	Maximum height.	Length, weir.	Volume.
			Feet.	*Feet.*	*Cubic yds.*
Oregon:					
Umatilla	Feed Canal (Echo)	Concrete weir arch	2½	400	296
Do	Three-Mile Falls [1]	Concrete multiple arch	24	935	4,160
Oregon-California: Klamath.	Lost River [1]	Hollow reinforced concrete	40	290	5,550
South Dakota: Belle Fourche.	Diversion [1]	Concrete weir	23	400	12,149
Utah: Strawberry Valley	Spanish Fork	Reinforced-concrete weir	16	70	1,261
Washington:					
Okanogan	Salmon Creek [1]	Concrete weir	4½	50	132
Yakima	Sunnyside [1]	Concrete ogee weir	8½	500	2,291
Do	Tieton [1]	Concrete and rock-filled crib	3	110	334
Wyoming: Shoshone	Corbett [1]	Reinforced-concrete weir	18	400	4,951
Total					797,135

CANALS.[2]

Projects.	Principal canals.			Mileage, with capacity in second-feet.				
	Name.	Maximum capacity.	Length.	Over 800.	301-800.	50-300.	Less than 50.	Total.
		Sec.-ft.	*Miles.*					
Arizona:								
Salt River	Power [1]	225	19					
Do	Arizona [1]	2,000	22					
Do	South [1]	1,200	2	32	71	78	566	747
Do	Consolidated [1]	1,000	7½					
Arizona-Cal.: Yuma	Main [1]	1,700	12					
Do	West Main	520	23	17	17	110	260	404
Do	East Main	880	24½					
California:								
Orland	East Park Feed [1]	250	7	.....	.....	7	.....	7
Do	North Main [1]	80	4.5	.....	.....	8	32	40
Do	South Main [1]	225	9.1	.....	.....	23	75	98
Colorado:								
Grand Valley	Main [3]	1,425	62	5	39	21	232	297
Uncompahgre	South [1]	1,300	12	12	.....	1	50	63
Do	West [1]	120	22	.....	.....	14	27	41
Do	Montrose and Delta [1]	450	32	.....	16	37	80	133
Do	Loutsenhizer [1]	125	15	.....	.....	8	22	30
Do	Selig [1]	300	20	.....	4	17	70	91
Do	Ironstone	350	12	.....	5	13	50	68
Do	East [1]	325	11	.....	4	10	50	64
Do	Garnet [1]	50	10	.....	.....	8	4	12
Idaho:								
Boise	Main South [1]	2,500	34					
Do	Mora [1]	915	56	40	57	165	788	1,050
Do	Deer Flat, Low Line [1]	780	37					
Minidoka	North Side [1]	1,450	8	21	23	106	600	750
Do	South Side [1]	950	13					
Kansas: Garden City	Main [1]	115	4	.....	.....	2	2	4
Montana:								
Blackfeet (Indian)	Two Medicine	350	25					
Do	Fisher	370	30					
Do	Cutbank North	250	30	.....	40	144	600	784
Do	Cutbank South	300	20					
Do	Four Horns Supply	165	12					
Flathead (Indian)	St. Mary Feeder	300	11					
Do	Pablo Feeder	300	44					
Do	Kickinghorse Feeder [1]	400	4					
Do	Ninepipe Feeder	250	2	.....	14	82	800	896
Do	Pablo Lateral A	400	17					
Do	Camas A	300	20					

[1] Completed.
[2] Exclusive of drains and waste ditches. Mileage given in front of brackets is for entire project; mileage on line with a principal canal is entire system under that canal.
[3] Under construction.

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Engineering data for projects when completed—Continued.

CANALS [1]—Continued.

Projects.	Principal canals.			Mileage, with capacity in second-feet.				
	Name.	Maximum capacity.	Length.	Over 800.	301-800.	50-300.	Less than 50.	Total.
		Sec.-ft.	*Miles.*					
Montana—Continued.								
Fort Peck (Indian)	Little Porcupine [2]	250	1			1	13	14
Do	Poplar River B	100	29			11	22	33
Do	Poplar River C	100				18	48	66
Do	Big Porcupine	100	7			7	25	32
Do	Missouri Gravity	625	100		10	30	60	100
Huntley	Main [2]	500	32		10	19	198	227
Do	Pumping High Line	60	12					
Milk River	St. Mary [2]	850	29	29				29
Do	Dodson South [2]	900	44	44		156	260	460
Do	Dodson North [2]	200	29			41	60	101
Do	Vandalia South [2]	300	48			45	50	95
Do	Nelson North [2]	250	45			40	30	70
Do	Nelson South [2]	250	27			34	50	84
Do	Chinook	550	56		30	45	10	85
Sun River	Fort Shaw [2]	175	12			18	103	121
Do	Pishkun Reservoir supply. [3]	2,500	12	12				12
Do	Sun River Slope [2]	1,000	34	34	10	74	286	404
Do	Other units				8	54	210	272
Montana-North Dakota: Lower Yellowstone.	Main [2]	830	66		49	19	190	258
Nebraska-Wyoming: North Platte.	Interstate [2]	1,400	95	90	18	91	607	806
Do	Ft. Laramie	1,430	26	62	42	44	[4] 300	398
Nevada: Truckee-Carson	Truckee [2]	1,500	31	42	62	80	511	695
Do	"V" Line [2]	1,500	8					
Do	"L" Line [2]	1,210	14.5					
Do	"S" Line [2]	1,210	18.7					
Do	"D" Line [2]	440	7					
Do	"AA" Line [2]	400	13.4					
Do	"T" Line [2]	400	9					
New Mexico:								
Carlsbad	Main [2]	450	[5] 3		13	12	120	145
Hondo	Main Inlet [2]	[6] 2,900	1.6		3	2	45	50
New Mexico-Texas:								
Rio Grande	Leasburg [7]	485	11					
Do	Franklin [2]	450	31½					
Do	West Side [2]	493	14½		34½	78½	27	140
Do	East Side	240	10					
Do	Palomas	70	8					
Do	Garfield	225	13					
North Dakota:								
North Dakota Pumping.	Buford Trenton [2]	60	6			6	39	45
Do	Williston [2]	90	3			3	57	60
Oklahoma: Lawton	Main	60	8			10		10
Oregon:								
Umatilla	Feed [2]	300	25					
Do	West extension [2]	375	30		33	52	90	175
Do	Maxwell	140	8					
Oregon-California:								
Klamath	Main [2]	1,400	9					
Do	Keno [2]	635	1					
Do	Lost River Diversion Channel [2]	250	8	9	9	42	250	310
Do	East Branch [2]	260	4.5					
Do	South Branch [2]	205	13.2					
Do	Adams [2]	205	12					
Do	Griffith Lateral [2]	190	9					
South Dakota:								
Belle Fourche	Inlet [2]	1,600	6½	7	55	105	460	627
Do	North Side [2]	700	45					
Do	South Side [2]	300	40					

[1] Exclusive of drains and waste ditches. Mileage given in front of brackets is for entire project; mileage on a line with a principal canal is entire system under that canal.
[2] Completed.
[3] Under construction.
[4] Estimated.
[5] Main and Southern canals 31 miles.
[6] Sidehill canal, built to be utilized as wasteway; length, 8,275 feet.
[7] 5.9 miles completed, Leasburg Canal.

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Engineering data for projects when completed—Continued.

CANALS—Continued.

Projects.	Principal canals.			Mileage, with capacity in second-feet.				
	Name.	Maximum capacity.	Length.	Over 800.	391-800.	50-300.	Less than 50.	Total.
Utah:		*Sec.-ft.*	*Miles.*					
Strawberry Valley	Power [1]	500	3	.....	3	.....	.....	3
Do	Trail Hollow Feeder [1]	125	4	.....	.....	4	.....	4
Do	Indian Creek [1]	750	2	.....	2	.....	.....	2
Do	High Line [2]	300	17.5	.....	.....	17.5	.....	17.5
Do	Lateral 20 [2]	55	6.1	.....	.....	1.1	5	6.1
Do	Lateral 30 [2]	66	8.5	.....	.....	4	4.5	8.5
Do	Lateral 31 [2]	10	2.4	.....	.....	.....	2.4	2.4
Do	Lateral 32 [2]	50	2.9	.....	.....	0.9	2	2.9
Do	Lateral 33	150	2	.....	.....	2.0	.....	2
Do	Lateral 34	55	11.1	.....	.....	1.3	9.8	11.1
Do	Miscellaneous	10	33.6	.....	.....	.....	33.6	33.6
Washington:								
Okanogan	Main [1]	110	2	.....	.....	10	51	61
Yakima	Sunnyside Main [1]	1,200	60	31	19	15	342	407
Do	Snipes Mountain	160	13	.....	.....	10	42	52
Do	Rocky Ford	100	13	.....	.....	1	29	30
Do	Mabton	110	14	.....	.....	8	44	52
Do	Benton Extension	80	16	.....	.....	9	13	22
Do	Tieton [1]	300	12	.....	12	32	291	335
Wyoming: Shoshone	Garland [1]	1,000	18	11	44	100	710	865
Total				448	756.5	2,207.3	10,008.3	13,420.1

[1] Completed.
[2] Under construction.

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Engineering data for projects when completed—Continued.

TUNNELS.			TUNNELS—Continued.		
Projects.	Name.	Length.	Projects.	Name.	Length.
		Feet.			*Feet.*
Arizona: Salt River. (All Salt River tunnels built.)	Power Canal:[1]		Nebraska-Wyoming: North Platte.	Pathfinder:[1]	
	Intake	1,695		North[1]	480
	Lee	122		South[1]	360
	Wehri cut-off—			Drainage[1]	155
	No. 1	428		Auxiliary[1]	209
	No. 2	129		Crosscut[1]	55
	No. 3	271		Fort Laramie:	
	Wehri	151		No. 1	2,700
	Pinto	999		No. 2	2,150
	Chilton	1,027		No. 3	3,700
	Robinson	152	Nevada: Truckee-Carson.	Truckee Canal:[1]	
	Gray	761		No. 1[1]	901
	Moffet	214		No. 2[1]	309
	Grapevine	872		No. 3[1]	1,515
	No. 6	206		Gilpin Spillway[1]	115
	No. 7	342	New Mexico: Carlsbad.	Spillway:	
	No. 8	553		No. 1[1]	97
	No. 9	320		No. 2[1]	103
	No. 10	489	Oregon: Umatilla	Spillway from Feed Canal.[1]	34
	No. 11	625	Oregon-California: Klamath.	Main Canal[1]	3,300
	No. 12	70	South Dakota: Belle Fourche.	South Canal[1]	1,306
	No. 13	110	Utah: Strawberry Valley.	Strawberry[1]	19,897
	Roosevelt:[1]			Strawberry Dam[1]	532
	Sluicing	480		Power Canal:	
	Outlet	167		No. 1[1]	800
	Penstock	620		No. 2[1]	705
Arizona-California: Yuma.	Colorado River siphon.[1]	930		Aqueduct[1]	750
Colorado:				Highline Canal[1]	227
Grand Valley	Main Canal:		Washington:		
	No. 1[1]	3,723	Okanogan	Conconully outlet[1]	395
	No. 2[1]	1,655	Yakima, Tieton	Steeple, No. 1[1]	55
	No. 3[1]	7,292		Steeple, No. 2[1]	48
Uncompahgre	Gunnison[1]	30,645		Trail Creek[1]	3,120
	South Canal:[1]			Columnar[1]	1,200
	No. 1	482		Tieton[1]	2,729
	No. 2	395		North Fork[1]	3,811
	No. 3	1,000	Wyoming: Shoshone[4]	Dam:[1]	
	No. 4	400		Lower outlet	498
	No. 5	390		Spillway	405
	West Canal[1]	1,750		Upper outlet	315
	West Canal Exten.[1]	800		Corbett[1]	17,355
	Selig Extension:[1]			Ralston Reservoir[1]	245
	No. 1	160		Shoshone Road:[1]	
	No. 2	360		No. 1	39
	No. 3	100		No. 2	45
	No. 4	310		No. 3	14
Idaho: Boise	Arrowrock[2]	487		No. 4	28
	Penitentiary	322		No. 5	136
	Arrowrock Logway.	159		No. 6	166
Montana:				Highline Canal:	
Flathead (Indian).	Newell[3]	1,800		No. 1	4,497
	St. Marys Lake Outlet.	1,620		No. 2	247
	Pablo 31A[1]	441		No. 3	2,100
Huntley	Main Canal:			No. 4	835
	No. 1[1]	724		No. 5	265
	No. 2[1]	1,545		No. 6	2,025
	No. 3[1]	385		No. 7	240
Sun River	Willow Creek[1]	584		No. 8	283
	Sun River Storage.	200		No. 9	120
	Pishkun Canal:			No. 10	185
	No. 1[1]	695		Willwood:	
	No. 2[1]	1,022		No. 1	560
	No. 3[1]	2,277		No. 2	375
	Sun River Diversion Tunnel.[1]	87			
	Muddy Creek Reservoir.	700	Total		157,029

[1] Completed.
[2] Arrowrock Tunnel, 190 feet of the 487 feet under dam section, has been filled with concrete.
[3] 1,703 feet driven. Completed for first development (unlined).
[4] Ralston Reservoir tunnel is a sluicing tunnel for the settling basin of Corbett tunnel.

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA.

Projects.	Name of units.	Area. Unit.	Area. Total.
		Acres.	*Acres.*
Arizona: Salt River	Gravity system	182,754	191,754
	Pumping system	9,000	
Arizona-California: Yuma	Gila Valley (Ariz.)	19,000	127,257
	Yuma Valley (Ariz.)	53,130	
	Mesa pumping (Ariz.)	40,000	
	Reservation (Cal.), Indian, 8,130 acres	15,127	
California: Orland	North side	6,764	20,320
	South side	13,556	
Colorado:			
Grand Valley	Gravity system	42,750	53,000
	Pumping system	10,250	
Uncompahgre	South Canal system	13,600	140,000
	Montrose and Delta system	33,600	
	West Canal system	7,200	
	Loutsenhizer Canal system	11,200	
	Selig Canal system	22,400	
	East Canal system	22,000	
	Ironstone Canal system	26,000	
	Garnet Canal system	4,000	
Idaho: Boise	Boise division (Penitentiary subdivision, 810; New York, 12,234; Cole, 4,899; Rawson, 11,331; Kuna, 7,779; Beatty, 14,028; Meridian 15,763; Sonna, 8,152; Ridenbaugh, 2,371).	77,367	255,000
	Nampa division (Ridenbaugh High Line, 4,171; Ridenbaugh Low, 5,391; Mora, 17,223; Deer Flat N., 3,308; Robinson Hill, 1,762; Deer Flat S., 11,444; Madden, 1,295; Melba, 15,000; Nampa, 4,119).	63,713	
	Caldwell division (Homestead, 2,535; Valley Mound, 5,850; Golden Gate, 13,594; Deer Flat, north, 2,334; Pipe Gulch, 5,653; Deer Caldwell, 2,898; Arena (2,000 acres in Oregon), 9,186; Deer High Line, 3,742; Fargo, 4,800; Crest, 4,824; Frohman, 7,094; Forest, 2,668).	65,178	
	Small pumping areas	742	
	Pioneer irrigation district and extensions	48,000	
Minidoka	Gravity system	71,300	120,100
	Pumping system	48,800	
Kansas: Garden City	All units	10,677	10,677
Montana:			
Blackfeet (Indian)	Cutbank north and south units	38,000	122,500
	Two Medicine unit	48,000	
	Badger-Fisher unit	33,000	
	Birch unit	3,500	
Flathead (Indian)	Jocko division	16,000	152,000
	Mission division	23,000	
	Post division	30,000	
	Crow division	14,000	
	Pablo division	40,000	
	Polson division	6,000	
	Big Arm division	3,000	
	Camas division	20,000	
Fort Peck (Indian)	Little Porcupine	2,000	152,000
	Poplar River	28,000	
	Big Porcupine	4,000	
	Big Muddy	16,000	
	Missouri River	84,000	
	Galpin Bottom Pumping	10,000	
	Milk River	8,000	
Huntley	First unit (pumping 3,420 Ac.)	28,998	32,877
	Second unit	1,815	
	Third unit (Pumping 2,035 Ac.)	2,064	
Milk River	Dodson, north unit	12,000	219,557
	Dodson, south unit	42,000	
	Nelson Reservoir, north unit	24,000	
	Nelson Reservoir, south unit	22,000	
	Vandalia, south unit	22,500	
	Chinook	97,057	

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA.

Projects.	Present status.							
	Public land.			State land.	Indian land.	Private land.		Total.
	Entered.	Open.	Withdrawn.			Railroad.	Other.	
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Salt River	14,339	.....	.....	11,030	(Notes)	.....	166,385	191,754
Yuma..Ariz.	7,112	3,239	33,600	7,138	.....	.....	61,041	112,130
Yuma..Cal.	4,940	60	160	.....	8,130	.....	1,837	15,127
Orland	.....	.....	4	.....	.....	.....	20,316	20,320
Grand Valley	13,250	.....	16,820	.....	.....	.....	22,930	53,000
Uncompahgre	16,332	.....	21,920	.....	.....	.....	101,748	140,000
Boise	73,700	205	300	18,500	.....	.....	162,295	255,000
Minidoka	97,373	727	.....	19,900	.....	.....	2,100	120,100
Garden City	.....	.....	.....	.....	.....	.....	10,677	10,677
Blackfeet (Indian)	11,000	.....	53,000	.....	58,500	.....	.....	122,500
Flathead (Indian)	45,350	.....	10,000	.....	95,760	.....	890	152,000
Fort Peck (Indian)	.....	.....	107	180	142,000	.....	9,713	152,000
Huntley	24,870	1,945	2,065	.....	.....	.....	3,997	32,877
Milk River	45,740	.....	25,889	9,266	30,000	120	108,542	219,557

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA—Continued.

Projects.	Name of units.	Area. Unit.	Area. Total.
Montana—Continued.		*Acres.*	*Acres.*
Sun River	Fort Shaw unit	16,325	174,025
	Great Falls unit	15,700	
	Sun River Slope, Spring Valley	15,000	
	Sun River Slope, Greenfields Bench	75,000	
	Greenfields Lake	15,000	
	Benton Lake	21,000	
	Muddy Creek Canal	16,000	
Montana-North Dakota: Lower Yellowstone.	First unit	42,450	60,116
	Extensions	17,666	
Nebraska-Wyoming: North Platte (interstate unit).	North Platte Canal & Colonization Co.	17,837	129,684
	First lateral district	39,559	
	Second lateral district	33,727	
	Third lateral district	38,561	
Fort Laramie unit		100,000	100,000
Nevada: Truckee-Carson	Lahontan Valley (Lower Carson)	151,000	206,000
	Truckee Canal district	13,800	
	Lahontan Bench	7,200	
	Churchill Valley	14,000	
	Pyramid Lake extension	20,000	
New Mexico:			
Carlsbad	First unit	20,261	24,796
	Second unit	4,535	
Hondo	All units	10,000	10,000
New Mexico-Texas: Rio Grande	Palomas Valley	6,985	155,000
	Rincon Valley	21,781	
	Mesilla Valley, Leasburg unit	36,772	
	Mesilla Valley, other units	60,432	
	El Paso Valley	29,030	
North Dakota: North Dakota pumping.	Buford-Trenton unit, first division	4,050	15,025
	Extensions	1,375	
	Canal "B," Upper Bottom division	2,600	
	Canal "B" Lower Bottom division	4,000	
	Trenton Flat	3,000	
	Williston unit, first division	8,189	11,289
	West Bottom division	1,900	
	East Bottom division	1,200	
Oklahoma: Lawton	Lawton unit	2,500	2,500
Oregon: Umatilla	West extension	11,100	36,300
	Hermiston unit (first)	6,968	
	Second unit	4,350	
	Third unit	3,957	
	Fourth unit	1,976	
	Fifth unit	155	
	Umatilla unit	1,150	
	Other units	6,644	
Oregon-California: Klamath	First unit	29,600	144,430
	Second unit	6,600	
	Third (Tule) unit	35,000	
	Sand Hollow unit	13,500	
	Horsefly unit	22,000	
	Pine Grove	3,730	
	Additional units	34,000	
South Dakota: Belle Fourche	First unit	11,245	97,916
	Second unit	35,852	
	Third unit	18,378	
	Fourth unit	13,116	
	Other units	19,325	
Utah: Strawberry Valley	Mapleton unit	3,500	50,000
	Lake Shore unit	2,500	
	High Line unit	24,000	
	Old canals	20,000	
Washington:			
Okanogan	First unit	2,018	10,099
	Second unit	6,085	
	Third unit	464	
	Old water rights	1,381	
	Town of Okanogan	151	

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA—Continued.

