Irrigation of Acid Lands Committee

66TH CONGRESS } HOUSE OF REPRESENTATIVES { COMMITTEE
3d Session. } { PRINT

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE

PRELIMINARY REPORT

ON

PROBLEMS OF IMPERIAL VALLEY AND VICINITY

REQUIRED BY

ACT OF CONGRESS, APPROVED MAY 18, 1920

PUBLIC NO. 208, 66TH CONGRESS

Printed for the use of the Committee on Irrigation of Arid Lands, House of Representatives
(41 U. S. Statutes, 600.)

JANUARY, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

'TH CONGRESS } HOUSE OF REPRESENTATIVES { COMMITTEE
3d Session } { PRINT

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE

PRELIMINARY REPORT

ON

PROBLEMS OF IMPERIAL VALLEY AND VICINITY

REQUIRED BY

ACT OF CONGRESS, APPROVED MAY 18, 1920

PUBLIC NO. 208, 66TH CONGRESS

Printed for the use of the Committee on Irrigation of
Arid Lands, House of Representatives
(41 U. S. Statutes, 600.)

JANUARY, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

66TH CONGRESS, 3d Session } HOUSE OF REPRESENTATIVES { COMMITTEE PRINT

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE

PRELIMINARY REPORT

ON

PROBLEMS OF IMPERIAL VALLEY AND VICINITY

REQUIRED BY

ACT OF CONGRESS, APPROVED MAY 18, 1920

PUBLIC NO. 208, 66TH CONGRESS

Printed for the use of the Committee on Irrigation of Arid Lands, House of Representatives
(41 U. S. Statutes, 600.)

JANUARY, 1921

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

COMMITTEE ON IRRIGATION OF ARID LANDS.

HOUSE OF REPRESENTATIVES.

SIXTY-SIXTH CONGRESS.

MOSES P. KINKAID, Nebraska, *Chairman.*

NICHOLAS J. SINNOTT, Oregon.	CHARLES J. THOMPSON, Ohio.
EDWARD C. LITTLE, Kansas.	EDWARD T. TAYLOR, Colorado.
ADDISON T. SMITH, Idaho.	CARL HAYDEN, Arizona.
JOHN M. BAER, North Dakota.	MILTON H. WELLING, Utah.
BENIGNO C. HERNANDEZ, New Mexico.	CHARLES R. EVANS, Nevada.
JOHN W. SUMMERS, Washington.	CLAUDE HUDSPETH, Texas.
HENRY E. BARBOUR, California.	

DAN F. REYNOLDS, *Clerk.*

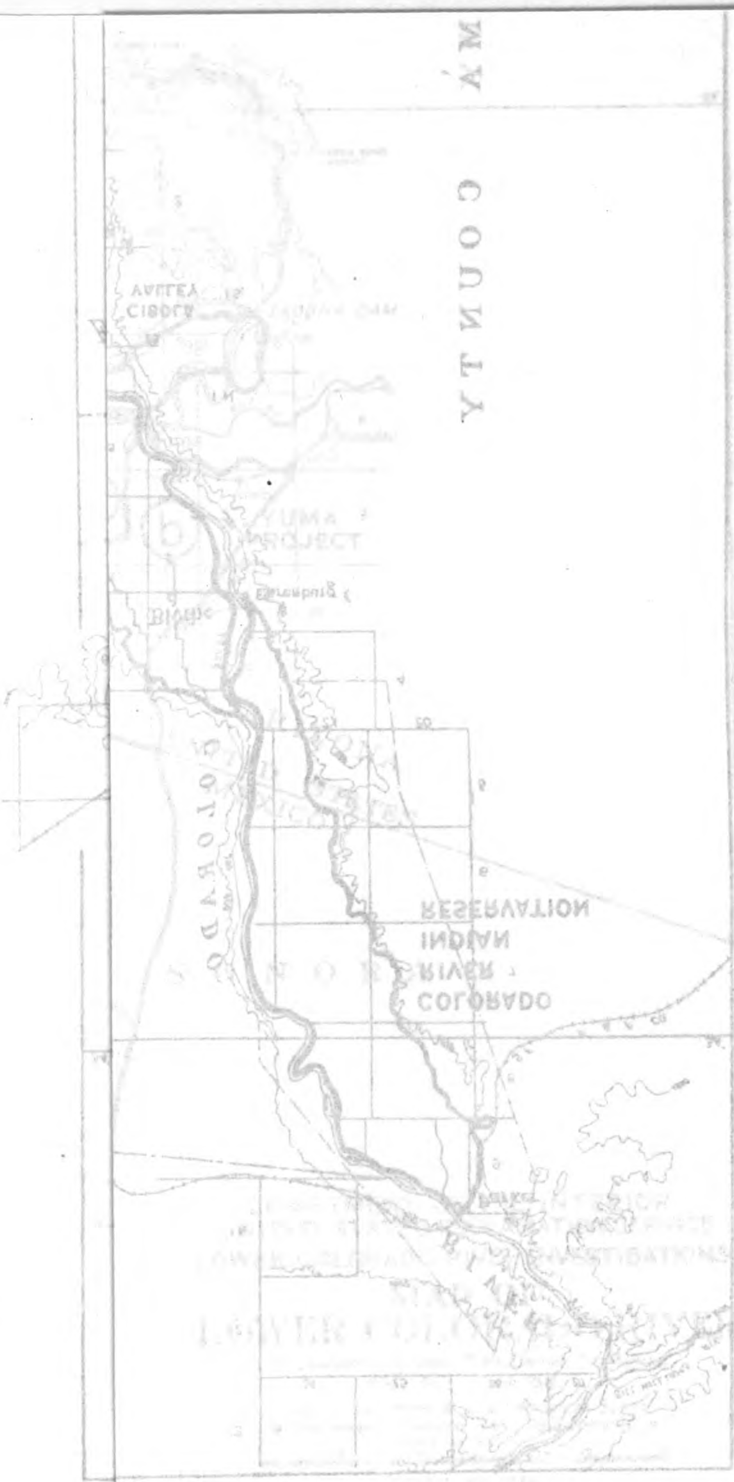


TABLE OF CONTENTS.

LETTER OF TRANSMITTAL.

YUMA, ARIZ., *November 27, 1920.*

The SECRETARY OF THE INTERIOR,
Washington, D. C.

SIR: I transmit herewith a "Preliminary report on problems of Imperial Valley and vicinity," required by the act of Congress approved May 18, 1920, entitled "An act to provide for an examination and report on the condition and possible irrigation development of the Imperial Valley in California." (41 Stat., 600.) Alternative plans for a portion of the development are now under investigation and will be made the subject of further report in future, at which time the subject can be treated in a more complete manner.

Very respectfully,

A. P. DAVIS, *Director.*

PRELIMINARY REPORT ON PROBLEMS OF IMPERIAL VALLEY AND VICINITY.

This report and the investigations upon which it is based were authorized by an act of Congress approved May 18, 1920, entitled "An act to provide for an examination and report on the condition and possible irrigation development of the Imperial Valley in California." (See Appendix A.)

