REPORT ON
SANTA CRUZ RESERVOIR PROJECT

BY

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SANTA CRUZ RESERVOIR CO., and Others

PLANS AND SPECIFICATIONS FOR COMPLETE

STEAM, ELECTRIC, HYDRAULIC AND
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SUPERVISION
EXAMINATIONS AND REPORTS ON
IRRIGATION OR POWER PROJECTS

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SUBJECT

REPORT UPON THE SANTA CRUZ RESERVOIR PROJECT

BRIEF OUTLINE OF PROJECT:

Briefly, the Santa Cruz Reservoir project, which it is proposed to rehabilitate, involves a reservoir (now partially completed) formed by the construction of an earth-fill dam, 22,000′ long at the crest and 45′ high from its base, and the impounding, therein, of the flood waters of the Santa Cruz and Santa Rosa rivers. The reservoir so constructed would have a maximum impound capacity of 295,330 acre-feet. The site of this reservoir is a natural depression at the point of confluence between the two rivers above mentioned.

The land susceptible of irrigation from this reservoir is far in excess of that for which there is an available water supply. In fact, about 400,000 acres of irrigable land lie north, east, and west of the Santa Cruz reservoir site and could have been irrigated had the Santa Cruz project been completed upon the stupenduous scale proposed at one time and which contemplated the construction of two additional dams to form what is known as the Black Mountain Reservoir, and an extension of the present Santa Cruz Reservoir.

This proposed larger project contemplated a diversion dam upon the Gila River, some 35 miles north-east of the Black Mountain Reservoir site, and the diverting of the flood-waters from the Gila River for storage in this reservoir which would have had an impound capacity of 780,000 acre-feet.

While rights-of-way and title to the Black Mountain as well as the Santa Cruz reservoir sites have been approved by the Department of the Interior, I do not consider the project, upon the large scale outlined, feasible or practicable, because of lack of adjudication of water rights.

HISTORY OF THE SANTA CRUZ PROJECT AND ITS PRESENT STATUS:

The Santa Cruz Reservoir Project was conceived by Colonel Epes Randolph, General L. H. Manning, a Mr. Griffith, and associates, who expended $40,000.00 in the partial construction of a dam which was to form the Santa Cruz reservoir, situated in Pinal County in Townships 9 and 10 South, Range 6 and 7 East of the G. & S. R. B. Meridian, and in the construction of diversion canals to this reservoir from the Santa Cruz and Santa Rosa rivers. (See Plate III. on Page 33.)

Appreciating the possibilities of a more extended system, whereby the reclamation of a much larger area of land than was contemplated under the original project would be involved, a Company was formed, December 15, 1908, under the name of the Santa Cruz Reservoir Company, with a capitalization of $10,000,000.00.

This Company acquired the holdings of the original owners and plans were considered with a view to the construction of the Black Mountain Reservoir; also a diversion dam on the Gila River and a diversion canal from that point to the Black Mountain reservoir.

Appropriations of the necessary water from the Gila River, as well as from the Santa Cruz and Santa Rosa rivers, and work was renewed in the construction of the Santa Cruz reservoir dam and the Santa Cruz diversion dams and canals, as well as upon the surveys and preliminary engineering work in connection with the Black Mountain reservoir and canal system for diverting water from the Gila River. The total capacity of the reservoirs contemplated under this project (and which include an extension of the Santa Cruz reservoir), was something over 2,000,000 acre-feet, while the area which it was contemplated reclaiming was some 400,000 acres.

The leading spirit in the promotion of this enterprise was Colonel Green, but upon his death, in 1911, work was discontinued, temporarily, and all of his personal interests are now held by the Cananea Cattle Company, while the remaining stock is owned by Colonel Randolph and General Manning.

During the period when construction was being carried on, the dam which was started by the original owners was completed to an elevation of 24′ above the floor of the discharge gates. The length of this dam is 7800′ at the crest and its width 12′ at the crest and 220′ at the base. The impound capacity at this elevation is 33,000 acre-feet, covering an area of 4500 acres. (See Plate III.)

There is situated, within a radius of ten miles from the outlet gates of the original Santa Cruz reservoir, ample land to utilize all the of water impounded

S½ Section 12, Township 8-S, Range 6-E, 320 acres; All of Section 13, Township 8-S, Range 6-E, 640 acres; All of Section 14, Township 8-S, Range 6-E, 640 acres; E½ Section 22, Township 8-S, Range 6-E, 320 acres; S½ Section 23, Township 8-S, Range 6-E, 320 acres; W½ Section 25, Township 8-S, Range 6-E, 320 acres; All of Section 26, Township 8-S, Range 6-E, 640 acres; SE¼ Section 27, Township 8-S, Range 6-E, 160 acres; E½ Section 34, Township 8-S, Range 6-E, 320 acres; SE¼ of NE¼ Section 35, Township 8-S, Range 6-E, 40 acres; W½ of NE¼ Section 35, Township 8-S, Range 6-E, 80 acres; W½ Section 35, Township 8-S Range 6-E, 320 acres; Lots 3 and 4, Section 5, Township 8-S, Range 7-E, 79.20 acres; S½ of NW¼ Section 5, Township 8-S, Range 7-E, 80 acres; SW¼ Section 5, Township 8-S, Range 7-E, 160 acres; All of Section 6, Township 8-S, Range 7-E, 627.08 acres; All of Section 7, Township 8-S, Range 7-E, 628.54 acres; ~~SE¼~~ Section 35, Township 8-S, Range 6-E, 160 acres; NE¼ of NE¼ ~~Range~~ 35, Township 8-S, Range 6-E, 40 acres; NE¼ Section 27, Township 8-S, Range 6-E, 160 acres; SW¼ (fractional) Section 2, Township 7-S, Range 6-E, 120 acres; S½ of SW¼ Section 21, Township 4-S, Range 3-E, 40 acres; SE¼ of SE¼ Section 21, Township 4-S, Range 3-E, 40 acres; NE¼ of NW¼ Section 28, Township 4-S, Range 3-E, 40 acres; NW¼ of NE¼ Section 28, Township 4-S, Range 3-E ,40 acres; being 6,300. acres more or less of patented land. ~~Also, the reservoir site owned by this Company, as approved by the Commissioner of the United States General Land Office, as per the records in his office at Washington, D.C., and containing about 17,000 acres.~~

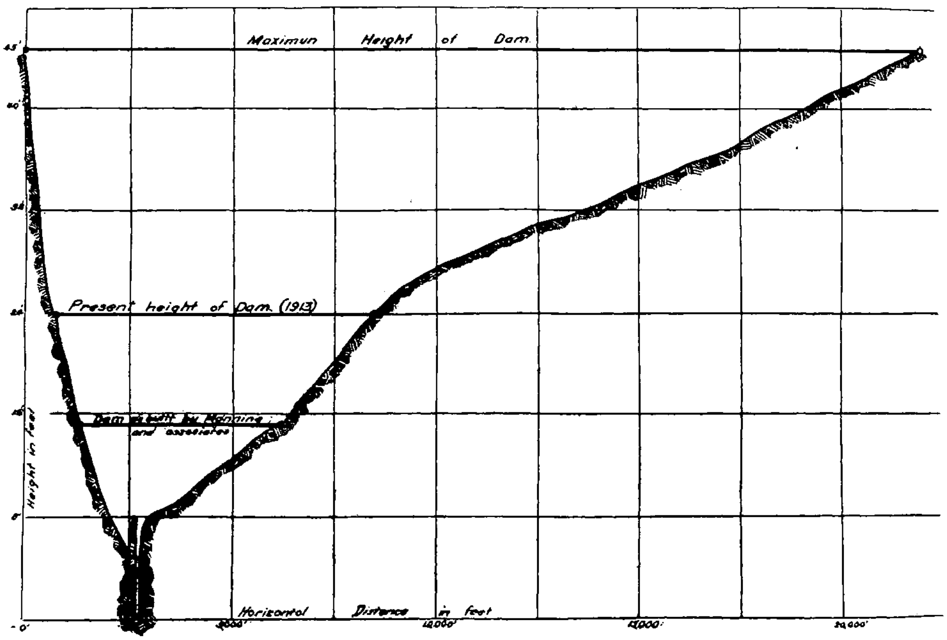
therein. At the inception of this project it was proposed to acquire title to the land not already patented but included in the project under the "Desert Land Act," whereby the development and application of water, and the cultivation and cropping of one-eighth of the area, would comply with the provisions of the above Act and procure title thereto.

Upon suspension of operations, however, these original filings reverted to the public domain. Hence, to protect the reservoir rights and make available the use of water thereform, it was deemed advisable to acquire title to such of the most desirable land as was most strategically situated with respect to the reservoir. Therefore, the Company, on November 7, 1912, purchased Moqui Scrip and applied it to 6,334.82 acres—this in addition to the 840 acres, title to which had already passed to the Reservoir Company. The location of the land upon which this scrip was applied is as follows:

AREA OF LAND COVERED BY SCRIP

	SEC.	TWSP.	RANGE*	ACRES
~~SE¼~~	~~21~~	~~7-S~~	~~7-E~~	~~160~~
~~SW¼~~	~~22~~	~~7-S~~	~~7-E~~	~~160~~
~~NW¼~~	~~27~~	~~7-S~~	~~7-E~~	~~160~~
~~NE¼~~	~~28~~	~~7-S~~	~~7-E~~	~~160~~
S½..............	12	8-S	6-E	320
All of............	13	8-S	6-E	640
All of............	14	8-S	6-E	640
E½..............	22	8-S	6-E	320
S½..............	23	8-S	6-E	320
W½.............	25	8-S	6-E	320
All of............	26	8-S	6-E	640
SE¼.............	27	8-S	6-E	160
E½..............	34	8-S	6-E	320
SE¼ of NE¼	35	8-S	6-E	40
W½ of NE¼.....	35	8-S	6-E	80
W½.............	35	8-S	6-E	320
Lots 3 and 4......	5	8-S	7-E	79.20
S½ of NW¼......	5	8-S	7-E	80
SW¼............	5	8-S	7-E	160
All of............	6	8-S	7-E	627.08
All of	7	8-S	7-E	628.54
				6,334.82

*Gila and Salt River Base and Meridian.



CROSS SECTION OF SANTA CRUZ STORAGE RESERVOIR DAM

All of the above land is situated in Pinal County and is shown on Plate III, Page 3J.

The necessary requirements in the matter of the selecting, posting, and publishing of notices relative to the application of scrip upon this area have been complied with and, since no protest has been made within the proper period and title has been granted to other lands in this vicinity upon which the same scrip has been applied, there is no question, whatsoever, as to title soon being granted the Santa Cruz Reservoir Company for all of the area above described.

While much of the area originally included in the project, and to which it was proposed to obtain title under the Desert Land Act, has since been located by outside entrymen. I find that the following land is open to entry or to the application of scrip:

All of	Section	19,	Township	8	South,	Range	6	East.
" "	"	20,	"	"	"	"	"	"
W ½ of	"	21,	"	"	"	"	"	"
W ½ of	"	27,	"	"	"	"	"	"
All of	"	28,	"	"	"	"	"	"
All of	"	29,	"	"	"	"	"	"
" "	"	30,	"	"	"	"	"	"
" "	"	31,	"	"	"	"	"	"
" "	"	33,	"	"	"	"	"	"
S 1-2 off	"	30,	"	"	"	"	"	"
All of	"	31,	"	"	"	"	"	"

All of this land would join to make up a tract contiguous to the land now included under this project.

Of the 7,174.82 acres (comprising the scripped and patented lands) now involved, 460 acres could not economically be included under the irrigation system proposed. Hence, it would be necessary to acquire some 3300 acres additional, but I have not made personal inspection of the lands yet open to entry and cannot say that it is all desirable. However, the desired area could be made up of such of the land as is desirable and the remainder be composed of school land or that acquired by purchasing relinquishments from those who have already entered land.

It will be noted that, included in the list of scripped land, there are 640 acres, upon part of which is situated the railroad station at Toltec, and the remaining area will no doubt have considerable value as a townsite or become valuable agricultural land.

Attention is also called to the fact that of the patented land (list of which follows), 160 acres is located at Maricopa and adjoins the railroad right-of-way. Similiar value to that of Toltec will, no doubt, attach to the land.

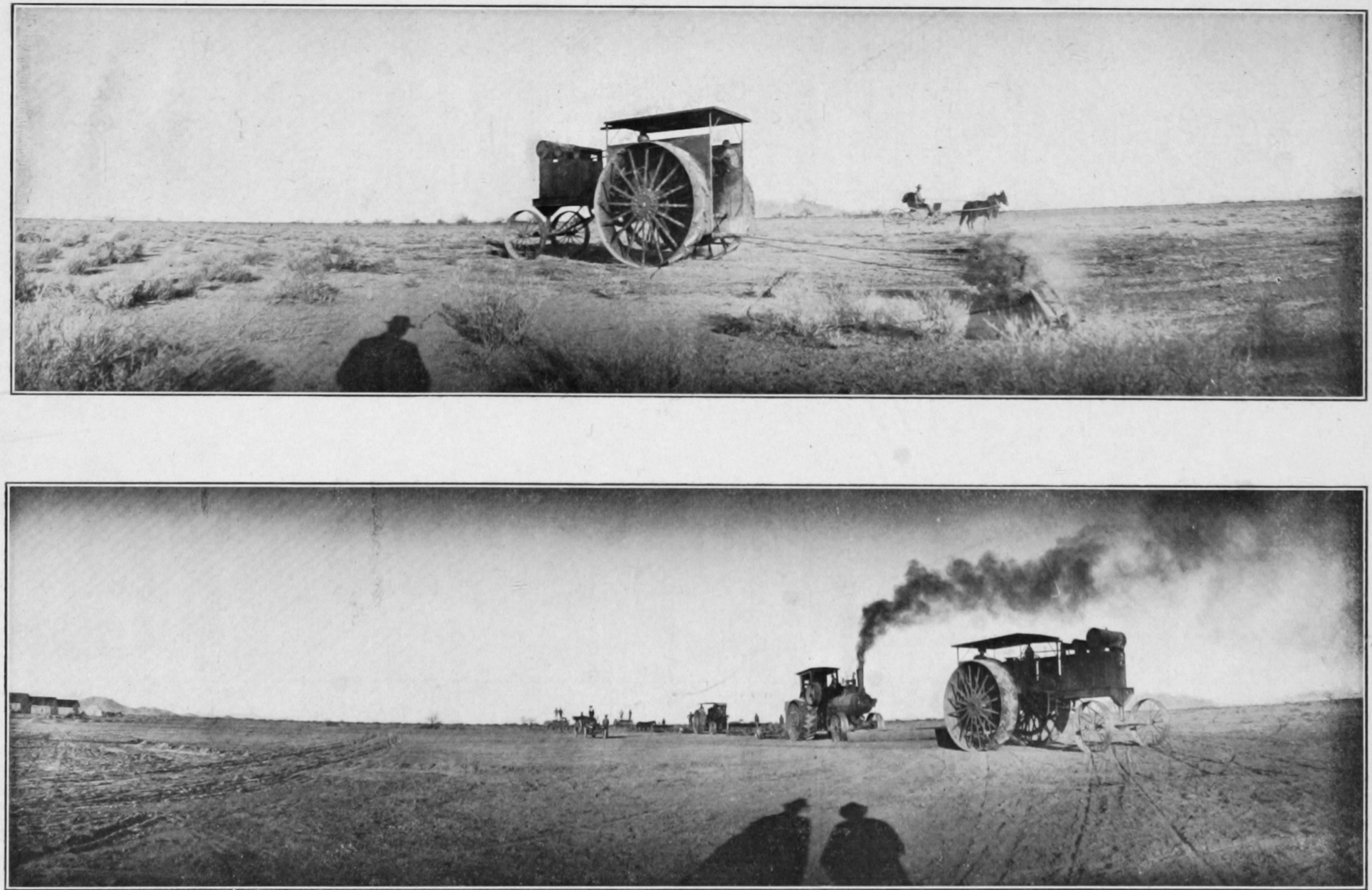
AREA OF PATENTED LAND

	SEC.	TWNSP.	RANGE	ACRES
SE¼	35	8-S	6-E	160
NE¼ of NE¼	35	8-S	6-E	40
NE¼	27	8-S	6-E	160
E½ of SW¼	9	8-S	~~7-E~~	~~80~~
W½ of SW¼	~~10~~	~~8-S~~	~~7-E~~	~~80~~
~~NW¼ of NW¼~~	~~35~~	~~7-S~~	~~7-E~~	~~40~~
SW¼ (fractional) .	2	7-S	6-E	120
SE¼ of SW¼	21	4-S	3-E	40
SE¼ of SE¼	21	4-S	3-E	40
NE¼ of NW¼	28	4-S	3-E	40
NW¼ of NE¼	28	4-S	3-E	40
				840

The necessary farm machinery, including graders, canal construction apparatus, and four 40-horse-power traction engines (including extra fittings and various supplies therefor), wagons, trucks, buggies, etc., was purchased and the work of clearing and preparing over 3,000 acres of land for cropping was commenced. This equipment had a capacity for plowing and seeding, at one operation, 160 acres of land per day.