Projects.		Present status.							
		Public land.			State land.	Indian land.	Private land.		Total.
		Entered.	Open.	Withdrawn.			Railroad.	Other.	
		Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Sun River		46,349	2,777	36,088	12,559	.....	.....	76,252	174,025
Lower Yellowstone	Mont.	8,593	405	333	1,514	.....	3,839	25,267	39,951
	N. Dak.	7,631	.....	325	145	.....	.....	12,064	20,165
North Platte (interstate unit).	Nebr.	71,061	2,821	6,204	4,962	.....	.....	23,967	109,015
	Wyo.	2,165	454	.....	.....	.....	.....	18,050	20,669
Fort Laramie unit	Nebr.	8,542	.....	7,191	3,315	.....	.....	26,179	45,227
	Wyo.	17,153	.....	27,282	3,861	.....	.....	6,477	54,773
Truckee-Carson		18,401	4,340	100,779	180	4,640	26,900	50,760	206,000
Carlsbad		.....	.....	.....	923	.....	.....	23,873	24,796
Hondo		240	.....	.....	.....	.....	.....	9,760	10,000
Rio Grande	N. Mex.	300	.....	4,335	2,813	.....	.....	102,552	110,000
	Tex.	.....	.....	.....	.....	.....	360	44,640	45,000
Buford-Trenton		326	212	1,931	111	.....	.....	12,445	15,025
Williston unit		54	289	.....	67	.....	.....	10,879	11,289
Lawton		.....	.....	.....	.....	600	.....	1,900	2,500
Umatilla		3,328	61	4,381	.....	.....	3,342	25,188	36,300
Klamath	Oreg.	44	23	1,346	.....	.....	.....	77,270	78,683
	Cal.	.....	.....	65,187	.....	.....	.....	560	65,747
Belle Fourche		28,097	8,381	14,603	5,000	.....	.....	41,835	97,916
Strawberry Valley		.....	.....	3,500	.....	.....	.....	46,500	50,000
Okanogan		.....	.....	.....	.....	.....	.....	10,099	10,099

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA—Continued.

Projects.	Name of units.	Area.	
		Unit.	Total.
Washington—Continued.		*Acres.*	*Acres.*
Yakima, Sunnyside unit	Konnewock lands	3,080	110,828
	Main project	74,617	
	Mabton division	9,000	
	Prosser division	1,169	
	Pumping lands	18,362	
	Benton extension	4,600	
Yakima, Tieton unit	Naches Ridge, division 1	10,799	33,601
	Cowiche-Yakima, division 2	7,941	
	Wide Hollow, division 3	14,881	
Wyoming: Shoshone	First unit	15,245	149,360
	Second unit	15,756	
	Third unit	3,722	
	Fourth unit	6,375	
	Fifth unit (lateral A extension)	3,562	
	Subsequent units	104,700	
Total, all projects		3,118,011	3,118,011
Per cent		100	100

NOTES.

Arizona, Salt River.—Total area within project boundaries, 219.691 acres; uncultivated area (27,936 acres) excluded, leaving 191,754 acres, net present estimated area of project. Of the private land, 8,324 acres are in town sites. Entered land is under water rental. In addition to above, there are 2,814 acres of Indian lands.

Arizona-California, Yuma.—(1) Arizona lands: Entered land not under public notice. Withdrawn lands include 29,300 acres mesa lands. Private lands include Gadsden town site, 225 acres, and Somerton town site, 80 acres. (2) California lands: Entered land under public notice. Withdrawn, Bard town site, 160 acres. Private land includes agricultural experiment farm, 160 acres.

California, Orland.—Private land includes farms with total area of 320 acres under vested water rights, and 500 farms, 19,996 acres, under rental contract.

Colorado, Uncompahgre Valley.—No public notices issued. Entered lands are under water-right application, rental contracts, and vested water rights. Withdrawn land, water not available. Private land, under water-right application, and 12,505 acres under vested water rights.

Idaho, Boise.—No public notice issued. Area for which canals built and full water supply furnished, 150,000 acres. Pioneer irrigation lands to receive storage water from Arrowrock, 34,000 acres. Nampa and Meridian lands voted to receive Arrowrock water, 24,600 acres; New York lands applied to receive Arrowrock water, 21,000 acres. Future extensions, 25,000 acres.

Montana, Blackfeet.—Entered land is land outside of Blackfeet Reservation opened for entry and homesteaded, but construction not yet begun. Withdrawn land is vacant land on reservation not yet open to entry. Indian land includes 18 farms, 1,000 acres, irrigated; 642 farms, 25,650 acres, water available; and 800 farms, 31,850 acres, for which water not available.

Montana, Flathead.—No public notice. Entered lands under water rental.

Montana, Fort Peck.—Of the 142,000 acres Indian lands, 54,857 acres not allotted. No lands open to entry.

Montana, Huntley.—All entered and private land under public notice. Withdrawn land, water not available.

Montana, Milk River.—No public notices. Entered land includes 100 farms, 15,767 acres, under rental contract; 320 farms, 29,973 acres, for which water not available. Withdrawn land is that for which water not available. Private lands include 46,700 acres under vested water rights.

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Engineering data for projects when completed—Continued.

IRRIGABLE AREA—Continued.

Projects.	Present status.							
	Public land.			State land.	Indian land.	Private land.		Total.
	Entered.	Open.	Withdrawn.			Railroad.	Other.	
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
Sunnyside unit	1,526	.....	1,078	1,158	.....	.....	107,066	110,828
Tieton unit	1,953	201	.....	2,274	.....	329	28,844	33,601
Shoshone	30,072	8,005	101,715	6,346	.....	.....	3,132	149,360
.....	599,841	34,235	540,143	111,242	339,630	34,890	1,458,030	3,118,011
.....	19.2	1.1	17.3	3.6	10.9	1.1	46.8	100

NOTES.

Montana, Sun River.—Entered lands include 10,421 acres under public notice, 200 acres in towns, and 51,928 acres for which water is not available. Open lands include 2,716 acres under public notice and 160 acres in towns. Withdrawn land includes land for which water is not available. Private land includes 1,899 acres under public notice, 58,726 acres for which water is not available, and 218 acres under vested water rights. State lands include 281 acres entered under public notice and 11,538 acres not entered.

Montana-North Dakota, Lower Yellowstone.—Montana lands: 5,385 acres public lands entered under public notice. North Dakota lands: 910 acres public lands entered under public notice.

Nebraska-Wyoming, North Platte.—Nebraska lands: All open public lands and 62,343 acres entered lands under public notice. Withdrawn lands include 463 acres reserved for camp sites in first and second lateral districts. Wyoming lands: All public lands under public notice. Private lands include 17,837 acres under North Platte Canal & Colonization Co.

Nevada, Truckee-Carson.—Entered lands are under public notice. Private lands, 19,423 acres under vested water rights.

New Mexico, Carlsbad.—All private and State lands under public notice; 20,168 acres covered by approved water-right applications.

New Mexico, Hondo.—No public notice. Private lands, 1,200 acres under water-rental contracts.

New Mexico-Texas, Rio Grande.—No lands under public notice. Under vested water rights: In New Mexico, 18,946 acres; in Texas, 13,180 acres.

North Dakota, North Dakota pumping.—All entered and open land under public notice.

Oklahoma, Lawton.—No public notices issued. No farm units established. No charges announced. Duty of water not fixed.

Oregon, Umatilla.—Entered lands, 2,673 acres under public notice; 2,048 acres private lands under vested water rights.

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SUMMARY OF CONSTRUCTION RESULTS.

Summary of construction results to June 30, 1915.

Projects.	Irrigable lands.										Available (original) reservoir capacity.
	Estimated on completion.		Service could have supplied June 30, 1915.[1]		June 30, 1915.						
					Under water rights.		Under rental contracts.		Total under contract.		
	Acres.	Farms.	Acres.	Farms.	Acres.	Farms.	Acres.	Farms.	Acres.	Farms.	*Acre-feet.*
Arizona: Salt River	191,754	3,600	191,754	3,600			191,754	3,600	191,754	3,600	1,367,300
Arizona-California: Yuma	127,257	2,450	71,200	1,750	6,500	174	32,653	563	39,153	737	
California: Orland	20,320	502	20,320	502			20,320	502	20,320	502	51,600
Colorado:											
Grand Valley	53,000	900									
Uncompahgre Valley	140,000	3,500	65,000	1,100			65,000	1,100	65,000	1,100	
Idaho, Boise:											
Distribution unit	255,000	3,312	230,000	2,987			93,130	1,908	93,130	1,908	177,660
Storage unit											190,000
Minidoka	120,100	2,229	119,800	2,229	65,700	1,203	43,064	689	108,764	1,892	53,500
Idaho-Wyoming:											
Snake River storage unit											380,000
Jackson Lake enlargement											45,000
Kansas: Garden City	10,677	284									
Montana:											
Blackfeet (Indian)	122,500	3,060	26,649	661			1,500	30	1,500	30	16,000
Flathead (Indian)	152,000	2,980	49,400	820			10,075	180	10,075	180	10,000
Fort Peck (Indian)	152,000	2,790	10,220	255							3,900
Huntley	32,877	691	30,813	646	25,775	579			25,775	579	
Milk River	219,557	3,000	39,674	221			5,000	70	5,000	70	830
Sun River	174,025	2,900	16,346	261	10,748	194	588	4	11,336	198	16,700
Montana-North Dakota: Lower Yellowstone	60,116	723	36,250	465	3,301	51	27,120	345	30,421	396	
Nebraska-Wyoming: North Platte, Interstate and Fort Laramie	229,684	2,556	129,684	1,456	81,116	1,034	20,260	156	101,376	1,190	1,148,400
Nevada: Truckee-Carson	206,000	3,394	65,000	732	32,509	483	13,048	107	45,557	590	350,000
New Mexico:											
Carlsbad	24,796	616	24,796	616	20,553	519	50	1	20,603	520	77,000
Hondo	10,000	150	1,605	29			1,605	29	1,605	29	40,000
New Mexico-Texas, Rio Grande:											
Distribution unit	155,000	5,000	47,160	1,182			47,160	1,182	47,160	1,182	
Storage unit											625,000

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North Dakota, North Dakota pumping:											
Buford-Trenton unit	15,025	250	4,050	41	1,998	20	.....	.....	1,998	26	.....
Williston unit	11,289	186	8,189	131	4,762	112	.....	.....	4,762	112	.....
Oklahoma: Lawton	2,500	100	.....	.....	.....	.....	.....	.....	.....	.....	14,000
Oregon: Umatilla	36,300	1,450	16,000	640	13,413	537	200	5	13,613	542	50,000
Oregon-California: Klamath	144,430	2,600	35,400	590	27,222	437	4,200	65	31,422	502	662,000
South Dakota: Belle Fourche	97,913	1,310	78,591	1,020	51,581	663	.....	.....	51,581	663	203,770
Utah: Strawberry Valley	50,000	1,500	26,000	780	23,147	765	.....	.....	23,147	765	278,000
Washington:											
Okanogan	10,099	560	10,099	560	8,123	475	1,590	67	9,713	542	15,600
Yakima—											
Storage unit	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	263,000
Sunnyside unit	110,828	4,440	81,807	3,790	27,618	1,156	47,904	2,400	75,522	3,556	.....
Tieton unit	33,601	1,480	30,000	1,300	27,500	1,220	.....	.....	27,500	1,220	2,000
Wyoming: Shoshone	149,360	2,100	44,600	650	30,066	494	150	5	30,216	499	458,100
Total to June 30, 1915	3,118,011	60,603	[1] 1,450,407	29,017	461,632	10,122	626,371	13,008	1,088,003	23,130	6,500,360
Total to June 30, 1914	2,921,165	58,323	1,343,193	27.115	416,644	8,559	566,843	12,416	983,487	20,975	5,460,510
Increase	196.846	2,280	107,214	1,902	44,988	1,563	59,528	592	104,516	2,155	1,039,850

[1] Estimated June 30. More accurate figures prepared at close of season.

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Summary of construction results to June 30, 1915—Continued.

Projects.	Canals and drains (miles).										Tunnels.		Storage dams.				Diversion dams.					Levees and dikes.	
	Canals.					Waste-water ditches.	Drains.		Total drains and ditches.	Grand total.													
	Capacity (second-feet).				Total.																		
	Over 800.	301 to 800.	50 to 300.	Less than 50.			Open.	Closed.			Number.	Length (feet).	Masonry.	Earth.	Rock fill.	Total.	Masonry.	Earth.	Rock fill.	Crib.	Total.	Length.	Volume.
													Cubic yards.	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Miles.*	*Cubic yards.*
Arizona:																							
Salt River	32	71	78	552	733	14			14	747	23	10,803	342,325			342,325	46,729		740		47,469	1.1	63,804
Water users' work		6			6					6													
Southside work			17	49	66					66													
Gila River (Indian)			11	9	20	1			1	21													
Arizona-California: Yuma	17	12	62	224	315		12	4	16	331	1	930					66,714		375,018		441,732	55.4	2,930,074
California: Orland			38	107	145					145			12,200			12,200	1,868				1,868	.4	6,900
Colorado:																							
Grand Valley	4	30		40	74		1	1	2	76	3	12,670					16,612				16,612		
Uncompahgre Valley	12	23	91	232	358	10			10	368	12	36,792					1,500			1,700	3,200	.6	10,825
Idaho, Boise:																							
Distribution unit	40	57	165	712	974	66	56	1	123	1,097	1	322		2,420,380		2,420,380	21,749				21,749	.2	3,761
Storage unit											2	646	583,340			583,340							
Minidoka	25	19	106	463	613	11	108		119	732			16,564	146,677	79,321	242,562						.6	3,472
Idaho-Wyoming:																							
Snake River storage unit													3,649	63,345	4,037	71,031							
Jackson Lake													10,996	52,065	7,290	70,351							
Kansas: Garden City			2	2	4					4													
Montana:																							
Blackfeet (Indian)			85	250	335					335			2,370	35,750		38,120	290				290		
Flathead (Indian)		11	83	279	373					373	2	2,144		337,271		337,271				2,738	2,738		
Fort Peck (Indian)			36	83	119					119				34,000		34,000	475			450	925		
Huntley		10	19	198	227	72	6	29	107	334	3	2,654											
Milk River	8	36	72	110	226	88		1	89	315				5,150		5,150	10,763	5,900	8,350	8,363	33,376	6.8	188,418
St. Mary storage	25				25					25												2.4	134,400
Sun River	6	28	21	103	158	12			12	170	5	4,632		191,756	9,709	201,465	6,184				6,184	.7	4,890
Montana-North Dakota:																							
Lower Yellowstone		49	19	144	212	34	2		36	248									14,500		14,500	6.9	138,276

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Nebraska-Wyoming: North Platte	90	18	91	607	807	20	13	9	42	848	5	1,259	61,444	998,220	.....	1,059,664	4,966	75,775	.....	.....	80,741	.3	131,110
Nevada: Truckee-Carson	42	62	80	340	524	13	165	4	182	706	4	2,840	69,327	346,377	265,550	681,254	6,028	29,803	.....	.....	35,831	10.9	92,176
New Mexico:																							
Carlsbad	....	13	12	120	145	....	5	3	8	153	2	200	.....	100,643	50,101	150,744	6,251	107,146	55,376	.....	168,773	1.3	171,000
Hondo	....	3	2	45	50	....	....	....	....	50	....	.....	.....	616,282	23,710	639,992	.....	.....	3,700	.....	3,700	.....	.....
New Mexico-Texas, Rio Grande:																							
Distribution unit	....	35	24	....	59	....	....	....	....	59	....	.....	.....	.....	.....	.....	2,673	1,878	.....	.....	4,551	.4	18,859
Storage unit	....	....	....	....	....	....	....	....	....	....	....	.....	548,200	164,650	.....	712,850	.....	.....	.....	.....	.....	.4	4,200
North Dakota, North Dakota pumping:																							
Buford-Trenton unit	....	....	1	14	15	....	....	....	....	15	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Williston unit	....	....	3	43	46	15	....	....	15	61	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oklahoma: Lawton	....	....	....	....	....	....	....	....	....	....	....	.....	9,500	.....	.....	9,500	.....	.....	.....	.....	.....	.....	.....
Oregon: Umatilla	....	33	34	60	127	....	10	....	10	137	1	34	3,900	757,000	32,500	793,400	4,640	7,830	890	500	13,860	.3	8,000
Oregon-California: Klamath	9	1	51	126	187	10	29	....	39	226	1	3,300	.....	23,100	33,500	56,600	5,600	13,100	.....	.....	18,700	1.1	40,300
South Dakota: Belle Fourche	7	43	101	424	575	12	....	....	12	587	1	1,306	26,160	1,546,000	.....	1,572,160	12,149	4,800	.....	.....	16,949	.....	.....
Utah: Strawberry Valley	....	5	4	....	9	....	....	....	....	9	5	22,161	.....	108,415	.....	108,415	1,261	23,705	.....	.....	24,966	.3	102,517
Washington:																							
Okanogan	....	....	10	53	63	....	1	....	1	64	1	395	.....	336,000	.....	336,000	132	630	130	.....	892	.....	.....
Yakima—																							
Storage unit	....	....	....	....	....	....	....	....	....	....	....	.....	.....	670,191	.....	670,191	.....	.....	.....	.....	.....	.....	.....
Sunnyside unit	31	19	43	479	572	10	....	....	10	582	....	.....	.....	.....	.....	.....	2,291	.....	.....	.....	2,291	.3	18,000
Tieton unit	....	12	32	291	335	....	1	....	1	336	6	10,963	2,516	.....	.....	2,516	609	2,070	301	.....	2,980	.1	584
Wyoming: Shoshone	11	14	27	212	264	26	9	39	74	338	11	19,249	75,576	.....	.....	75,576	4,951	5,200	.....	.....	10,151	.1	5,200
Total to June 30, 1915	359	619	1,429	6,371	8,760	414	418	91	923	9,683	89	133,300	1,768,037	8,953,272	505,718	11,227,057	224,435	277,837	459,005	13,751	975,028	90.6	4,076,766
Total to June 30, 1914	325	538	1,318	5,826	8,007	548	....	....	....	8,555	83	129,341	.....	.....	.....	.....	.....	.....	.....	.....	.....	85.4	3,790,950
Increase	34	72	102	545	753	284	....	....	....	....	3	3,959	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.2	285,816

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Summary of construction results to June 30, 1915.

Projects.	Canal structures—number.									Bridges—number and length.													
	Over $2,000.		$500 to $2,000.		$100 to $500		Less than $100.			Steel.			Combination.			Wood.			Concrete.			Total.	
	Concrete.	Wood.	Concrete.	Wood.	Concrete.	Wood.	Concrete.	Wood.	Total.	Over 50.	Under 50.	Length.	Over 50.	Under 50.	Length.	Over 50.	Under 50.	Length.	Over 50.	Under 50.	Length.	No.	Length.
										Ft.	*Ft.*	*Feet.*	*Ft.*	*Ft.*	*Feet.*	*Ft.*	*Feet.*	*Feet.*	*Ft.*	*Ft.*	*Feet.*		*Feet.*
Arizona:																							
Salt River	45		267	9	289	461	35	849	1,955	2	1	186	13	33	1,882	9	270	3,759	4	11	694	343	6,521
Water users' work	6		3		6				15				2	1	131	1		67	1		66	5	264
South side work			1		38		1	207	247					12	344		31	203				43	547
Indian project, Gila River	5		5		40				50		9	270								1	25	10	295
Arizona-California: Yuma	27	2	36	16	186	413	280	1,329	2,289				5	16	795	10	70	2,572	6	17	714	124	4,081
California: Orland	8		15	1	69	12	1,693	21	1,819					72	693		5	110		199	1,025	276	1,828
Colorado:																							
Grand Valley	16		42	31	25	35	2	610	761							9	23	1,640				32	1,640
Uncompahgre Valley	28	29	22	54	31	99	5	1,749	2,017					4	83	11	179	3,613				194	3,696
Idaho:																							
Boise—																							
Distribution unit	72		107	35	2,071	1,913	1,079	7,136	12,413							35	974	16,057				1,009	16,057
Storage unit										1		96				4	16	1,248				21	1,344
Minidoka	27	2	74	10	865	286	52	6,257	7,573					4	160	75	254	11,390				333	11,550
Idaho-Wyoming: Jackson Lake enlargement																1		360				1	360
Kansas: Garden City	1							3	4								3	60				3	60
Montana:																							
Blackfeet (Indian)	9	1	6	7	35	8	102	1,076	1,244							1	43	997				44	997
Flathead (Indian)	22	2	23	6	102	80	118	1,375	1,728							2	146	2,785				148	2,785
Fort Peck (Indian)	9		6		37	3	129	175	359					1	36		33	667				34	703
Huntley	26	3	28	4	88	106	150	2,115	2,520	1	1	104					143	2,048				145	2,152
Milk River	40		66	21	132	99	30	782	1,170	1	1	115				14	105	3,356				121	3,471
St. Mary storage	5			9					14	1		200				11	27	1,232				39	1,432
Sun River	12		22		39	16	135	545	769		8	225	1		60	4	29	1,151				42	1,436
Montana-North Dakota: Lower Yellowstone	59	1	111	2	45	70	104	1,363	1,755	15	16	1,474		6	141	6	150	2,398				193	4,013
Nebraska-Wyoming: North Platte	32	24	149	25	1,055	34	1,036	4,090	6,445	11		726	11		726	7	142	3,943				171	5,395
Nevada: Truckee-Carson	63	3	172	5	260	154		1,200	1,862				6	6	692	9	119	3,816	3		417	143	4,925
New Mexico:																							
Carlsbad	7		6		34		380		427							1		225				1	225
Hondo			10		77			11	98								11	130				11	130

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New Mexico-Texas Rio Grande:																							
Distribution unit	21	3	34	37	24	37	.....	111	267	....	....	.....	6	13	855	3	70	2,444	1	10	259	103	3,558
Storage unit	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	....	300	.....	.....	.....	3	.....	886	....	....	.....	4	1,186
North Dakota: North Dakota pumping:																							
Buford-Trenton unit	2	.....	1	.....	8	.....	.....	80	91	....	....	.....	.....	4	68	.....	.....	.....	....	....	.....	4	68
Williston unit	8	.....	11	.....	22	.....	3	445	489	....	....	.....	.....	12	225	.....	3	31	....	....	.....	15	256
Oregon: Umatilla	15	.....	10	.....	35	.....	517	255	832	1	....	185	.....	.....	.....	.....	49	1,030	....	3	66	53	1,281
Oregon-California: Klamath	10	5	11	22	52	37	4	825	966	....	....	.....	.....	.....	.....	20	152	5,218	....	....	.....	173	5,218
South Dakota: Belle Fourche	28	1	101	19	238	189	26	3,057	3,659	5	....	360	.....	.....	.....	3	316	3,638	....	2	28	326	3,996
Utah: Strawberry Valley	13	.....	1	.....	70	.....	.....	.....	84	....	....	.....	.....	11	280	.....	28	680	2	13	330	54	1,290
Washington:																							
Okanogan	1	.....	2	.....	58	3	223	1,645	1,932	....	....	.....	.....	.....	.....	.....	3	100	....	....	.....	3	100
Yakima—																							
Storage unit	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	....	276	1	.....	140	4	.....	300	....	....	.....	7	716
Sunnyside unit	58	13	24	2	220	6	150	6,022	6,495	1	....	500	.....	.....	.....	7	47	1,513	....	1	20	56	2,033
Tieton unit	19	16	79	6	327	43	.....	43	533	....	....	.....	.....	.....	.....	8	165	3,518	....	....	.....	173	3,548
Wyoming: Shoshone	31	2	37	2	118	25	972	778	1,965	4	3	416	.....	.....	.....	12	137	2,737	....	10	96	166	3,249
Total, June 30, 1915	730	107	1,482	323	6,696	4,129	7,226	44,154	64,847	46	39	5,433	45	195	7,311	270	3,743	85,922	17	267	3,740	4,622	102,406
Total, June 30, 1914	645	75	1,264	206	5,978	3,748	5,622	37,087	54,625	45	39	5,337	40	155	6,094	209	3,177	70,603	16	194	3,191	3,875	83,225
Increase	85	32	218	117	718	381	1,604	7,067	10,222	1	0	96	5	40	1,217	61	566	15,319	1	73	549	747	17,181

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Summary of construction results to June 30, 1915—Continued.