Four principal lines of information were required to make this report complete:

1. Water supply for irrigation;
2. Protection from the floods of the Colorado River;
3. Available land for irrigation; and
4. The canal system or systems necessary to reach these lands.

The source of water supply bearing on this problem, as well as the source of the floods which must be controlled, is the Colorado River. The observations of the water supply have been in progress for many years, and a large number of gauging stations in different parts of the basin have been maintained for varying periods. These data have accumulated in the various reports of the Geological Survey and of the Reclamation Service, and shed much light upon the fluctuations of water supply, the need for storage, and the problem of flood control.

The investigations required for this report consisted mainly of the examination in detail and classification of the lands to be covered in order to determine the irrigable area and their location and their relation to the waste lands with which they are surrounded or interspersed. This work has been undertaken by Prof. Charles F. Shaw, of the University of California, and Mr. A. T. Strahorn, of the Bureau of Soils, Department of Agricultlure, assisted by Mr. S. W. Cosby. A special credit is due to the interest, efficiency, and energy with which these gentlemen undertook the work and pushed it to completion. It has resulted in a large amount of much-needed information regarding the character and extent of the lands. The preliminary report concerning the same is incorporated herewith. (See Appendix D.)

Section 5 of the act of Congress above referred to provides:

> That no expenditure shall be made or obligation incurred hereunder by the Secretary of the Interior until provision shall have been made for the payment of at least one-half the cost of the examination and report herein provided for by associations and agencies interested in the irrigation of the lands of the Imperial Valley.

Upon the passage of the act various interests involved were notified of the requirements of the work and the need for a much larger sum than that appropriated by Congress if the examinations were to be carried to completion. In response to this the Imperial irriga-

tion district passed a resolution appropriating $20,000, or sufficient to carry out the provisions of this act and enable the work to proceed. As soon as practicable after this was accomplished and a contract entered into work was started on the surveys and equipment was assembled near Boulder Canyon, where existing information indicated that a large reservoir site might be built to impound irrigation water and subdue the floods of the Colorado. Owing to high water conditions in the river this work could not be undertaken with results until September. It has been pushed vigorously, but the extremely difficult conditions in the canyon have prevented its completion up to the present time, and it early became obvious that to carry this work to completion in a proper manner would require much larger sums than had been provided.

The State of Arizona contributed $5,000, the Coachella Valley County water district contributed $5,000, the Palo Verde irrigation district contributed $5,000, and appropriations have been made by the Imperial irrigation district up to a total of $60,000, making altogether available for the entire examination to date $95,000, which it is hoped will be sufficient to reasonably complete the examinations.

Section 4 requires a recommendation for a general plan of operations and the extent to which the United States should contribute to the cost of carrying it out, also the approximate portions of the total cost that should be borne by the various irrigation districts or associations concerned. This matter has been taken up with the various districts concerned, and the responses received are inserted hereafter in this report.

In addition to the benefits from irrigation and flood control, the works will make possible incidental power developments. There are several drops on the canal system and it will be possible to develop power as the water is drawn from the storage reservoir, so that this makes possible a certain amount of benefit which can not in advance be foretold, but which is useful in pumping water for irrigation purposes and to supply the needs of the local communities for lighting and other needs for electric current.

All the interests consulted on these matters are agreed that the best method of settling these details is for all parties to agree that benefits are to be determined by the Secretary of the Interior after time has elapsed and the work is in progress, and after ample notice to all interests and full hearing and argument. This is similar to the provisions of most irrigation district laws, except that in those cases it is customary for benefits to be fixed by a constituted board, sometimes subject to review in court.

The assurances required by section 4, so far as obtained, are given in Appendix B.

There is a general desire on the part of the irrigation districts to have the enterprise financed by themselves in conjunction with the United States and the power by-products disposed of at commercial rates for their benefit. On the other hand, the city of Los Angeles, Calif., appears anxious to participate in the investment and to receive as much power as possible from the reservoir if built in Boulder Canyon.

It seems advisable for the United States to conduct and supervise the work, and this is desired by all interests. It also seems desirable

for the United States to participate in the investment to an equitable extent in proportion to the area of the public lands and Indian lands involved.

LAND CLASSIFICATION.

A classification of lands into irrigable and nonirrigable to be reliable requires a careful examination of the soils, and this has been undertaken and is well along toward completion. A reconnoissance of the lands not classified in detail has been made. The results of these examinations are given in detail in Appendix D, and are summarized in the following report by Prof. Chas. F. Shaw, under whose direction they were made:

During the week of November 21 the writer, in company with Mr. A. T. Strahorn and Mr. S. W. Cosby, made a brief examination of the soils bordering the Imperial Valley, covering the east mesa from the international boundary to Niland and covering the west mesa and the west side generally from the State highway north to the Santa Rosa Mountains. Most of the area covered had been mapped by Mr. Strahorn and Mr. Cosby, the writer having the benefit of their maps and experience. The work they have done was carefully examined and found satisfactory and their classifications and decisions on the soils were uniformly approved.

The soils of the east mesa are prevailingly sandy, ranging from a light sandy loam to a gravelly sand, with by far the larger part of a medium sand texture. The subsoils are generally a fine sand, uniform to considerable depths. There are a few small spots where the soil is heavy—clay or clay loam—with stratified clay subsoil, and a few spots of clay surface soil with sandy subsoils. The former probably contain considerable alkali and the latter may also carry some alkali. Aside from these few areas of alkali and of heavy soils the nonagricultural lands of the east mesa are mainly the included bodies of sand dunes. These cover considerable area, probably totaling over 45,000 acres.

There are probably over 150,000 acres of irrigable land of good quality on this mesa. Much of this is relatively smooth and level, but large areas have scattered or numerous low mounds or dunes of fine sand, and will need considerable work in leveling to prepare them for irrigation. The land should give good results with crops suited to the climate of this region, more particularly with alfalfa, sorghums, barley, cotton, vegetables, and truck crops. Tomatoes, lettuce, and cantaloupes for the early markets should prove successful. Thompson seedless and possibly other varieties of grapes may prove profitable if sufficient demand and adequate marketing facilities are developed.

The west-side area is much less promising. Much of the good land lies above the gravity-canal location, some of it at considerable elevation and distance. Most of the good land lies southwest and west of the Superstition Mountains, in a broad belt extending from the vicinity of the State highway north nearly to San Felipe Creek. This area consists of sands and sandy loams with some small areas of heavier-textured soils. It occupies sloping alluvial plains and smooth to gently undulating low mesas, and covers an area of something over 40,000 acres. Probably the larger part of this area will prove to lie at such an elevation that it will be impracticable to pump water to irrigate it.

There are a few other small areas of good land on the west side, usually of small extent, and more or less isolated in bodies of poor land. Most of the land is of low agricultural value, due either to topographic features, to unfavorable soil texture and subsoil conditions, or to the presence of alkali. Large areas of land with favorable topography and good surface appearance have a subsoil composed of old, partially indurated, stratified clays, usually containing considerable alkali. If irrigated, these soils would develop alkali in the surface and would soon become worthless. There are also broad areas of alluvial soils on the delta of San Felipe Creek which are strongly impregnated with alkali and which are of little or no agricultural value.