The work included the construction of canals, laterals, field laterals, and the installation of the necessary head-gates and controlling works. Numerous buildings were built at the site known as Santa Cruz, among which are storehouses, blacksmith shops, and dwellings. While I have examined the personal property of the Company at Santz Cruz, I did not attempt to check over, in detail, the various items shown in the inventory with they provided me, but, in my opinion, the account representing the larger expenditures is in accord with their statement. I am inclined to believe, however, that some of the property is obsolete and the prices given in the inventory are, in some instances, in excess of their intrinsic value. This list is entirely too exhaustive to include in this report but may be seen at the offices of the Company. I have checked over the itemized statements of moneys expended in the construction of the dams ditches, head-gates, canals, laterals, etc., and find the costs given to be consistent and reasonable.

Up to the present time the amount of money expended upon this project is as follows:



Traction engines used in farm operations at Santa Cruz.

Expended by Randolph, Manning, and associates, on dams, canals, etc.	$ 40,000.00
Cost of scripping or otherwise obtaining title to Company lands—840 patented; 6335 pending,	31,000.00
Plowing and clearing of lands	30,000.00
Twenty-five miles of fence	2,500.00
Expended by Santa Cruz Reservoir Company on buildings, dams, canals, laterals, machinery, supplies, etc.	150,000.00
Engineering and legal expense; management; and miscellaneous	46,500.00
Total Expenditures	$300,000.00

At the point of the interception of the Santa Cruz River by the diversion canal, an earth-fill diversion dam, some 2,000′ long and 10′ high, has been constructed across the Santa Cruz River channel. Also, there is constructed a diversion canal, from this point to the reservoir, which has an average width of 20′, an average depth of 5′, and a gradient of 14′ per mile. At the extreme west end of the Santa Cruz diversion dam there is constructed a waste-way with gates, having a waste-way area of closely 100 square feet. The water discharged through these waste gates flows into the old channel of the Santa Cruz River below the point of diversion.

The diversion dam of the Santa Rosa River is in the form of a levee which continues and forms the south bank of the Santa Rosa diversion canal which has been constructed for a distance of some 6 miles. The gradient of this canal is 12′ per mile and the width is about 20′, with a depth varying from 1′ to 1.5′. The upstream face of the Santa Cruz diversion dam is well protected against erosion from wave action by mesquite posts set into the embankment and an-anchored in place with barbed wire. Between these panels is interlaced brush which forms an excellent protective face. The Santa Cruz diversion dam is protected from erosion by spur revetments of posts wired in place and a brush grillage.

The main discharge outlet at the Santa Cruz dam is composed of concrete and, aside from the superstructure installed for the operation of the gates, is in good condition. On the whole, the construction in connection with the main Santa Cruz dam, the diversion dams, and the diversion canals, is of excellent character and the works are in good condition at the present time, requiring but small expenditure upon the outlet gates.

From the outlet gates of the Santa Cruz reservoir there has been constructed a main supply canal to a point some 9 miles north. This canal is 15′ in width, 4′ in depth, with a maximum gradient of 7′ per mile. Branching from this main canal there are about 30 miles of laterals and distributing canals, varying in width from 8′ to 12′ and in depth from 2′ to 3′.

Of the land now owned or controlled by the Company, 3,700 acres has been cleared, plowed, leveled, bordered, ditched, and sowed to crops, and 3,200 acres of this improved land is under fence composed of five lines of barbed wire. A telephone line has been constructed from the town of Toltec, through Santa Cruz, to the Santa Cruz dam site, a distance of 14 miles.

WATER SUPPLY AND DRAINAGE BASIN:

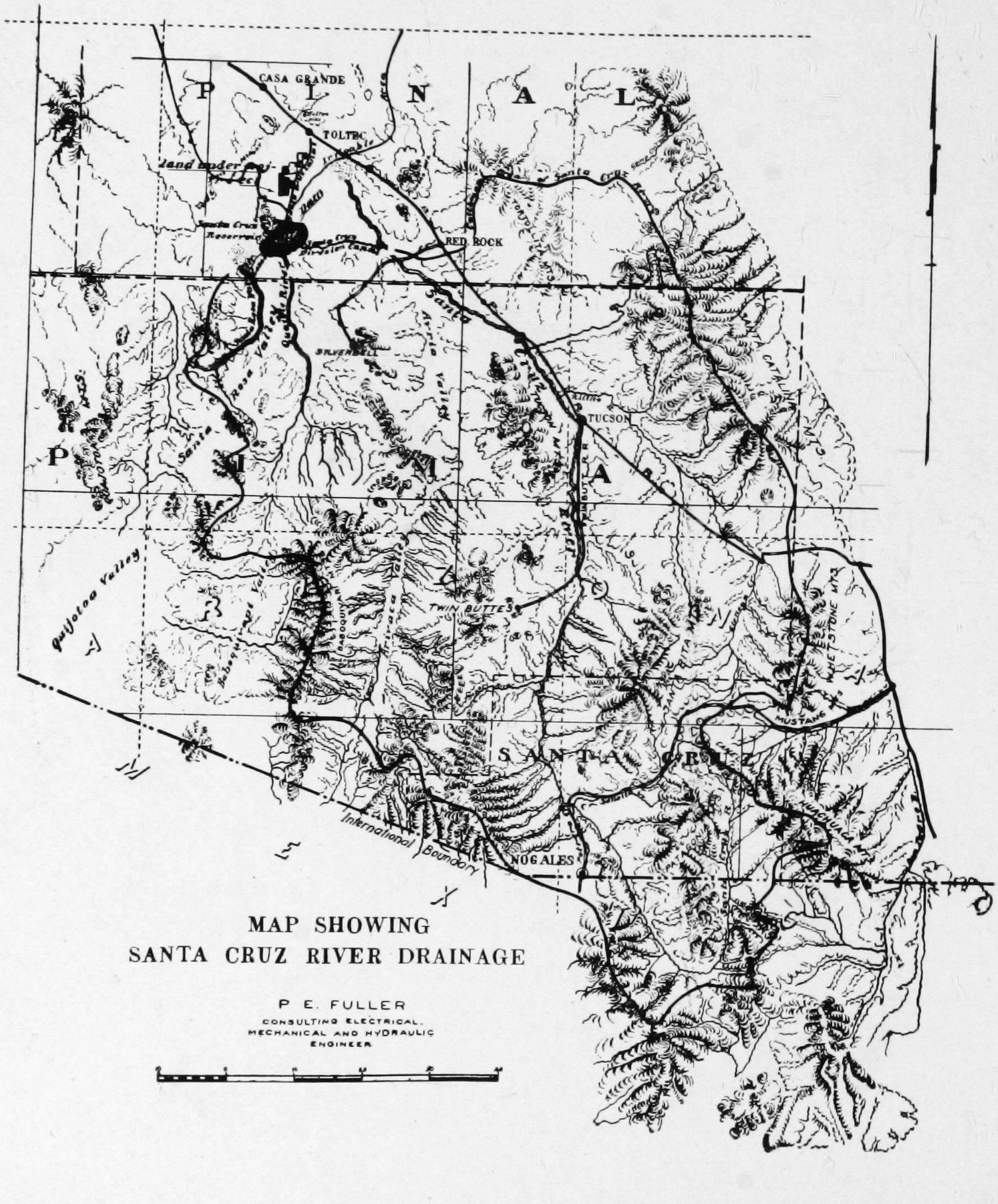
Since the magnitude of the area of irrigable land, which may be ultimately included in this project, will depend entirely upon the available water supply and no gaugings of flow into the reservoir have been made, it is necessary to compute the probable run-off from the catchment area contributary to the Santa Cruz and the Santa Rosa rivers, based upon the relation of run-off to rainfall which has been found to apply to this section.

The drainage area which feeds the Santa Cruz and Santa Rosa rivers includes the east slope of the Sierrza de Pinitos Mountains, in old Mexico, and the Patagonia and Huachuca ranges in Old Mexico and Southern Arizona, as well as the Patagonia, Canelo, West slope of the Whetstone and Mustang Mountains; all of the Santa Rita and Santa Catalina ranges; the East slope of the Baboquivari Mountains, the Tucson Mountains, the Tortollita, and numerous other small mountains.

Many of these mountains reach elevations above 5,000′, and considerable of the basin is forested. The total area of this water-shed is 6,077 square miles.

The Santa Cruz river rises in the Patagonia range, between the Patagonia and Huachuca ranges in Arizona, flowing thence south into old Mexico where it is augmented in flow by the run-off from the Sierra de Pinitos Mountains, and flows thence in a northerly direction through Tucson, and thence in northwesterly direction to a point where its waters are intercepted by the Santa Cruz diversion dam and diverted to the Santa Cruz Reservoir. (See Plate II, on following page).

Just north of Tucson, the Rillito River joins the Santa Cruz and adds the drainage from the Santa Catalina and Whetstone Mountains. Many creeks



MAP SHOWING
SANTA CRUZ RIVER DRAINAGE

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contribute their discharge to the Santa Cruz at points along its course. The Santa Rosa river, as well as Quajote Wash, drains the Santa Rosa and Baboquivari Mountains. While these latter streams are not as large as the Santa Cruz river, they drain a relatively large area and convey their waters to the Santa Cruz reservoir in a direct course, losing but a small percentage of this flow to evaporation and percolation.

The total length of the Santa Cruz river is closely 130 miles, while the length of the Rillito, including the Pantano tributary, is closely 100 miles. The Santa Rosa and the Quajote Wash have a combined length of about 90 miles.

As characterizes all the mountain streams in the West, notwithstanding that the area of the water-shed may be vast, the discharge from the Santa Cruz and the Santa Rosa rivers is of a flash nature, often in the form of devastating floods and rarely ever as a perennial flow. This characteristic is emphasized in the Gila and Salt rivers, having some 21,000 miles of catchment area in the former and 12,000 square miles in the latter, yet the stream flows are perennial only to the extent of a few-hundred second-feet, but the annual run-off is ample, if regulated, to supply water for the irrigation of over 400,000 acres of land.

While gaugings have been made of the Santa Cruz and its tributary, the Rillito, for a period of several years near Tucson, they gave no reliable information as to what may be expected in subsequent years for the reason that it is only since 1873 that the stream channels were eroded, except at the upper reaches. Prior to that time the valleys were verdant with luxuriant growths of native grass, and the run-off spread over the entire area as a sheet of water, offering favorable conditions for evaporation and percolation loss.

With the over-stocking of the ranges and the consequent denuding of this area, each cow trail offered a flow path which soon eroded to form stream channels. The result of this action has been to rapidly increase the ratio of runoff to rainfall and to decrease the conveyance losses.

It is for this reason that I view with skepticism any stream gauging data over short periods when relating to conditions of stream building which are transitory, though such gaugings may be of value in ascertaining the relation of rainfall to run-off to be used in computing the runoff from precipitation records. This transitory condition not only applied to the stream channels and the influence thereon of the catchment area having gentle slopes, but to that part which is being changed by deforestation as well.

PRECIPITATION AND RUN-OFF:

The average annual precipitation at Fort Lowell, at an elevation of 2,435′, is 12.66″. The record of this precipitation has been kept for a period of over 21 years and shows that it occurs as winter precipitation during the months of November to March and as summer rainfall during July, August, and September. Computing the rainfall upon the Santa Cruz, Rillito, and Santa Rosa watersheds, resolved to a 4,000′ elevation, using the rainfall at Fort Lowell as a base, we have the following.

STATION	Length of Record		Elevation feet	Elevation above Ft. McDowell	Measured Rain	Constant increase per 100 ft. rise
	Years	Mths.			Inches	
McDowell,	25	10	1250	....	10.38	Base
Lowell,	19	5	2435	1150	12.37	0.17
Breckenridge,	6	10	3800	2350	17.03	.26
Fort Grant,	17	2	4860	3610	16.85	.18
Fort Buchman,	3	11	5330	4080	21.58	.27
Fort Apache,	18	10	5050	3800	21.04	.28
Verde,	22	..	3160	1910	13.13	.15
Prescott,	23	11	5390	4140	17.06	.16
Mean,	.....	.....	....	....	....	.21

Using the mean here given, with Fort McDowell as a base, it would show the average rainfall for the Santa Cruz catchment area to be 16.15 inches. Using the mean increase per 100′ elevation at .20, and applying Lowell as a base, we would have 15.95 as the average rainfall over the Santa Cruz catchment area.

After discontinuing observations at Fort Lowell, a station was established at Tucson (which is slightly lower in elevation) and records for the subsequent years were taken from observations at that pont.

The relation of run-off to rainfall, from the total catchment area, may be closely computed from a comparison of the gaugings of the Santa Cruz and Rillito rivers with the precipitation upon this part of the drainage area.

During 1909, 1910, and 1911 the Rillito River gaugings at the Oracle Road showed a total annual flow of 22,252, 4,610, and 11,300 acre-feet respectively. The point where these gaugings were made is about 5 miles east of the confluence of the Rillito and the Santa Cruz rivers; hence takes account of practically all of the losess in this stream from its heading. In other words, it is the net flow that may be considered as water for storage at this point.

During this period, the total precipitation at Tucson (elevation 2390′) was from the U. S. Weather Bureau records, 11.58 inches for 1909, 9.8″ for 1910, and 11.25″ for 1911. The total catchment area for the Rillito River is 947 square miles, part of which is above the 6,000′ elevation. Assuming that the mean elevation of the entire Rillito catchment area is 4,000′, the precipitation over that area, using the same increase per 100′ rise, as heretofore computed; that is .21″, would be $\frac{(4000\text{-}2390)}{100}$ x .21″) + 11.57 = 14.96″ for 1909, 13.18″ for 1910. and 14.63″ for 1911, or a total of 757,600 acre-feet for 1909, 660,600 for 1910 and 739,400 for 1911.

The measured flow of the Rillito River is 2.94% of this precipitation for 1909, closely 7% for 1910, and 1.52% for 1911. Considering this run-off with that computed from the Newell Curve for Relation of Run-off to Rainfall—which shows a run-off, from gentle slopes, of 40,300 acre-feet in 1909, 25,200 in 1910, and 39,500 in 1911, it will be seen that it represents a higher percentage of run-off, but deducting from these quantities the loss in stream channels, which was found from measurement, to average 12.9% per mile of main channel, the results compare quite closely to those found actually to abtain.

The Santa Cruz catchment area, south of Tucson, is computed to be 2,100 square miles, while the gaugings at the Congress street bridge shows the stream to flow a total of the following:

YEAR	Discharge in Sec-feet			Volume in Acre-feet			Total
	Maxi-mum.	Mini-mum.	Mean	River	Manning Ditch	Farmer Ditch	
1905 (Partial)............	3200	....	....	.....	....	....	.....
1906....................	1575	0	20.3	14670	4900	2800	22370
1907....................	5000	0	41.1	29780	5610	1810	37200
1908....................	6780	0	20.8	15130	5000	2400	22530
1909....................	1740	0	....	15820	4220	2235	22275
1910....................	....	....	....	5710	4920*	**	10600
1911....................	....	....	....	6250	**	**	
							36694

*Now owned by the Tucson Farms Company. **Incomplete.