Projects.	Culverts.										Pipe.							Grand total.
	Concrete.		Metal.		Terra cotta.		Wood.		Total.					Total.				
	No.	Length.	No.	Length.	No.	Length.	No.	Length.	No.	Length.	Pressure.	Culvert.	Drain.	Concrete.	Metal.	Terra cotta.	Wood.	
		Feet.		*Feet.*		*Feet.*		*Feet.*		*Feet.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*	*Lin. ft.*
Arizona:																		
Salt River	58	3,089	38	1,170			123	3,107	219	7,366	2,825	4,424	11,246	14,155	1,515		2,825	18,495
Water users' work													4,244	4,244				4,244
South side work	40	1,214							40	1,214				416	6,060	618		7,094
Indian project, Gila River	15	300							15	300	6,060	6,034						
Arizona-California: Yuma	139	2,680	3	61	5	260	384	6,332	531	9,333	500	301	21,075	240	61	21,075	500	21,876
California: Orland	119	4,210	2	40					121	4,250	8,938	4,082		12,920	40	60		13,020
Colorado:																		
Grand Valley	6	885	22	2,784	53	4,065			81	7,734	1,500	15,930	4,850		10,720	10,060	1,500	22,280
Uncompahgre Valley	25	2,901	22	1,218	2	140	47	825	96	5,084	18,573	1,974	4,558	1,509	8,514	4,758	10,324	25,105
Idaho:																		
Boise—																		
Distribution unit	17	1,009					360	5,048	377	6,057	69,129	1,009	4,000	50,205	728	322	22,883	74,138
Storage unit							100	2,980	100	2,980	6,870		4,780		2,770	4,780	4,100	11,650
Minidoka	22	2,196	677	17,948			312	9,163	1,011	29,307	10,171	15,197		2,255	4,717		18,396	25,368
Idaho-Wyoming: Jackson Lake enlargement											3,872				3,872			3,872
Montana:																		
Blackfeet (Indian)	26	2,088	2	36			87	5,629	115	7,753		6,128		4,782	1,346			6,128
Flathead (Indian)	25	1,446	2	78			90	1,614	117	3,138	2,163	4,438		4,363	2,235			6,598
Fort Peck (Indian)	7	180					13	218	20	398		2,042		1,534	508			2,042
Huntley	39	2,055	95	3,214	28	1,440	381	8,471	543	15,180	3,120	6,280	150,480	2,826	3,214	153,840		159,880
Milk River	28	2,252	32	1,599	103	5,254	9	160	172	9,265	5,355	9,713	2,000	6,208	1,723	9,137		17,068
St. Mary storage	2	370					85	1,700	87	2,004	2,434				2,434			2,434
Sun River	79	5,476			1	22	127	2,363	207	7,861	610	3,013		1,647	610	1,240	126	3,623
Montana-North Dakota: Lower Yellowstone	40	3,822			45	3,848	212	4,108	297	11,778		17,947				17,947		17,947
Nebraska-Wyoming: North Platte	48	1,439	114	2,799	90	1,816	54	864	306	6,948	5,019	12,436	57,261	3,496	4,345	62,721	4,154	74,716
Nevada: Truckee-Carson					5	258	28	1,258	33	1,516	5,727	258	24,803	2,227	3,500	25,061		30,788
New Mexico:																		
Carlsbad	1	400							1	400		400	16,598	1,902		15,096		16,998
Hondo			1	448					1	448		448			448			448
New Mexico-Texas: Rio Grande:																		
Distributive unit			13	1,214					13	1,214	220	1,214			1,434			1,434
Storage unit							12	250	12	250								

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North Dakota: North Dakota pumping:																		
Buford-Trenton unit	6	230	.....	.....	.....	.....	23	398	29	628	3,196	.....	.....	2,762	434	.....	.....	3,196
Williston unit	25	1,112	.....	.....	.....	.....	78	2,263	103	3,375	326	2,283	.....	2,283	326	.....	.....	2,609
Oregon: Umatilla	6	194	.....	.....	.....	.....	.....	.....	6	194	97,000	3,500	8,349	90,000	.....	8,349	10,500	108,849
Oregon-California: Klamath	5	751	64	4,459	40	2,590	8	400	117	8,200	.....	7,189	.....	140	4,459	2,590	.....	7,189
South Dakota: Belle Fourche	32	2,812	20	1,996	101	4,924	12	180	165	9,912	22,622	.....	.....	7,162	3,436	22,628	5,822	39,048
Utah: Strawberry Valley	9	350	25	325	30	900	25	450	89	2,025	336	1,900	.....	.....	336	1,900	.....	2,236
Washington:																		
Okanogan	12	592	3	80	.....	.....	.....	.....	15	672	126,523	.....	1,650	.....	122,106	1,650	4,417	128,173
Yakima—																		
Storage unit	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,936	.....	.....	1,936	.....	.....	.....	1,936
Sunnyside unit	16	1,900	.....	.....	26	1,022	.....	.....	42	2,922	208,718	1,022	.....	6,921	1,000	56,097	145,722	209,740
Tieton unit	62	4,214	.....	.....	.....	.....	.....	.....	62	4,214	279,161	11,226	5,200	246,132	.....	3,622	29,407	279,161
Wyoming: Shoshone	364	11,011	11	650	38	2,483	158	4,852	571	19,026	6,354	14,144	205,079	14,370	650	210,557	.....	225,577
Total, June 30, 1915	1,273	61,112	1,146	40,119	567	29,052	2,728	62,663	5,714	192,946	899,255	149,532	526,173	486,635	193,541	634,108	260,676	1,574,960
Total, June 30, 1914	1,120	51,105	880	26,338	306	16,191	2,329	54,628	4,635	148,262	.....	.....	.....	454,584	153,638	451,928	192,036	1,252,186
Increase	153	10,007	266	13,781	261	12,861	399	8,035	1,079	44,684	.....	.....	.....	32,051	39,903	182,180	68,640	322,774

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Summary of construction results to June 30, 1915—Continued.

Projects.	Flumes.								Canal lining.		Buildings.						Wells.	
	Concrete.		Metal.		Wood.		Total.											
	Number.	Length.	Number.	Length.	Number.	Length.	Number.	Length.	Concrete.	Wood.	Offices.	Residences.	Power plants.	Pumping stations.	Barns, storehouses, etc.	Total.	Number.	Depth.
		Feet.		*Feet.*		*Feet.*		*Feet.*	*Miles.*	*Miles.*								*Feet.*
Arizona:																		
Salt River	9	297	10	679	34	1,559	53	2,535	0.5		1	17	1	9	10	38	34	8,511
Water users' work	1	595					1	595				3	2			5	1	165
South Side work					1	16	1	16						1		1		
Indian project, Gila River												1	1	8	2	12	10	2,054
Arizona-California: Yuma	1	30			12	1,159	13	1,189		0.2	1	5		3	5	14		
California: Orland			2	365	5	500	7	865	16.0		1	1			4	6	3	200
Colorado:																		
Grand Valley			8	792	32	5,005	40	5,797	.1			1				1		
Uncompahgre Valley			106	16,001	52	7,955	158	23,956	5.8	1.2	3	15	2		15	35		
Idaho:																		
Boise—																		
Distribution unit	1	13	82	43,520	233	8,126	316	51,659	7.4		10	11			25	46	4	760
Storage unit											1	33	1		29	64		
Minidoka	2	190	13	908	192	12,464	207	13,562	.1		3	11	1	8	19	42	15	980
Idaho-Wyoming:																		
Snake River storage unit												1			2	3		
Jackson Lake enlargement											1	10		2	10	23	1	25
Kansas: Garden City												1	1	23	1	26	216	8,800
Montana:																		
Blackfeet (Indian)			3	1,216	3	503	6	1,719			1	1			2	4	6	184
Flathead (Indian)			2	3,028	48	8,174	50	11,202	.5		6	19			21	46	3	80
Fort Peck (Indian)			4	608	2	90	6	698	.1		3	7			8	18	3	75
Huntley	2	168	15	2,640	20	2,285	37	5,093	.1		1	11		1	11	24	4	625
Milk River			19	4,111	10	623	29	4,734	.6		4	3			7	14	3	95
St. Mary storage			1	720			1	720			4	49			43	96	2	60
Sun River			2	330	4	190	6	520	.4		6	40			37	83	7	323
Montana-North Dakota: Lower Yellowstone	10	841	2	580	31	1,221	43	2,642			4	16			8	28	8	214
Nebraska-Wyoming: North Platte	2	466	38	11,198	3	120	43	11,784			2	7			6	15	15	1,516
Nevada: Truckee-Carson			2	300	2	220	4	520	2.5		5	15	1	1	7	29		
New Mexico:																		
Carlsbad	1	497	1	40			2	537	9.3		1	5			10	16	1	127
Hondo												1			1	2	1	365
New Mexico-Texas:																		
Rio Grande—																		
Distribution unit			6	204	3	142	9	346	2.0			2			2	4	2	28
Storage unit											1	126	1	1	39	168	1	20

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North Dakota:																		
North Dakota pumping—																		
Buford-Trenton unit	1	42	1	296			2	338			1	3		2	2	8	1	30
Williston unit			4	376	1	133	5	509			2	6	1	3	5	17	2	100
Oregon: Umatilla			21	1,000	4	365	25	1,365	48.0		1	5			6	12	5	348
Oregon-California: Klamath			6	751	14	11,736	20	12,487	.6	1.4	1	6			12	19	6	690
South Dakota: Belle Fourche			14	5,080	20	5,640	34	10,720	.4	.2	3	9			9	21	2	1,968
Utah: Strawberry Valley	1	950					1	950	8.0		1	5	1		4	11		
Washington:																		
Okanogan	1	46	4	1,480	2	1,225	7	2,751	21.4		1	5	2	1	5	14		
Yakima—																		
Storage unit												4				4		
Sunnyside unit			9	5,178	501	195,800	510	200,978	4.6		1	19	4		4	28	4	610
Tieton unit			16	9,551	121	67,847	137	77,398	11.7		2	15			3	20		
Wyoming: Shoshone	1	54	16	1,581	111	2,226	128	3,861	.4		3	34		1	16	51	7	384
Total June 30, 1915	33	4,189	407	112,533	1,461	335,324	1,901	452,046	140.5	3.0	75	520	19	64	390	1,068	367	29,337
Total June 30, 1914	29	3,123	297	90,126	1,264	328,375	1,590	421,624	86.4	1.7	74	483	13	63	385	1,018	361	28,717
Increase	4	1,066	110	22,407	197	6,949	311	30,422	54.1	1.3	1	37	6	1	5	50	6	620

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Summary of construction results to June 30, 1915—Continued.

Projects.	Roads.	Railroads.	Telephone lines. Mileage.	Telephone lines. Telephones.	Transmission lines.	Power developed.	Material excavated. Class 1, earth.	Material excavated. Class 2, indurated material.	Material excavated. Class 3, rock.	Material excavated. Total.	Riprap placed.	Paving placed.	Stone masonry.	Concrete.	Cement used.	Cement and sand cement manufactured.
					Mi.		*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Sq. yds.*	*Cu. yds.*	*Cu. yds.*	*Barrels.*	*Barrels.*
Arizona:																
Salt River	147	....	215	72	119	8,640	3,736,489	1,024,762	580,664	5,341,915	7,000	11,172	916	341,627	420,572	338,452
Water users' work	5	....	.....	.....	12	4,250	314,781	14,300	117,180	446,261	.....	15,284	.....	13,842	17,722	.....
South Side work	....	....	.....	.....	3	.....	223,496	18,284	4,468	246,248	.....	1,058	.....	1,702	3,058	.....
Indian project, Gila River	10	....	23	7	23	.....	302,285	16,261	9,452	327,998	.....	2,154	.....	1,687	2,109	.....
Arizona-California: Yuma	25	36	140	114	....	.....	11,034,701	373,057	1,314,257	12,722,015	600,431	100,903	.....	97,534	98,210	.....
California: Orland	....	....	[1] 50	[1] 9	....	.....	552,418	192,123	14,425	758,966	1,397	3,223	.....	30,920	34,428	.....
Colorado:																
Grand Valley	1	....	43	3	....	.....	2,324,000	270,500	105,300	2,699,800	4,200	11,760	.....	52,800	62,100	.....
Uncompahgre Valley	22	7	34	27	7	.....	2,113,304	715,492	456,729	3,285,525	6,680	1,420	.....	88,627	83,092	.....
Idaho:																
Boise—																
Distribution unit	15	....	167	95	....	.....	11,069,642	1,250,928	237,241	12,557,811	9,425	19,093	24,357	63,868	90,216	.....
Storage unit	29	19	52	54	26	2,550	970,650	107,850	545,600	1,624,100	6,900	.....	.....	614,150	415,967	585,240
Minidoka	8	....	140	112	73	10,000	10,906,615	201,688	416,239	11,524,542	.....	93,486	.....	39,984	44,726	.....
Idaho-Wyoming:																
Snake River storage unit	36	....	70	7	....	.....	183,000	.....	6,749	189,749	4,037	11,364	.....	3,649	3,182	.....
Jackson Lake enlargement	....	....	.....	.....	....	.....	87,085	.....	6,381	93,466	837	.....	.....	10,996	10,506	.....
Kansas: Garden City	....	....	5	4	5	[2] 700	66,400	.....	.....	66,400	.....	.....	.....	5,388	7,571	.....
Montana:																
Blackfeet (Indian)	7	....	115	11	....	.....	1,779,030	41,068	92,728	1,912,826	1,550	5,920	.....	4,020	3,980	.....
Flathead (Indian)	24	....	107	19	....	.....	2,414,825	115,444	41,019	2,571,288	486	23,004	.....	5,851	7,288	.....
Fort Peck (Indian)	....	....	.....	.....	....	.....	1,003,415	2,200	.....	1,005,615	20	123	.....	1,802	1,872	.....
Huntley	....	....	23	12	....	286	1,897,552	22,190	12,600	1,932,342	1,680	1,609	.....	13,033	17,658	.....
Milk River	6	....	2	[1] 9	....	.....	5,364,737	75,210	19,322	5,459,269	10,558	18,500	.....	23,563	30,040	.....
St. Mary storage	75	....	111	17	....	.....	2,118,836	16,673	73,455	2,208,964	.....	10,025	.....	7,695	10,900	.....
Sun River	35	....	177	34	43	.....	2,941,320	163,945	372,123	3,477,388	8,042	5,159	.....	19,673	21,714	.....
Montana-North Dakota: Lower Yellowstone	12	....	78	35	....	.....	6,602,593	183,017	195,013	6,980,623	21,831	.....	.....	23,131	30,495	.....
Nebraska-Wyoming: North Platte	....	....	[1] 186	[1] 34	....	.....	11,655,291	632,436	201,560	12,489,287	50,288	61,965	60,210	126,637	151,340	.....
Nevada: Truckee-Carson	65	....	128	58	20	2,400	9,299,566	282,899	465,826	10,048,291	46,281	47,635	.....	112,202	124,046	29,305
New Mexico:																
Carlsbad	25	....	.....	.....	....	.....	927,385	63,897	61,007	1,053,289	80,127	7,657	6,251	23,291	26,859	.....
Hondo	....	....	15	4	....	.....	815,382	3,118	35,946	854,446	27,226	969	.....	3,830	2,850	.....

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New Mexico-Texas:																
Rio Grande—																
Distribution unit	10	....	25	5	....	.....	1,453,391	12,040	1,870	1,467,301	7,312	7,023	164	13,016	15,589	.....
Storage unit	22	13	23	44	10	[2] 2,000	456,850	90,100	413,400	960,350	12,710	.....	.....	557,500	302,430	562,670
North Dakota:																
North Dakota pumping—																
Buford-Trenton unit	....	....	29	2	29	.....	69,600	50	.....	69,650	.....	240	.....	1,654	2,599	.....
Williston unit	....	....	4	5	4	[2] 1,550	219,100	16	.....	219,116	.....	990	.....	2,632	3,369	.....
Oregon: Umatilla	7	....	20	18	....	.....	2,850,500	152,700	51,400	3,054,600	34,600	4,320	.....	52,930	70,960	.....
Oregon-California: Klamath	....	....	88	46	....	.....	2,799,892	514,363	137,290	3,451,545	7,900	5,727	.....	18,532	19,559	.....
South Dakota: Belle Fourche	....	7	88	28	....	.....	7,231,659	133,750	42,144	7,407,553	1,712	68,495	.....	53,713	69,452	.....
Utah: Strawberry Valley	55	....	44	17	[1] 50	1,600	1,210,219	137,776	190,946	1,538,941	8,835	18,280	.....	51,323	58,000	.....
Washington:																
Okanogan	2	....	35	21	5	550	690,800	100,200	50,250	841,250	1,000	1,000	.....	9,150	11,175	.....
Yakima—																
Storage unit	46	....	63	28	....	.....	1,610,115	32,724	8,135	1,650,974	38,555	14,062	.....	13,288	17,254	.....
Sunnyside unit	....	....	124	50	....	.....	2,957,361	99,942	106,898	3,164,201	9,000	11,260	428	20,598	24,368	.....
Tieton unit	39	....	68	48	....	.....	762,258	470,374	258,574	1,591,236	5,423	19,087	.....	27,137	39,770	.....
Wyoming: Shoshone	56	....	62	25	....	.....	2,582,711	54,571	316,945	2,954,227	7,265	11,616	472	123,002	144,356	
Total June 30, 1915	784	82	2,554	1,069	429	34,526	115,599,284	7,585,948	6,964,136	130,149,368	1,023,398	615,583	92,798	2,674,977	2,501,382	1,515,667
Total June 30, 1914	733	78	2,376	1,003	402	33,376	100,432,925	6,668,156	6,067,391	113,168,472	616,493	564,037	([3])	1,933,263	1,965,499	936,368
Increase	51	4	178	66	27	1,150	15,166,359	917,792	896,745	16,980,896	406,905	51,546	.....	741,714	535,883	579,299

[1] Telephone lines leased. [2] Steam plants. [3] No report.

General.—Number farms estimated for projects on completion, when data not available.

Arizona, Salt River.—Area is the irrigable lands within project boundary less the uncultivated area. Cement was manufactured in Government mill and used for construction of Roosevelt dam and structures. Work by water users' association was under general supervision of the Reclamation Service. Gila River work was done several years ago by Reclamation Service.

California, Orland.—Telephone lines are leased by Reclamation Service.