The development of the west side will depend largely on the possibilities of lifting water high enough to cover a sufficient area of the good land lying west of the Superstition Mountains. The east mesa can largely be irrigated by gravity, and includes a large area of soils of good quality that can probably be brought to a high state of development. No examination was made of

the soils of the Coachella Valley and no report can be made regarding their character or quality.

Respectfully submitted.

CHAS. F. SHAW,
Professor of Soil Technology, University of California.

NOVEMBER 26, 1920.

The relative areas of irrigable lands, classified according to ownership, are given in the following tables:

STATUS OF LANDS.

Lower Colorado River.

Tract.	Irrigable area.						
	Private.	Entered.	Public.	Indian.	State.	Southern Pacific Railroad.	Total.
Cottonwood Island	.....	.....	4,400	.....	.....	.....	4,400
Mohave Valley	12,700	.....	1,500	12,500	.....	.....	26,700
Chemehuevis Valley	.....	.....	1,400	2,300	.....	.....	3,700
Parker project	.....	.....	.....	110,000	.....	.....	110,000
Palo Verde Valley	72,000	6,600	.....	.....	.....	.....	78,600
Palo Verde Mesa	3,500	12,400	800	.....	1,300	.....	18,000
Chucawalla Valley	500	32,500	8,500	.....	2,500	.....	44,000
Cibola Valley	6,800	2,500	4,700	.....	1,700	.....	15,700
Isolated tracts	2,900	.....	.....	.....	.....	.....	2,900
Yuma project	62,000	19,000	38,200	9,000	1,800	.....	130,000
Imperial irrigation district	515,000	.....	.....	.....	.....	.....	515,000
Imperial Valley extensions.							
East side mesa	1,070	970	139,830	.....	7,570	3,560	153,000
Dos Palmas	370	2,800	1,280	.....	550	5,000	10,000
Coachella Valley	15,490	4,610	5,190	12,750	5,580	46,380	90,000
West side	800	11,320	19,530	120	2,240	5,990	40,000
Total in United States	693,130	92,700	225,330	146,670	23,240	60,930	1,242,000

Mexican lands.

UNDER IMPERIAL CANAL.	Irrigable area.
Compania de Terrenos y Aguas de la Baja California (Lower California Land & Water Co.)	54,000
Small tracts, private owners	8,000
International Co	9,000
Imperial Development Co	11,000
E. Easton	11,000
Colorado River Land Co	176,000
Government land	6,000
Subtotal	275,000

UNDER ALL-AMERICAN CANAL.	
Compania de Terrenos y Aguas de la Baja California (Lower California Land & Water Co.)	2,600
Government land	28,000
Subtotal	30,000

COLORADO DELTA.	
Colorado River Land Co	250,000

SONORA.	Irrigable area.
Andrade tract	41,000
Del Rio	180,000
Government land	44,000
Subtotal	265,000
Total Mexican lands	820,000

The distribution of benefits is difficult of exact determination, and because they are very complicated. For example, various regions have used water and claim a right thereto, but in some years at low water there might be a shortage and storage would be required. Who should pay for this storage, and how much, involves the question of the basis for each claim and its priority. The allocation of benefits from flood protection is equally involved, as some regions are adequately provided with levees and others are but slightly menaced by floods, while in other cases this is the most important benefit of all. The tracts above Yuma are not menaced by the Gila, so that the control of the Colorado will solve their flood problems, while those below Yuma will still be menaced.

The urgent problems of the Imperial Valley and the regions adjacent thereto are dual in character. One is flood protection and the other is the security of water supply for areas now irrigated and for additional areas to be added to the present development.

In 1905 the Colorado River left its banks 3 miles below Andrade, on the international boundary line, and flowed down the Imperial Canal through the Imperial Valley and into the Salton Sea, cutting the channel larger and larger until the entire river in flood stage was running into the valley. The fall in this distance was much greater than the soil would stand without erosion, and the channel cut rapidly, forming cascades at intervals and deepening its channel toward the heading. The expense of stopping the flow and turning the river back into its old channel was very great and the task was difficult. From time to time the river shifts its channel and threatens to resume its course into the Imperial Valley. If it should do this and continue long enough in this course, the valley would eventually be entirely submerged. This would occur quickly in the lower levels near the Salton Sea and more slowly as the sea rises and its area becomes greater. As the Colorado River carries a large amount of sediment, it is continually building up its lower channel on Mexican territory south of the Imperial Valley, and the tendency to break away from its ridge continually increases, and therefore the menace is a growing one. Considerable work is done each year upon levees to prevent the inundation of the Imperial Valley, but this work has in the past been hampered by the fact that the protection works are necessarily located within Mexican jurisdiction.

The present investigation did not include any surveys in Mexico, as these were not authorized, and surveys on the part of the United States Government in Mexico probably would not be permitted. Examination was made, however, of the possibility of storing the waters of the Colorado and thus reducing the floods to a moderate amount, which could be more easily controlled. Such storage in connection with irrigation might be made to remove the chief danger.

There are now irrigated in the Imperial Valley about 400,000 acres of land. In addition to this there are within the Imperial irrigation district about 115,000 acres of irrigable land to which water has not yet been applied but which it is desirable to develop. In reaching the Imperial Valley the present canal, which heads on the Colorado River a short distance above the Mexican line, runs through Mexico and back into the United States, this being required by the topography of the country. For much of the distance it follows an old channel of the Colorado River. From this channel laterals are diverted which at the present time are serving about 190,000 acres of land in Mexico with irrigation water from the Colorado River. There are large areas of Mexican lands adjacent to these which might also be watered from the Imperial Canal.

Adjacent to the Imperial irrigation district are additional large areas of land which require water supply, but most of which lie above the present irrigated areas and would require a higher line canal to serve them. To reach these lands it has been proposed to take a canal from the Laguna Dam of the United States Reclamation Service above Yuma and carry it on proper hydraulic grade line into the Imperial Valley. This would cover large additional area, but its construction is very expensive. On the line topographically most advantageous it would pass through Mexico, but even this line would require much heavy cutting through the intervening ridge in order to reach the necessary elevation, and it is thought that a line on American soil is not much more expensive, although that on Mexican soil has never been closely examined or estimated.

The report of the All-American Canal Board, published in 1920, contains detailed description of the problem of the high-line canal, together with plan and profile and estimates of cost. These estimates will be subject to revision when construction is undertaken on account of the rapidly fluctuating industrial and commercial conditions since the report was written. The report and its appendices contain much information, which it is not necessary to duplicate here and to which reference is made.

REQUIREMENT FOR STORAGE.

A proposition has been broached for developing the additional areas on the lower Colorado River from the natural flow of the stream without any provision for storage, and this, of course, would be desirable if the water supply were sufficient. On the other hand, the development of additional acreage without adequate water supply in all years would be productive of heavy losses and would produce much human suffering and bitter criticism.