The precipitation at Tucson during these years, and the computed precipitation over the Santa Cruz catchment area, resolved to an elevation of 4,000 feet, using the same formula $\frac{(E\text{-}e) \times C)}{100}$ + p. as previously used, together with the percentage of run-off, is as follows:

YEAR	Precipitation at Tucson	Precipitation over Santa Cruz Catchment area		Precentage of Run-off
		Inches	Acre-feet	
1905	24.17	26.55	3,091,200.00	Incomplete
1906	11.75	15.13	1,693,000.00	1.23
1907	14.09	17.47	1,948,000.00	1.33
1908	14.04	17.42	1,948.000.00	1.41
1909	11.58	14.96	1,666,000.00	1.36
1910	9.80	13.18	1,478,000.00	.79
1911	11.25	14.63	1,639,000.00	.640*
1912	9.84	13.22	1,505,000.00	.....
1913 (4 months)	2.88	.....	....	......
Mean	....	....	....	1.126

*Based upon previous year

A comparison of the relation between run-off and rainfall, using the Newell Curve, is given in acre-feet and in percentage in the following table:

Year	Acre-feet	Percentage
1905	553.413	17.90
1906	111,930	6.60
1907	195,986	10.30
1908	195,980	10.30
1909	89,544	5.38
1910	55.965	3.78
1911	87,600	5.35
1912	56,079	3.73
Mean...	....	7.85

Obviously the percentage of run-off from the Newell Curve is greatly in excess of that found in actual gauging. However, it should be borne in mind that the gaugings of the Santa Cruz river, here considered, take into account all losses occurring along practically 75% of its entire course, from its headings to the point of gauging. This loss, with respect to perculation alone, is very great, as was found from an investigation which was previously made by the writer upon the Santa Cruz river with a view to determining the extent of the underground resources of that river. This is explained by the large area of sandy bottom over which the river flows. In other words, the amounts available from gaugings represent the quantity available for net storage at this point.

There being no gauging upon the Santa Rosa river, it will be necessary to assume the same relation between rainfall and run-off as obtains for the Santa Cruz drainage basin; but, since the typographical and physiological conditions are quite the same for this as well as for the entire catchment area, we may ascertain the hypothetical performance of the Santa Cruz reservoir during the years in which precipitation records were made, or for 45 years, beginning with the year 1867, based upon a run-off of 1,126% of the computed precipitation over the entire 6,077 square miles, an assumption which, considering the fact that the run-off is based upon the rate actually obtaining, is not open to question.

It should be noted that in preparing this table in which the annual contributions to the Santa Cruz river are given, I have deducted 10,000 acre-feet, annually, as that quantity which must be allowed for prior appropriations from the Santa Cruz river, and have also made a deduction of 20% from the remaining quantities to care for evaporation and seepage losses from the points of gauging to the Santa Cruz reservoir. This allowance of 20% is ample in view of the fact that the conveyance of water from the diversion dams will be largely influenced by evaporation alone, since the material through which the canal is excavated is a relatively impervious clay-loam formation, in which the total loss should be a minimum.

EVAPORATION:

Evaporation in this section is high. Based on the loss obtaining over the surface at Salton Sea, and for which the records cover a longer period of time than elsewhere, and upon the fact that the rates of evaporation are to each other as the excess above freezing of the temperatures of their respective water surfaces, the evaporation loss from the Santa Cruz reservoir would be 60″ annually, divided over the months as follows:

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
.0857	.1385	.2725	.4545	.463	.4665	.756	.761	.551	.470	.299	.282	4.9997*

*In decimals of a foot.

WATER DUTY AND USE:

The duty of water in this section of the country, considering the character of the soil, will be quite the same as in the Salt River Valley, which, from statements of the Reclamation Service, is now 3 acre-feet applied to the land.

At the inception of the Roosevelt (Salt River Valley) Project it was assumed that 4 acre-feet would be required, but, as the evil effects of over-irrigation are becoming evident, there is a strong tendency towards a more economic use of the water. Hence, the wasteful practices resulting from an enforced over-use, because of a formerly unregulated supply, are fast subsiding. While, no doubt, some land, planted to forage crops, may require more water than other, due to the greater porosity or low gradient, a diversity of cropping tends toward a higher duty. Therefore, I believe a duty of 3 acre-feet applied to the land, considering its character and slope, will be ample for this project. In fact, by an intelligent and conservative use of water under improved farming methods, and which must, sooner or later, become a factor in the successful pursuit of irrigation farming, I believe a still higher duty will obtain—possibly 2.5 acre-feet. However, a duty of 3 acre-feet at the land or 3.5 acre-feet at the reservoir has been adopted in determining the yearly and monthly demand upon which to base the performance of this reservoir. This duty, based upon past practice in different sections of the West—and particularly with respect to the Salt River Valley—and applying to diversified cropping, is distributed throughout the year as follows:

Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL
.1272	.159	.191	.262	.336	.446	.573	.509	.356	.242	.165	.140	3.5

In allowing 5 feet to cover distribution losses from the reservoir to the land attention is called to the fact that the total length of the main distributing canal is 12 miles, but application commences within 6 miles from the reservoir. Further, the material through which the canal is constructed will resist percolation in an excellent manner.

RESERVOIR CAPACITY:

In considering the reservoir performance, the amount deducted to allow prior appropriation is distributed over the months in a ratio as nearly consistent with the present practice as was possible to obtain. The following table gives the capacity of the Santa Cruz reservoir for each foot in depth up to 24-foot the contour as now constructed and from that contour to a 45-foot future elevation, to which point it may be constructed at a moderate cost. In this table is also given the area of the surfaces up to each contour interval of 1 foot. (See Table 1 on Page 17, following).

TABLE NO. 1.

Contour Intervals in Feet	Area of Contour in Acres	Total Content up to Contours in Acre-feet
.5	93	664
1	196	1,329
2	392	2,706
3	588	4,083
4	784	5,460
5	980	6,837
6	1,175	8,214
7	1,371	9,591
8	1,567	10,968
9	1.763	12,345
10	1,958	13,722
11	2,154	15,099
12	2,350	16,476
13	2,546	17,853
14	2,742	19,230
15	2,937	20,607
16	3,133	21,984
17	3,329	23,361
18	3,625	24,738
19	3,721	26,115
20	3,916	27,493
21	4,112	28,869
22	4,308	30,246
23	4,504	31,623
24	4,700	33,000
25	5,181	40,729
26	5,662	48,458
27	6,143	56,187
28	6,624	63,916
29	7,105	71,645
30	7,586	79,374
31	8,067	87,103
32	8,548	94,832
33	9,038	102,561
34	9,519	110,290
35	10,000	118,019
36	10,481	125,748
37	10,962	133,477
38	11,443	141,206
39	11,924	148,935
40	12,405	156,664
41	12,886	164,393
42	13,367	172,122
43	13,848	179,851
44	14,329	187,576
45	14,810	195,330

TABLE NO. 2.

YEAR	Precipitation in inches	Gross Run-off	Net Run-off
1868	11.54	54.449	35.559
9	14.69	65.945	44,756
1870	6.21	35.000	20,000
1	9.04	45,400	28,320
2	13.58	61,850	41,480
3	7.42	39,400	23,520
4	14.23	64,300	43,440
5	11.58	54,600	35,680
6	14.02	63,500	42,800
7	12.77	58,900	39,120
8	16.66	73.200	50,560
9	12.01	56,100	36,880
1880	6.61	36,400	21,120
1	14.92	85,100	60,080
2	15.59	69,200	47,360
3	17.53	76,400	53,120
4	15.03	67,200	45,760
5	5.26	31,500	17,200
6	8.63	43,800	19,040
7	12.95	59,600	39,680
8	10.60	51,000	32.800
9	18.37	79,400	55,520
1890	15.04	67,200	49,760
1	7.27	38,850	23,280
2	9.61	47,350	29,880
3	13.12	60,150	41,200
4	7.29	38,900	23,120
5	11.13	53,000	34,400
6	11.39	53,800	35,040
7	10.77	51,600	33,280
8	12.72	58,750	39,000
9	8.39	42,850	26,280
1900	7.79	40,700	24,560
1	9.72	47,800	30,240
2	8.60	43,650	26,920
3	8.80	44,450	27,560
4	7.85	41,000	24,800
5	24.17	100,500	72,400
6	11.75	55,300	36,240
7	14.09	63,750	43,000
8	14.04	63,600	42,880
9	11.58	54,600	35,680
1910	9.80	48,050	34,400
11	11.25	53,450	34,760
12	9.84	48,250	30,600

Table No. 1 has been prepared from the surveyed areas and capacities at Contours Nos. 24 and 45, by taking the tangents of the curves between zero and these points. While an error will exist in this, it is the only possible method in the absence of a greater number of surveyed areas and the error thus arising will be small and inconsequential.

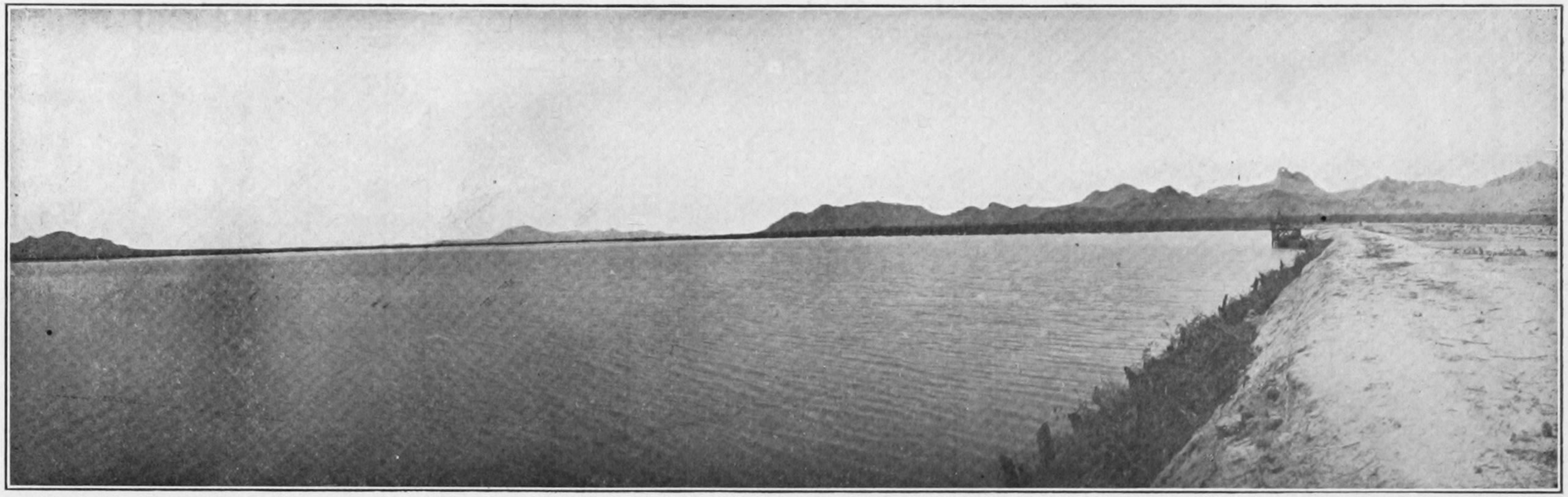
ANNUAL STORAGE SUPPLY:

Table No. 2, following, gives the precipitation; the gross run-off from the total catchment area of 6,077 square miles, corrected for difference in elevations, and the net run-off available for storage in the Santa Cruz reservoir, taking the run-off at 1.126% of the total precipitation over the catchment area. These records cover observations at Fort Lowell and Tucson. All quantities, excepting precipitation, are in acre-feet. (See Table No. 2 on Page 18.

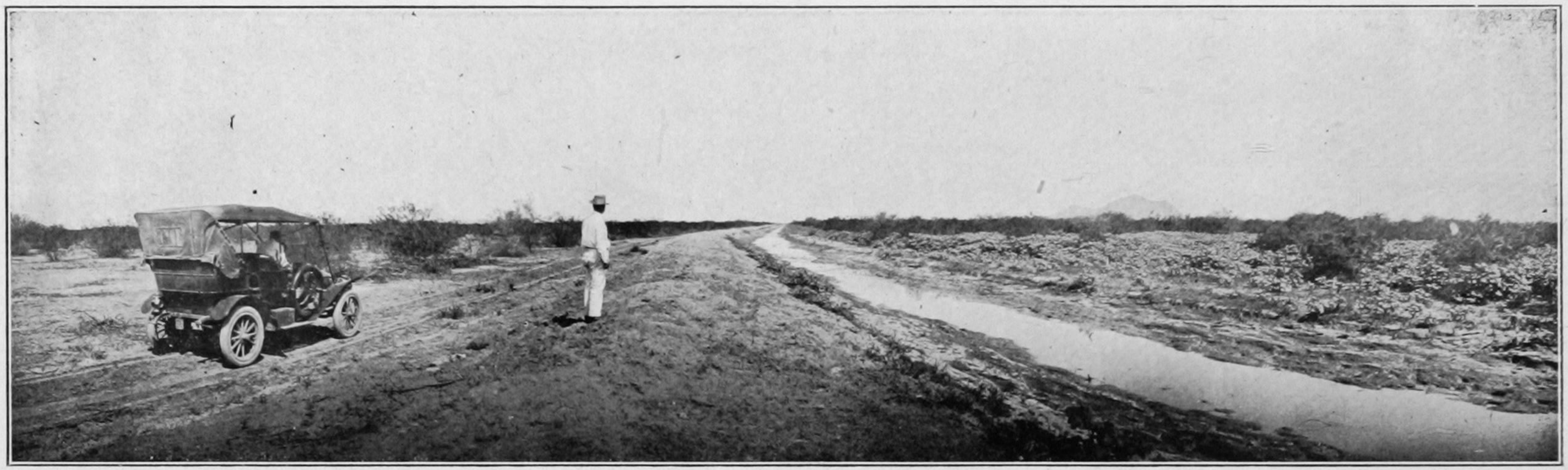
The net run-off in Table No. 2, is arrived at after allowing 10,000 acre-feet for prior appropriation and deducting 20% for conveyance. It will also be noted that a maximum run-off occurred during the year 1905, when the total net annual quantity available for storage amounted to 72,400 acre-feet, while the minimum annual run-off occurred during the year 1885, when it amounted to 17,200 acre-feet. The mean annual run-off available for impounding amounts to 36,300 acre-feet.

Table No. 2 also shows that, during 25 out of 45 years, the run-off was at or below the mean, and that during only two years did the run-off reach a point near the minimum above given, but that just preceding each year, where the minimum was recorded, the run-off was considerably in excess of the average.

The influence of these high rates of run-off upon the minimum values will be seen from a study of the hypothetical performance of the reservoir during a minimum, a maximum, and an average year. These performances are given in the following tables, Nos. 3, 4, and 5 (on Pages 21, 22, and 23, respectively) and are shown in acre-feet.



View of Santa Cruz Reservoir with approximately 10,000 acre-feet in storage.



View of Santa Cruz Diversion Canal near Dam.

TABLE NO. 3.

Minimum Year—1885

MONTH	Gross Run-off	Deducted for Prior Appropr'n	Remainder	Net Run-off	Reserve	Evapor-ation	Available	Demand	Excess	Deficiency
Jan.	.....	381.6	......	......	......	.....	......	1,272	......	1,272.0
Feb.	2,542	477.3	2,064.7	1,651.8	......	17.1	1,634.7	1,590	44.7	......
Mar.	2,422	573.0	1,849.0	1,479.2	44.7	35.4	1,488.5	1,910	......	422.5
Apr.	......	786.0	......	......	......	.....	......	2,620	......	2,620.0
May	......	1,005.0	......	......	......	.....	......	3,350	......	3,350.0
Jun.	788	1,338.0	......	......	......	.....	......	4,460	......	4,460.0
Jul.	6,057	1,719.0	4,338.0	3,470.4	......	302.4	3,168.0	5,730	......	2,562.0
Aug.	10,580	1,527.0	9,053.0	7,242.4	......	760.0	6,482.4	5,090	1392,.4	......
Sep.	621	1,068.0	......	......	1,392.4	110.0	1,282.4	3.560	......	2,277.6
Oct.	......	726.0	......	......	......	.....	......	2,420	......	2,420.0
Nov.	2,420	470.0	1,950.0	1,569.0	......	75.0	1,485.0	1,650	......	165.0
Dec.	6,070	420.0	5,650.0	4,520.0	......	204.2	4,310.8	1,400	2,910.8	......
	31,500									

TABLE NO. 4.