Idaho, Boise.—Area includes 80,000 acres of vested water-right lands and 25,000 acres under proposed extensions. Tunnels include Arrowrock, 487 feet long, now closed with concrete and log conveyor tunnel 159 feet long.

Idaho, Minidoka.—"Concrete" canal structures include 44 "metal" ones.

Montana, Milk River.—Wells include two aggregate depth 40 feet now abandoned.

Montana, Sun River.—Buildings include camp buildings reported in preceding year.

Nebraska-Wyoming, North Platte.—Area includes lands of North Platte Canal & Colonization Co. Concrete includes mortar in dams. Telephone lines are leased by the Reclamation Service.

New Mexico-Texas, Rio Grande.—Buildings include all camp structures.

North Dakota pumping.—Area service could supply Williston unit does not include 71 lots, leaving an acreage of less than 5 acres.

Oregon, Umatilla.—Number of farms service can supply included number of existing water-right applications.

Oregon-California, Klamath.—Area for "completed" project includes 76,600 acres approved.

Utah, Strawberry Valley.—Transmission lines: Of 50 miles; 30 miles to Strawberry tunnel and dam removed.

Wyoming, Shoshone.—Mileage of canals includes 5 miles of distributing canals built and abandoned on account of construction of drains, changes in farm units, etc.

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Summary of equipment June 30, 1915.

Projects.	Air compressors.	Automobiles.	Boats.	Boilers.	Cableways.	Standard-gauge cars.	Narrow-gauge cars.	Concrete cars.	Dump carts.	Other carts.	Concrete mixers.	Stiff-leg derricks.	Guy derricks.	Dredges.	Diamond drills.	Well drills.	Air and steam drills.	Electric drill.
Arizona: Salt River	2	9	1	6			13	1	2	12	5	2	3			2	5	3
Arizona-California: Yuma	3	3	1	20	1	116	19			3	3	1	5					
California: Orland		2	1				4				2			1				
Colorado:																		
Grand Valley	2	1		4	1		58	28	2		4	3					12	1
Uncompahgre Valley	5	2		9			78	8	1		3				1		18	
Idaho:																		
Boise—																		
Distribution unit		8	2				34		20		6	1			1			
Storage unit	3		3	3	2	44	65	3			4	8	1		2		22	
Minidoka	1	4		3						1	2	1	1	1			2	1
Jackson Lake enlargement			4	10				6			1		3	1			3	
Kansas: Garden City				1			2											
Montana:																		
Blackfeet (Indian)		1	1							2	1							
Flathead (Indian)		1	2				6		5	22		2					1	
Fort Peck (Indian)										3	2							
Huntley		1		2					2	6		1						
Milk River			1	2			6	3		8	1	1	1			1		
St. Mary storage			9	3			3		1	6	3	1						
Sun River	1	2	1	3			24	6	5	9	1	2			1		8	
Montana-North Dakota: Lower Yellowstone	1	2	2	1	1		12				1	3	3					
Nebraska-Wyoming: North Platte	2	2		3	1		6		1	12			4			1	7	
Nevada: Truckee-Carson	2	2	2	3	1		42		2	4	2	3	2		1		11	1
New Mexico:																		
Carlsbad		1	1				5				2							
Hondo																		
New Mexico-Texas: Rio Grande		5	1			1			2	8	5							
Storage unit	2			2	3	66	5		20		5	15	8			2	42	
North Dakota: North Dakota pumping			2				24			5								
Oklahoma: Lawton		1																
Oregon: Umatilla				1			2	7		6	3	3						
Oregon-California: Klamath		2	7	1			13		7	2	1		3				4	
South Dakota: Belle Fourche		1					26	22									7	
Utah: Strawberry Valley		1		1		2	8	12	2	3	3	2					9	
Washington:																		
Okanogan		1						4			1						4	
Yakima:																		
Storage unit	2	1	9	6			109	4	4		2	2	3	2	1	1	10	
Sunnyside unit		3	2	2							4							
Tieton unit	1	2	4															
Wyoming: Shoshone	1	1	2	2	2			16		6	1						10	
Washington and field offices		2	3	2											4			
Total, June 30, 1915	28	61	61	90	12	229	564	120	76	118	68	51	37	5	11	7	175	6
Total, June 30, 1914	27	58	58	84	18	264	621	132	81	92	60	113		5	9	8	172	

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Summary of equipment June 30, 1915—Continued.

Projects.	Electric generators.		Electric motors.		Electric-light plants.	Gasoline engines.		Steam engines.		Drag-line excavators.	Other excavators.	Elevating graders.	Road graders.	Horses and mules.	Hydraulic rams.	Locomotives, electric.	Locomotives, steam.
		K. W.		K. W.			Hp.		Hp.								
Arizona: Salt River	4	385	30	442		10	43	3	62	1			1	53	1	1	
Arizona-California: Yuma	2	27	1	10	1	16	385	24	1,000	2			1	70			4
California: Orland			1	3		4	19							5			
Colorado:																	
Grand Valley	7	538	33	1,141	1	5	43	3	435	1				40		5	
Uncompahgre Valley	4	350	5	112	2	1	12	10	775				1	16		3	
Idaho:																	
Boise—																	
Distribution unit			5	7		7	35	1	12	1	3		1	36			2
Storage unit	4	1,950	73	2,000	1			1	40	1			3	7			7
Minidoka	1	10	9	73	1	5	159	1	10	3				41			
Jackson Lake enlargement	1	50			1	3	60	10	345		2	1	1	27			
Kansas: Garden City	6	470	16	340	1	5	33										
Montana:																	
Blackfeet (Indian)						2	19					1		19			
Flathead (Indian)						4	13	1	40			1	1	50	1		
Fort Peck (Indian)													1	22			
Huntley						4	12			2	1	1	2	15			
Milk River	1	15			1	2	4	7	104	1			1	30			
St. Marys storage	2	17			3	1	30	9	345	1			2	208	3		
Sun River			10	323		3	24	4	160				1	60			2
Montana-North Dakota: Lower Yellowstone						2	8	5	180					31			
Nebraska-Wyoming: North Platte	1	45	2	13		5	40	10	207	1	1		1	109	1		
Nevada: Truckee-Carson	3	1,500	24	2,255	1	5	30	3	58	2			2	49	1		4
New Mexico:																	
Carlsbad						3	35			1	1	1	1	2	1		
Hondo														1			
New Mexico-Texas:																	
Rio Grande			2	8		5	50	3	45	2			1	18			
Storage unit	5	1,530	78	2,746		2	33	2	20					29			4
North Dakota: North Dakota pumping			1	2				1	15					3			
Oregon: Umatilla						8	43	3	70	1				19			
Oregon-California: Klamath						3	19	2	34	2			1	32	1		
South Dakota: Belle Fourche	1	3			1	3	22	1	30			1		62			1
Utah: Strawberry Valley	3	163	2	60	1	1	32					1	1	12		3	
Washington:																	
Okanogan	2	374	2	300		1	2							6	1		
Yakima:																	
Storage unit	4	282	19	375	2	3	28	8	176	1			1	142	1		6
Sunnyside unit						4	40	2	45				1	3	1		
Tieton unit	1	2				2	10	4	48				1	6			
Wyoming: Shoshone	1	5	1	5		9	55	1	40	1	1	1	3	21	3		
Washington and field offices						1	4										
Total, June 30, 1915	53	7,716	314	10,215	17	129	1,348	119	4,296	24	9	8	29	1,244	15	12	30
Total, June 30, 1914	55	9,221	317	11,064	17	121	1,450	119	4,011	28		12	27	1,411	12	41	

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Summary of equipment June 30, 1915—Continued.

Projects.	Motor cycles.	Pile drivers.	Plows.	Pumps.	Rock crushers.	Rollers.	Fresno scrapers.	Slip scrapers.	Wheel scrapers.	Sleighs and sleds.	Sprinklers.	Steam shovels.	Traction engines.	Dump wagons.	Heavy freight wagons.	Light freight wagons.	Spring wagons.
Arizona: Salt River	21	....	41	38	....	....	123	117	6	....	....	....	....	....	7	76	12
Arizona-California: Yuma	2	1	58	52	2	....	136	25	13	....	1	2	....	4	25	14	13
California: Orland	1	1	8	7	....	....	10	8	4	....	....	....	....	....	3	3	4
Colorado:																	
Grand Valley	....	1	17	9	2	....	27	83	16	....	3	....	....	....	6	3	5
Uncompahgre Valley	2	4	21	15	1	....	27	151	36	2	....	....	....	4	17	....	4
Idaho:																	
Boise—																	
Distribution unit	5	....	35	24	....	....	74	68	14	....	....	1	....	....	11	11	17
Storage unit	....	1	11	14	3	....	3	33	8	1	....	1	....	....	12	....	2
Minidoka	4	2	7	11	....	....	9	12	10	1	....	....	....	....	2	10	12
Jackson Lake enlargement	....	2	3	5	....	....	11	75	24	8	....	....	....	20	2	2	2
Kansas: Garden City	....	....	3	31	....	....	....	....	....	....	....	....	....	....	....	....	....
Montana:																	
Blackfeet (Indian)	1	1	28	5	....	....	....	41	17	....	....	....	....	....	10	2	2
Flathead (Indian)	1	....	20	1	....	2	51	38	18	11	....	1	....	....	14	11	9
Fort Peck (Indian)	1	1	28	4	....	....	103	7	6	....	....	....	....	....	4	9	3
Huntley	1	....	11	7	....	....	2	50	10	....	....	....	....	....	3	3	5
Milk River	1	3	10	13	....	....	17	12	17	6	....	....	....	8	4	12	3
St. Marys storage	2	1	36	5	....	1	30	43	....	8	....	2	1	31	18	6	4
Sun River	2	1	6	14	....	....	9	10	17	7	....	1	1	12	12	7	5
Montana-North Dakota: Lower Yellowstone	1	3	12	6	....	....	13	49	14	7	....	....	....	4	8	4	5
Nebraska-Wyoming: North Platte	1	1	20	25	1	....	19	74	53	....	....	....	....	17	6	32	19
Nevada: Truckee-Carson	1	1	16	36	1	1	56	36	9	....	....	1	1	10	16	6	6
New Mexico:																	
Carlsbad	....	....	7	4	....	1	6	29	25	....	1	....	....	15	1	....	1
Hondo	....	....	....	1	....	....	....	5	....	....	....	....	....	....	....	1	1
New Mexico-Texas:																	
Rio Grande	....	1	7	12	....	....	12	2	2	....	....	....	....	....	....	6	7
Storage unit	....	....	3	20	5	1	....	20	10	....	1	1	....	27	18	4	2
North Dakota: North Dakota pumping	....	....	2	....	....	....	....	8	....	....	....	....	....	....	1	1	2
Oregon: Umatilla	....	....	10	19	....	....	31	67	3	1	....	....	....	....	7	3	3
Oregon-California: Klamath	2	....	19	22	1	1	33	22	22	3	....	....	....	....	13	6	9
South Dakota: Belle Fourche	....	....	18	5	....	....	17	30	24	....	....	1	1	13	6	16	10
Utah: Strawberry Valley	....	....	8	6	1	....	12	15	8	4	....	....	....	2	1	8	3
Washington:																	
Okanogan	....	2	4	4	1	....	2	14	8	1	....	....	....	....	....	1	3
Yakima:																	
Storage unit	1	2	16	17	1	1	25	28	24	14	....	2	2	9	20	5	4
Sunnyside unit	....	....	9	12	....	....	18	28	11	....	....	....	....	....	5	2	2
Tieton unit	....	....	6	4	....	....	3	13	1	1	....	....	....	....	1	1	3
Wyoming: Shoshone	2	....	25	19	....	....	21	33	12	....	....	....	....	....	....	17	7
Washington and field offices	....	....	....	3	....	....	....	....	....	....	....	....	....	....	....	....	....
Total, June 30, 1915	52	29	525	470	19	8	900	1,246	442	75	6	13	6	176	253	282	189
Total, June 30, 1914	53	30	457	455	20	10	824	1,202	441	85	3	13	7	158	262	304	203

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Summary of employees June 30, 1915—Continued.

Projects.	Employees, 1915.													Approximate average wages per day for common labor.
	Average, January to June.						Maximum, January to June.[1]							
	Government force.				Contractors' force.	Grand total.	Government force.				Contractors' force.	Grand total.	Average all, June.[1]	
	Classified, educational.	Classified, non-educational.	Others.	Total.			Classified, educational.	Classified, non-educational.	Others.	Total.				
Arizona: Salt River	30	140	350	520	.....	520	32	160	500	692	.....	692	630	$1.90
Arizona-California:														
Yuma	11	61	561	633	.....	633	11	75	1,062	1,148	.....	1,148	499	2.00
California: Orland	6	7	83	96	6	102	6	15	168	189	20	209	122	2.40
Colorado:														
Grand Valley	15	53	364	432	185	617	16	62	632	710	290	1,000	505	2.31
Uncompahgre Valley	14	50	154	218	.....	218	14	65	256	335	.....	335	219	2.61
Idaho:														
Boise—														
Distribution unit	39	250	650	939	.....	939	42	304	1,197	1,543	.....	1,543	887	2.50
Storage unit	8	105	379	492	.....	492	10	125	551	686	.....	686	390	2.50
Minidoka	18	116	210	344	.....	344	19	156	443	618	.....	618	328	2.25
Jackson Lake enlargement	5	32	67	104	.....	104	8	64	153	225	.....	225	202	2.50
Kansas: Garden City	.....	.....	1	1	.....	1	.....	.....	1	1	.....	1	1	2.40
Montana:														
Blackfeet (Indian)	1	.....	4	5	.....	5	1	.....	10	11	.....	11	6	2.40
Flathead (Indian)	9	19	26	54	21	75	10	23	50	83	40	123	105	2.25
Fort Peck (Indian)	2	1	2	5	.....	5	2	3	5	10	.....	10	5	2.50
Huntley	9	11	35	55	.....	55	10	19	124	153	.....	153	152	2.24
Milk River	20	11	28	59	128	187	22	12	50	84	250	334	210	2.60
St. Mary storage	14	26	214	254	172	426	16	38	390	444	250	694	603	2.40
Sun River	23	20	30	73	340	413	25	23	51	99	479	578	516	2.18
Montana-North Dakota: Lower Yellowstone	5	10	23	38	.....	38	5	14	42	61	.....	61	30	2.25
Nebraska-Wyoming: North Platte	15	48	105	168	34	202	16	99	192	307	126	433	335	2.40
Nevada: Truckee-Carson	11	31	185	227	.....	227	14	31	283	328	.....	328	170	2.50
New Mexico:														
Carlsbad	3	10	275	288	35	323	3	10	381	394	53	447	163	1.50
Hondo	.....	1	6	7	.....	7	.....	1	28	29	.....	29	3	1.76
New Mexico-Texas:														
Rio Grande	26	76	650	752	.....	752	29	111	1,250	1,390	.....	1,390	513	1.50
Storage unit	15	65	859	939	.....	939	18	99	1,333	1,450	.....	1,450	572	1.67
North Dakota: North Dakota pumping	3	6	9	18	.....	18	3	8	9	20	.....	20	16	2.50
Oklahoma: Lawton	1	3	.....	4	.....	4	1	5	.....	6	.....	6	4	2.00
Oregon: Umatilla	12	25	163	200	15	215	12	30	238	280	15	295	295	2.40
Oregon-California: Klamath	6	20	229	255	41	296	6	25	475	506	65	571	182	2.48
South Dakota: Belle Fourche	8	15	70	93	14	107	8	35	125	168	16	184	164	2.50
Utah: Strawberry Valley	15	51	75	141	600	741	15	60	218	293	900	1,193	1,193	2.50
Washington:														
Okanogan	4	8	30	42	.....	42	4	8	97	109	.....	109	32	2.20
Yakima—														
Storage unit	12	83	300	395	.....	395	13	121	494	628	.....	628	628	2.20
Sunnyside unit	13	70	250	333	100	433	15	91	300	406	200	606	396	2.00
Tieton unit	5	12	15	32	.....	32	5	18	30	53	.....	53	43	2.20
Wyoming: Shoshone	11	27	87	125	23	148	12	34	116	162	33	195	136	2.40
Washington and field offices	186	30	39	255	.....	255	225	32	50	307	.....	307	265	2.45
Total, June 30, 1915	575	1,493	6,528	8,596	1,714	10,310	648	1,976	11,304	13,928	2,737	16,665	10,520	2.26
Total, June 30, 1914	514	1,207	5,954	7,675	854	8,437	563	1,641	9,458	11,662	1,637	13,299	9,228	2.23

[1] Totals of all projects are not necessarily the number at any one time.
[2] See p. 480 for details showing average in June.

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Summary of equipment and employees June 30, 1915—Continued.

NOTES.

Arizona, Salt River.—Boat is a launch. Narrow-gauge cars are ore cars. Pumps of different sizes.

Arizona-California, Yuma.—In addition to the above, one gasoline motor car. Pumps of different sizes.

California, Orland.—Pumps include one, each, 6-inch centrifugal, 3-inch diaphragm, 4-inch triplex, and 4 tank pumps.

Colorado, Grand Valley.—Pumps include one, each, 6-inch, 4 by 6 inch triplex, 5 by 8 inch triplex, and two, each, 4-inch, 8-inch, and 12-inch pumps. Sprinklers are wagon tanks. Wages: Contractors, $2.12½; United States, $2.50 per day. Contractors have large equipment, including 362 horses.

Colorado, Uncompahgre Valley.—Pumps, 3-inch, 4-inch, 5-inch, 6-inch, and 7-inch. Wages range from $2.50 to $2.72 per day.

Idaho, Boise (distribution unit).—Derrick is a hoisting derrick. In addition to above, 1 ditcher, 1 sawmill outfit, 9 tongue scrapers, and 1 gasoline speeder. Other excavators are electric.

Idaho, Boise (storage unit, Arrowrock).—Graders are Bagley graders. Locomotives, 3 standard gauge, 4 narrow gauge. In addition to above, 1 ice plant, 1 motor car, 1 sawmill, and 1 sand-cement plant.

Idaho, Minidoka.—Pumps are 3-2-inch centrifugal, 5-2-inch tank, and 3-4-inch diaphragm.

Idaho-Wyoming, Jackson Lake enlargement.—Includes Snake River storage.

Montana, Flathead.—Other carts include 7 concrete carts. Rollers are horse rollers. Contractors have large equipment, including 100 horses.

Montana, Huntley.—Pumps include one 5-inch centrifugal pump.

Montana, Milk River.—Pumps include 2 over 6 inches and 10 under 3 inches. Contractors have large equipment, including 150 horses.

Montana, St. Mary storage unit.—Not included in above, 2 tank wagons. Contractors also have large equipment, including 185 horses.

Montana, Sun River.—Narrow-gauge cars include 23 4-yard dump and 1 flat car. Locomotives are narrow-gauge. Not included in above, 2 boiler trucks and 11 transformers; total kilowatts, 58. Contractors also have large equipment, including 440 horses. Wages: Contractors, $2.12; United States, $2.24 per day.

Montana-North Dakota, Lower Yellowstone.—Pumps include one 12-inch centrifugal, 3-3-inch and 2 lift and tank pumps.

Nebraska-Wyoming, North Platte.—Not included in above, 1 cesspool wagon.

Nevada, Truckee-Carson.—Not included in above, 1 track speeder, 3 back-up scrapers. Shovel is an electric one.

New Mexico, Carlsbad.—Pumps include 2-5-inch, 7 horsepower; one 3-inch suction, and one 4-inch suction pump.

New Mexico, Hondo.—Pump is a 3-inch cylinder.

New Mexico-Texas, Rio Grande.—Car is push car. Pumps include one 10-inch, two 6-inch, one 4-inch, and 8 small hand pumps. In addition, United States has rented 160 horses and other equipment.

New Mexico-Texas, Elephant Butte storage.—Not included in above, 1 cement gun, 2 channelers, 2 drill sharpeners, 1 Calyx drill, 1 grouting machine, 1 motor car, 134 skips, one 7-ton machinery wagon.

North Dakota, North Dakota pumping.—Boats are the pumping barges.

Oregon, Umatilla.—Concrete mixers include 2 steam and 1 hand mixers. Pumps include sewer, pitcher, duplex, centrifugal, Red Jacket, and tank pumps.

Oregon-California, Klamath.—Pumps include 3-inch, 6-inch, 7-inch, and others. Contractors' force was only engaged part of two months.

South Dakota, Belle Fourche.—Pumps are 2-inch, 2½-inch, 3-inch, and 4-inch sizes. Contractors have small equipment, including 34 horses.

Utah, Strawberry Valley.—Other carts are concrete carts. Contractors have large equipment, including 375 horses.

Washington, Okanogan.—Drills are steam drills. Pile drivers are hammers. Pumps include No. 2 diaphragm and 5-inch piston pump.

Washington, Yakima storage.—Drills: 10 are pneumatic. Boats: 3 launches, 6 row. Pumps: 4-inch, 5-inch, 6-inch, etc.; also pulsometer.

Washington, Sunnyside unit.—Pumps: 9 hand, 1 small power, 2-4 by 6-inch centrifugal.

Washington, Tieton unit.—One automobile is a 1-ton motor truck. Pumps: 2-2-inch, 1-3-inch, 1-4-inch. In addition to above, 1 donkey engine.