Fortunately, enough experience has been obtained in the past 20 years to shed much light upon the flow of the river, the duty of water, and the other uncertainties which attend the determination of this question.

The years 1902, 1903, and 1915 were years of low-water flow, the first two being about the time of the beginning of irrigation in the lower valleys and the third when this had proceeded to a substantial degree.

In 1915 the management of the Imperial irrigation canal reported that for considerable periods the waters of the Colorado River were

all, or practically all, diverted at the intake of that canal and applied in irrigation of the Imperial Valley, with the result that an actual shortage existed there part of the time. The shortage was not severe nor disastrous, but it has a high value as indicating the actual requirements for water in the Imperial Valley.

Since 1915 no such low year has occurred, but there has been a progressive development from the Colorado River on the various projects receiving water therefrom.

The Imperial Valley has increased its irrigated area over 60,000 acres in the United States and in Mexico about 150,000 acres. Both of these areas are susceptible of considerable increase. The Imperial irrigation district can increase its irrigated area more than 100,000 acres and the same valley in Mexico can increase over 40,000 acres and is in a physical position to take the necessary water.

The Yuma project has increased its irrigated area since 1915 about 26,000 acres and has a recognized right to extend up to a limit of 120,000 acres.

The Palo Verde Valley has increased its irrigated acreage since 1915 by about 30,000 acres, is in physical position to increase this up to the limit of 79,000 acres, and has the same right to do so that Imperial Valley has to increase its use.

Two Government projects in Colorado, taking water from the Colorado River drainage, have increased their areas since 1915 about 30,000 acres and have established rights by which these can be further increased by over 50,000 acres.

In addition to the above, there has been increased irrigation in the Uinta and Spanish Fork Basins in Utah and at numerous other points, most of which are either small in amount or only partially known at present but which aggregate a considerable amount and will reduce the water supply of the lower basin by a substantial amount. These may be taken as roughly offsetting the practicable improvements in duty of water in the Imperial Valley.

Assembling the more important of the above data, we have the following table showing increase over 1915.

Project.	Irrigated.		
	1915	1920	Ultimate.
Imperial district	336,000	400,000	515,000
Mexico	40,000	190,000	(?)
Yuma	28,000	54,000	120,000
Palo Verde	20,000	50,000	79,000
Grand Valley project	.....	13,000	53,000
Uncompahgre project	50,000	70,000	110,000
Total	474,000	777,000	.....

This indicates that the increased irrigation in the basin in 1920 over 1915 is about 300,000 acres, or nearly as much as was irrigated in the Imperial Valley in 1915, and that the desired expansion in the Imperial irrigation district and incontestible or unpreventable expansion in other regions will bring this acreage up to 877,000 acres, or about 400,000 acres more than in 1915.

In addition to this, there are large areas in the Colorado River Reservation, the Mohave Valley, and at some other points where

development has been undertaken, or is likely to be undertaken in the near future, and which should be taken into account. Not including this, however, the above data are certainly convincing that no large area, such as the East Mesa lands and Coachella Valley, can be added to the irrigated acreage without certainty of water shortage and a serious menace to the water supply of the Imperial Valley and the Yuma projects, unless a large amount of storage is provided. For the full development of all the lands that can be reached by gravity and reasonable pumping lifts from the lower Colorado River, large storage capacity will be required, estimated at about 10,000,000 acre-feet, if provided by a reservoir below the Grand Canyon in the Colorado. This must be increased by at least 2,000,000 acre-feet if the storage is provided above the canyon on account of the unavoidable losses due to the impossibility of regulating the flow in exact accordance with the needs of irrigation from a reservoir so far distant, and for other reasons. This capacity can be somewhat reduced if the acreage is reduced by cutting off the more doubtful and less desirable areas which have been included.

Studies of the water supply are to be found in Appendix C.

CONTROL OF FLOODS.

Owing to the gradual upbuilding of its deltaic bed and banks, the flood menace from the Colorado River is an increasing and ever-recurring problem of great importance.

The Gulf of California formerly extended northwestward to a point a few miles above the town of Indio, about 144 miles from the present head of the gulf. The Colorado River, emptying into the gulf a short distance south of the international boundary, carried its heavy load of silt into the gulf for centuries, gradually building up a great delta cone entirely across the gulf and cutting off its northern end, which remains as a great depression from which most of the water has been evaporated, leaving in its bottom the Salton Sea of 300 square miles, with its surface about 250 feet below sea level.

The river flowing over its delta cone steadily deposits silt in its channel and by overflow on its immediate banks, so that it gradually builds up its channel and its banks and forms a ridge growing higher and higher until the stream becomes so unstable that it breaks its banks in the high-water period and follows some other course. In this manner the stream has in past centuries swung back and forth over its delta, until this exists as a broad flat ridge between the gulf and the Salton Sea, about 30 feet above sea level, and on the summit of this has formed a small lake called Volcano Lake, into which the river flows at present, the water then finding its way to the southward into the gulf.

The direct distance from Andrade on the Colorado River, where it reaches Mexico, to the head of the gulf is about 75 miles, and the distance to the margin of Salton Sea is but little more. As the latter is about 250 feet lower than the gulf, the strong tendency to flow in that direction needs no demonstration. This, coupled with the inevitable necessity for such an alluvial stream to leave its channel at intervals, constitutes the menace of the lands lying about Salton Sea, called the Imperial Valley. As there is no escape of water from Salton Sea except by evaporation, the river flowing into this sea

would, unless diverted, gradually fill it to sea level or above and submerge the cultivated land and the towns of Imperial Valley, nearly all of which are below sea level. Any flood waters that overflow the bank to the north must therefore without fail be restrained and not allowed to flow northward into Salton Sea. This is now prevented by a large levee, north of Volcano Lake, extending eastward and connecting with high land near Andrade. This levee is in Mexico and its maintenance is complicated thereby.

In 1905 the river scoured out the channel of the Imperial Canal and turned its entire volume into the Salton Basin, eroding a deep gorge and raising the level of Salton Sea. It submerged the salt works and forced the removal of the main line of the Southern Pacific Railroad. At great difficulty and expense, after several unsuccessful attempts, the river was returned to its old channel in February, 1907. The control of the river would be greatly facilitated if the floods were reduced in volume by storage. Investigations have been made concerning the feasibility of storing the floods and reducing their volume to an amount easily controlled.

The floods divide themselves naturally into two general classes—those from the Colorado River, which drains large areas in Wyoming, Colorado, New Mexico, Nevada, and Arizona, and those from the Gila, which lies mostly in Arizona and partly in New Mexico and Mexico. While the area drained is much larger for the Colorado than for the Gila and the water supply vastly greater, the habits of flow are such that the Gila River, owing to its flashy character, sometimes furnishes flood waves at its mouth near Yuma almost as large as the maximum discharge of the Colorado at the same point. These floods from the Gila, however, are infrequent and of relatively short duration. While their sudden character and erratic occurrence make them peculiarly menacing to the levees or other property on the banks of the river, they do not present so great a menace to the Imperial Valley on account of their short duration and relatively small volume. The Colorado River rises very gradually, carries a large volume of water for several weeks, and declines gradually. Should it break into the Imperial Valley at time of flood, the long duration of high water would cause great erosion and render its control exceedingly difficult. This is the experience actually obtained when this occurred. The Gila, on the other hand, might break into the Imperial Valley but the relatively short duration would not furnish nearly so much water to the Salton Sea, and consequently not incur the danger of submerging the entire valley. The quick decline would make its control comparatively easy. The great floods of the Gila occur in the winter, while those of the Colorado occur in summer. So far as known, they never have coincided; but if this ever should occur, it would greatly increase the menace.