Maximum Year—1905

MONTH	Gross Run-off	Deducted for Prior Appropr'n	Remainder	Net Run-off	Reserve	Evapor-ation	Available	Demand	Excess	Deficiency
Jan.	9,350	381.6	8,968.4	7,174.7	....	85.7	7,089,0	1,272	6,917.0	....
Feb.	17,220	477.3	16,742.7	13,394.2	16,917.0	405.4	19,905.8	1,590	18,315.8	....
Mar.	16,100	573.0	15,527.0	12,421.6	18,315.8	1188.8	29,548.6	1,910	27,638.6	....
Apr.	14,670	786.0	13,884.0	11,107.2	27,638.6	2270.0	36,475.8	2,620	33,855.8	....
May	83	1,005.0	....	....	33,855.8	2171.4	31,684.4	3,350	28,334.4	....
Jun.	999	1,338.0	....	....	28,334.4	1910.6	26,423.8	4,460	21,963.8	....
Jul.	4,575	1,719.0	2,856.0	2,284.8	21,963.8	2646.0	19,317.8	5,730	13,587.8	....
Aug.	2,425	1,527.0	898.0	718.4	13,587.8	1444.0	12,143.8	5,090	7,053.8	....
Sep.	11,800	1,068.0	10,732.0	8,585.6	7,053.8	1182.5	14,456.9	3,560	10,896.9	....
Oct.	374	726.0	....	....	10,896.9	733.2	10,163.7	2,420	7,743.7	....
Nov.	19,204	495.0	18,709.0	14,967.2	7,743.7	956.8	21,754.1	1,650	20,104.1	....
Dec.	3,700	420.0	3,280.0	2,624.0	20,104.1	888.3	19,215.8	1,400	17,815.8	....
	100,500									

TABLE NO. 5.

Average Year—1906

MONTH	Gross Run-off	Deducted for Prior Appropr'n	Remainder	Net Run-off	Reserve	Evapor-ation	Available	Demand	Excess	Deficiency
Jan.	2,355	381.6	1,973.4	1,578.0	....	16.85	1,561.15	1,272	289.15	....
Feb.	1.554	477.3	1,076.7	861.0	289.15	20.00	1,130.	1,590	....	460.
Mar.	1,554	573.0	981.0	785.0	....	27.20	757.8	1,910	....	1,152.2
Apr.	2,355	786.0	1,569.	1,255.	....	86.26	1,168.74	2,620	....	1,451.26
May	....	1,005.0	....	....	....	.....	....	3,350	....	3,350.
Jun.	....	1,338.0	....	....	....	.....	....	4,460	....	4,460.
Jul.	8,570	1,719.0	6,851.	5,480.	....	740.8	4,739.2	5,730	....	990.8
Aug.	12,000	1,527.0	10,378.	8,378.	....	912.1	7,466.	5,090	2,376.00	....
Sep.	2,022	1,068.0	954.	763.	2,376.	220.	2,156.	3,560	....	1,404.
Oct.	....	726.	....	....	....	.....	....	2,420	....	2,420.0
Nov.	3,490	495.	2,995.	2,396.	....	104.6	2,291.4	1,650	641.4	....
Dec.	21,400	420.	20,980.	16,784.	641.4	705.	16,720.4	1,400	15,320.4	....
	55,300									

It will be noted from Table No. 5, of performance during a year of average run-off, that partial deficiencies occur during the months of February, March, April, July, and September, while total deficiencies occur through May, June, and October, whereas Table No. 4, of performance during a year of maximum precipitation shows no deficiency whatsoever, but that, at the end of December, 1905, there would have been carried over, as excess storage water, 17,815.8 acre-feet, which would have tended to greatly augment the resource during the year 1906, which is a period of mean precipitation. Similarly, had the period of minimum precipitation, as shown by Table No. 3, immediately followed a year of maximum or average precipitation, it would have augmented the storage so as to lessen the shortage during a major portion of that minimum year.

This indicates that, if the project were thrown open to colonization and development during a period of minimum or mean precipitation, it would show a shortage for several years; whereas, if operations were commenced during a year of abundant precipitation, the excess would make up the deficiency during the succeeding years of low run-off, thereby changing the aspect of the project.

To illustrate this, I give a fourth table (No. 6, on Page 25, following) which takes the excess from the end of the year 1905 (which is a maximum) and credit it to the reserve at the beginning of the year 1906 (which is given in the preceding table, No. 5, as a year of mean performance).

From this Table it will be seen that the deficiency (previously shown to exist, if the year 1906 were considered alone) is eliminated, with the exception of from the month of October, when a deficiency of 50% occurs.

It is not unusual, in a reservoir project, for a partial shortage to occur during a cycle of dry years. The Roosevelt reservoir, for example, shows that a shortage of 49% would have occurred during 5 months in 1902 and 73% for 5 months in 1902-3; 43% in 1903-4 (for 14 months); and 71% for 1 month in 1904.

However, we have to consider in the Santa Cruz project, the fact that, just prior to 1906, the run-off was a maximum, and, if a minimum year preceded the mean, we should have a deficiency nearly as great as that shown by the table of performance for years of mean run-off rather than the desirable condition shown in Table No. 6. Furthermore, the table of run-off (No. 2) shows this condition to be of probable frequent occurence, but where this deficiency overcome by lessening the area of land to be served—unless to an area which would not justify rehabilitation of the project—it would not compensate the

TABLE No. 6.

Years 1905 and 1906

MONTH	Gross Run-off	Deducted for Prior Appropr'n	Remainder	Net Run-off	Reserve	Evapor-ation	Available	Demand	Excess	Deficiency
Jan.	2,355	381.6	1,973.4	1,578.0	17,815.4*	235.7	19,157.3	1,272	17,885.3	....
Feb.	1,554	477.3	1,076.7	861.0	1,788.53	372.5	18,373.8	1,590	16,783.8	....
Mar.	1,554	573.0	981.0	785.0	16,783.8	680.0	16,888.8	1,910	14,978.8	....
Apr.	2,355	786.0	1,569.0	1,255.0	14,978.8	1070.0	15,163.8	2,620	12,543.8	....
May	....	1,005.0	....	....	12,543.8	818.0	11,725.8	3,350	8,375.8	....
Jun.	....	1,338.0	....	....	8,375.8	559.2	7,816.6	4,460	3,356.6	....
Jul.	8,570	1,719.0	6,851.0	5,480.0	3,356.6	907.2	7,929.4	5,730	2,199.4	....
Aug.	12,000	1,527.0	10,473.0	8,378.0	2,199.4	1178.0	9,399.4	5,090	4,309.4	....
Sep.	2,022	1,068.0	954.0	763.0	4,309.4	412.5	4,659.9	3,560	1,099.9	....
Oct.	....	726.0	....	....	1,099.9	61.10	1,038.8	2,420	....	1,381.2
Nov.	3,490	495.0	2,995.0	2,396.0	....	104.6	2,291.4	1,650	641.4	....
Dec.	21,400	420.0	20,980.0	16,784.0	641.4	70.5	16,720.4	1,400	15,320.4	....
	55,300									

*Reserved from 1905.

shortage during all time, since, in May, June, and October the deficiency shown in Table No. 5 is equal to the full demand. Hence an auxilliary supply must be provided, and, as underground resource is the only means of augmenting the supply, it must be considered in connection with the project.

AREA FEASIBLE TO IRRIGATE FROM SANTA CRUZ RESERVOIR:

From the preceding tables, after carefully considering the reservoir performance upon the basis of 10,000 acres served, I would recommend that the area of land contemplated under this project should not exceed that amount, with a duty of 3.5 feet at the reservoir, and the shortages that occur, based upon the average years, be made up by the use of underground water.

In adopting 10,000 acres as the area which it is feasible to supply with water from the Santa Cruz reservoir and from underground resources (as a supplemental supply), the following factors are considered:

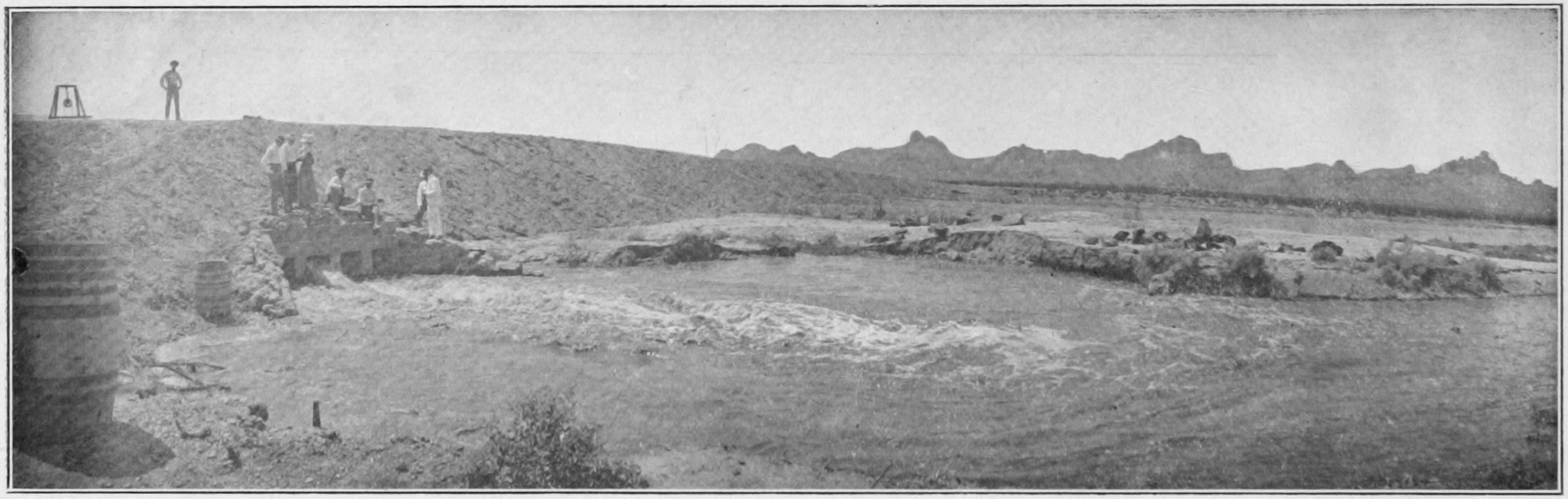
The mean annual stored run-off is 36,300 feet while the demand is for 35,000 acre-feet to which should be added sufficient to compensate for evaporation loss. The run-off from the catchment area is of such magnitude that a reservoir, of capacity greater than that now constructed, would avail nothing. Further, since flood flows occur at definite periods during the year and the maximum run-off is not sufficient to carry over and supply the entire demand during certain months, the area should be such as would require operation of a pumping plant of the necessary capacity to make up the maximum deficiency at maximum load capacity of the plant during the entire period when such shortage occurs.

It is not to be inferred, however, that a greater area than 10,000 acres could not be included in this project, but, if the area be increased beyond that amount, the additional irrigation supply therefor must, at all times, be obtained from underground resources and the capacity of the pumping stations and power plant must be sufficiently greater in order to handle the added area as a unit in itself.

To reduce this area of 10,000 acres, with a view to carrying over sufficient water to supply the demand during the shortage periods shown to exist, would be to lose a large percentage of the reserve water thus available to evaporation, and the area so included would be too small to justify the maintenance and administration charges.

HEIGHTH OF DAM RECOMMENDED:

From the table of performance of the reservoir, covering a period of 45 years, during a year of maximum run-off the greatest storage capacity was found to be 38,745.8 acre-feet for the month of April, which included that lost



Outlet gates from reservoir open and discharging.

Head of Santa Cruz Canal.

to evaporation, amounting to 2,270 acre-feet, and, since such part of the flood flow as would have been required to serve the land during that month, amounting to 2,620 acre-feet, would be diverted for use during impounding, it would over-tax the impound capacity but about 9% if the heighth of the dam were not increased beyond that of present. Therefore, I should recommend that only a slightly increased storage capacity be considered, until the present storage capacity has become materially impaired due to silt deposits, at which time the dam could be increased in heighth as required. In other words, if the present dam were raised 3.5′, it would impound the maximum flood flow recorded for any one month, when the flow line would be 24.5′, leaving the crest of the dam 2′ above flow line.

As a precaution against wave action under these conditions, a boom would be required, to be floated across the face of the dam.

In this consideration of the project, I have not taken into account the depreciation in storage capacity due to silting for the reason that, normally, streams do not carry large percentages of silt and because, as just stated, the decreased capacity may be subsequently compensated by adding to the heighth of the dam, which, if raised to the 45′ contour, would make the life of the reservoir 150 years if the water carried 4% of silt continually during discharge, a condition which never obtains.

CAPACITY OF DIVERSION CANALS:

At the time of the examination of the present property of the Santa Cruz Reservoir Company, there was impounded about 1,000 acre-feet, but this quantity represented only a small part of the flow during the spring months, for the reason that the waste gates upon the Santa Cruz diversion canal had been washed out during the period of desuetude in the project and were not repaired until after the principal flood flows had subsided.

High water marks beyond the waste gates showed that the Santa Cruz diversion canal had carried water to a depth of 3 feet, which upon a gradient of 14 feet per mile and a ditch width of 20′, with almost perpendicular banks, represents a flow of closely 180 second-feet.

Indications in the reservoir show that it had held in storage about 10,000 acre-feet. This was, no doubt, at a time soon after its completion several years ago and prior to the failure of the waste gates.

The maximum capacity of this canal, upon its present gradient and cross-section, is 600 second-feet. However, its capacity will be automatically greatly increased by erosion as it is called upon to carry the flood flows, though it is doubtful if its course will remain in the present alignment since the old course of the river, below the point of diversion, is a tortuous one, presenting a greater length upon the same gradient as the present canal.

The Santa Rosa diversion canal has a present capacity of 50 cubic feet per second in its excavated channel, but this canal will similarly increase in capacity as it is called upon to convey flood flows. Further, the excavated material has been deposited upon the lower side slope, producing banks several feet in heighth; hence its true carrying capacity is much in excess of that given for the excavated area—probably 200 second-feet. This is still further augmented by the Quajote Wash, which is an independent water-way.

To carry the maximum flood flow of the Santa Cruz of which there is record; i. e., 6,780 second-feet, it would require that the canal be widened to about 200 feet, or approximately the present width of the river channel, at the point of diversion. This might readily be accomplished during one flood flow, as a channel of nearly equal area was eroded within a few days at a point above Tucson upon the Santa Cruz river, when it was desired to change the course of that river.

AUXILIARY OR SUPPLEMENTAL IRRIGATION SUPPLY:

Pumping from the underground resources the only way by which to insure a permanent and adequate supply against shortage in the storage reservoir during periods of deficiency in run-off, and since, as above shown, the deficiency during years of mean precipitation is representative of the average performance which may be expected of the reservoir, the quantity to be recovered from underground resources will be determined from Table No. 5, on Page 23 preceding.

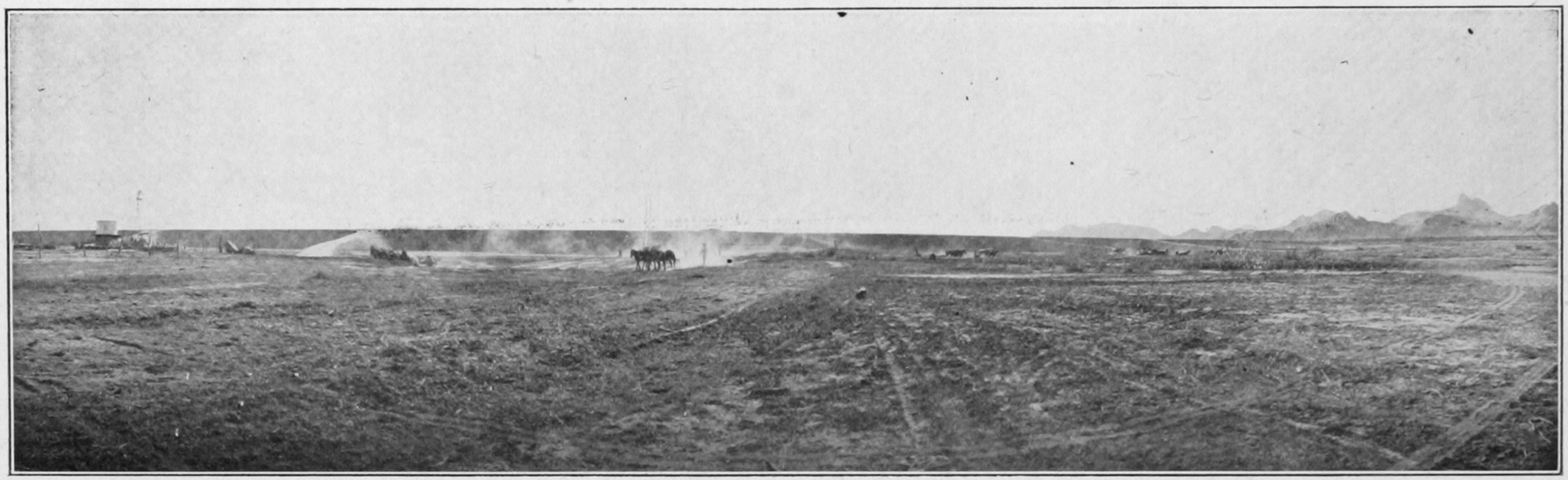
Since electric power is not available from a commercial plant in the vicinity, it will be necessary, in this connection, to consider the construction of a central power plant to be located at Toltec, upon the main line of the Southern Pacific Railway. Therefore this outline contemplates such a plant.