Wyoming, Shoshone.—Concrete cars are 20-inch gauge. Drills: 4 rock and 6 pneumatic. In addition to above, 1 cement gun. Contractors' force worked only 5 months.

Washington and field offices.—Washington office, 99 to 112 employees (exclusive of consulting engineers).

Colorado River Basin.—3 boats, 2 boilers, 3 diamond drills, and 2 duplex pumps, and average 32 to 35 employees. Wages, $2.50.

Denver office, chief of construction: 27 employees in June.

Denver cement inspection: 6 employees.

Oregon cooperative work: 1 diamond drill; 1 Calyx shot; 1 gasoline engine, 4 horsepower; 1 duplex pump; and 16 to 32 employees. Wages, $2.40.

California cooperative work: 4 employees; no equipment.

Billings office: 2 employees.

Chief electrical engineer's: 11 to 13 employees.

Transportation office: 17 to 18 employees.

Six district offices, 4 to 12 employees each. Two automobiles are at the Yakima manager's office.

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CROP STATISTICS AND OPERATION AND MAINTENANCE DATA.

Acreage cropped and irrigated on reclamation projects in 1914.[1]

State and project.	Cereals.						Other grain and seed.							Hay and forage.							
	Barley.	Corn, Indian.	Oats.	Rye.	Wheat.	Total.	Alfalfa seed.	Clover seed.	Corn sorghum.	Flaxseed.	Millet seed.	Other.	Total.	Alfalfa hay.	Clover hay.	Corn fodder.	Peas.	Other hay.	Other forage.	Pasture.	Total.
Arizona: Salt River	17,066	2,315	1,930	....	9,744	31,055	.....	.....	12,651	....	....	....	12,651	86,733	.....	628	.....	1,037	.....	22,261	110,659
Arizona-California: Yuma	1,653	257	.....	....	570	2,480	5,485	.....	3,066	....	....	....	8,551	10,426	.....	.....	.....	671	551	7,058	18,706
California: Orland	.....	.....	.....	....	.....	.....	.....	.....	146	....	....	....	146	5,817	.....	.....	.....	.....	.....	4,099	9,916
Colorado: Uncompahgre Valley	162	400	6,166	26	5,244	11,998	20	3	.....	....	....	....	23	12,028	185	186	188	402	.....	825	13,814
Idaho:																					
Boise—																					
Farms reported	1,936	6,836	5,060	126	11,096	25,054	240	6,334	.....	....	28	1	6,603	18,128	6,110	714	41	334	.....	4,816	30,143
Farms not reported [2]	562	1,982	1,471	37	3,226	7,278	70	1,838	.....	....	8	....	1,916	5,267	1,775	207	12	97	.....	1,397	8,755
Minidoka—																					
Gravity unit	666	442	4,391	148	4,633	10,280	5	31	.....	....	....	....	36	19,028	914	39	151	191	9	5,397	25,729
South side pumping unit	874	11	3,774	6	7,407	12,072	5	67	.....	....	....	....	72	12,385	128	32	803	7	8	3,164	16,527
Montana:																					
Huntley	363	497	3,226	9	1,671	5,766	69	.....	.....	....	....	....	69	6,038	36	56	51	321	.....	.....	6,502
Milk River	112	.....	405	....	629	1,146	3	.....	.....	55	....	....	58	322	.....	.....	.....	616	.....	5	943
Sun River	376	1	2,123	14	518	3,032	10	.....	.....	....	4	....	14	2,627	.....	.....	5	306	3	377	3,318
Montana-North Dakota: Lower Yellowstone	407	107	575	....	1,071	2,160	.....	.....	.....	157	....	....	157	2,884	.....	.....	.....	90	.....	108	3,082
Nebraska-Wyoming: North Platte	2,261	6,024	7,017	245	609	16,156	922	.....	.....	....	43	....	965	32,464	.....	.....	.....	363	230	2,873	35,930
Nevada: Truckee-Carson	1,329	.....	417	....	1,446	3,192	.....	.....	.....	....	....	....	.....	21,556	.....	.....	.....	1,564	.....	19,398	42,518
New Mexico:																					
Carlsbad	5	496	.....	....	2	503	275	.....	559	....	....	....	834	7,637	.....	.....	.....	49	.....	374	8,060
Hondo	.....	21	.....	....	.....	21	.....	.....	.....	....	....	....	.....	668	.....	233	.....	6	357	20	1,284
New Mexico-Texas: Rio Grande	62	3,772	677	....	1,650	6,161	.....	.....	341	....	....	....	341	18,420	.....	152	.....	.....	.....	419	18,991
North Dakota: North Dakota pumping	17	13	16	1	25	72	.....	.....	.....	5	....	....	5	865	.....	.....	.....	22	.....	25	912
Oregon: Umatilla	.....	52	.....	3	7	62	.....	1	.....	....	....	....	1	2,048	5	81	.....	111	.....	542	2,787
Oregon-California: Klamath	4,066	.....	2,268	137	1,466	7,937	.....	.....	.....	....	....	....	.....	9,334	.....	.....	.....	2,399	.....	4,166	15,899
South Dakota: Belle Fourche	1,448	4,415	6,392	14	7,885	20,154	1,416	9	.....	....	58	....	1,483	9,745	52	880	.....	2,236	.....	3,604	16,517
Washington: Okanogan	.....	70	.....	....	.....	70	.....	.....	.....	....	....	....	.....	1,095	10	55	.....	200	.....	113	1,473
Yakima—																					
Sunnyside unit	.....	6,004	.....	....	481	6,485	.....	.....	.....	....	....	....	.....	26,164	802	.....	.....	1,347	.....	2,448	30,761
Tieton unit	500	1,522	740	....	1,125	3,887	8	60	.....	....	....	....	68	5,370	430	140	.....	840	.....	580	7,360
Wyoming: Shoshone	930	3	3,826	....	1,976	6,735	83	23	.....	....	1	....	107	12,627	17	2	2	94	.....	972	13,714
Total	34,795	35,240	50,474	766	62,482	183,756	8,611	8,367	16,763	217	142	1	34,100	329,676	10,464	3,405	1,253	13,303	1,158	85,041	444,300

[1] Data are for calendar year (irrigation season) except for Salt River project, Arizona, data are for corresponding agricultural year, October, 1913, to September, 1914.
[2] Irrigated area known; other figures assumed in same proportion as for farms reported.

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Acreage cropped and irrigated on reclamation projects in 1914—Continued.

State and project.	Vegetables and truck.						Fruits and nuts.							
	Beans.	Onions.	Potatoes, white.	Potatoes, sweet.	Truck.	Total.	Apples.	Citrus fruit.	Peaches.	Pears.	Prunes.	Small fruit.	Other.	Total.[1]
Arizona: Salt River	567		232		3,851	4,650		707				1,060		3,013
Arizona-California: Yuma	128				314	442								40
California: Orland					72	72		87				22	90	287
Colorado: Uncompahgre Valley	105	234	4,557		97	4,993	1,660		158	32	22	88		1,960
Idaho:														
Boise—														
Farms reported	442	8	1,107	9	562	2,128	211		42		9	104		366
Farms not reported	128	2	322	3	164	619	61		12		3	30		106
Minidoka—														
Gravity unit	5	15	1,837		338	2,195	320			10	2	42		374
South Side pumping unit	9	13	2,298		727	3,047	10					3		13
Montana:														
Huntley	40		120		297	457								
Milk River			14		2	16								
Sun River	1		115		78	194	1					1		2
Montana-North Dakota: Lower Yellowstone			54		81	135								
Nebraska-Wyoming: North Platte			1,097		305	1,402								
Nevada: Truckee-Carson		20	283		646	949								
New Mexico:														
Carlsbad		2		4	30	36			57					57
Hondo							57						7	64
New Mexico-Texas: Rio Grande	320				2,032	2,352	447					76		523
North Dakota: North Dakota pumping		1	36		20	57								
Oregon: Umatilla		3	61		55	119	53		118	8		65		244
Oregon-California: Klamath			461		130	591								13
South Dakota: Belle Fourche	42		195		159	396								
Washington:														
Okanogan	20	3	95		79	197	1,476		175	35	4	26	75	1,791
Yakima—														
Sunnyside unit			3,828		597	4,425	7,168		1,165	857	188	586		9,964
Tieton unit	75	70	3,380		230	3,755	620		215	140		32		1,007
Wyoming: Shoshone	4	1	87		131	223	1					1		2
Total	1,886	372	20,179	16	10,997	33,450	12,085	794	1,942	1,082	228	2,136	172	19,826

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State and project.	Miscellaneous.						Duplicated areas.	Total cropped.	Irrigated, not cropped.					Total irrigated.
	Beets, sugar.	Cotton.	Hops.	Cane.	Other.	Total.			Young alfalfa.	Young fruit.	Fall plowing.	Miscellaneous.	Duplicated areas.	
Arizona: Salt River		11,501		901	115	12,517	4,826	169,719		696		2,615		173,030
Arizona-California: Yuma		2,268				2,268	9,919	22,568				2,639		25,207
California: Orland					3	3	3,884	6,540		630		184		7,354
Colorado: Uncompahgre Valley	865				217	1,082	779	33,091	4,353	971	828	17	5,387	33,873
Idaho:														
Boise—														
Farms reported	7			19	3	29	6,259	58,064	6,344	6,096	741	54	6,532	64,767
Farms not reported	2			6	1	9	1,815	16,868	1,845	1,775	220	15	1,900	18,823
Minidoka—														
Gravity unit	563				13	576	52	39,138	4,581	766	1,117	1,657	1,529	45,730
South Side pumping unit	1,797					1,797	16	33,512	1,970	502	364	1,487	2,047	35,788
Montana:														
Huntley	4,274					4,274		17,068						17,068
Milk River								2,163				38		2,201
Sun River	1					1		6,561				52		6,613
Montana-North Dakota: Lower Yellowstone					87	87		5,621				122		5,743
Nebraska-Wyoming: North Platte	5,083					5,083		59,536	4,888				3,892	60,532
Nevada: Truckee-Carson							7,374	39,285		231				39,516
New Mexico:														
Carlsbad	5	1,303		208		1,516	275	10,731	940	238		781		12,690
Hondo				36		36	233	1,172				52		1,224
New Mexico-Texas: Rio Grande							1,066	27,302		975		165		28,442
North Dakota: North Dakota pumping							1	1,045	11					1,056
Oregon: Umatilla					27	27	227	3,013	439	1,274		530	154	5,102
Oregon-California: Klamath								24,440						24,440
South Dakota: Belle Fourche	37				45	82	1,923	36,709	4,940	91		15	4,301	37,454
Washington:														
Okanogan					42	42	393	3,180	328	4,260	178	882	1,088	7,740
Yakima—														
Sunnyside unit			187			187	2,549	49,273	1,776	8,266		8,337	3,600	64,052
Tieton unit			286			286	443	15,920		6,280	105	1,695	3,400	20,600
Wyoming: Shoshone	119				5	124		20,905	1,917	134	689	158	1,577	22,226
Total	12,753	15,072	473	1,170	558	30,026	42,034	703,424	34,332	33,185	4,242	21,495	35,407	761,271

[1] Includes 1,387 acres not reported in detail.

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Average yields per acre of irrigated crops harvested on reclamation projects in 1914.[1]

State and project.	Cereals.						Other grain and seed.					Hay and forage.				
	Barley.	Corn, Indian.	Oats.	Rye.	Wheat.	All.	Alfalfa seed.	Clover seed.	Corn, sorghum.	Flax-seed.	Millet seed.	Alfalfa hay.	Clover hay.	Other hay.	Corn fodder.	Field peas.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Bushels.*
Arizona: Salt River	25	20	35		20	24			25			3		1.5	0.6	
Arizona-California: Yuma	30	53			22	28	3.8		33			3.1		1.6		
California: Orland									40			[2] 5				
Colorado: Uncompahgre Valley	23	33	36	16	27	32	1.3	0.7				2.9	0.9	1.5	3	3
Idaho:																
Boise	22	19	25	10	19	20	1.7	1.9			23	3.6	1.6	1.1	3	8
Minidoka—																
Gravity unit	30	21	30	17	19	25	1	1				3.4	3.3	2.1	3.8	22
South side pumping unit	23	17	25	10	17	20	2	5				3.1	3.4	2.6	2.6	18
Montana:																
Huntley	18	24	30	3	23	27	6.1					2.9	1.7	1.3	1.5	8
Milk River	6		34		15	21	2			4		1.9		.8		
Sun River	25	85	30	19	22	28	2.4				25	2.1		1		30
Montana-North Dakota: Lower Yellowstone	20	33	31		20	23				12		2.5		1		
Nebraska-Wyoming: North Platte	23	15	21	6	16	19	.9				1.5	2.2		.6		
Nevada: Truckee-Carson	23		43		20	25						[3] 2.8		.9		
New Mexico:																
Carlsbad	25	25			15	25	1.1		25			2.5		.6		
Hondo		24				24						2.2		3	1	
New Mexico-Texas: Rio Grande	32	18	44		30	24			22			3.6			2	
North Dakota: North Dakota pumping	26	56	42		18	32				10		2.6		2.1		
Oregon: Umatilla		35		14	39	34		1.5				3.7	2.9	1	3	
Oregon-California: Klamath	35		34	9	19	31						2.4		1.5		
South Dakota: Belle Fourche	24	24	33	17	14	23	2.3	1.5			15	2.1	.9	.9	1.3	
Washington:																
Okanogan		25				25						3.4	2.4	.8	1.5	
Yakima—																
Sunnyside unit		53										5	3	3		
Tieton unit	28	29	41		21	29	12	3				3.5	2.7	1.7	8	
Wyoming: Shoshone	18	16	25		15	21	1.4	.8			15	2.3	1.3	.9	2.2	1
Average	26	26	29	10	19	25	3.1	1.9	26	10	13	3.1	1.9	1.4	2.2	16

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State and project.	Vegetables.				Fruit and nuts.							Miscellaneous.			
	Beans.	Onions.	Potatoes, white.	Potatoes, sweet.	Apples.	Citrus fruit.	Peaches.	Pears.	Prunes.	Small fruit.	All.	Beet sugar.	Cotton.	Hops.	Cane.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Tons.*	*Pounds.*	*Pounds.*	*Tons.*
Arizona: Salt River	16		30			3,500				[4] 3,100	[5] 3,600		[6] 341		12
Arizona-California: Yuma	16										4,000		373		
California: Orland						8,820					[7] 3,800				
Colorado: Uncompahgre Valley	14	246	148		10,268		3,572	1,439	1,150	2,323	9,100	14			
Idaho:															
Boise	3	25	118	31	1,671		577		2,800	744	1,300	3.3			
Minidoka—															
Gravity unit	16	38	180		1,210			34	798	617	1,100	12			
South side pumping unit	13	24	115		1,888					3,446	2,200	10			
Montana:															
Huntley	13		89									10			
Milk River			188												
Sun River	32		135		810							14			
Montana-North Dakota: Lower Yellowstone			140												
Nebraska-Wyoming: North Platte			145									11			
Nevada: Truckee-Carson		380	84												
New Mexico:															
Carlsbad		228		200			351				351	7	276		3
Hondo					1,965						[8] 1,800				2.2
New Mexico-Texas: Rio Grande	6				9,615					2,630	8,600				
North Dakota: North Dakota pumping		300	193												
Oregon: Umatilla		179	91		560		441	302		1,290	690				
Oregon-California: Klamath			61												
South Dakota: Belle Fourche	7		101									8			
Washington:															
Okanogan	13	70	110		1,285		3,085	1,745	3,350	2,350	[9] 1,400				
Yakima—															
Sunnyside unit			230		8,347		7,405	11,327	16,440		8,500			2,606	
Tieton unit	19	96	120		4,400		7,200	2,700		2,050	4,700			1,400	
Wyoming: Shoshone	1	35	132		700					93	250	9			
Average	10	200	150	73	7,200	4,100	5,900	9,400	13,900	3,300	6,400	9.6	340	1,870	10

[1] Data are for calendar year (irrigation season); except for Salt River project, Arizona, data are for corresponding agricultural year, October, 1913, to September, 1914.
[2] Includes old alfalfa, 5.6; new, 1.3.
[3] Includes old alfalfa, 3.3; new, 0.3.
[4] Includes olives, 500; other small fruits, 3,500.
[5] Includes deciduous fruit, 4,000, not reported in detail.
[6] Long staple, 350; short staple, 300.
[7] Includes deciduous fruit, 2,455, not reported in detail, and almonds, 721.
[8] Includes miscellaneous fruit, 500.
[9] Includes apricots, 2,535.

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Estimated total yields of irrigated crops on reclamation projects in 1914.[1]

State and project.	Cereals.						Other grain and seed.					Hay and forage.				
	Barley.	Corn, Indian.	Oats.	Rye.	Wheat.	Total.	Alfalfa seed.	Clover seed.	Corn, sorghum.	Millet seed.	Total.	Alfalfa hay.	Clover hay.	Other hay.	Corn fodder.	Field peas.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Bushels.*
Arizona: Salt River	426,644	46,295	67,550	.....	194,890	735,371	.....	.....	316,275	.....	316,275	260,198	.....	1,556	393	.....
Arizona-California: Yuma	48,964	8,595	.....	.....	12,710	70,269	20,772	.....	100,153	.....	120,925	32,525	.....	1,067	.....	.....
California: Orland	.....	.....	.....	.....	.....	.....	.....	.....	5,794	.....	5,794	28,539	.....	.....	.....	.....
Colorado: Uncompahgre Valley	3,695	13,309	222,244	410	142,152	381,810	27	2	.....	.....	29	34,638	162	618	567	541
Idaho:																
Boise—																
Farms reported	43,161	126,509	124,833	1,321	205,925	501,749	396	12,213	.....	652	[2]15,061	64,753	9,798	382	2,331	329
Farms not reported [3]	12,500	36,700	36,200	383	59,600	145,383	115	3,540	.....	189	[2]4,366	18,780	2,840	111	676	95
Minidoka—																
Gravity unit	19,906	9,226	133,057	2,540	87,334	252,063	5	28	.....	.....	33	63,982	3,006	410	146	3,289
South side pumping unit	20,564	185	94,625	60	128,128	243,562	10	320	.....	.....	330	38,749	436	18	82	14,706
Montana:																
Huntley	6,689	11,755	96,014	28	39,127	153,613	419	.....	.....	.....	419	17,440	59	430	85	470
Milk River	645	.....	13,947	.....	9,158	23,750	5	.....	.....	.....	[4]235	604	.....	.....	.....	.....
Sun River	9,407	85	63,312	264	11,343	84,411	24	.....	.....	97	121	5,471	.....	303	.....	165
Montana-North Dakota: Lower Yellowstone	8,072	3,512	17,628	.....	20,998	50,210	.....	.....	.....	.....	[5]1,954	6,482	.....	90	.....	.....
Nebraska-Wyoming: North Platte	53,022	93,186	146,211	1,363	9,979	303,761	863	.....	.....	63	926	71,405	.....	255	.....	.....
Nevada: Truckee-Carson	31,084	.....	18,000	.....	29,164	78,248	.....	.....	.....	.....	.....	61,002	.....	1,504	.....	.....
New Mexico:																
Carlsbad	125	12,410	.....	.....	30	12,565	309	.....	13,850	.....	14,159	19,420	.....	31	.....	.....
Hondo	.....	495	.....	.....	.....	495	.....	.....	.....	.....	.....	1,492	.....	18	222	.....
New Mexico-Texas: Rio Grande	1,965	68,809	29,843	.....	49,750	150,367	.....	.....	7,630	.....	7,630	66,028	.....	.....	304	.....
North Dakota: North Dakota pumping	441	712	665	.....	456	2,274	.....	.....	.....	.....	[5]50	2,213	.....	47	.....	.....
Oregon: Umatilla	.....	1,800	.....	42	290	2,132	.....	1	.....	.....	1	7,511	16	108	244	.....
Oregon-California: Klamath	143,347	.....	77,031	1,295	27,281	248,954	.....	.....	.....	.....	.....	22,235	.....	3,589	.....	.....
South Dakota: Belle Fourche	34,718	106,280	209,813	244	108,880	459,935	3,305	14	.....	889	4,208	20,473	47	1,911	1,159	.....
Washington:																
Okanogan	.....	1,750	.....	.....	.....	1,750	.....	.....	.....	.....	.....	3,754	24	150	85	.....
Yakima—																
Sunnyside unit	.....	321,281	.....	.....	18,000	339,281	.....	.....	.....	.....	.....	130,820	2,406	4,041	.....	.....
Tieton unit	14,000	45,000	30,450	.....	23,500	112,950	96	180	.....	.....	276	18,850	1,180	1,470	1,120	.....
Wyoming: Shoshone	16,921	45	93,644	.....	30,315	140,925	118	17	.....	15	150	29,638	23	82	5	.....
Total	895,870	907,939	1,475,067	7,950	1,209,010	4,495,836	26,466	16,315	443,702	1,905	493,942	1,027,002	19,997	18,191	7,419	19,595

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Average prices of irrigated crops on reclamation projects in 1914.[1]