A reservoir site of 2,200,000 acre-feet capacity has been investigated near Sentinel, on the lower Gila, which if built and maintained would practically eliminate the menace from the floods of the Gila, but the investigations show such poor conditions for foundation and abutments that the feasibility of this reservoir is subject to grave doubt.

The control of the Colorado River proper is, however, the main element involved, for the reasons above stated, and this has been investigated extensively.

Possible reservoir sites have been found on the Grand and the Green Rivers which, if constructed and operated for the purpose of flood protection, would greatly reduce the volume of the floods, for though the areas intercepted by each are small compared with the total area of the Colorado River Basin, they drain mountains with high precipitation that furnish a relatively large volume of water. A reservoir site also exists on the San Juan River, which is the next tributary of importance, but the feasibility of this has not been determined.

The total area drained by the Colorado River is 251,000 square miles. Of this, 96,000 is drained by the Grand, the Green, and the San Juan, which, though draining less than two-fifths of the total area, furnish approximately 84 per cent of the total water supply. There would still, however, be nearly 100,000 square miles below these rivers, exclusive of the Gila, which would be uncontrolled by such reservoirs. These areas, though furnishing a relatively small quantity of water, owing to their aridity, are yet of such extent and declivity that they furnish occasional floods of magnitude from direct precipitation, due to which their control is important from the standpoint of the flood menace.

In the study of this problem it was demonstrated that for several reasons it is desirable to have a reservoir below the Grand Canyon of the Colorado which would intercept most of the drainage of the Colorado River and therefore be a more complete solution of the flood-control problem. Such reservoir would also be more valuable in the irrigation of the lands on the lower river on account of its greater proximity to them and the consequent possibility of regulating its flow more nearly in accordance with the fluctuating needs. Incidentally, it would furnish a large amount of power.

For these reasons a reservoir site has been surveyed in the Boulder Canyon on the northern boundary of Arizona, below the mouth of the Virgin River. The surveys show a basin of large capacity providing a high dam is constructed, but investigations so far have not shown favorable foundation conditions. These investigations are still in progress and it has been impossible to complete them in time for the incorporation of an estimate in this report approximating the cost of storage at this point. This report, therefore, will deal with the storage of water in the upper basin, which has heretofore been the plan and which is known to be feasible, as well as the plan for storage below, which is more desirable if feasible. A study of the water supply and methods of controlling it will be found in Appendix C.

The most feasible reservoir sites on the upper river and tributaries yet explored are the following:

Reservoir site.	Stream.	Height of water surface above river.	Capacity.
		Feet.	*Acre-feet.*
Flaming Gorge	Green River	230	3,120,000
Juniper	Yampa River	200	1,500,000
Dewey	Grand River	215	2,270,000
Total			6,890,000

In all these cases bedrock has been found at reasonable depth and data exist for making preliminary estimates of the cost of the necessary structures. The storage capacity furnished by these reservoirs would be sufficient for the additional lands immediately adjacent to Imperial Valley, with which the present studies have been most concerned, but would not be sufficient for all the lands in Mexico that could be irrigated.

Capacity table—Boulder Canyon Reservoir.

[Computed from original plane-table sheets; scale, 2 inches equals 1 mile.]

Contour elevation.	Area.	Capacity.	Contour elevation.	Area.	Capacity.
	Acres.	*Acre-feet.*		*Acres.*	*Acre-feet.*
700	.....	.....	1,050	53,160	7,130,500
750	2,350	58,750	1,100	67,740	10,153,000
800	7,950	316,250	1,150	84,110	13,949,250
850	15,260	846,500	1,200	105,100	18,679,500
900	21,620	1,818,500	1,250	127,660	24,498,500
950	29,160	3,088,000	1,260	131,000	26,000,000
1,000	39,690	4,609,250			

NOTE.—The canyon walls extend up to above the 2,000-foot contour, or about 800 feet higher than the last one for which capacity is calculated.

CANAL LINES.

The proposed canal systems for the Imperial district and adjacent lands are described in detail in Appendix E. The principal channel proposed is a high line All-American Canal from Laguna Dam at elevation 153 to and across Imperial Valley, a distance of 75 miles.

All the canals are designed with a mean velocity of from 2.5 to 3 feet per second and with carrying capacity of 1 second foot for 85 acres.

The "A" line canal heads at a point on the high line All-American Canal, 39 miles from Laguna Dam, and runs along the easterly edge of Imperial Valley and Salton Basin to and around the Coachella Valley, a distance of 139 miles. This canal, with the auxiliary "E" line, would irrigate 202,000 acres by gravity. Diversions from the south side of the All-American Canal would irrigate 30,000 acres of mesa land in the United States and Mexico. The higher lands of the east mesa, comprising 33,000 acres, will be supplied by the "D" line, 17.5 miles long. For this canal a pumping plant with a 30-foot lift is required at the 31-mile point of the All-American high-line canal. A pumping plant near Indio with a lift of about 60 feet will irrigate approximately 10,000 acres of the higher lands of Coachella Valley.

For the west side mesa, the "B" line runs from the end of the All-American high-line canal to a point opposite the south end of Superstition Mountain, a distance of 21 miles, and irrigates approximately 10,000 acres. In addition, a pumping plant with about 120 feet lift will irrigate 30,000 acres of good land lying to the west of Superstition Mountain. The "B" canal is designed large enough to supply all lands now under the west main canal, amounting to 21,300 acres, together with the extensions and the west mesa pump lands.

The canal systems for projects above Laguna Dam have been surveyed and preliminary estimates of cost made by engineers employed by the various districts.

No branch canal lines were surveyed for Mexican lands. The lands in Lower California would probably be best supplied by extensions from the Imperial Canal as constructed, and those in Sonora by enlargement and extension of the main canal of the Yuma project.

CONCLUSION.

In case the Boulder Canyon Reservoir does not prove feasible, or for any reason is not constructed, the solution of the problems of irrigation under discussion can best be reached by the construction of the following works:

Preliminary estimate.

Dewey Reservoir on Grand River	$11,160,000
Main High Line Canal from Laguna Dam	29,470,000
Canal "A" and "E," East Side Canals	6,166,000
Power plant No. 1, on main canal	1,232,000
Power plant No. 2	1,633,000
Canal "B," West Side Canal	1,570,000
Canal "D" to pump from main canal East Mesa	574,000
Canal "R" for West Mesa pumping	1,400,000
Canal "C" for Coachella pumping	400,000
Lateral systems in Imperial Valley, $20 per acre	5,860,000
Parker project	7,804,000
Total	67,269,000

The above will furnish a dependable water supply to the following lands:

Status of lands in United States.