It would not be feasible to consider the recovery of all of the supplemental supply from one point, due to the limited depth of the water-bearing strata found in this section of the Santa Criz Valley and its consequent limited transmission capacity. Hence, it becomes necessary to utilize the storage capacity of the water bearing strata during pumping periods by locating a number of pumps distributed over the entire area of the land involved.

Practice has demonstrated that the least rate of flow that can be successfully employed in irrigation is 2 second-feet, and, even with this nead, it requires that the land be prepared so as to employ it efficiently.

A head of 2 second-feet will deliver an acre-foot of water in 6.05 hours. Hence, during the months when pumps would be required to make up the defi-

View of dam during construction, showing protection of stream face against erosion.



View from borrow pits of dam during construction.

ciency, they would generally be operated for short periods of time only. It might be stated that the great majority of all pumping plants in the west, used for irrigation areas of from 160 to 320 acres, are of from 2 to 3 second-feet capacity.

Since it is desirable to distribute the pumping stations, I would recommend that they be so located as to provide one plant (of not less than 2 second-feet capacity) for each 320 acre subdivision, contemplating an alternate use upon areas of 160 acres or less. Upon the basis of 10,000 acres, this arrangement would require 32 plants. If each plant delivered 2 second-feet, the time the total number of plants would be required to operate to make up deficiencies during a year of average run-off would be a shown in the following table:

TABLE No. 7.

MONTH	Feb.	Mar.	Apr.	May	Jun.	Jul.	Sep.	Oct.
Deficiencies*..........	460.	1152.2	1451.26	3350.	4460.	990.8	1404.	2420.
Hours all pumps must operate to make up deficiency..........	82.00	218.00	276.00	635.00	845.00	187.00	266.00	460.00
Percentage of total number hours per month plant must operate full load,....	12.2%	39.3%	38.4%	85.4%	117.3%	25.5%	37.0%	62.0%

*Shown in acre-feet.

Obviously, with this number of pumping stations—32—the deficiency during an average year would be taken care of with a power plant capacity to operate 75% that number of plants, except for the months of May and June, and, while the former month could be cared for from the overload capacity of this plant, to provide for the load during June would require a greater power plant capacity. An adoption of power plant units, of the proper sizes, could however, care for the demand during June, at a small additional cost. If, on the other hand, we provide pumping plant capacity sufficient for the shortage during years of minimum run-off (see Table No. 3, Page 21), the periods of operation and percentage of time necessary to operate would be as appears in the following table (Table No. 8 on the following page):

TABLE No. 8

MONTH,	Jan.	Mar.	Apr.	May	Jun.	Jul.	Sep.	Oct.	Nov.
Deficiencies*..........	1272.	422.5	2620.	3350.	4460.	2562.	2227.6	2420	105.
Hours all pumps must operate to make up deficiency,..........	242.00	80.00	495.00	635.00	845.00	485.00	430.00	457.00	20.00
Percentage of total number hours per month plant must operate full load,....	32.6%	10.75%	68.8%	85.5%	117.0%	65.0%	60.0%	62.0%	2.78%

*Shown in acre-feet.

Under conditions of minimum run-off, this table shows that the maximum demand is almost identical with that obtaining under years of mean run-off (see Table No. 7), both maximum demands upon the pumping plants occurring in June, when 32 plants if of but 32 cubic feet per second capacity, would hardly supply the water needed, though if 22 of the 32 plants were of 2.5 second-feet capacity instead of 2 second-feet it would ideally meet the maximum requirements of the most severe demand that has occurred during the 45 years of run-off and reservoir performance in this report.

The average power demand is also quite similar, in the latter case, to that under conditions of average run-off, the only material difference being that, in the one case, the pumping station would be required to operate over a greater period of time.

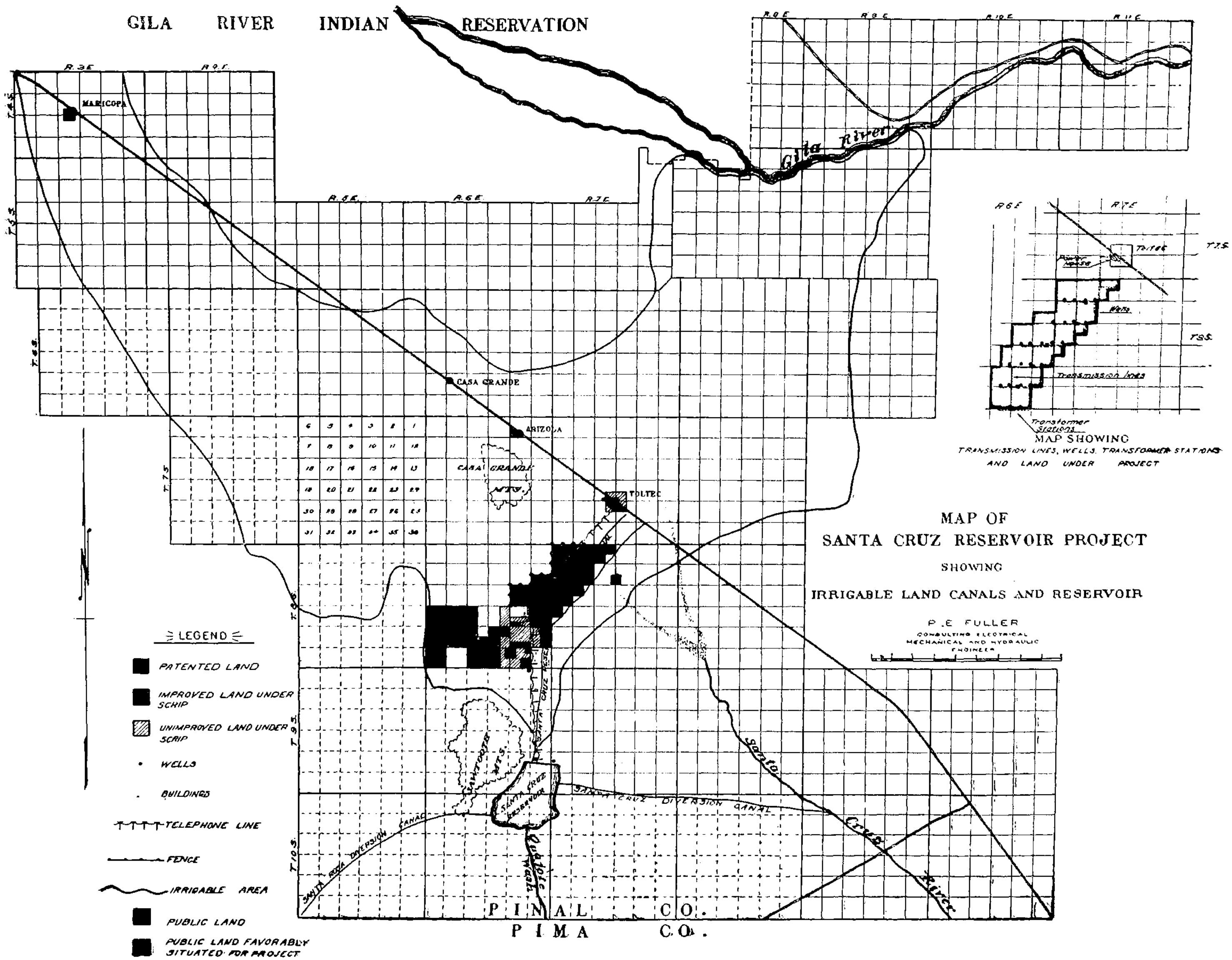
Should such increase in the individual pumping plant capacity not be obtainable, due to limited well supply (though this is a most remote possibility), the added supply could, of course, be obtained by 6 additional pumping stations of 2 second-feet capacity each. Similarly, if it were found that 64 second-feet were obtainable from less than 32 plants, as here considered, at a reasonable down head, then the number of plants would be decreased in the same ratio.

The location of the pumping stations here recommended, together with the transmission lines, is shown on Plate III, on page 33 following.

CAPACITY OF POWER PLANT REQUIRED AND ECONOMY:

The depth that the water plane occurs below the surface varies from 40 to 70 feet, an average being 55 feet. Adding to this the probable draw-down of 30 feet, which allows for friction, velocity, entry, and exit heads, the total pumping head would be 85 feet.

The net water horse-power, represented by the delivery of 75 cubic feet of water per second (11 second-feet to closely provide for the 17% deficiency) against an average head of 85 feet, would be 725 horse power.



MAP OF
SANTA CRUZ RESERVOIR PROJECT
SHOWING
IRRIGABLE LAND CANALS AND RESERVOIR

P. E. FULLER
CONSULTING ELECTRICAL MECHANICAL AND HYDRAULIC ENGINEER

It should be possible to obtain the following efficiencies in a plant of the character here contemplated; 68% pump; 87% motor; 93% transmission line (length 4.5 miles); 98% for step-down transformers; or a combined efficiency of 51.8%. Thus, the brake horse power required at a central power plant would be 1475 h. p., allowing 93% for generator efficiency. Considering the short periods of operation at the overload capacity, a plant of 1200 i.h.p. capacity would meet all requirements under all conditions.

This would be equivalent to electric generator capacity of 1000 K.V.A. at the switch-board.

Owing to the fact that producer gas plants are not wholly successful in their operation as yet and that internal combustion engines, in large units, using liquid fuel, require skilled labor of the highest degree in their operation, and the initial cost, as well as maintenance charges, are much higher than obtains in steam plants, I would not recommend their use in this instance, notwithstanding a higher thermal efficiency is obtainable from the internal combustion engine.

Were the plant to operate continuously, whereby the higher initial cost of a gas engine installation and its higher maintenance cost would be offset by the consequent annual saving in fuel, it might be good engineering practice to consider its use. The guaranteed steam economy of he latest type of engine, based upon actual results from plants in operatin, is as follows:

LOAD	½	¾	Full	1-¼
Lbs. steam per kilowatt hour	18-¾	18	17-½	18

From this table it shows but slight change in steam consumption between a range of ½ and 1-¼ loads. This performance is from units of 600 I. H. P. (400 true kilowatts) or 500 K. V. A. capacity; hence, by using two 500 K. V. A. generators, an excellent economy may be obtained throughout all of the load factors shown in Table 7 representing conditions of demand during years of mean reservoir performance.

Further, the combined overload plant capacity would 1000 true kilowatts, or 1250 K. V. A., at 80% power factor, continuously, or 1500 K. V. A. during periods of two hours' duration, and, since the maximum pumping demand is closely 1000 true kilowatts and the full load capacity of the power plant here considered is 800 true kilowatts, the overload during the month of June would tax it to its full overload capacity, when the steam consumption would be but a ½ lb. in excess of that at full load, but, considering the saving in installation otherwise necessary, this slightly lower economy is justified.

In determining the operative cost of the plant, I have not assumed these high economics, since, in actual practice, the cost per hour, of fuel from 140 to 160 Beaume, and the number of barrels, of 42 gallons per barrel, at ½, ¾, full, and 1-¼ loads, is as follows:

LOAD,	½	¾	Full	1-¼
Number barrels	2.11	3.1	4.	5.14
Cost of fuel				
$1.45 per bbl	$3.06	$4.50	$5.80	$7.45

EXTENT OF UNDERGROUND WATER RESOURCES:

As to the adequacy and permanency of the underground resources, I would say that, some two years ago, I made an exhaustive investigation of the underground water possibilities of the Santa Cruz Valley and found that, of the run-off from 2,100 square miles of catchment area of the Santa Cruz basin, some 158,103 acre-feet were available as underflow in the vicinity of Tucson.

Referring to the table giving the relation of Run-Off to Rainfall from the Newell Curve (See Page 14), it shows an average of 7.85% of the amount of runoff at the stream headings, whereas we have considered but 1.26% as that quantity representative of the live waters at Tucson. This would leave 6.73% of the total run-off to be credited to evaporation and percolation, much the larger part of which is in the nature of percolation. However, the present and proposed development in the vicinity of Tucson will utilize a large portion of the underground water, up to the point where the underground recovery system of the Tucson Farms Company is situated, but, from this point to the site of the Santa Cruz diversion dam, there has been deducted 20% of the live waters to care for evaporation and percolation, of which, conservatively estimated, 5% is lost to percolation. That is to say, 9,050 acre-feet are contributed to the underflow during years of maximum run-off and 2,265 acre-feet are contributed during years of average flow. This from the Santa Cruz Valley only.

A very elaborate investigation was made, several years ago, of the Rillito River, and it disclosed the fact that the quantity of water which could be recovered from the Rillito and Pantano tributaries to the Santa Cruz was between 20,000 and 30,000 acre-feet.

In a report to the Secretary of the Interior, by Mr. C. R. Olberg and F. R. Schenck, on the Papago Indian Irrigation Project (Senate Document No. 973—62nd Congress, 3rd Session), the following appears, on Page 17, relating to the run-off from the Santa Cruz catchment area.:

"On the assumption that the above figures indicate approximately what occurs, it seems reasonable to assume that about 6 inches of the total precipitation of 12 inches either runs off as surface flow, percolates into the soil, or disappears in the stream channels. From the records of the stream measurements it appears that only .165 of an inch passes off as surface flow, leaving considerably over 5 inches for percolation and seepage".

From this statement would be indicated a much greater underground supply than I have here considered. However, if we regard only the underground water which may originate from the Santa Cruz and Rillito drainage beyond any polnt of present development, thus assuming that the Tucson Farms Company and other appropriators of underground water above this point utilize all of the water lost to underflow from percolation above, though this assumption is hardly justifiable, we should yet have 35,000 acre-feet available from the underground resources as an annual contribution thereto.

In addition to the above, there must be as great an underflow from the Santa Cruz catchment area, and it is not at all improbable that, during pre-tertiary records or periods, much of the run-off of the Gila drainage area flowed in a more southwesterly course and aided in the fluviatic construction of the debris sheet composing the tertiary sand and gravel beds which are found throughout this entire valley, and a part of the underflow from the upper Gila now finds its way into the extensive underground strata from its upper course.

YIELD FROM WELLS:

I have visited numerous wells in the Casa Grande and Santa Cruz valleys, during their drilling and found a continuance of these strata of sand; sand and gravel; and sand, gravel and boulders, from the upper Gila to the point of confluence with the Colorado, and, while the finer formation occurs near the headings of the various streams and the coarser formation near the lower reaches, this graduation does not signify that the deposits have not issued from a common series of mountains through their canyon openings.

Some very remarkable yields have been obtained from shallow wells in the vicinity of Casa Grande, one of which is situated in the NW¼ of Sec. 34, T. 5 S, R. 7 E., some 18 miles north of the center of the area of land embraced in this project. In this well from 6 feet of water bearing sand and gravel, which was separated by several impervious strata of clay of various thicknesses, 700 gallons per minute was pumped when lowering the normal water plane but 3 feet. This well being a dug one, the inflow could be observed during pumping, and it was noted that there was no decrease in the quantity or persistency of the incoming water and that it entered in large streams which were the strongest from a north-easterly direction or from the direction of the upper Gila river.