State and project.	Cereals.						Other grain and seed.					Hay and forage.				
	Barley.	Corn, Indian.	Oats.	Rye.	Wheat.	All.	Alfalfa seed.	Clover seed.	Corn, sorghum.	Flaxseed.	Millet seed.	Alfalfa hay.	Clover hay.	Other hay.	Corn fodder.	Field peas.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Ton.*	*Ton.*	*Ton.*	*Ton.*	*Bush.*
Arizona: Salt River	$0.65	$0.85	$0.55		$1.10	$0.77			$0.50			$6.00		$6.00	$20.00	
Arizona-California: Yuma	.58	.65			1.00	.67	$7.80		.70			6.05		7.64		
California: Orland									.83			4.20				
Colorado: Uncompahgre Valley	.56	.91	.42	$0.99	.88	.61	8.00	$11.50				5.99	$5.96	6.75	3.79	$0.96
Idaho:																
Boise	.55	.70	.45	.65	.90	.71	7.50	7.50			$1.50	5.50	7.00	5.00	7.00	1.80
Minidoka—																
Gravity unit	.43	.70	.38	.63	.70	.51	6.00	8.40				5.00	5.00	5.15	5.00	.90
South side pumping unit	.43	.70	.38	.63	.70	.55	6.00	8.40				5.00	5.00	5.00	5.00	.90
Montana:																
Huntley	.53	.62	.32	.60	.98	.46	7.00					5.00	12.00	11.50	6.00	.75
Milk River	.55		.70		.95	.79	9.00			$1.22		11.00		12.00		
Sun River	.70	.80	.50	.74	.90	.58	10.63				1.00	6.50		8.60		1.00
Montana-North Dakota: Lower Yellowstone	.43	.72	.34		1.00	.66				1.24		7.20		9.18		
Nebraska-Wyoming: North Platte	.60	.75	.40	.70	.85	.56	8.00				1.00	4.50		8.00		
Nevada: Truckee-Carson	.60		.40		1.35	.83						5.00		3.00		
New Mexico:																
Carlsbad	.46	1.00			1.27	1.00	5.36		1.00			8.55		9.84		
Hondo		.75				.75						8.26		10.00	6.29	
New Mexico-Texas: Rio Grande	.71	.83	.54		.90	.77			.74			10.34			7.00	
North Dakota: North Dakota pumping	.41	.50	.35	.85	1.00	.54				1.25		12.00		5.60		
Oregon: Umatilla		.85		1.20	.98	.88		14.00				8.00	8.00	6.67	3.40	
Oregon-California: Klamath	.45		.40	.75	.90	.49						7.00		7.30		
South Dakota: Belle Fourche	.70		.40	.90	.90	.61	7.30				1.00	4.50	5.00	10.00		
Washington:																
Okanogan		.60				.60						8.50	10.00	10.00	7.00	
Yakima—																
Sunnyside unit		.71				.71						7.25	8.50	8.41		
Tieton unit	.90	.75	.40		1.00	.73	10.00	10.00				6.00	6.00	8.50	2.00	
Wyoming: Shoshone	.85	.50	.50		.85	.62	12.00	12.00			.40	6.50	6.50	6.50	5.00	3.00
Average	.60	.74	.42	.70	.94	.65	7.60	7.60	.57	1.24	1.22	6.18	6.80	7.82	6.20	.88

[1] Data are for calendar year (irrigation season), except on Salt River project, Ariz., data are for corresponding agricultural year October, 1913, to September, 1914. The effort has been to secure the value received by the farmer for his crops, whether sold on the farm or in town, with or without baling, boxing, etc. If fed by the farmer, the crop is given a value representing the selling price on the farm.

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Average prices of irrigated crops on reclamation projects in 1914—Continued.

State and project.	Vegetables and truck.				Fruit and nuts.							Miscellaneous.			
	Beans.	Onions.	Potatoes, white.	Potatoes, sweet.	Apples.	Citrus fruit.	Peaches.	Pears.	Prunes.	Small fruit.	All.	Beets, sugar.	Cotton.	Hops.	Cane.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Ton.*	*Lb.*	*Lb.*	*Ton.*
Arizona: Salt River	$2.40		$0.95			$0.04				[1] $0.04	[2] $0.033		[3] $0.17		$4.00
Arizona-California: Yuma	2.24										.025		.08		
California: Orland						.017					[4] .029				
Colorado: Uncompahgre Valley	2.46	$0.30	.31		$0.006		$0.01	$0.026	$0.023	.04	.007	$4.74			
Idaho:															
Boise	3.00	.80	.48	$2.50	.007		.007		.015	.05	.014	5.00			
Minidoka—															
Gravity unit	1.80	1.00	.30		.015			.04	.064	.08	.019	4.75			
South side pumping unit	1.80	1.00	.30		.015					.08	.038	4.75			
Montana:															
Huntley	3.00		.62									6.00			
Milk River			1.00												
Sun River	2.67		.60		.03					.05	.043	5.47			
Montana-North Dakota: Lower Yellowstone			.65												
Nebraska-Wyoming: North Platte			.35									5.50			
Nevada: Truckee-Carson		.60	.48												
New Mexico:															
Carlsbad		1.23		1.00			.04				.04	5.00	.075		7.46
Hondo					.006						[5] .007				7.75
New Mexico-Texas: Rio Grande	1.80				.025						.025				
North Dakota: North Dakota pumping		1.00	.60												
Oregon: Umatilla		.87	.89		.017		.015	.04		.05	.033				
Oregon-California: Klamath			.80												
South Dakota: Belle Fourche	3.00		.80									4.00			
Washington:															
Okanogan	3.50	1.35	.60		.02		.01	.02	.01	.04	.019				
Yakima—															
Sunnyside unit			.36		.012		.014	.015	.026		.013			$0.10	
Tieton unit	2.40	.30	.30		.02		.005	.01		.05	.015			.09	
Wyoming: Shoshone	3.00	1.70	.50		.04					.25	.10	6.65			
Average	2.23	.41	.35	1.48	.012	.035	.012	.014	.026	.04	.015	5.90	.16	.10	4.25

[1] Includes olives, $0.03.
[2] Includes deciduous fruit, $0.025, not reported in detail.
[3] Includes long staple, $0.20, and short staple, $0.08.
[4] Includes deciduous fruit, $0.019, not reported in detail, and almonds, $0.168.
[5] Includes miscellaneous fruit, $0.04, not reported in detail.

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Estimated total values of irrigated crops harvested on reclamation projects in 1914.[1]

State and project.	Cereals.					Other grain and seed.			Hay and forage.					
	Barley.	Corn, Indian.	Oats.	Wheat.	Total.[2]	Alfalfa seed.	Corn, sorghum.	Total.[3]	Alfalfa hay.	Clover. hay.	Other hay.	Corn fodder.	Pasture.	Total.[4]
Arizona, Salt River	$277,318	$39,351	$37,153	$214,379	$568,201	.....	$158,137	$158,137	$1,561,189	.....	$9,335	$7,850	$267,138	$1,845,512
Arizona-California, Yuma	28,590	5,584	.....	12,783	46,957	$159,806	70,915	230,721	196,716	.....	8,150	.....	87,061	299,324
California, Orland	.....	.....	.....	.....	.....	.....	4,795	4,795	119,863	.....	.....	.....	12,645	132,508
Colorado, Uncompahgre Valley	2,069	12,142	93,079	125,273	232,969	216	.....	239	207,517	$966	4,169	2,149	4,614	219,935
Idaho, Boise:														
Farms reported	23,739	88,556	56,175	185,464	354,792	2,970	.....	95,807	356,143	68,585	1,912	16,314	43,751	487,297
Farms not reported [5]	6,890	25,700	16,300	53,800	102,940	862	.....	27,813	103,600	19,900	555	4,740	12,700	141,667
Idaho, Minidoka:														
Gravity unit	8,560	6,458	50,562	61,134	128,314	30	.....	269	319,910	15,030	2,111	733	33,167	374,454
South side pumping unit	8,843	129	35,958	89,690	134,658	60	.....	2,748	193,745	2,180	90	410	23,535	232,668
Montana, Huntley	3,545	7,288	30,724	38,339	79,913	2,933	.....	2,933	87,200	708	4,968	510	.....	93,739
Montana, Milk River	355	.....	9,762	8,700	18,817	45	.....	326	6,644	.....	5,748	.....	50	12,442
Montana, Sun River	6,585	68	31,656	10,208	48,711	253	.....	350	35,563	.....	2,606	.....	1,837	40,243
Montana-North Dakota, Lower Yellowstone	3,451	2,519	6,062	21,025	33,057	.....	.....	2,421	46,603	.....	826	.....	478	47,907
Nebraska-Wyoming, North Platte	31,813	69,890	58,484	8,482	169,623	6,904	.....	6,967	321,323	.....	2,040	.....	22,984	359,725
Nevada, Truckee-Carson	18,650	.....	7,200	39,371	65,221	.....	.....	.....	305,010	.....	4,512	.....	23,500	333,022
New Mexico, Carlsbad	57	12,410	.....	38	12,505	1,684	13,920	15,604	165,950	.....	305	.....	3,206	169,461
New Mexico, Hondo	.....	369	.....	.....	369	.....	5,635	5,635	12,287	.....	180	1,397	200	14,064
New Mexico-Texas, Rio Grande	1,396	57,132	16,115	44,775	119,418	.....	5,628	5,628	682,414	.....	.....	2,128	5,012	689,554
North Dakota, North Dakota pumping	181	356	233	456	1,226	.....	.....	63	26,559	.....	265	.....	900	27,724
Oregon, Umatilla	.....	1,539	.....	284	1,873	.....	.....	21	60,088	128	720	829	7,063	68,828
Oregon-California, Klamath	64,506	.....	30,812	24,553	120,842	.....	.....	.....	155,645	.....	26,208	.....	12,497	194,350
South Dakota, Belle Fourche	24,303	74,396	83,925	97,992	280,836	23,397	.....	24,384	92,129	235	19,110	5,804	12,078	129,356
Washington, Okanogan	.....	1,050	.....	.....	1,050	.....	.....	.....	31,909	240	1,500	595	1,695	35,939
Washington, Yakima:														
Sunnyside unit	.....	228,834	.....	14,369	243,203	.....	.....	.....	948,445	20,451	33,985	.....	48,960	1,051,841
Tieton unit	12,600	33,750	12,180	23,500	82,030	960	.....	2,760	113,100	7,080	12,500	2,240	10,500	145,420
Wyoming, Shoshone	14,383	23	46,822	25,768	86,996	1,414	.....	1,630	192,647	149	533	25	11,554	204,914
Total	537,834	667,544	623,202	1,100,383	2,934,521	201,534	259,030	589,251	6,342,199	135,652	142,328	45,724	647,125	7,351,894

[1] Data are for calendar year (irrigation season), except for Salt River project, Arizona, data are for corresponding agricultural year, October, 1913, to September, 1914.

[2] Includes rye $5,558 on following projects: Uncompahgre Valley, $406; Boise, $1,108; Minidoka, gravity unit, $1,600, pumping unit, $38; Huntley, $17; Sun River, $194; North Platte, $954; Umatilla, $50; Klamath, $971; Belle Fourche, $220.

[3] Includes: Clover seed $123,534 on following projects: Uncompahgre Valley, $23; Boise, $118,455; Minidoka, gravity unit, $239, pumping unit, $2,688; Umatilla, $21; Belle Fourche, $98; Yakima, Tieton unit, $1,800; Shoshone, $210. Flaxseed $2,765 on following projects: Milk River, $281; Lower Yellowstone, $2,421; North Dakota pumping, $63. Millet seed $2,318 on following projects: Boise, 1,263; Sun River, $97; North Platte, $63; Belle Fourche, $889; Shoshone, $6. Pop corn, $70 on Boise project.

[4] Includes: Field peas $17,203 on following projects: Uncompahgre Valley, $520; Boise, $764; Minidoka, gravity unit, $2,960; pumping unit, $12,435; Huntley, $353; Sun River, $165; Shoshone, $6. Cane and corn fodder $7,439 on following projects: Yuma, $7,397; North Platte, $42. Mangels or stock beets, $345 on following projects: Minidoka, pumping unit, $273; Sun River, $72.

[5] Estimated at same average value per acre as for farms reported.

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Estimated total values of irrigated crops harvested on reclamation projects in 1914—Continued.

State and project.	Vegetables and truck.					Fruit and nuts.			Miscellaneous.				Total.
	Beans.	Onions.	Potatoes, white.	Truck.	Total.[1]	Apples.	Small fruit.	Total.[2]	Beets, sugar.	Cane.	Other.	Total.[3]	
Arizona, Salt River	$21,792		$6,619	$320,723	$349,134		$131,713	$355,239		$43,248	$4,313	$762,856	$4,039,079
Arizona-California, Yuma	4,531			18,377	22,908			4,080			26,980	105,419	709,409
California, Orland				6,627	6,627		2,974	31,091			1,310	1,310	176,331
Colorado, Uncompahgre Valley	3,703	$17,516	210,417	5,371	237,007	$105,749	8,418	121,697	$56,253		2,281	58,534	870,381
Idaho, Boise:													
Farms reported	4,141	166	62,761	20,411	88,206	2,350	3,857	6,746	120	468	11	599	1,033,447
Farms not reported [4]	1,200	48	18,200	5,930	25,588	682	1,120	1,958	35	136	3	174	300,140
Idaho, Minidoka:													
Gravity unit	146	563	99,280	16,600	116,589	5,808	2,073	7,996	33,150		1,024	34,174	661,796
South side pumping unit	218	316	79,038	21,945	101,517	283	827	1,110	85,358			85,358	558,059
Montana, Huntley	1,533		6,622	23,663	31,818				246,180			246,180	454,583
Montana, Milk River			2,633	400	3,033								34,618
Montana, Sun River	64		9,288	7,758	17,110	13	50	63	117			117	106,594
Montana-North Dakota, Lower Yellowstone			4,923	6,371	11,294						2,028	2,028	96,707
Nebraska-Wyoming, North Platte			55,659	5,177	60,836				293,051			293,051	890,202
Nevada, Truckee-Carson		4,560	11,424	26,791	42,775								441,018
New Mexico, Carlsbad		562		1,531	2,893			800	175	4,904		36,400	237,663
New Mexico, Hondo						620		770		620		620	21,458
New Mexico-Texas, Rio Grande		3,528		228,684	232,212	107,908	6,000	113,908					1,160,720
North Dakota, North Dakota pumping		300	4,147	2,980	7,427								36,440
Oregon, Umatilla		548	5,000	6,522	12,070	495	4,181	5,547			275	275	88,614
Oregon-California, Klamath			22,445	8,727	31,172			980					347,344
South Dakota, Belle Fourche	942		15,837	8,036	24,815				988		809	1,797	461,188
Washington, Okanogan	910	283	6,300	6,030	13,523	37,969	2,484	49,588			4,475	4,475	104,575
Washington, Yakima:													
Sunnyside unit			318,664	67,083	385,747	718,009	63,173	1,129,309				48,745	2,858,845
Tieton unit	3,430	2,010	120,120	11,500	137,060	54,600	3,280	69,460				35,750	472,480
Wyoming, Shoshone	13	59	5,768	7,450	13,290	14	35	49	6,922		25	6,947	313,826
Total	42,623	30,459	1,065,145	834,687	1,974,651	1,034,500	230,185	1,900,391	722,349	49,376	43,534	1,724,809	16,475,517

[1] Includes sweet potatoes $1,737 on following projects: Boise, $937; Carlsbad, $800.

[2] Includes: Citrus fruit $111,940 on following projects: Salt River, $98,910; Orland, $13,030. Peaches $141,527 on following projects: Uncompahgre Valley, $5,768; Boise, $233; Carlsbad, $800; Umatilla, $780; Okanogan, $5,404; Yakima, Sunnyside unit, $120,782, Tieton unit, $7,760. Pears $151,939 on following projects: Uncompahgre Valley, $1,178; Minidoka, gravity unit, $13; Umatilla, $91; Okanogan, $1,222; Yakima, Sunnyside unit, $145,615, Tieton unit, $3,820. Prunes $83,012 on following projects: Uncompahgre Valley, $584; Boise, $462; Minidoka, gravity unit, $102; Okanogan, $134; Yakima, Sunnyside unit, $81,730. Almonds $10,922 on Orland project. Apricots $2,375 on Okanogan project. Deciduous fruit not reported in detail, $155,707 on following projects: Salt River, $124,616; Orland, $31,091. Fruit not reported in detail, $5,210 on following projects: Yuma, $4,080; Hondo, $150; Klamath, $980.

[3] Includes: Cotton $825,055 on following projects: Salt River, $715,295; Yuma, $78,439; Carlsbad, $31,321. Hops $84,495 on Yakima project: Sunnyside unit, $48,745; Tieton unit, $35,750.

[4] Estimated at same average value per acre as for farms reported.

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Inventory of live stock and equipment on reclamation project farms at close of 1914.[1]

State and project.	Horses.			Mules.			Cattle.		
	Number.	Value.		Number.	Value.		Number.	Value.	
		Each.	Total.		Each.	Total.		Each.	Total.
Arizona: Salt River	12,184	$96	$1,175,175	1,106	$142	$157,095	[2] 40,451	$56	$2,262,086
Arizona-California: Yuma	2,465	99	245,227	544	138	75,272	[3] 4,894	56	273,769
California: Orland	[4] 798	99	78,665	.....	.....	.....	[5] 2,904	59	172,164
Colorado: Uncompahgre Valley	3,405	93	315,797	164	119	19,460	5,719	39	223,638
Idaho:									
Boise—									
Farms reported	5,118	84	428,835	247	93	23,003	[6] 5,901	51	298,817
Farms not reported [7]	1,480	84	124,500	72	93	6,700	1,712	51	86,700
Minidoka—									
Gravity unit	3,850	105	405,660	160	109	17,415	4,394	49	215,363
South side pumping unit	2,063	102	209,914	44	104	4,575	2,150	53	113,520
Montana:									
Huntley	2,008	109	218,640	53	135	7,150	[8] 2,921	47	138,625
Milk River	688	96	66,150	2	100	200	454	56	25,575
Sun River	537	116	62,330	14	115	2,035	786	57	44,760
Montana-North Dakota: Lower Yellowstone	1,298	132	171,330	30	93	2,800	[9] 1,574	54	84,483
Nebraska-Wyoming: North Platte[10]	[4] 4,618	80	369,440	.....	.....	.....	3,190	45	143,550
Nevada: Truckee-Carson	3,079	87	267,575	404	86	34,905	[11] 6,043	51	308,949
New Mexico:									
Carlsbad	679	91	62,105	109	128	13,915	672	50	33,430
Hondo	228	45	10,190	28	77	2,150	390	35	13,510
New Mexico-Texas: Rio Grande	1,828	82	150,495	215	101	21,800	1,740	51	88,702
North Dakota: North Dakota pumping	86	113	9,750	.....	.....	.....	118	48	5,620
Oregon: Umatilla[12]	633	87	55,305	26	129	3,345	[13] 847	59	49,680
Oregon-California: Klamath	2,356	91	214,970	90	84	7,580	4,660	40	188,350
South Dakota: Belle Fourche	2,848	87	249,150	59	112	6,635	[14] 4,092	51	208,067
Washington:									
Okanogan	587	100	58,700	16	125	2,000	459	80	36,720
Yakima—									
Sunnyside unit	6,641	86	570,665	109	107	11,665	8,967	62	554,449
Tieton unit	1,340	94	125,900	17	105	1,785	1,425	62	88,400
Wyoming: Shoshone	1,412	117	165,185	63	117	7,390	2,163	54	116,292
Total and average	62,247	93	5,811,653	3,572	120	428,875	108,626	53	5,775,219

[1] Taken at close of irrigation season; for Salt River project, Ariz., at end of agricultural year, Sept. 30. Reports cover only irrigated farms.
[2] 19,508 dairy cattle, $1,141,971, and 20,943 beef cattle, $1,120,115.
[3] 2,043 dairy cattle, $166,335, and 2,851 beef cattle, $107,434.
[4] Horses and mules.
[5] 2,549 dairy cattle, $159,404, and 355 beef cattle, $12,760.
[6] 5,150 dairy cattle, $273,827, and 751 beef cattle, $24,990.
[7] Figures assumed in same proportion to those for reported farms as known irrigated areas.
[8] 789 milch cows, $52,060, and 133 calves, $3,995.
[9] 744 dairy cattle, $44,865, and 830 beef cattle, $39,618.
[10] Figures are exclusive of stock brought to the project for wintering or fattening, numbering about 75,000 sheep, 4,700 cattle, and 500 horses.
[11] 1,503 dairy cattle, $127,190, and 4,540 other cattle, $181,759.
[12] Reduced total stock value represents reduction in number of sheep brought to project for wintering. About 400 hogs were lost by cholera during the year.
[13] 641 dairy cattle, 206 beef cattle.
[14] 1,578 dairy cattle, $58 each, and 2,514 beef cattle, $47 each.

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Inventory of live stock and equipment on reclamation project farms at close of 1914—Con.