Tract.	Irrigable area.						
	Private.	Entered.	Public.	Indian.	State.	Southern Pacific R. R.	Total.
Parker project	.....	.....	.....	110,000	.....	.....	110,000
Palo Verde Valley	72,000	6,600	.....	.....	.....	.....	78,600
Yuma project	62,000	19,000	38,200	9,000	1,800	.....	130,000
Imperial irrigation district	515,000	.....	.....	.....	.....	.....	515,000
Imperial Valley extensions:							
East Side Mesa	1,070	970	139,830	.....	7,570	3,560	153,000
Dos Palmas	370	2,800	1,280	.....	550	5,000	10,000
Coachella Valley	15,490	4,610	5,190	12,750	5,580	46,380	90,000
West Side	800	11,320	19,530	120	2,240	5,990	40,000
Total in United States	666,730	45,300	204,030	131,870	17,740	60,930	1,126,600

If all possible development on the upper river and its tributaries is ever carried out and storage in Dewey Reservoir only is provided, it would cause a moderate shortage of water for the above lands in two years out of twenty-one, according to past records, if all the lands listed participate. This is so far in the future and involves so many doubts of its realization that it would not be wise to make all storage provisions at present that would prevent it, but it would be wiser to construct more storage when the need develops, if it ever

does. The contracts for water should provide for this contingency, however.

The authorities which should finance this undertaking and the areas pertaining to each are as follows:

	Irrigable area.
American lands:	
United States public lands	204,030
United States Indian lands	131,870
Arizona State lands	1,800
California State lands	15,940
Imperial irrigation district	515,000
Palo Verde irrigation district	78,600
Yuma project	81,000
Coachella Valley County water district	66,480
Southern Pacific R. R. (outside organized districts)	8,560
West Side irrigation district	18,100
Private lands in unorganized districts	5,210
Total American	1,126,600
Mexican lands:	
Under Imperial Canal—	
Compania de Terrenos y Aguas de la Baja California (Lower California Land & Water Co.)	54,000
Small tracts, private owners	8,000
International Co	9,000
Imperial Development Co	11,000
E. Easton	11,000
Colorado River Land Co	176,000
Government land	6,000
Total	275,000
Under All-American Canal:	
Compania de Terrenos y Aguas de la Baja California (Lower California Land & Water Co.)	2,000
Government land	28,000
Total	30,000
Total Mexican	305,000
Grand total	1,431,600

The above areas should be assessed for construction purposes in proportion to benefits to be hereafter determined by the Secretary of the Interior after due notice and full hearing of all interested parties. Any which refuse to contribute should be excluded from benefits as far as possible.

As the Colorado River is legally a navigable stream, Congress has exclusive jurisdiction over its waters. Any legislation authorizing their use in irrigation should be conditioned upon payment of an equitable share in the costs of development. Participation in benefits by Mexican lands should require equitable participation in expenses and satisfactory arrangements with the Mexican Government for the construction and maintenance of flood-protection works on Mexican soil.

APPENDIX A.

AN ACT To provide for an examination and report on the condition and possible irrigation development of the Imperial Valley in California. (41 Stat., 600.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior is hereby authorized and directed to have an examination made of the Imperial Valley in the State of California, with a view of determining the area, location, and general character of the public and privately owned unirrigated lands in said valley which can be irrigated at a reasonable cost, and the character, extent, and cost of an irrigation system, or of the modification, improvement, enlargement, and extension of the present system, adequate and dependable for the irrigation of the present irrigated area in the said valley, and of the public and privately owned lands in said valley and adjacent thereto not now under irrigation which can be irrigated at a reasonable cost from known sources of water supply by diversion of water from the Colorado River at Laguna Dam.

SEC. 2. That the said Secretary shall report to Congress not later than the 6th day of December, 1920, the result of his examination, together with his recommendation as to the feasibility, necessity, and advisability of the undertaking or the participation by the United States, in a plan of irrigation development with a view of placing under irrigation the remaining unirrigated public and privately owned lands in said valley and adjacent thereto, in connection with the modification, improvement, enlargement, and extension of the present irrigation systems of the said valley.

SEC. 3. That the said Secretary shall report in detail as to the character and estimated cost of the plan or plans on which he may report, and if the said plan or plans shall include storage, the location, character, and cost of said storage, and the effect on the irrigation development of the other sections or localities of the storage recommended and the use of the stored water in the Imperial Valley and adjacent lands.

SEC. 4. That the said Secretary shall also report as to the extent, if any, to which, in his opinion, the United States should contribute to the cost of carrying out the plan or plans which he may propose; the approximate proportion of the total cost that should be borne by the various irrigation districts or associations or other public or private agencies now organized or which may be organized; and the manner in which their contribution should be made; also to what extent and in what manner the United States should control, operate, or supervise the carrying out of the plan proposed, and what assurances he has been able to secure as to the approval of, participation in, and contribution to the plan or plans proposed by the various contributing agencies.

SEC. 5. That, for the purpose of enabling the Secretary of the Interior to pay not to exceed one-half of the cost of the examination and report herein provided for, there is hereby authorized to be appropriated the sum of $20,000: *Provided*, That no expenditure shall be made or obligation incurred hereunder by the Secretary of the Interior until provision shall have been made for the payment of at least one-half the cost of the examination and report herein provided for by associations and agencies interested in the irrigation of the lands of the Imperial Valley.

Approved, May 18, 1920.

Appendix B.

In order to comply with section 4 of the act, the following letter was addressed to the Imperial Irrigation District and similar letters to the other interests involved:

Washington, D. C., *November 11, 1920.*

Imperial Irrigation District,
El Centro, Calif.

Gentlemen: In connection with the investigations required by the Kinkaid Act we have now under way the making of the necessary surveys, borings, examinations, and studies required for the report, and so far as these are available they will be reported to Congress in accordance with the above act on the 6th of December. The one question that has not yet been covered is required by section 4, as follows:

> What assurances he (the Secretary of the Interior) has been able to secure as to the approval of, participation in, and contribution to the plan or plans proposed by the various contributing agencies.

In general the character of report which I expect to make and which I hope the Secretary and Congress will approve, is that we should undertake to irrigate all of the American lands that can be feasibly irrigated by gravity and reasonable pumping lifts, and that this should be the primary use of the waters of the Colorado. Secondarily, we should develop as much power as can be done without seriously interfering with the primary use of the water above stated.

The principles to be followed in the distribution of the power are, as I take it, that each shall have preference in the following order: First, the pumping of Colorado River water for irrigation; second, the local needs of the municipalities irrigated from Colorado River water; third, use by other municipalities; and fourth, disposal to private interests for pumping or other uses. This means that the various irrigation districts should have first preference for such power as they need for pumping and municipal use; second, that municipalities like the city of Los Angeles, San Diego, or any other towns that can be reached by the lines of the system should be served to the extent that they desire, and anything that is left over after this should be disposed of to railroads or any other customer that can be reached.