A well located upon the south half of the same section, and penetrating but 3½ feet of similar water bearing material, delivered 225 gallons per minute when drawing the water down 1.3 feet. Upon this basis, the former well would yield 1400 gallons per minute (3.1 second-feet) if the water plane could have been lowered 6′, while the latter well would have yielded 2 second-feet with a draw-down of 2.34 feet.

These wells are by no means indicative of what might be expected if they had been drilled to depths sufficient to penetrate the numerous additional

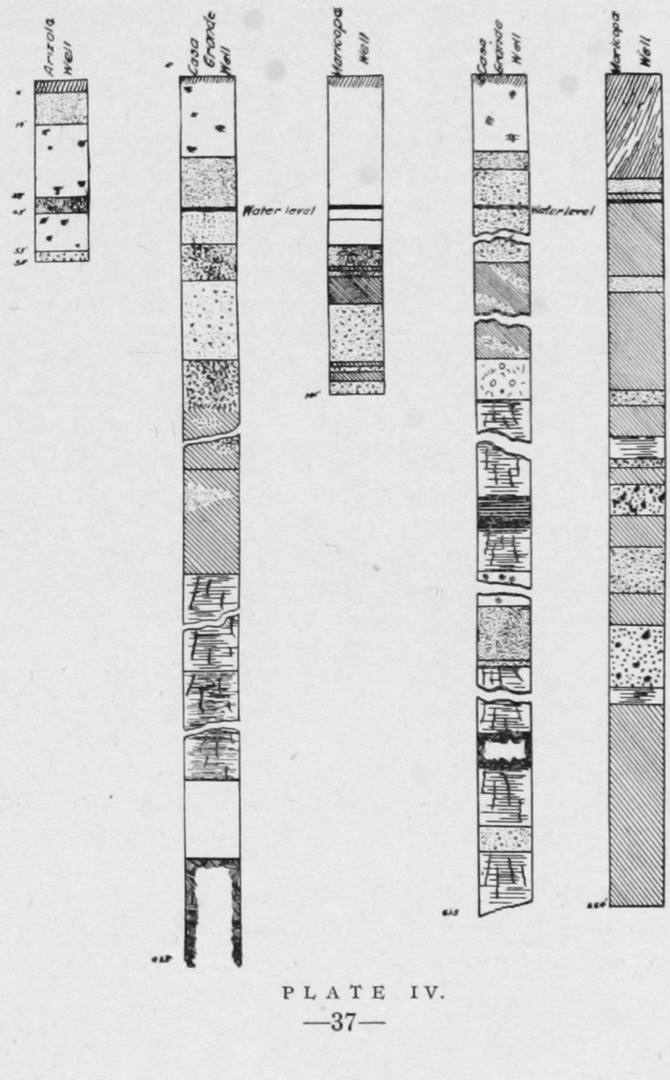
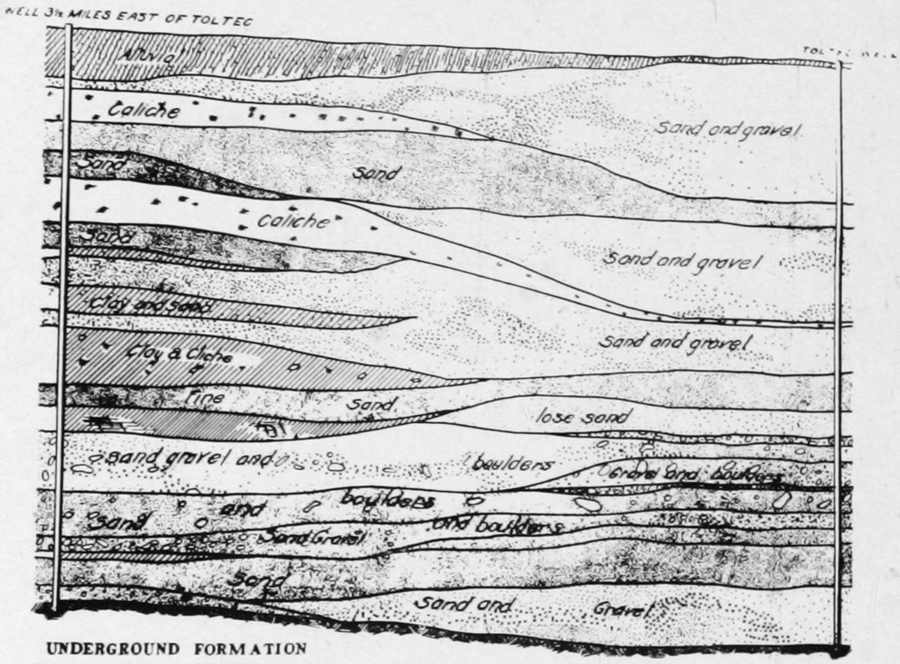


PLATE IV.

strata which occur down to a depth of 200 or more feet when the trassic clay beds or rock floor of the valley fill is encountered.

No material difference in the yield of wells, per square foot of strainer area, is noted in any of the wells from the upper Santa Cruz valley to the section where is located the town of Maricopa, some 32 miles northwest of the station of Toltec, excepting in the depth of water-bearing strata, it being more extensive and broken up into numerous thinner strata.

As evidence of the existence of water-bearing material, of the same character as is found throughout the Santa Cruz valley, beneath the surface of the



UNDERGROUND FORMATION
SHOWN BY LOGS OF TWO WELLS AT TOLTEC

lands herein considered, some 14 wells were dug at various points and, in each instance, it was impossible to lower the water plane with the sinking pump used, to enable the workmen to penetrate the top water-bearing stratum more than 2 or 3 feet, the flow for this limited excavation being strong and evidently very pure.

On the preceding page (37) is shown Plate IV, giving the logs of different wells located in what is called the Casa Grande valley but which is a mere continuation of the Santa Cruz valley.

On the opposite page, is shown Plate V., giving the logs of two wells recently completed near Toltec and which are indicative of the character of the formation that will be encountered beneath the lands contemplated to irrigate under this project, though the stratification will, no doubt, be somewhat more separated. These wells show a remarkably favorable formation, both in character and extent, and should yield 3 second-feet continuously. In fact one of them (recently tested) delivered 1000 gallons per minute for a time, but sanded up due to too coarse a strainer being used, though repeated sand pumping has practically eliminated the inflow of sand, and a very successful well is anticipated when it is finally put into continuous operation.

HYPOTHETICAL CONSIDERATION OF UNDERGROUND RESERVOIR:

By referring to Plate II., it will be noted that the land contemplated to irrigate is situated in a basin almost surrounded by mountains. Therefore, the storage reservoir in the underground strata formed thereby is almost complete as though it was a surface impound, and will not be influenced by the development of water at any point within several miles of the points of proposed development of underground water under this project.

The total surface area of this basin is 420 square miles. Upon the assumption that the total depth of water-bearing strata were 32 feet, a very conservative estimate of the storage capacity (allowing 25% of the material to be voids) would be 2,352,000 acre-feet.

From Table VII., the annual deficiency necessary to make up from underground resources during years of average run-off, was found to be 15,688. Therefore, a period of 150 years would lapse before this storage were entirely exhausted. Under such a condition the water plane would become uniformly lowered .23 feet each year, so that, at the end of 10 years, the pumping head would be 2.3 feet greater than at the outset.

This hypothetical consideration is based upon the assumption that the storage capacity was not replenished to any extent, or, in other words, there was no underflow, in a strict sense, but that the water in the underground strata was merely the gradual accumulation of slow percolation, a condition, of course, which could not obtain but which is assumed so that the adequacy of the supply may not be questioned.

WELL INTERFERENCE:

In the matter of possible well interference, if the pumping stations were located upon each 320 acres or at a distance of, say, at some polnts, ½ mile from each other, I would say that, at the plant of the Avondale Company. situated upon the Agua Fria River, a tributary of the Gila, near Phoenix and where the under-ground water-bearing strata is almost identical in character, and extent to that found in the Santa Cruz valley, and where the conditions of catchment area, run-off, and topography are exactly comparable, the water plane lowered a distance of 2100 feet from a group of wells from which 16 cubic feet was recovered per second. This plant has been in operation for several years and, after starting the pumps, the water plane continued to lower until after 336 hours of continuous pumping, when it reached its maximum, and its influence is felt, as above stated, 2100 ft. radially.

This is over five times the quantity expected to develop from any one well upon the lands under the Santa Cruz project. Hence, there will probably be no effect from one well upon another if situated even much nearer than ½ mile apart. At the site upon the Santa Cruz river where the Tucson Farms Company are developing some 25 second-feet of water from a group of wells, the water plane is lowered by 7 feet between any two wells when located 200 feet apart. This confirms the above statement as to there being no probable interference of wells in this valley when spaced ½ mile apart.

I wish to call attention to the importance of using a proper strainer or strainers in all wells which may be drilled, as the formation in the Santa Cruz valley is of such character as to require strainers of the maximum safe area of perforation and of such character as will permit of proper development when the wells are completed.

CHARACTER OF WATER:

While no analysis has been made of the water from the Santa Rosa drainage basin, analyses have been made of the water from the Santa Cruz and Rillito drainage basins and it has been found exceptionally pure, draining, as they do, areas of rock containing no soluble properties. Sodium sulphate and chloride, together with sodium carbonate, are not infrequently found in the underground waters, however, though the underground supply here considered is quite free from these properties. Herewith I give analyses of the Rillito Valley underground waters, taken from 12 different wells in that section. (See following page, No. 41.)

ANALYSES OF WATER IN RILLITO VALLEY

	DATE	Depth in feet	Soluble Solids 110° C.	Chlorides as NcCl (Common salt)	Hardness as $CaSO_4$ (Sulphate of lime)	Alkalinity as Na_2CO_3 (Black alkali
1.—Spring near summit of Rincon Mts.,	Sep. 7, '07	.....	7.0	.5	....	1.27
2.—Agua Caliente spring,	Dec. 26, '01	.....	52.0	2.	....	7.42
3.—Sahuaro spring, Gibbon Ranch,	Oct. 19, '02	.....	27.8	5.56	....	10.80
4.—Sabino Creek at mouth of Canyon,	Apr. 15, '99	.....	5.5	.6	....	Slight
5.—Monthan well,	Nov.25, '06	30′	24.0	2.0	....	1.7
6.—Cole well, Fort Lowell,	Jun. 26, '02	35′	34.0	2.20	....	2.96
7.—Cole underflow ditch,	Oct. 19, '02	9′	11.2	1.6	....	1.06
8.—Well No. 3, Bingham Ranch,	Mar 5, '07	80′	21.4	1.4	....	.8
9.—Well No. 5, Kimball Ranch,	Jul. 24, '08	210′	22.2	2.2	0.0	0.0
10.—Well No. 4, Benedict Ranch	Sep. 18, '08	132′	18.2	1.7	0.0	0.0
11.—University well,	Mar. 3, '02	90′	24.8	2.05	....	3.50
12.—Steinfeld well, near Jaynes,	Feb. 1, '09	32′	44.0	5.0	6.0	....

It will be noted that the underground waters of the Rillito are slightly alkaline, though not to a deleterious degree. Samples Nos. 2 and 3 are from very deep sources, which would indicate that they are the result of springs ising from the mountains. They, however, form a very small part of the underground supply. Sample No. 5 is representative of the surface streams of the valley.

Samples Nos. 5 and 12 represent analyses of well waters, while Sample No. 11, together with many others not included in the table indicate the wide extent of the Rillito underflow. Where the Rillito joins the Santa Cruz the alkalinity changes and the water becomes hard, as indicated by No. 12.

During several terrible floods from tne Pantano drainage basin, tne waters were extremely muddy and carried, in one instance, 6.9% silt by weight; in another, 6.7%; and in still anotner, 10.3%. This is exceptional and indicates that cloud bursts occurred over the Pantano section of tne drainage basin. This silt was of considerable fertilizing value.

The analyses of the underground waters of the Berger Ranch; upon the Santa Cruz river east of the Berger Ranch; and the Carlos Rios well near San Xavier, follow below:

WELL AT EAST END OF BERGER RANCH:	Parts in 100,000
Soluble solids,	62.
Chlorides (common salt),	2.8
Bicarbonate of lime,	47.
Black alkali,	10.2

WELL UPON SANTA CRUZ RIVER EAST OF BERGER RANCH:	
Soluble solids,	48.6
Chlorides,	3.6
Sulphate of lime,	6.5
Bicarbonate of lime,	35.6
Black alkali,	None

CARLOS RIOS WELL, NEAR SAN XAVIER:	Parts in 100,000
Soluble solids,	41.
Chlorides,	2.2
Sulphate of lime,	.27
Bicarbonate of lime,	30.4
Black Alkali,	None

It will be noted that the first of these three waters contains sodium carbonate, while other wells in this same valley contain calcium sulphate which neutralizes the carbonate. This is shown in the following analyses of the water at the University well at Tucson:

UNIVERSITY WELL AT TUCSON:	Parts in 100,000
Total soluble solids at 110° C.,	44.
Chlorides as NaCl—common salt,	5.
Hardness as $CaSO_4$—sulphate of lime,	6.
Alkalinity as Na_2CO_3—black alkali,	0.

Particular attention is called to the fact that, even though the underground waters of the Santa Cruz valley were to carry large percentages of sodium carbonate, the underground drainage is such, as will be noted, that, with the application of the reservoir water, the deleterious effect would be entirely overcome. For confirmation of this statement I would refer to Professor Forbes, of the University of Arizona, at Tucson, who has conducted experiments in this valley along these lines and who concurs in the same.

In this connection it might be stated that the cultivation of crops on both the Berger Ranch and the Flowing Wells property, comprising some 3000 acres, as well as some 800 acres under what is known as the Farmer's Ditch, has been carried on for periods of time covering some 10 or 12 years, and a large part of the water for the irrigation thereof has been obtained from the underflow with the use of flood waters at such times as they were available. I have examined, particularly, all of this area, and fail to find an instance where any ill effect was experienced from the use of this supply in irrigation. In fact the crops raised upon this excellent soil are unusually large. The allowable percentage of sodium carbonate and sodium sulphate, which may be present in irrigation water without injury to agricultural crops is 3.10% by weight of the former and 1% of the latter. The water in the Berger well contains but 1-100% by weight of sodium carbonate.

SOIL CONDITIONS:

No analyses of the soil comprising the land embodied in this project are available. However, since the same agents which created the alluvial deposits in the Santa Cruz and Rillito valleys contributed to building up the surface of the lands herein considered, it is justifiable to apply the analyses of the soil of the Rillito and Santa Cruz valleys to those under this project.

Generally this soil has been derived from the disintegration of granite rocks, which have undergone but little chemical change in weathering. The principal mineral compositions are quartz, feldspar, magnetite, hemetite, kaolin, calcite and garnet.

As characterizes all arid region soils, they are supplied with mineral plant foods but are lacking in organic and introgeneous matter, which lack, however may be applied by organic and nitrogenious fertilizers. The deficiency in humus, usual in desert soils, while it decreases their retentive power for moisture and injures the tilth, it does not lessen their value from an agricultural standpoint, since, by the planting of leguminous crops—including peas, lupines, sour and burr clover, and chiefly alfalfa—the necessary organic and nitrogenious properties may be supplied and, at the same time, profitable returns result.

In addition to the beneficial effects from such natural fertilizers, too much importance cannot be attached to the value of the fertilizing properties carried in suspension by these live streams. A mechanical analyses of the soils in the upper Rillito section, in proximity to the confluence of the Rillito with the Santa Cruz river, follows. (See page 45, following).