State and project.	Sheep.			Hogs.			Fowls.		
	Number.	Value.		Number.	Value.		Number.	Value.	
		Each.	Total.		Each.	Total.		Each.	Total.
Arizona: Salt River	6,419	$4.01	$25,721	18,807	$5.86	$110,365	169,240	$0.50	$84,620
Arizona-California: Yuma	1,384	4.65	6,432	4,982	7.60	37,848	35,935	.79	28,342
California: Orland	565	4.98	2,815	2,400	9.14	21,938	11,223	.55	6,238
Colorado: Uncompahgre Valley	14,710	3.69	54,227	4,941	8.47	41,848	39,226	.50	19,501
Idaho:									
Boise—									
Farms reported	5,738	4.38	25,125	25,095	6.39	160,328	81,498	.53	43,249
Farms not reported [1]	1,665	4.38	7,300	7,280	6.39	46,500	23,620	.53	12,600
Minidoka—									
Gravity unit	11,098	5.85	64,950	14,128	7.52	106,273	50,842	.44	22,328
South side pumping unit	2,490	3.70	9,234	15,691	7.46	117,075	25,534	.43	10,853
Montana:									
Huntley	847	3.22	2,730	4,612	9.68	44,536	23,345	.49	11,356
Milk River	.....	.....	.....	1,003	10.54	10,569	2,246	.72	1,615
Sun River	34	9.41	320	3,215	8.61	27,675	11,105	.55	6,082
Montana-North Dakota: Lower Yellowstone	2,152	3.60	7,754	3,333	6.84	22,786	13,118	.55	7,181
Nebraska-Wyoming: North Platte [2]	605	3.00	1,815	22,143	8.00	177,144	43,898	.40	17,559
Nevada: Truckee-Carson	1,981	5.20	10,214	3,815	8.65	32,899	[3] 34,371	.95	32,747
New Mexico:									
Carlsbad	.....	.....	.....	625	8.79	5,493	6,237	.62	3,866
Hondo	.....	.....	.....	200	8.60	1,720	892	.61	546
New Mexico-Texas: Rio Grande	[4] 103	4.27	440	4,189	7.66	32,091	34,147	.85	29,080
North Dakota: North Dakota pumping	56	5.00	280	309	9.21	2,850	1,510	.49	750
Oregon: Umatilla [5]	42	5.38	226	2,185	8.37	18,284	12,189	.63	7,735
Oregon-California: Klamath	361	4.63	1,673	6,542	11.45	74,851	16,917	.46	7,793
South Dakota: Belle Fourche	25,740	3.76	96,782	11,988	8.97	107,772	29,186	.49	14,252
Washington:									
Okanogan	.....	.....	.....	540	9.00	4,860	7,410	.45	3,335
Yakima—									
Sunnyside unit	1,958	4.65	9,104	23,948	8.21	196,629	113,039	.57	64,500
Tieton unit	71	3.90	276	4,990	7.20	35,850	20,330	.57	11,480
Wyoming: Shoshone	1,151	3.66	4,214	4,679	7.71	36,054	23,888	.44	10,448
Total and average	79,140	4.19	331,632	191,640	7.69	1,474,238	830,946	.55	458,056

[1] Figures assumed in same proportion to those for reported farms as known irrigated areas.
[2] Figures are exclusive of stock brought to the project for wintering or fattening, numbering about 75,000 sheep, 4,700 cattle, and 500 horses.
[3] 6,972 turkeys, $15,988, or $2.30 each, and 27,399 other fowl, $16,759, or $0.60 each.
[4] Includes goats.
[5] Reduced total stock value represents reduction in number of sheep brought to project for wintering. About 400 hogs were lost by cholera during the year.

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Inventory of live stock and equipment on reclamation project farms at close of 1914—Con.

State and project.	Bees (hives).			Total stock value.	Value of equipment.	Total stock and equipment.	Increase in value over 1913.		
	Number.	Value.					Stock.	Equipment.	Total.
		Each.	Total.						
Arizona: Salt River	10,430	$5.00	$52,150	[1]$4,400,662	[2]$640,377	$5,047,039	[3]$483,705	[3]$176,997	[3]$660,702
Arizona-California: Yuma	4,066	4.80	19,490	[4]687,464	150,863	838,327	77,772	5,342	83,114
California: Orland	243	4.87	1,185	283,005	59,682	342,687	80,664	5,052	85,716
Colorado: Uncompahgre Valley	2,558	4.77	12,188	686,650	180,535	867,194	81,005	[3]12,570	68,435
Idaho:									
Boise—									
Farms reported	1,809	3.25	5,885	985,242	339,637	1,324,879	172,066	49,544	221,610
Farms not reported[5]	524	3.25	1,700	286,000	98,500	384,500	[6]286,000	[6]98,500	[6]384,500
Minidoka—									
Gravity unit	1,331	5.15	6,850	[7]839,139	202,899	1,042,038	119,987	18,596	138,583
South side pumping unit	387	6.46	2,499	467,670	160,238	627,908	118,429	25,768	144,197
Montana:									
Huntley	247	3.07	758	423,795	97,881	521,676	83,907	[3]1,907	82,000
Milk River	.....	.....	.....	104,109	27,112	131,221	29,482	[3]2,678	26,804
Sun River	8	5.00	40	143,242	31,150	174,392	34,077	7,836	41,913
Montana-North Dakota: Lower Yellowstone	.....	.....	.....	296,334	103,838	400,172	60,881	19,012	79,893
Nebraska-Wyoming: North Platte[8]	476	3.00	1,428	710,936	275,000	985,936	148,310	25,000	173,310
Nevada: Truckee-Carson	1,621	4.40	7,104	694,393	151,254	845,647	134,765	[3]16,268	118,497
New Mexico:									
Carlsbad	1,397	5.00	6,985	125,794	22,540	148,334	19,063	[3]4,590	14,473
Hondo	.....	.....	.....	28,116	3,825	31,941	1,412	[3]50	1,362
New Mexico-Texas: Rio Grande	5,723	4.95	28,305	[9]362,913	179,802	542,715	59,930	34,569	94,449
North Dakota: North Dakota pumping	.....	.....	.....	19,250	5,550	24,800	3,940	280	4,220
Oregon: Umatilla[10]	464	4.28	1,988	136,563	50,591	187,154	[3]20,937	2,466	[3]18,471
Oregon-California: Klamath	299	5.25	1,566	496,783	130,850	627,633	184,299	57,809	242,108
South Dakota: Belle Fourche	129	6.20	801	683,459	132,274	815,733	223,475	14,031	237,506
Washington:									
Okanogan	250	5.00	1,250	106,865	47,100	153,965	11,005	[3]22,900	[3]11,895
Yakima—									
Sunnyside unit	3,640	3.35	12,182	1,419,194	431,753	1,850,947	72,676	68,312	140,988
Tieton unit	408	3.00	1,250	264,941	87,856	352,797	53,188	10,913	64,101
Wyoming: Shoshone	952	4.17	3,966	343,549	103,189	446,738	73,663	25,643	99,306
Total and average	36,962	4.59	169,579	15,002,077	3,714,296	18,716,373	1,625,354	230,713	1,856,067

[1] Includes 4,119 ostriches, valued at $539,450, or $130.97 per bird.
[2] Includes 98 automobiles, valued at $120,300, belonging to farmers who live on their farms; automobiles of town farmers not included.
[3] Decrease.
[4] Includes 193 ostriches, valued at $1,075, or $5.57 per bird.
[5] Figures assumed in same proportion to those for reported farms as known irrigated areas.
[6] These farms not included in figures given in Thirteenth Annual Report for Boise project.
[7] Includes 2 elk, valued at $300 or $150 each.
[8] Figures are exclusive of stock brought to the project for wintering or fattening, numbering about 75,000 sheep, 4,700 head of cattle, and 500 horses.
[9] Includes 120 ostriches, valued at $12,000, or $100 per bird.
[10] Reduced total stock value represents reduction in number of sheep brought to project for wintering. About 400 hogs were lost by cholera during the year.

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Estimated investment and value in irrigated farms on reclamation projects at close of 1914.[1]

State and project.	Irrigated farms.		Acreage cleared and leveled.
	Number.	Irrigible acreage.	
Arizona: Salt River	3,068	194,866	194,866
Arizona-California: Yuma	698	35,685	26,680
California: Orland	296	8,638	7,280
Colorado: Uncompahgre Valley	910	52,338	33,873
Idaho:			
Boise—			
Farms reported	1,577	93,011	70,997
Farms not reported [2]	331	27,100	20,670
Minidoka—			
Gravity unit	1,151	66,110	45,730
South side pumping unit	562	37,800	36,206
Montana:			
Huntley	526	23,160	19,974
Milk River	36	5,800	.....
Sun River	172	8,320	1,490
Montana-North Dakota: Lower Yellowstone	184	16,461	12,000
Nebraska-Wyoming: North Platte	944	74,216	60,532
Nevada: Truckee-Carson	504	52,039	32,780
New Mexico:			
Carlsbad	390	15,712	15,000
Hondo	25	3,025	.....
New Mexico-Texas: Rio Grande	773	30,800	.....
North Dakota: North Dakota pumping	44	2,485	.....
Oregon: Umatilla	311	9,411	6,913
Oregon-California: Klamath	275	24,000	28,000
South Dakota: Belle Fourche	615	49,426	36,704
Washington:			
Okanogan	448	8,960	7,800
Yakima—			
Sunnyside unit	2,450	66,525	66,525
Tieton unit	900	22,700	22,700
Wyoming: Shoshone	429	25,599	23,701
Total	17,619	[3] 954,187	770,421

[1] Close of irrigation season; on Salt River project, Arizona, close of agricultural year, Sept. 30. Figures cover land and improvements only and are exclusive of live stock, equipment, and crops. See preceding tables.

[2] Areas known; other figures estimated by proportion from those for reported farms.

[3] Less than total irrigable acreage of projects, or acreage the service was prepared to supply, as given in other tables, because this table is restricted to farms actually irrigated.

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Estimated investment and value in irrigated farms on reclamation projects at close of 1914—Continued.

State and project.	Farmers' investment.					Value.
	Purchase price of land.	Clearing and leveling.	Improvements.	Paid construction charges.	Total.	
Arizona: Salt River	$23,392,033	.....	$6,940,856	.....	$30,332,889	$38,112,371
Arizona-California: Yuma	2,242,631	$1,132,417	452,975	$146,093	3,974,116	3,500,000
California: Orland	950,180	243,880	335,415	.....	1,529,475	2,073,965
Colorado: Uncompahgre Valley	1,308,450	169,365	991,343	.....	2,469,158	3,848,925
Idaho:						
Boise—						
Farms reported	2,244,817	859,753	1,793,045	.....	4,897,615	8,543,577
Farms not reported [1]	654,000	250,000	522,500	.....	1,426,500	2,480,000
Minidoka—						
Gravity unit	937,360	1,229,974	1,110,640	461,560	3,739,534	4,900,010
South side pumping unit	485,395	456,424	560,375	.....	1,502,194	2,679,600
Montana:						
Huntley	[2] 92,640	212,382	426,394	242,747	974,163	1,389,600
Milk River	31,500	.....	48,500	.....	80,000	178,000
Sun River	([3])	8,173	217,880	97,030	323,083	575,650
Montana-North Dakota: Lower Yellowstone	230,000	50,000	200,000	34,394	514,394	600,000
Nebraska-Wyoming: North Platte	1,000,000	302,660	888,680	217,829	2,409,169	3,339,720
Nevada: Truckee-Carson	838,028	1,524,270	565,606	254,102	[4] 3,268,846	4,090,875
New Mexico:						
Carlsbad	1,200,000	.....	400,000	115,000	1,715,000	2,000,000
Hondo	189,000	.....	56,000	.....	245,000	218,000
New Mexico-Texas: Rio Grande	2,859,336	.....	707,696	.....	3,567,032	5,032,440
North Dakota: North Dakota pumping	79,444	.....	104,947	5,903	190,294	199,089
Oregon: Umatilla	543,855	130,776	918,721	182,161	1,775,513	1,528,500
Oregon-California: Klamath	500,000	504,000	300,000	220,000	1,524,000	1,600,000
South Dakota: Belle Fourche	572,188	280,544	709,173	108,009	1,669,914	2,333,376
Washington:						
Okanogan	1,760,854	156,000	465,000	24,500	2,406,354	3,060,000
Yakima—						
Sunnyside unit	4,296,250	1,663,125	8,416,201	616,958	14,992,534	11,641,875
Tieton unit	1,500,000	248,000	600,000	150,000	2,498,000	3,600,000
Wyoming: Shoshone	9,010	108,193	432,906	222,914	773,023	1,673,015
Total	47,916,971	9,529,936	28,164,853	3,099,200	88,797,800	109,198,588

[1] Areas known; other figures estimated by proportion from those for reported farms.
[2] $4 per irrigable acre payable to Indians.
[3] Land entered subject to reclamation act.
[4] Includes vested water rights, $86,840.

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Estimated investment and value in irrigated farms on reclamation projects at close of 1914—Continued.

State and project.	Increase during 1914.				
	Acreage cleared and leveled.	Farmers' investment.			Value.
		Clearing and leveling.	Improvements.	Total.	
Arizona: Salt River	9,263	.....	$102,839	$70,312	$1,448,653
Arizona-California: Yuma	5,154	$221,126	51,566	710,157	500,000
California: Orland	180	36,156	47,809	201,115	364,930
Colorado: Uncompahgre Valley	2,445	12,225	78,320	76,120	168,950
Idaho:					
Boise—					
Farms reported	1,222	99,672	170,098	811,239	750,340
Farms not reported [1]	350	29,000	49,800	236,000	218,600
Minidoka—					
Gravity unit	1,857	246,026	158,565	683,070	736,875
South side pumping unit	3,333	109,962	39,356	237,788	387,746
Montana:					
Huntley	3,474	72,132	37,016	114,943	19,374
Milk River	.....	.....	5,000	15,000	12,000
Sun River	1,490	8,173	123,460	142,834	150,000
Montana-North Dakota: Lower Yellowstone	1,438	6,000	35,000	100,000	80,000
Nebraska-Wyoming: North Platte	13,703	18,515	133,857	289,367	86,715
Nevada: Truckee-Carson	[2] 892	9,030	[2] 21,043	19,790	302,337
New Mexico:					
Carlsbad	.....	.....	200	8,000	500
Hondo	.....	.....	500	22,850	25,350
New Mexico-Texas: Rio Grande	.....	.....	96,787	269,855	298,660
North Dakota: North Dakota pumping	.....	.....	4,190	5,215	5,215
Oregon: Umatilla	[2] 1,157	9,676	[2] 261,239	[2] 315,382	[2] 562,395
Oregon-California: Klamath	.....	.....	6,000	16,000	.....
South Dakota: Belle Fourche	3,140	49,696	122,726	186,988	144,130
Washington:					
Okanogan	100	2,000	24,905	44,671	[2] 133,160
Yakima—					
Sunnyside unit	4,525	113,125	2,537,776	2,956,576	791,875
Tieton unit	2,070	5,230	50,000	100,000	300,000
Wyoming: Shoshone	2,500	25,239	[2] 10,251	41,591	188,615
Total	54,195	1,072,983	3,583,237	7,044,099	6,285,310

[1] Areas known; other figures estimated by proportion from those for reported farms.
[2] Decrease

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Summary of farms irrigated on reclamation projects in 1914.[1]

State and project.	Irrigated farms.		Average per farm.							
	Number.	Irrigable acreage.[2]	Irrigable acreage.	Irrigated acreage.	Cropped acreage.	Crop value.	Farmers' investment.			Value of land and improvements.[3]
							Land and improvements.[3]	Stock and equipment inventory.	Total.	
Arizona: Salt River	3,068	194,866	63	56	55	$1,317	$9,887	$1,860	$11,747	$12,423
Arizona-California: Yuma	698	35,685	51	36	32	1,016	5,693	1,201	6,895	5,000
California: Orland	296	8,638	29	25	22	596	5,167	1,158	6,325	7,600
Colorado: Uncompahgre Valley	910	52,338	57	37	36	956	2,713	953	3,666	4,230
Idaho:										
Boise—										
Farms reported	1,577	93,011	59	41	37	655	3,106	840	3,946	5,418
Farms not reported	331	27,100	.....	.....	.....	.....	.....	.....	.....	.....
Minidoka—										
Gravity unit	1,151	66,110	57	40	34	575	3,249	905	4,154	4,257
South side pumping unit	562	37,800	67	64	60	993	2,673	1,117	3,790	4,768
Montana:										
Huntley	526	23,160	44	32	32	864	1,852	992	2,844	2,642
Milk River	36	5,800	161	61	60	962	2,216	2,187	4,403	4,940
Sun River	172	8,320	48	38	38	620	1,880	1,014	2,894	3,347
Montana-North Dakota: Lower Yellowstone	184	16,461	89	31	31	526	2,314	1,099	3,413	3,202
Nebraska-Wyoming: North Platte	944	74,216	79	64	63	943	2,849	1,044	3,893	3,538
Nevada: Truckee-Carson	504	52,039	103	78	78	875	6,486	1,678	8,164	8,108
New Mexico:										
Carlsbad	390	15,712	40	33	28	609	5,265	380	5,645	5,744
Hondo	25	3,025	121	49	47	858	9,800	1,278	11,078	8,720
New Mexico-Texas: Rio Grande	773	30,800	40	37	35	1,502	4,615	702	5,317	6,510
North Dakota: North Dakota pumping	44	2,485	56	24	24	830	1,931	569	2,500	1,244
Oregon: Umatilla	311	9,411	30	16	10	285	5,709	602	6,311	4,915
Oregon-California: Klamath	275	24,000	105	89	89	1,263	5,990	2,156	8,146	6,804
South Dakota: Belle Fourche	615	49,426	80	61	60	750	2,718	1,326	4,040	3,798
Washington:										
Okanogan	448	8,960	20	17	7	233	5,371	343	5,723	6,780
Yakima—										
Sunnyside unit	2,450	66,525	27	26	20	1,167	6,119	755	6,874	4,752
Tieton unit	900	22,700	25	23	18	525	3,800	382	4,182	6,000
Wyoming: Shoshone	429	25,599	60	52	49	732	1,802	1,041	2,843	3,900
Total and average	17,619	[2] 954,187	54	43	40	936	5,040	1,062	6,102	6,200

[1] Data are for calendar year or irrigation season, except on Salt River project, Arizona, data are for corresponding agricultural year October, 1913, to September, 1914. The figures in this table are derived largely from those in foregoing tables. Where this table gives figures per farm or per acre the totals for the same items are given in the preceding tables.
[2] Less than total irrigable acreage of projects, or acreage the Service could have supplied, as given in other tables because this table is restricted to farms actually irrigated.
[3] Includes purchase price of land, improvements, preparation of surface for irrigation, and paid construction (water-right) charges.

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Summary of farms irrigated on reclamation projects in 1914—Continued.

State and project.	Average per acre.[1]				Increase during 1914.											
	Farmers' investment.			Value of land and improvements.[2]	Number of irrigated farms.	Average per farm.							Average per acre.[1]			
									Farmers' investment.			Value of land and improvements.[2]	Farmers' investment.			Value of land and improvements.[2]
	Land and improvements.	Stock and equipment inventory.	Total.			Irrigated acreage.	Cropped acreage.	Crop value.	Land and improvements.[2]	Stock and equipment inventory.	Total.		Land and improvements.[2]	Stock and equipment inventory.	Total.	
Arizona: Salt River	$156	$29	$185	$196	388	[3] 4.6	[3] 5	[3] $382	[3] $1,405	[3] $23	[3] $1,428	[3] $1,258	[3] $7.39	[3] $2.10	[3] $5.29	[3] $1.96
Arizona-California: Yuma	111	24	135	98	82	4.3	5.1	23	393	[3] 49	365	150	19.90	2.33	22.23	6.00
California: Orland	177	40	217	239	50	[3] 2.1	[3] 2.2	[3] 233	[3] 233	114	[3] 119	653	1.67	5.74	7.39	13.26
Colorado: Uncompahgre Valley	47	17	64	74	22	1.8	2.1	[3] 165	18	54	72	86	1.96	1.47	3.43	4.00
Idaho:																
Boise, farms reported	53	14	67	92	200	.1	1.1	72	138	39	177	242	5.22	1.43	6.65	1.38
Minidoka—																
Gravity unit	57	16	73	74	26	.7	1.2	48	935	102	1,037	556	16.61	1.89	18.50	10.21
South side pumping unit	40	17	57	71	39	3	4	[3] 46	255	192	447	386	3.94	2.81	6.55	5.54
Montana:																
Huntley	42	23	65	60	[3] 1	2.5	2.5	[3] 18	222	158	380	42	5.64	3.87	9.49	1.88
Milk River	14	14	28	31	[3] 5	[3] 4	[3] 6	266	425	503	928	477	1.77	2.31	4.08	.80
Sun River	39	21	60	69	[3] 7	[3] 3	.1	36	871	268	1,139	.....	19.61	6.82	26.43	.....
Montana-North Dakota: Lower Yellowstone	30	14	44	41	26	[3] 17	[3] 16	[3] 117	138	82	220	48	5.95	3.00	8.95	6.76
Nebraska-Wyoming: North Platte	36	13	49	45	36	1.4	3	77	206	149	355	[3] 45	3.23	2.04	5.27	.....
Nevada: Truckee-Carson	63	16	79	79	10	[3] 8.8	[3] 8.9	[3] 248	[3] 91	206	115	439	5.77	3.48	9.22	12.07
New Mexico:																
Carlsbad	101	7	108	110	28	[3] 6	[3] 4	[3] 64	[3] 385	10	[3] 375	446	1.00	.....	1.00	[3] 1.00
Hondo	81	11	92	72	3	7	10	211	10,100	1,390	[3] 412	[3] 40	[3] 26.00	[3] 3.00	[3] 29.00	[3] 20.00
New Mexico-Texas: Rio Grande	116	18	134	163	11	1.6	1.6	680	409	130	539	472	4.14	2.44	6.58	3.07
North Dakota: North Dakota pumping	51	15	66	33	[3] 10	[3] 8	[3] 6	110	[3] 461	[3] 27	[3] 488	[3] 282	.84	2.52	3.36	.86
Oregon: Umatilla	189	20	209	162	.....	.3	[3] .1	15	[3] 1,014	[3] 59	[3] 1,073	[3] 1,808	[3] 18.00	.....	[3] 18.00	[3] 45.00
Oregon-California: Klamath	57	21	78	65	[3] 8	22	22	243	801	970	1,771	[3] 383	[3] 1.05	6.55	5.50	[3] 16.32
South Dakota: Belle Fourche	34	17	51	47	11	4.4	3.6	138	263	368	527	193	2.77	4.41	7.17	1.30

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Washington:																
Okanogan	269	17	286	341	7	[3] .2	.9	38	15	[3] 32	[3] 17	[3] 461	[3] 7.00	[3] 2.00	[3] 9.00	[3] 31.00
Yakima—																
Sunnyside unit	225	28	253	175	2	2.3	3.1	14	1,203	57	1,260	320	38.00	1.80	39.80	.....
Tieton unit	150	15	165	240	160	[3] 2	1	[3] 45	[3] 670	[3] 8	[3] 678	[3] 700	[3] 10.00	1.00	[3] 9.00	.....
Wyoming: Shoshone	30	17	47	65	33	2.8	2.8	69	[3] 45	164	119	151	[3] 1.52	2.39	1.48	1.00
Total and average	93	20	113	114	1,133	.....	1	[3] 18	.....	60	.....	.....	.....	2.00	.....	.....