The general principle I doubt not will be that all interests will contribute in proportion to benefits as nearly as these can be determined, the United States standing the proper proportion for the public lands served and each of the districts standing the requisite assessment in proportion to benefits rendered it. This will involve some difficult determinations of relative benefits, such as the relative values of water for power and for irrigation and the benefits of flood control, and these problems will not be easy to solve. The general discussion of the subject held in San Diego, I believe you will recall, was to the effect that the Secretary of the Interior was to be designated as the arbiter concerning such matters, and his opinion as to the proportion the United States should bear is required by the Kinkaid Act.

The general application of this principle is not insisted upon and should not be if any better method can be suggested. On these points we would like to have the opinion of your district and eventually have something in writing which I can quote in my report expressing the desire of your district for participation in the power development, if you have such desire, of course, accompanied by the expression of your willingness to participate in the expenses of construction.

I am starting west and will spend some weeks in the study of the Colorado River problem, preparing the report required by Congress on the 6th of December. My address will be Yuma, Ariz., and I should like to hear from you at that point as to whether the above principles are satisfactory and whether or not your district will contribute its proportion on this basis.

Very truly, yours, A. P. DAVIS, *Director.*

Several replies to the above have been received, as follows:

IMPERIAL IRRIGATION DISTRICT,
El Centro, Calif., November 23, 1920.

Mr. ARTHUR P. DAVIS,
Director United States Reclamation Service,
Washington, D. C.

DEAR SIR: We have your favor of November 11, 1920, advising that the Secretary of the Interior will, in accordance with the terms of the Kinkaid Act, report to Congress on December 6th next the result of the investigations required by the act, and will recommend a definite plan of construction procedure adequate to meet the needs of Imperial Valley.

We are gratified, indeed, by the progress made by your department in the prosecution of necessary surveys and investigations required to be made in order that Congress may be fully advised as to the scope, feasibility, and immediate necessity for the construction of works on the lower Colorado River outlined in the bill introduced at the last session of Congress known as H. R. 11553, and we have the greatest confidence that the effect of your work in this connection and your report on existing conditions will result in the present formulation of a feasible plan for the safeguarding and proper development of the Imperial Valley and adjacent lands, which will be authorized by necessary congressional action.

You state,

> In general, the character of report which I expect to make, and which I hope the Secretary and Congress will approve, is that we should undertake to irrigate all of the American lands that can be feasibly irrigated by gravity and reasonable pumping lifts, and that this should be the primary use of the waters of the Colorado. Secondarily, we should develop as much power as can be done without seriously interfering with the primary use of the water above stated.

With this general statement of plan to be advocated we heartily concur.

Your letter points out that the report to Congress must disclose—

> "What assurances he (the Secretary of the Interior) has been able to secure as to the approval of, participation in, and contribution to the plan or plans proposed by the various contributing agencies."

We feel that the general plan covered in the report and recommendations soon to be submitted by you to the Secretary of the Interior and by him to Congress very largely results from the long-continued efforts of the people of Imperial Valley, acting through the Imperial Irrigation District, to safeguard our property and improve and stabilize conditions affecting the right of our people to the continued and sufficient use of the waters of the Colorado for irrigation purposes. We therefore state unreservedly that we approve of the plan of work and policy to be adopted, as stated in paragraph 3 of your letter, and will, when lawfully authorized so to do, participate ratably and equitably in the cost thereof, as the same may be hereafter properly determined.

At the meeting held in San Diego, Calif., August 2 last, which was called primarily for the purpose of securing an expression of views of owners of lands tributary to the flow of the Colorado River in order to determine how large an area would participate in the investigations contemplated and in the cost of works found to be feasible, a discussion of "power development" and an offer of "participation in cost and interest in proportion to benefits received" was developed by some of those present who were not landowners adjacent to the Colorado River along lines in which we do not concur.

We hold that it is necessary to build a storage dam at Boulder Canyon site for the purpose fundamentally of impounding and controlling a sufficient amount of water to permanently and adequately irrigate all lands below that point, both public and private, which are susceptible of economic reclamation by the use of such waters. The storage of such waters and their daily discharge under control will very largely decrease the element of danger of loss to lands resulting from flood and overflow waters of the Colorado River, and hence is to be reckoned as an additional benefit accuring to lands irrigated from storage.

Some lands, by reason of location with respect to the channel of the Colorado River, will be benefited more than others by the lessening of the danger of flood and overflow just as other lands which are not now irrigated may be more greatly benefited by storage and the development of a supply of water for irrigation purposes. These and similar questions which should determine the cost per acre to be paid by lands benefiting by works to be undertaken on the lower Colorado River should be arbitrated and acreage charges fixed by the Secretary of the Interior. The Government of the United States should contribute in proportion to benefits so derived to the extent of its public lands served by such works.

If it is found to be possible and expedient to develop hydroelectric power at the storage-dam site without seriously interfering with the primary use of the structure for storage and flood-control purposes, such power should be regarded as a by-product belonging to the lands which pay for the construction of the works, and the proceeds derived from the sale of such by-product should be applied to the reduction of cost charges to be paid by the owners of the lands contributing thereto. We believe that all matters relative to the sale and disposition of power may under this theory be properly left for determination to the Secretary of the Interior or other governmental department or agency which shall have the administrative charge of the property.

However, since the investigation of the Boulder Canyon storage-dam site has not yet been completed, and it can not now be determined whether such site will be found to be feasible, nor to what extent it can be utilized for the development of hydroelectric power, it seems to us that it would be extremely difficult at this time to consider or determine the relative proportions of the total cost which might properly be assigned to storage, flood control, and power development.

Until the investigations are completed and cost estimates based thereon submitted to the different irrigation districts now cooperating under the terms of the Kinkaid Act so that they may be examined and an approximation made of the acreage charges necessary to cover the cost of the proposed works, it would be impossible for us to decide whether or not we can cooperate in power development.

We would prefer, then, that the investigations be continued to completion at the expense of the irrigation districts now contributing, and that the matter of the nature and extent of participation to be guaranteed by the several districts affected be thereafter considered and determined.

In our judgment, Mr. Davis, it is more vitally necessary now than ever before that a definite plan for development of the lower Colorado River Basin must be decided upon, and that Congress must assist by appropriate legislative action in the accomplishment of the work, if disaster to our valley is to be averted. You know personally and officially the elements of hazard, uncertainty, and extreme danger in our situation which will not permit of longer delay in dealing with the situation in a broad and permanent way.

We trust that the work now in progress will be prosecuted as rapidly as possible and that you will soon be able to report definitely upon the feasibility of the Boulder Canyon Dam, and that a bill may be framed to give full force and effect to the recommendations contained in the Secretary's report to Congress.

Respectfully submitted.

By order of the board of directors.

J. S. NICKERSON, *President.*

DEPARTMENT OF PUBLIC SERVICE
OF THE CITY OF LOS ANGELES,
November 22, 1920.