MECHANICAL ANALYSIS OF SOILS FROM THE RILLITO VALLEY, ARIZONA

		Fine gravel 2 to 1 mm.	Coarse sand 1 to 0.5 mm.	Medium sand 0.5 to mm.	Fine sand 0.25 to 0.1 mm.	Very fine sand 0.1 to 0.05 mm.	Silt 0.05 to 0.005 mm.	Clay 0.005 to 0 mm.
21,335	S-E ¼ Sec. 32 T 13 S, R 14 E	3.9	20.1	11.2	21.5	14.0	22.4	6.7
21,336	N-E " " 32 " " " " " "	9.4	21.0	9.8	15.6	16.2	21.3	7.0
21,337	S-W " " 29 " " " " " "	11.0	17.0	7.6	18.2	17.1	24.2	5.2
21,338	S-E " " 30 " " " " " "	10.0	17.5	11.1	23.4	16.0	16.8	5.2
21,339	S-E " " 19 " " " " " "	3.6	5.6	3.9	25.4	29.5	28.3	3.8
21,340	N-E " " 23 " " " " 13 "	1.2	3.9	2.8	10.1	8.3	59.8	14.1
21,341	S-E " " 23 " " " " " "	3.6	11.9	6.3	23.4	17.1	29.2	8.5
21,342	S-W " " 25 " " " " " "	9.7	17.3	9.1	17.1	12.2	23.5	11.0

The depth of soil, as descerned from an examination of the numerous domestic supply wells which have been drilled over the lands of this project is from 30′ to 50′, this soil being of an ideal texture and homogeneous from the surface to that depth where there is encountered a sand, calcite, and clay conglomerate. The overlying soil being a sandy clay loam, which will not only absorb water but, due to its greater porosity—in excess of the underlying conglomerate—will afford ideal drainage to the northwest. In fact, the structural composition of this soil, in connection with the excellent gradient, will preclude the possibility of water-logging or alkalizing, regardless of the amount of water applied in irrigation.

As evidence of the capacity of the soil in this section to retain moisture, and of the fact that percolation into the lower soils is obstructed by the conglomerate above mentioned, I noted at Arizola, a few miles north-west of the center of this area, olive trees which seemed to be in a healthy and prospoerous condition notwithstanding they had had no moisture supply, other than that coming from natural precipitation, for several years.

WATER APPROPRIATIONS AND RIGHTS OF WAY:

I have examined the appropriations of water made by the Santa Cruz Reservoir Company from the Santa Rosa and Santa Cruz rivers, both in connection with the Santa Cruz and Black Mountain reservoirs, and find them very complete and in entire accordance with the laws of the State relating to appropriations of such resources. They cover the appropriation of surface, underground, surplus, and flood waters as follows:

Appropriation from	Quantity Appropriated	Appropriated for	Date of filing	Book and No. of Page in County as shown
Santa Cruz River,.....	3000 sec. ft.	Black Mtn. Reservoir	Mar. 16, 1910	12 of Misc. Records, 123 Pinal County.
" " "	3000 " "	Santa Cruz Reservoir	June 3, 1909	11 of Misc. Records, 144 Pinal County.
" " "	3000 " "	Santa Cruz Reservoir	Oct. 14, 1909	2 of Misc. Records, 216 Pima County.
Santa Rosa River.....	3000 " "	Santa Cruz Reservoir	June 3, 1909	11 of Misc. Records, 440 Pinal County.

These appropriations recite, among other things, that the above waters are the flows from the different streams and all of their tributaries, and their use is designated as being for irrigation and delivery to consumers, rental, milling, mechanical, domestic, and other beneficial uses and purposes. Also stipulating that the appropriator (The Santa Cruz Reservoir Company) intends to build a dam, giving explicitly the location thereof and the area of submergence when the dam is built to a height of 45 feet. It also describes the type of diversion dam and method of construction; the course of the diversion canal; etc., further providing for the supply canal from the reservoir to the point of its use. These notices of appropriation were properly posted at the points of diversion.

The Constitution of the State of Arizona provided, among other things, that all waters within the boundaries of the State were thereby declared public waters and that beneficial use and priority of appropriation should determine the rights thereto. Further, that to become an appropriator of water in Arizona, there must be an ownership or possessorship of irrigable lands upon which to use the water. Therefore, since the above approrpiations of water from the Santa Rosa River took priority because of the fact that no other appropriations from that stream had been made, and since appropriations from the Santa Cruz are for amounts less than the maximum flood flow, thereby providing ample water for prior appropriations which, so far as I have been able to ascertain, did not exceed a rate of flow of 50 second-feet, and ample land is possessed for the use of that amount of water, I do not question the right of the Santa Cruz Reservoir Company to the quantities claimed under their appropriations. Further, since they have actively and dilligently prosecuted work in connection with this project, which is an evidence of their good faith, and since they now own or control the necessary land and have completed substantial irrigation works for the purpose of diverting and storing waters so appropriated, there can, of course, be no question as to their perpetuity of rights.

While it will be noted that one of the appropriations from the Santa Cruz river was in connection with the Black Mountain reservoir storage, and that no active work other than the preliminary engineering investigations has been carried on, it is doubtful whether the rights to water so appropriated for the Black Mountain reservoir are of any force or effect, though the latter site, having been part of the original project, it might be considered by law, that these appropriations would equally apply to the Santa Cruz reservoir proper. However, since the appropriation of 3,000 second-feet will use practically all of the water available at the Santa Cruz diversion site, it is hardly necessary to consider the legal aspect in this latter appropriation.

CROPS INDIGENOUS AND PRODUCTIVITY OF LAND:

The productivity of the land under this project, in the range of agricultural crops possible of growth, is similar to that of the Salt River Valley, which crops, on account of the low elevation (1500′ to 1600′) and favorable temperature, can be marketed early and excellent prices obtained. The following table shows the more important crops particularly adaptable to the Santa Cruz section and, with irrigation, of certain yield:

CEREALS.

Corn.
Oats.
Wheat.
Barley.

OTHER GRAINS AND SEEDS:

Alfalfa seed.
Dry edible beans.

HAY AND FORAGE:

Timothy alone.
Timothy and clover mixed.
Clover alone.
Alfalfa.
Other tame or cultivated grasses (including millet or Hungarian grasses).
Grains cut green.
Coarse forage.
Milo maize.
Kaffir corn.

SUNDRY CROPS:

Potatoes.
Sugar beets.
Orchard fruit and grapes.
Small fruits.
Sugar cane.

HORTICULTURAL:

Oranges.
Lemons.
Grape fruit.
Peaches.
Nectarines.
Apricots.
Pears.

Plums.
Grapes.
Cantaloupes.
Dates.
Figs.
Olives.
Berries.
Garden truck.

Cotton growing is a newer industry but a rapidly developing one, and, in the Salt River Valley, not over 50 miles distant from the lands under the Santa Cruz project, its popularity bids fair to soon excel that of alfalfa for the reason that a net profit of $80.00 to $100.00 per acre, with indications of a distinct increase as a better market is made, will favorably commend it as a crop in preference to alfalfa. Cotton is grown and thrives, on lands in no way so fertile as those under this project. In 1912 an average yield of over 500 lbs. to the bale was made in the vicinity of Mesa, and, where close account was kept, it was found that it produced more than a bale and one-half to the acre.

In consequence of the favorable climatic conditions and the low cost of maturing alfalfa, ostrich raising is becoming an important industry in this part of Arizona.

While the citrus fruits in the Salt River Valley suffered during the last winter, the injury was principally to young trees and, considering the fact that such fruit ripens earlier here than in the California citrus belt and can be marketed before frost occurs, the demand for land where such horticultural crops can be raised is becoming greater each year. Several thousand acres adjoining the town of Maricopa have been entered upon, during the past year, by those who have owned citrus groves in California but who, appreciating the excellent advantages and possibilities of this locality, have changed their fields of activity.

Particular mention might be made of the productive possibilities in the raising of peaches, apricots, and other deciduous fruits, for, in my opinion, these fruits—especially the peaches and apricots—when grown in these semi-tropical climates are of better flavor and more delicious than those from any other part of the United States, not excepting the East.

The yield of corn and oats is not up to the standard achieved by the middle west, though the yield per acre could, no doubt, be increased beyond that of the present if more improved methods were employed.

Grains, kaffir corn, and milo maize, because of their early maturity—which permits of double cropping on any given acreage—are a very profitable crop to raise, yeild from two to three tons per acre.

Sugar beets yield a large tonnage containing a high percentage of saccharine matter.

The production of honey is a most profitable enterprise and yields large returns. The product from the Salt River Valley alone amounts to about one million pounds annually, which returns an average of 5 cts. per pound.

Cattle, horses and sheep will find easy access, through the advantageous location of these lands from a railroad standpoint, to the markets of the East and West. Poultry and eggs have an unsupplied demand.

Alfalfa raising, dairying and hogs go together. In this section of the United States alfalfa flourishes as it does in no other, giving a larger yield (10 tons per acre per season is not an infrequent record in the Salt River Valley) and having a more consisteat growth. With all-the-year-round pasturage on green feed for cows; with the consequent large milk yield and with the increased quantities of skimmed milk available for hog feeding, it would seem that for the ordinary intelligent and industrious man, who is willing to undergo some hardship at the start, success should be as surely certain in the Santa Cruz valley as it is in any region where soil and climate and all conditions favor the agriculturist.

MARKETS:

The market possibilities for crops which may be raised upon the lands under this project are exceptional, since their location is adjacent to the main line of the Southern Pacific Railway, thus eliminating long wagon hauls to shipping depots.

Notwithstanding the large area of irrigated land under this Salt River project, as well as that which is rapidly being put under cultivation in the vicinity of Tucson, the demand for forage crops this year has been far in excess of the supply, the prices paid for Salt River valley hay shipped into California being higher than during any previous year. It is doubtful, in my mind, whether the Salt River Valley will be a competitor in the open market in the line of hay or grain produce, since the cattle industry is increasing at a rapid rate and a local demand being created for the products raised in that valley. This will also, no doubt, be true as regards the products from lands under the San Carlos project (which it is proposed to construct and which will irrigate some 50,000 acres near Florence, Arizona.

Products from the irrigated areas being reclaimed in the Santa Cruz Valley near Tucson, could not, under the most extensive cultivation, supply the local demand existing in Tucson, which city occupies the unique position of importing nearly all of its food stuffs and supplies, exporting nothing whatsoever. These irrigated areas are practically the only ones in central or southern Arizona which will ever become a factor in the State supply. Therefore, it is not unreasonable to assume that there will be a ready demand for all of the products from the cultivation of these areas as well as those contemplated to place under irrigation.

As evidence of the inadequacy of this section, agriculturally, to supply the demand existing in Tucson, I give on this page a list of products shipped into Tucson, via the Southern Pacific Railway, from June 1st., 1910 to May 31st., 1911.

ARTICLES	Number Carloads	Est. weight lbs.	Wholesale Price	Value
Barley	179	9,845,000	$ 1.35 per cwt.	$132,908
Beans and peas,	17	1,020,000	6.00 " "	61,200
Canned goods,	22	1,100,000	.... " "	....
Corn,	14	840,000	1.60 " "	13,440
Dried fruits,	1	40,000	.... " "	....
Hay,	300	6,000,000	14.50 per ton	43,500
Mill stuff,	80	4,000,000	1.50 per cwt.	60,000
Perishable goods,	123	4,305,000	1.00 " "	43,050
Potatoes	82	3,280,000	2.00 " "	65,600
Live stock	58 (2088 head)	1,879,200	3.00 " "	56,376
Wheat	108	6,480,000	1.75 " "	113,400
Wood	9	135 cords	5.00 per cord	
				$589,466

In addition to the above, one of the large mercantile establishments, and similar houses, at Tucson, imported large quantities of butter, eggs, poultry, cured meats, lard, etc., for which unusually high prices were paid.

A statement by the Wells Fargo Express Company indicates that the farm products alone, handled by that Company as imports, amounted to $144,000 per year.

The Eagle Milling Company, at Tucson, paid the Southern Pacific Railway Company, for freight charges upon grain imports during 1911, $180,000, which represents a yearly average of 13,500,000 lbs. of barley and 9,000,000 lbs. of wheat, for which was paid an average of $1.35 and $1.75 per cwt. respecively. It is claimed by this Company that if they could purchase these products at a discount of 35 cts. per cwt. on the above prices, thereby enabling them to export the finished product, they could double their present importations. Upon this basis it would require 9,000 acres of land to supply this demand locally, or an area nearly equal to that involved in the Tucson Farms Company project.

The above imports are, of course, in addition to the home grown products from approximately 3,000 acres of land.

From this statement it will be seen that should the entire area, involving some 8,000 or 10,000 acres, be utilized to meet the local demand at Tucson, it would yet be inadequate, and I believe I am justified in saying that the entire product from this area under the Santa Cruz project would find a ready market in this section.

The importations from California and eastern points, to supply the demands of various mining camps near Tucson, at Bisbee, Douglas, and Nogales in Arizona, and at Cananea, Nacozan, and other points in Mexico, not a great distance from the Santa Cruz valley, are a large item in themselves, and no attempt has been made to supply this demand by local producers.

Should, however, the Salt River Valley and the upper Casa Grande valley (under the San Carlos project) attempt to supply this demand which is inherent to the Santa Cruz section, it should be borne in mind that the existing freight rates will always serve as a protection against competition.

An unsupplied demand will always exist for sugar beets if raised in this section, since the sugar factory located at Glendale, near Phoenix, has been unable during the past three years of its existence, to obtain a supply sufficient to operate the plant to its normal capacity.

While demands for alfalfa for feeding purposes will undoubtedly tend towards maintaining a high price, there is a great probability that much of the alfalfa raised in the present irrigated regions will be required to supply alfalfa meal mills which must, sooner or later, be established in this part of the West, since the demand for western grown alfalfa meal, by eastern markets, is far in excess of the supply from the middle western states. The adaptability of the soil and climate in this country, in the raising of grain, favors the local production rather then the shipment of the ground alfalfa to other markets for compounding, as is done in some districts, whereas, this particular commodity can be produced in its entirety here.

I am advised that the Coats Thread Company have contracted for the entire cotton output from the Sacaton Indian Reservation, at a price higher than is paid in any other locality, due to the greater desirability of the long fibre Egyptian cotton which is so successfully grown in this State.

It is not unreasonable to presume that, with a solution of the labor problem a more general cropping, of the various areas mentioned, to cotton will result and ultimately the establishment of cotton mills where the finished article may be manufactured, thus eliminating freight charges from Eastern markets on the finished commodity and the same charges on the raw material to Eastern mills, an expense which has, heretofore, fallen largely upon the people of this section.

Generally considering the markets for the agricultural products of the State of Arizona, it is an interesting fact that the irrigable area within the limits is less than 500,000 acres while the area of the entire State is 113,956 square miles, of which over 99.9% is land surface. This is a very small percentage as compared with California, Colorado, and other western states of relatively no greater area but which states supply only a small part of the export demands, In other words, since Arizona can produce a greater variety of crops than almost any other state in the Union, it will be unnecessary to go outside its own boundaries to meet its entire demands, both agriculturally and horticulturally.

CLIMATALOGICAL:

Temperature observations are, of course, not available for this particular area, but complete records are available for Casa Grande where the elevation is but about 100′ lower than at Santa Cruz and which is situated about 12 miles north-west of the center of the Santa Cruz tract.

Highest, lowest and mean monthly temperatures for 25 years at Casa Grande, as well as the mean relative humidity and hourly wind movement, taken at Phoenix, appear in the following table:

MONTHS	Mean Temp.	Highest Temp.	Lowest Temp.	Mean relative humidity 8 A.M.	8 P.M.	Average Hourly Wind movement in miles
Jan.	51.5	82.	21	64	37	3.4
Feb.	55.8	95	24	62	28	4.0
Mar.	61.7	99	33	24	24	4.5
Apr.	69.6	104	28	45	18	4.6
May	79.4	110	40	38	15	4.6
Jun.	89.3	119	40	32	12	4.4
Jul.	93.5	122	63	49	21	4.5
Aug.	91.1	120	60	54	25	4.0
Sep.	85.8	114	50	51	25	3.8
Oct.	72.6	104	25	51	26	3.5
Nov.	62.3	90	24	57	32	3.3
Dec.	53.7	91	17	57	32	3.2
Annual	72.2	122	17	51	25	4.0

Average date of first killing frost is Nov. 22nd. while average date of last killing frost is March 5th.

Earliest killing frost was Oct. 13th., while the latest killing frost was April 3rd.

For comparison, the mean relative humidity at Los Angeles is 71% and at San Diego is 75%, both very much higher than for this section.

The mean annual temperature at Los Angeles in 60.30, while at San Diego it is 60.60. It will be noted that the mean annual wind velocity is exceedingly low.

Here, as in all arid localities, the precipitation is low, being, for the area under discussion (corrected for elevation), but about 6″ and the temperature is high. Similarly, the humidity is low.