[1] Per acre irrigable. [2] Includes purchase price of land, improvements, preparation of surface for irrigation, and paid construction (water-right) charges. [3] Decrease.

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Water storage by United States Reclamation Service, 1914.[1]

[Reservoirs operated by service in 1914.]

State and project.	Reservoir.	Capacity in 1914.	Contents beginning of year.	Water entering reservoir during year.			Water leaving reservoir during year.							Contents end of year.
							Outflow.		Losses.				Total.	
										Seepage.				
				Inflow.	Rain on reservoir.	Total.	Irrigation use.	Wasted.	Evaporation.	Total.	Mean area submerged.	Per acre.		
		Acre-feet.	*Acre-feet.*	*Acre-feet.*	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Acre-ft.*	*Acre-ft.*	*Acres.*	*Acre-ft.*	*Acre-feet.*	*Acre-feet.*
Arizona: Salt River	Roosevelt	1,367,300	182,173	628,907	8,209	637,116	616,859		43,895				660,754	158,535
California: Orland	East Park	45,600	16,300	115,700	2,364	118,064	33,654	84,533	7,177				125,364	9,000
Idaho:														
Boise	Deer Flat	177,640	29,267	275,242	4,164	279,406	201,585			82,080	5,337	15.4	283,665	25,008
Minidoka	Lake Walcott	150,000	63,635	7,413,480	11,465	7,424,945	615,200	6,719,000	38,580				7,372,780	115,800
	Jackson Lake[2]	380,000	[3]—9,000											102,700
Montana:														
Milk River	Point of Rocks	830	0	2,848	95	2,943	2,057			651	89	7.3	2,708	235
Sun River	Willow Creek[4]	16,700	11,700											0
Nebraska-Wyoming: North Platte.	Pathfinder	1,070,000	287,720	1,552,790	9,180	1,561,970	1,418,620	9,650	65,060				[5]1,501,990	347,700
	Lake Alice	11,400	6,446	96,972	842	97,814	43,737	39,250	2,024	12,803	581	22	97,814	6,446
Nevada: Truckee-Carson	Lahontan[6]	60,000	0			57,000	30,000	27,000						0
	Lake Tahoe[7]	750,000	120,000			429,740							177,740	372,000
New Mexico:														
Carlsbad	Lake McMillan	70,000	34,000	378,620	9,920	388,540		185,000	43,100	147,440	6,160	24	375,540	47,000
	Avalon	7,000	7,000	333,630	1,290	334,920	87,900	239,900	5,830	1,290	822	1.6	334,920	7,000
Hondo	Hondo	40,000	0			19,605				17,605			17,605	2,000
Oregon: Umatilla	Cold Springs	50,000	30,225	35,845	632	36,477	47,228		5,866	3,658	1,104	3.3	56,752	9,950
South Dakota: Belle Fourche.	Belle Fourche	203,770	88,450	135,358	18,473	153,831	107,935		15,822	45,664	4,800	.98	169,421	72,860
Washington:														
Okanogan	Conconully	13,000	4,150	33,160	557	33,717	26,161	5,414		993			32,568	5,299
	Salmon Lake[8]	2,600	180											2,220
Yakima	Bumping Lake	34,000	1,480	223,729	2,691	226,420	226,880						226,880	1,020
	Lake Kachess	210,000	47,450	178,435	9,970	188,405	209,030						209,030	26,825
	Lake Keechelus[9]	[9]15,000	11,500			248,100	259,600						259,600	0

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Wyoming: Shoshone	Lake Clealum	22,800	6,500	638,254	4,521	642,775	630,100	.....	.....	.....	.....	.....	630,100	19,175
	Shoshone	470,000	466,750	.....	.....	966,196	92,340	[10] 898,556	.....	.....	.....	.....	990,896	442,050
Total		5,167,640	1,405,926	12,042,970	84,373	13,847,984	4,628,139	8,208,303	227,354	312,184	18,893	.....	13,526,127	1,772,823

[1] Exclusive of Indian projects constructed by Reclamation Service for Indian Service. Data are for calendar year, except on Salt River project data are for corresponding agricultural year, Oct. 1, 1913, to Sept. 30, 1914.
[2] Data incomplete.
[3] Negative storage refers to an assumed zero due to obstructions in outlet channel.
[4] Not operated for irrigation in 1914.
[5] Includes unaccounted for loss of 8,660 acre-feet.
[6] Under construction, making reliable records impossible, but a maximum of 57,000 acre-feet storage was obtained during 1914.
[7] Approximate figures. Lake Tahoe was not under control of Reclamation Service in 1914.
[8] Empties into Conconully Reservoir; data incomplete.
[9] Data approximate, due to construction operations during the year, affecting regulation and capacity.
[10] Over Corbett Dam.

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Water diverted by Reclamation Service, 1914.[1]

State and project.	Diverted from—	Water diverted in acre-feet.													Acreage irrigated.[2]	Diversion, acre-feet per acre.
		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.		
Arizona: Salt River	Salt River	40,614	45,412	84,488	89,063	98,981	72,164	74,538	94,356	90,340	[3] 59,515	[4] 33,183	[5] 22,270	804,924	187,112	4.30
Arizona-California: Yuma.	Colorado River	7,567	5,221	12,569	11,900	21,255	22,444	26,939	24,963	26,538	27,120	13,199	5,492	[6] 205,207	25,207	[6] 8.16
California: Orland	Stony Creek	.....	.....	871	3,619	9,033	8,963	8,082	9,187	7,803	2,589	.....	.....	50,147	7,354	6.82
Colorado: Uncompahgre Valley.	Gunnison River[7]	.....	.....	.....	337	2,939	3,773	11,806	18,200	19,398	10,453	.....	.....	66,906	.....	.....
	Uncompahgre River.	.....	.....	.....	11,291	25,031	34,661	39,758	31,795	23,255	16,385	1,166	.....	183,342	32,911	5.66
Idaho:																
Boise	Boise River	23,053	21,960	46,455	70,326	131,971	116,809	47,854	5,401	13,687	11,678	5,132	1,339	495,665	83,714	5.92
Minidoka[8]	Snake River	.....	.....	.....	33,200	105,000	94,300	138,000	119,000	54,800	27,900	.....	.....	[8] 572,200	81,518	[8] 7.02
Montana:																
Huntley	Yellowstone River.	.....	.....	.....	.....	1,115	12,108	20,168	18,269	3,883	.....	.....	.....	55,543	17,068	3.25
Milk River	Milk River	.....	.....	.....	750	1,270	850	743	.....	.....	616	.....	.....	4,229	2,201	1.91
Sun River	Sun River	.....	.....	.....	.....	1,336	4,557	10,547	6,058	1,917	347	.....	.....	24,762	6,613	3.7
Montana-North Dakota: Lower Yellowstone.	Yellowstone River.	.....	.....	.....	.....	2,528	6,229	9,878	4,998	735	1,401	.....	.....	25,769	5,743	4.5
Nebraska-Wyoming: North Platte.	North Platte River.	.....	.....	.....	.....	50,464	83,252	87,692	87,472	69,000	38,100	.....	.....	415,980	67,700	6.16
Nevada: Truckee-Carson.	Carson River	.....	.....	17,126	30,369	40,682	42,687	39,166	28,902	18,660	7,962	.....	.....	225,554	36,590	6.16
New Mexico:																
Carlsbad	Pecos River	.....	2,580	2,740	15,720	10,600	7,010	16,600	19,800	11,970	880	.....	.....	87,900	12,690	6.9
Hondo[9]	Hondo River	20	.....	.....	29	.....	4,242	14,675	204	27	157	494	2,935	[9] 22,783	1,224	[9] 18.61
New Mexico-Texas: Rio Grande.[10]	Rio Grande	4,730	13,266	16,384	28,324	32,931	29,740	17,413	28,529	15,718	10,611	.....	.....	[10] 197,646	28,442	[10] 6.30
North Dakota: North Dakota pumping.	Missouri River	.....	.....	.....	.....	.....	687	804	1,180	.....	.....	.....	.....	3,671	1,056	2.53
Oregon: Umatilla	Umatilla River	13,001	9,685	9,229	14,940	10,266	4,995	1,010	560	604	2,141	4,138	2,856	73,425	5,100	14.2
Oregon-California: Klamath.	Lost River	.....	.....	.....	.....	771	1,051	1,313	823	218	.....	.....	.....	4,176	980	4.26
	Upper Klamath Lake.	.....	.....	.....	.....	11,248	11,034	15,690	8,880	2,400	.....	.....	.....	49,252	24,440	2.00
South Dakota: Belle Fourche.	Belle Fourche River.	.....	.....	11,418	17,102	25,438	14,612	6,584	20,026	1,380	18,658	15,980	14,136	145,284	37,454	3.88

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Washington:																
Okanogan	Salmon River	180	168	300	480	5,337	6,875	7,154	7,695	700	333	240	248	29,710	7,740	3.85
Yakima	Yakima River	.....	.....	.....	37,076	52,833	51,420	56,883	54,387	37,520	19,784	.....	.....	309,903	66,525	4.66
	Tieton River	.....	.....	.....	.....	13,402	11,633	16,860	16,658	9,235	.....	.....	.....	67,788	20,600	3.29
Wyoming: Shoshone	Shoshone River	.....	.....	.....	3,698	14,108	16,282	24,692	18,023	7,333	8,204	.....	.....	92,340	22,226	4.15
Totals and average.		89,165	98,292	201,580	368,224	668,539	662,378	694,849	625,366	417,121	264,834	73,482	49,276	4,213,106	782,208	5.38
Per cent of total		2.1	2.3	4.8	8.8	15.9	15.7	16.5	14.8	9.9	6.3	1.7	1.2	100.0	.....	.....

[1] Data are for calendar year, except on Salt River project, Arizona, data are for corresponding agricultural year, October, 1913, to September, 1914.
[2] Figures do not agree in all cases with those given in other tables for irrigated acreage of Government projects due to irrigation from wells, from private ditches supplied through project canals, etc.
[3] October, 1913.
[4] November, 1913.
[5] December, 1913.
[6] 50,537 acre-feet were wasted back into the river, making a net diversion of 154,670 acre-feet, or 6.14 acre-feet per acre.
[7] Discharges of Gunnison Tunnel at west portal. Used mainly to augment flow of Uncompahgre River. Not used in computing average diversion per acre.
[8] Figures for diversions are exclusive of amounts wasted to river and drainage canals.
[9] Figures include water diverted to Hondo Reservoir which was lost. Without this the total diversion was 3,178 acre-feet, or 2.6 acre-feet per acre.
[10] Figures are exclusive of water diverted for scouring and that returned to river through waste channels. There were sold to other than project canals 18,412 acre-feet, which are deducted from total diversion in computing diversion per acre.

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Distribution of water on reclamation projects, 1914.[1]

State and project.	Acreage irrigated.[2]	Acre-feet diverted for direct use.[3]				Acre-feet unused.		Acre-feet delivered to project farms.		Per cent of diversion delivered.
		Natural flow.	Reservoir flow.[4]	Pumped.	Total.	Wasted.	Lost.[5]	Total.	Per acre irrigated.	
Arizona: Salt River	187,112	511,896	264,531	30,481	806,908	5,055	355,122	446,731	2.62	55.5
Arizona-California: Yuma	25,207	201,348	.....	3,859	[6] 205,207	[6] 55,088	56,952	93,167	3.69	45.4
California: Orland	7,354	24,508	25,638	.....	50,146	7,069	13,066	30,011	4.08	59.5
Colorado: Uncompahgre Valley	33,873	185,227	.....	.....	185,227	.....	[7] 13,959	171,268	5.06	[7] 92.5
Idaho:										
Boise	83,714	205,401	201,585	.....	[8] 406,986	8,778	139,028	219,695	2.62	62.1
Minidoka	81,518	430,104	119,478	.....	549,582	[9] 43,710	236,886	277,148	3.40	50.5
Montana:										
Huntley	17,068	55,543	.....	.....	[10] 55,543	[10] 20,639	10,475	24,429	1.43	[11] 44.0
Milk River	2,201	3,276	.....	.....	3,276	181	1,335	1,760	.80	53.8
Sun River	6,613	24,762	.....	.....	24,762	3,471	9,823	11,468	1.73	46.3
Montana-North Dakota: Lower Yellowstone	5,743	25,769	.....	.....	25,769	3,138	[12] 13,488	9,143	1.59	35.4
Nebraska-Wyoming: North Platte	60,532	.....	.....	.....	[13] 415,980	38,654	152,899	176,915	2.92	54.0
Nevada: Truckee-Carson	39,516	.....	.....	.....	268,028	49,568	80,356	[14] 138,104	[14] 3.50	51.5
New Mexico:										
Carlsbad	12,090	.....	87,900	.....	87,900	8,244	48,756	30,900	2.44	35.3
Hondo	1,224	3,178	.....	.....	3,178	.....	2,070	1,108	.91	34.9
New Mexico-Texas: Rio Grande	28,442	235,332	.....	.....	[15] 235,332	.....	[16] 55,368	161,552	5.68	76.5
North Dakota: North Dakota pumping	1,056	.....	.....	2,671	[17] 2,671	20	732	1,791	1.70	72.0
Oregon: Umatilla	5,100	[18] 15,501	47,227	.....	62,728	1,281	25,147	36,300	7.11	58.0
Oregon-California: Klamath	24,440	49,252	4,176	.....	53,428	1,355	21,401	30,672	1.26	57.4
South Dakota: Belle Fourche	37,454	3,526	106,935	.....	110,461	7,988	48,211	54,262	1.45	49.2
Washington:										
Okanogan	7,740	684	31,550	.....	32,234	5,389	6,810	20,035	2.59	62.2
Yakima—										
Sunnyside	66,525	258,593	51,310	.....	309,903	17,399	88,000	204,504	3.07	66.1
Tieton	20,600	38,102	29,686	.....	67,788	6,237	18,452	43,099	2.09	63.6
Wyoming: Shoshone	22,226	92,340	.....	.....	[19] 92,340	4,858	34,061	52,789	2.38	57.2
Total and average	777,948	2,364,342	970,016	37,011	4,055,377	288,122	1,432,397	2,236,851	2.87	57.6

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[1] Data are for calendar year (irrigation season), except for Salt River project, Arizona, data are for corresponding agricultural year ending Sept. 30, 1914.
[2] Figures do not agree in all cases with those in other tables because of inclusion here of areas under private canals supplied through project systems, etc.
[3] Water entering canal systems for immediate irrigation. Exclusive of water diverted for filling storage reservoirs.
[4] Stored water.
[5] Seepage and evaporation.
[6] Includes 50,518 acre-feet returned to river through wasteway channels.
[7] Relatively small loss and high efficiency, due in part to seepage into project system from higher lands.
[8] Of this amount, 10,818 acre-feet were delivered to Pioneer irrigation district, 13,365 to Riverside Canal, 8,974 to Deer Flat Reservoir from Deer Flat High Line Canal, and 6,328 acre-feet were used for stock water and construction purposes, all of which are included in computing per cent of diversion delivered.
[9] 8,162 acre-feet returned to canals by wasteways and pumps.
[10] Of this amount, 18,948 acre-feet wasted by pumps.
[11] 73 per cent eliminating waste from pumps.
[12] High per cent loss because canal system was used only to small part of its capacity.
[13] Of this amount, 41,547 acre-feet were delivered to North Platte Canal & Colonization Co. and 5,965 acre-feet were delivered to Lake Alice and not withdrawn into canal system. These amounts are included in computing per cent of diversion delivered.
[14] Figures include Truckee Canal division, 23,030 acre-feet to 3,050 acres, or 7.55 per acre; unsettled Carson rights, 43,374 acre-feet to 10,865 acres, or 3.99 per acre, and Carson division project rights, 71,700 acre-feet to 25,601 acres, or 2.80 per acre.
[15] Of this amount, 18,412 acre-feet diverted for and sold by water users to Berino ditch; included in computing per cent of diversion delivered.
[16] Includes 49,685 acre-feet waste and loss from service canals and 5,683 loss from community canals.
[17] 128 acre-feet used at power house.
[18] Includes 2,212 acre-feet seepage from Cold Springs drain.
[19] Of this amount, 632 acre-feet remained in Ralston Reservoir at close of season.

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RIO GRANDE DAM APPROPRIATION.

The three tables that follow give for the Rio Grande Dam appropriation information similar to that appearing in Tables 5 to 8, inclusive, with corresponding titles for the reclamation fund:

TABLE 16.—*Special appropriation for Rio Grande (Engle) Dam (34 Stat., 1357) to June 30, 1915.*

	Debit.	Credit.
Appropriation warrant No. 79, Mar. 4, 1907	.....	$1,000,000.00
Disbursements, 2,896 vouchers	$1,000,091.78	.....
Collections, 24 vouchers	.....	91.78
Total	1,000,091.78	1,000,091.78

TABLE 17.—*Balances of appropriations for Rio Grande (Engle) Dam with Treasurer of the United States, June 30, 1907, to June 30, 1915.*

Fiscal year.	Appropriation.	Withdrawals.	Balances.
1907	$1,000,000.00	.....	$1,000,000.00
1908	.....	$33,113.21	966,886.79
1909	.....	137,074.22	829,812.57
1910	.....	247,217.23	582,595.34
1911	.....	327,875.96	254,719.38
1912	.....	214,052.49	40,666.89
1913	.....	39,165.89	1,501.00
1914	.....	1,501.00	.....
Total	1,000,000.00	1,000,000.00	.....

TABLE 18.—*Disbursement and collection vouchers, appropriation for Rio Grande (Engle) Dam, paid and collected to June 30, 1915.*

Fiscal year.	Disbursement vouchers.		Collection vouchers.	
	Number.	Amount.	Number.	Amount.
Balance from Twelfth Annual Report	2,895	$998,590.78	24	$91.78
June 30, 1914	1	1,501.00	.....	.....
Total	2,896	1,000,091.78	24	91.78

RECLAMATION DEPOSIT ACCOUNT.

Below is a statement of receipts, payments, and balances to June 30, 1915. A description of the nature of the account appears on page 51 of the tenth annual report.

TABLE 19.—*Receipts and payments from reclamation deposit account during fiscal year 1915.*

Dates.	Receipts.	Payments.	Balance.
Balance on hand—			
June 30, 1914	$53,777.29	.....	.....
July, 1914	214,360.82	$175,308.50	[illegible]
August, 1914	115,158.41	81,501.28	[illegible]
September, 1914	7,443.29	81,352.15	[illegible]
October, 1914	34,451.40	39,619.35	[illegible]
November, 1914	23,782.83	9,560.22	[illegible]
December, 1914	139,783.91	171,178.80	[illegible]
January, 1915	85,056.71	19,908.88	[illegible]
February, 1915	46,744.21	72,821.06	[illegible]
March, 1915	55,729.04	75,778.51	[illegible]
April, 1915	182,206.13	42,530.92	[illegible]
May, 1915	226,102.10	200,308.39	[illegible]
June, 1915	68,301.47	49,868.91	[illegible]
Total	1,252,895.61	1,019,722.08	[illegible]

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