This combination of conditions makes the habitation of such regions not only possible but preferable when compared with many eastern and middle-western states where, though lower temperatures prevail, precipitation is greater and the humidity much higher and more keenly felt. I mention this fact because a mistaken idea obtains amongst many that such high temperatures, in their relation to human life and comfort, are unbearable, which is by no means the case. For about 8 months in the year the climate is a delightful one—the nights being cool and the mornings bracing, while the days are bright and pleasant.

During June, July and August, and the early part of Septmber, the temperature is high and is usually continuous, though there is seldom a night, during this latter period, that a breeze does not accompany the setting of the sun, cooling the air to a most delightful degree. Sultry, sticky days, so common to the more humid sections are absolutely unknown in this section of the arid west, and I have yet to hear of an instance of heat prostration, even amongst the farmers who labor throughout the entire summer's day. Difference in temperatures between the wet and dry bulb thermometer, often exceeds 30°, which, to one understanding its significance, explains the reason why the effect of these high temperatures does not result in discomfort.

In nine years' residence in the hot, arid sections of Arizona much of which time I have spent in the field during our hottest periods, I have never experienced as great discomfort as I have in many Eastern and middle-western states during the summer seasons. It is this extreme aridity, mildness and almost continuous sunshine that commands such a climate to health- seekers

DESCRIPTION AND COST OF SUPPLEMENTAL SUPPLY:

On Plate III is shown the location of 32 pumping plants as well as the transmission lines from a central power station located at Toltec. These pumping stations cover an area in addition to that now owned by scrip application, and while other land, in lieu of the 3,300 acres shown, may be acquired, it will naturally affect the cost of the system if it be located elsewhere within the zone of irrigable land which is principally in Township 8 South, Ranges 6 and 7 East.

The dotted lines from the power station to the pumping plants (the latter indicated by red dots) show the direction and course of the pole lines, some of which carry 3-phase primary circuits, while others include 3-phase primary and secondary lines. All primary transmission lines are contemplated to safely transmit current at 10,000 volts potential, while all secondary linea are figured upon the basis of 550 volts.

The current leaving the station power at 10,000 volts would be stepped down at each of the transformer stations (shown by black squares) to 550 volts and carried to the motors, operaring the pumps, at that pressure.

Each transformer station would include 3 oil insulated transformers having primary winding connections of 10,670, 10,330 and 10,000 volts and secondary connections for 580, 560 and 540 volts respectively. These transformers would be connected, delta to delta. In each transformer station would be installed the necessary lightning arresters and switches. The buildings for housing the transformers would be of galvanized iron, properly ventilated.

The poles would be of cedar or cypress, having the butts treated with a preservative compound. All lines would be of medium hard drawn copper from No. 8 to No. 000 in size.

I have assumed that the depth of each well would be 175 feet, composed of 50′ of strainer and the necessary blank casing and well pit of No. 6 red ingot iron.

All of the pumps would be of the deep well, turbine type, having enclosed line shafting, enclosed impellers and clearance rings. Each pump would be direct connected to a three-phase, 550-volt, 60-cycle motor cable of operating the pump at the proper speed when delivering 2 and 2 1-2 cubic feet of water per second against the heads obtaining.

Each motor would be provided with an auto starter, over-load and under-load releases, switch and necessary spark gaps for lightning protection.

Each pumping statiom would have the necessary housing of concrete to properly shelter the motor and switchimg appartus, while the discharge from the pumps would be into a concrete bay.

The initail cost of the transmission lines and transformer stations, together with the pumping plants, would be as follows:

6½ miles No. 8 primary pole line,............................@	$1,050.00	$ 6,825.00
4½ " " 8 " and No. 2 and No. 4 secondary,.........	1,700.00	7,225.00
9 " " 000, 1, 2, 4 and 6 secondary line,.................	1,250.00	11,250.00
1 transformer station, 150-KVA, complete with housing,.......		1,600.00
1 " " 180- " " " "		1,900.00
1 " " 225- " " " "		2,350.00
3 " " 375- " " " "		8,550.00
32 pumping stations, complete with housings and bays,..........	4,000.00	128,000.00
Total net cost,..		167,700.00
Add for contingencies and engineering, 20%....................		33,540.00
Total Cost,...		$201,240.00

The central power station would consist of three 350 boiler horse power, water tube boilers, having furnaces arranged for the use of crude oil as fuel fuel and designed for a safe working pressure of 180 pounds. They would be equipped with wrought steel super-heaters for super-heating steam 100 above normal. There would also be included all necessary auxiliary equipment, consisting of economizers, beaters, feed pumps, breeching and stack. This would provide one reserve boiler at all times.

The engines would be two, of 600 horse-power capacity, direct connected to two 500-KVA 60-cycle, 2,200-volt, 3-phase generators, each designed to operate with 165 pounds at the throttle, 26″ vacuum, and run at a speed of 150-RPM. There would be included all necessary condensing apparatus, auxiliaries, piping, etc.

Also there would be three on I. S. C. 2,200 to 10,000 volt transformers of 350-KVA capacity each. The plant would include all necessary switchboards, exciters, and auxiliary equipment.

The building would be of re-inforced concrete, and concrete oil-storage a reservoir would be provided. All foundations would be of concrete, while the boiler settings would be of hard burned or clinker brick.

The cost of this plant complete, from manufacturer's prices would be as follows:

Machinery and buildings, complete..................	$ 83,920.00
Condenser, well, and pump,.........................	2,000.00
Add for contingencies and engineering, 20%,..........	21,380.00
Total cost of power plant,..........................	$107,300.00

The cost of operating this plant during the time required to make up shortages in reservoir water supply, based upon mean years, would be as follows:

Fuel cost for 164 hrs. at ½* load during	Feb.	364 bbls.	@ $1.45	
" " " 436 " " " " "	Mar.	970	" " "	
" " " 552 " " " " "	Apr.	1165	" " "	
" " " 638.0 " " full " "	May	2540	" " "	
" " " 720 " " 1¼ " "	June	3700	" " "	
" " " 374 " " ½ " "	Jul.	789	" " "	
" " " 532 " " " " "	Sep.	1122	" " "	
" " " 460 " " full " "	Oct.	1840	" " "	
Total,		12440 bbls.	@ $1.45	$18,038.00

*½ load means 1 engine at full load.
Full " " 2 engines " "
1¼ " " 2 " " over load.

Labor cost would be:	1 Chief engineer,	@		$1,800.00*
	2 Engineers,	@	$1,200.00 each,	2,400.00
	3 Water tenders,	@	$ 900.00 "	2,700.00
	1 Roustabout,	@		720.00
				$7,620.00

Thus, totalling, we would have;	Fuel cost,	$18,038.00
	Labor "	7,620.00
	Supplies,	1,200.00
Total Cost of Operating Plant,		$26,858.00

COST OF REHABILITATION OF PRESENT SYSTEM:

While the present diversion and -age to dams, and the diversion canals, are in good shape and require no expenditures for rehabilitation, unless the storage dam is raised, I should recommend a more appropriate head-gate arrangement at the outlet from the storage reservoir than that now installed. Also, there should be some protection provided for the floor and sides of the waste-way channel from the Santa Cruz diversion canal, to eliminate the cutting of the earth at the outlet, since no waste-way is possible at the storage dam, thus requiring this particular waste-way to care for excess water during period of full storage.

For a distance of some three miles, the main supply canal from the storage reservoir will requiıe realignment with proper area of excavated section. This canal was run upon a 7′ gradient and has a width of 15 feet and a depth of 4 feet, its sides being almost perpendicular. Its capacity, under these conditions, is closely 140 cubic feet per second.

Since the maximum use of water during July is .573 acre-feet per acre, or 5,730 acre-feet for the entire 10,000 acres, it would require but 100 second-feet continuous flow (allowing for conveyance losses) to provide this quantity. Therefore, the dimensions of this canal, as now built, will be ample for all needs.

The 30 miles branch distribution canals and laterals will all require more or less reconstruction, since the banks have becone eroded by the elements and, in a number of instances, the channels filled with debris.

It would be impossible to accurately estimate the cost of reconstruction of this part of the work without cross-sectioning the entire length. Hence, shall assume that the cost of reconstruction will be ½ that of the original cost of the work which amounted to $15,182.90.This will include the cost of reconstructing 9½ miles of the main canal.

COST OF REHABILITATION OF PRESENT SYSTEMS AND EXTENSIONS THERETO:

Riprapping of waste-way, 700 yds. @ 70c.	$ 490.00
Main outlet gates and tower at storage dam, estimated,	2,800.00
Raising the present dam 3½ feet above present height upon the basis of the upstream slope of added section being 1:2 and down stream slope being 1:1, with clay puddle core and upstream surface protected by brush. Total, 7500 yards @ 35c.	2,625.00
Surface protection, estimated,	1,500.00
Wood boom and anchorage for protection against wave cutting, 8x8" timbers, 4600 board feet, @ $45.00 per M.,	200.00
Recontruction of distributing system on basis of ½ original cost,	7,591.00
Estimated cost of laterals and ditches for 3300 acres new land	3,000.00
Total net cost of rehabilitation and extension to gravtiy works	$18,206.00
Add for contingencies and engineering, 20%	3,641.00
Total cost,	$21,847.00

The feasibility of utilizing such abrupt slopes for the section added to the top of the present dam may be questioned, but the character of the material which may be obtained for embankment is good, and, with proper face protection and the floating of a boom on the water surface of the upstream side, a 1:2 slope will be ample. Considering the limited precipitation at this low elevation, the effect of run-off upon the downstream slope will not be serious, though this face migiht be protected in a manner similar to that of the upstream face at a small additional cost, thus minimizing liability of cutting from this cause.

MAINTENANCE OF GRAVITY WORKS:

The maintenance cost of the project, insofar as the gravity system is concerned, which included dams and canals, will be low, consisting largely of the cost of cleaning canals and repairs of dams. (The cost of maintenance of the Tempe Canal system, embodying 25,000 acres, situated in the Salt River Valley but not under the Roosevelt dam, being a co-operative institution, is about 78c- per acre per annum, requiring two Zanjeros and clerical help, and this charge includes the cost of canal cleaning and the maintemance of a diversion dam). Considering the fact that the entire works of the Santa Cruz Reservoir project is situated over a relatively small area, I believe that a maintenance cost of $1.00 per acre per annum will cover all charges including ditch cleaning, canal, and dam repairs, and office expense in connection with the pumping and power plants as well, since one water master or Zanjero could attend to water distribution for both the gravity system and pumping plants, as they would not be required to operate simultaneously. This item would amount to an annual charge of $10,00 00.

RESUME OF INITIAL COST OF PROJECT, INCLUDING GRAVITY AND AUXILLIARY SUPPLY:

Expended on project to date (as per items on Page 7)	$300,000.00
Cost of acquiring 3300 acres new land by scrip @ $3.50 per acre,	11,550.00
Legal expense in connection with acquisition of new land (estimated)	1,000.00
Plowing and clearing new lands, @ $5.50 per acre,	18,150.00
Rehabilitation and extensions,	21,847.00
Total cost of gravity project and lands,	$352,547.00
Transmission lines, transformers, and 32 pumping plants with wells, as per itemized statement	201,240.00
Cost of power plant, complete,	107,300.00
Total cost of auxiliary water supply system,	$308,540.00
Grand total cost of completed project	$661,087.00

Assuming that bonds, to meet this expense, were discounted to 85%, the cost would be $760,250.00, or a charge for land and water amounting to $76.02 per acre. In the above estimates of initial cost, the figures given are those obtained from manufacturers and contractors upon the work and plant here considered. Hence, the amounts are accurate and dependable.

RESUME OF ANNUAL CHARGES:

Fixed charges:

Interest on total cost of project, excepting lands, assuming bonds discounted to 85%, @ 6% on $711,317.00,	$ 42,679.00
Depreciation on reservoir, assuming life to be 100 years, or .0833% on $100,-000.00***	38.30
Depreciation on auxiliary plant, exclusive of wells, lines, pumps, jotors, and transformers, assuming life to be 40 years, or .83% on 123,395.00**	1,024.17
Depreciation on wells, assuming life to be 100 years, or .038% on 123,623.00*	47.00
Depreciation on lines, pumps, motors, and transformer stations, assuming life to be 30 years, or 1.5% on $107,801.00	1,617.00
Taxes on personal property and buildings, @ 1%	7,113.17
Total fixed charges	$ 52,518.64

***Depreciation to care for cost of raising dam to overcome silt deposits
**This is in accord with latest steam engineering pract ce.
*Depreciation, in each instance, is based upon sinking fund so created being set aside and compounded at 5%

OPERATION AND MAINTENANCE:

Maintenance of gravity system, at $1.00 per acre	$ 10,000.00
Fuel for steam plant, @ $1.45 per bbl., delivered	18,038.00
Office and administration charges, estimated	5,000.00
Labor at plant	7,620.00
Maintenance of plant, 1% on $123,395	1,233.95
Lubricating oil, waste, and supplies	1,200.00
Total operating and maintenance charges	$ 43,091.95
Total fixed charges, as shown above	52,518.64
TOTAL ANNUAL COST	$ 95,610.59

This shows a charge, per acre, of $9.56 upon the basis of 3.5 acre-feet delivered at the reservoir, or a charge of $2.73 per acre-foot per annum.

Comparing the initial cost of the land and water under this project with that obtaining in other sections, it is from 1-2 to 1-3 the usual charge. The average cost of irrigation works in many of the states, as given partially in "The Engineering News" of May 15, 1913, and from original data, is as follows: (See table of average costs of projects in Western states on following page, No. 63).

Project	State	Number of projects Instituted	Average cost of Irrigation works Per Acre
Private	South Dakota	1	$ 40.00
"	Colorado	17	76.40
"	Montana	2	45.00
"	Nebraska	2	39.99
"	New Mexico	2	43.00
"	Oregon	5	58,00
"	Utah	2	60.00
"	Washington	8	110.00
Carey Acts	Colorado	6	44.00
"	Idaho	35	46.00
"	Montano	3	47.00
"	Oregon	7	53.00
"	Utah*	1	150.00
"	Wyoming	30	40.00
All U. S. R. S.	All western states	14	44.00

***Pumping plant project involving 8,000 acres.**

From the above table it will be noted that the cost of water alone is, in many instances higher than for water and land under the Santa Cruz project. Undoubtedly $50.00 per acre could be added to that here given and yet the price for the land with water would be below the average selling price of Class "C" land in the Salt River Valley under the Roosevelt Dam and considerably below the selling price of Class "B" land, exclusive of the water right charge which will, no doubt, exceed $50.00 per acre.

The Class "B" and "C" above mentioned is that land in the Salt River Valley, Arizona, which must first suffer from shortage of water in the Roosevelt Reservoir, Class "A" land being the only land for which water is assured. Class "C" land sells from $75.00 to $100.00 per acre, while Class "B" land brings from $100.00 to $150.00, and Class "A" land sells for from $150.00 to $200.00 per acre.

The average annual assessments for water under the Santa Cruz project, which, it is shown, will amount to $9.55 per acre, is somewhat higher than the cost of a similar quantity of water under the Roosevelt system, yet, if interest and depreciation be added to the administration charge under that project, it would greatly increase the amount, making it about 60% of the annual cost under the Santa Cruz project, but the land under this latter project is assured of ample water at all times, whereas only that of Class "A" is assured of water under the Roosevelt project and no distinction is made between the classes of land with respect to the water assessment charges.

The charges of $9.56 per acre is no higher than in many projects and, considering the all-year-round growing season in the Santa Cruz section, it is relatively a less charge than for water used upon lands located in the northwest where a short season, with limited crop returns only, is possible.

I regard this project as offering attractive possibilities with a small initial investment, and one in which the irrigation supply, if provided along these lines recommended, is excellent and assured.

A word in connection with the colonization of the lands under this project might not be amiss. It has been demonstrated that the engineering and constructive features are not the greatest factors in the successful consummation of an irrigation project, the colonization of the land being of equal importance, but, where the colonist is required to meet not only the expense of the land and water but must finance himself for one or two years, until his land brings a return, he is often handicapped. Hence, I would suggest that the lands be turned over to the colonist in a planted condition and that he be extended every concession consistent with a liberal policy of administration, and that principal and interest payments be deferred and added to the subsequent years by pro-ration.

P. E. FULLER.

June 11, 1913.