Hon. ARTHUR P. DAVIS,
Care United States Reclamation Service, Yuma, Ariz.

MY DEAR MR. DAVIS: I have your letter of the 11th instant in reference to proposed developments on the Colorado River, and in reply beg to say:

The principles outlined by you to govern participation and order of preference, appear to me sound and reasonable.

The city of Los Angeles, I am convinced, would be willing to participate in the expenses of power development.

Furthermore, I am equally confident that the city of Los Angeles would undertake special financing on a large scale, for the power project, under conditions prescribed by the Government, protecting the Government, the city, and other participants. This plan would

probably be in the interest of an early commencement and completion of the work.

Later, when you shall require it, a formal statement will, doubtless, be issued by the proper authorities defining the attitude of Los Angeles upon such power project.[1]

I should add that Mr. W. B. Mathews, special counsel of the Los Angeles Department of Public Service, with whom I have been conferring on the above matters, fully concurs in the views here expressed.

Very truly yours,

WM. MULHOLLAND,
Chief Engineer.

COACHELLA VALLEY COUNTY WATER DISTRICT
OF RIVERSIDE COUNTY,
Coachella, Calif., November 23, 1920.

Hon. ARTHUR P. DAVIS,
Director United States Reclamation Service,
Yuma, Ariz.

DEAR SIR: Your favor of November 11, in which you outline the general principles under which you propose to distribute the costs and benefits in carrying out the project to be considered in your report to Congress under the Kinkaid Act, has been received, and has been under discussion by this board upon several occasions.

This district board is in accord with and indorses the general principles as therein outlined by you, and wishes to state that it is desirous of participating in the project as a whole, provided, however—

First. That the final report shows that it will be practical from an engineering and economic standpoint to this district.

Second. That there be a fair, just and equitable distribution of the costs of the entire project.

This district board wishes to express itself as being in harmony with the idea that has been expressed by numerous organizations and bodies relative to having the Secretary of the Interior act as a final arbiter when the question of the distribution of costs and benefits will be considered.

Thanking you for your courtesy in this matter, and assuring you of our sincere desire to cooperate in working out the problems under consideration, we are,

Yours, very truly,

COACHELLA VALLEY COUNTY WATER DISTRICT.
By S. S. M. JENNINGS, *President.*

PALO VERDE JOINT LEVEE DISTRICT,
Blythe, Calif., November 27, 1920.

Mr. ARTHUR P. DAVIS,
Director United States Reclamation Service,
Yuma, Ariz.

DEAR SIR: Replying to your letter of November 11, I respectfully submit the following:

I have ascertained the opinion of the people of the Palo Verde Valley to an extent that enables me to assure you that if the investi-

[1] Page 28.

gations and surveys now being made at Boulder Canyon prove the feasibility of the construction of a reservoir at that place of sufficient capacity to control the flood waters of the Colorado River and to furnish water to all irrigable lands lying below that point, at a cost consistent to the benefits that should be derived by the construction of said reservoir, that the district will participate in the cost thereof to an extent compatible to the benefits that should be derived therefrom.

We feel that the primal motive for the dam's construction should be the reclamation of all lands that can be profitably irrigated below the Boulder Canyon site, both by gravity flow and where practicable by pump lift and that provided Mexico desires to participate in the costs of the undertaking, provisions be made to meet her requirements.

We believe that the development of hydroelectric power at the proposed reservoir is essential to the economical consummation of the great undertaking; that the revenue derived from the sale of this electric power should greatly lessen the burden that must be carried by the various districts participating in the work.

We believe that this power should be owned by and operated for the benefit of the districts, and we favor your plan of distribution as outlined in paragraph 4 of your letter.

We feel that in the development of hydroelectric power the fundamental object of the proposed reservoir's construction should never be lost sight of; that regardless of the desirability of maximum power production, the water level in the reservoir should be held at such levels as will at all times control the flood water and will provide adequate irrigation water during years of low-water run-off.

Paragraph 5 of your letter meets with our hearty approval.

We are greatly pleased by the progress that has been made by your department in the great undertaking, and deeply appreciate your personal interest and untiring efforts in the work.

Yours, very respectfully,

ED. F. WILLIAMS,
President.
W. J. BURTON,
President of the Palo Verde Mutual Water Co.

OFFICES OF YUMA COUNTY WATER USERS' ASSOCIATION,
Yuma, Ariz., November 29, 1920.

At a meeting of the board of governors, on motion of Gov. Johnson, seconded by Gov. Morrell, it was unanimously resolved that—

Whereas the Secretary of the Interior, under the provisions of the Kinkaid Act of May 18, 1920 (Public No. 208, 66th Cong.), has undertaken certain investigations to determine the feasibility of a storage dam in Boulder Canyon on the Colorado River for the storage of irrigation waters and the development of hydroelectric power for the use of irrigable lands adjacent to said river in the States of Arizona and California; and

Whereas Hon. A. P. Davis, Director of United States Reclamation Service, has, under date of November 12, 1920, directed the attention of the association to the provisions of said act, setting forth

his views of the general principles which should govern such construction and the manner of procuring funds therefor, and requesting that this association express its opinion thereon, and whether or not it desires to participate in the power to be developed as the result of such construction, and if it desires to contribute to the expenses of the construction: Therefore, it is

Resolved, That Yuma County Water Users' Association is heartily in favor of such construction and development, and desires to participate in the use, ownership, and control of the distribution of the power to be developed as the result of such construction; and, subject to the consent and approval of its constituent members, properly and timely expressed, the said association is willing to contribute ratably and equitably to the expense of such construction, as it shall hereafter be properly and timely determined, this board being of the opinion that such consent and approval of said constituent members can be easily and readily procured.

[SEAL.] A. Y. GREER, *President.*

Attest:

H. L. BELTZHOOVER, *Secretary.*

DEPARTMENT OF PUBLIC SERVICE
OF THE CITY OF LOS ANGELES,
645 SOUTH OLIVE STREET,
December 16, 1920.

Hon. ARTHUR P. DAVIS,
Director United States Reclamation Service,
Washington, D. C.

SIR: The city of Los Angeles is deeply interested in your investigation of the subject of water and power development on the Colorado River, regarding it as a matter directly and vitally affecting, in its possibilities, the prosperity and welfare of California and the whole Southwest.

The officials and the people of Los Angeles will, we are confident, specially welcome the opportunity to participate with other cities, districts, and communities in the cost of power development on the Colorado, under a plan or policy established by the United States Government.

Moreover, we firmly believe that the people of Los Angeles would authorize the city to undertake the financing of a major power project on that river, under conditions prescribed by the Government, assuring the city of a share in the power commensurate with its investment, and, at the same time, reserving the privilege for other communities to become participants in the benefits of such development,

Very truly yours,

MEREDITH P. SNYDER,
Mayor.
HOWARD ROBERTSON,
President of Board of Public Service Commissioners.
WM. MULHOLLAND,
Chief Engineer of Water Works.
E. F. SCATTERGOOD,
Chief Electrical Engineer.

APPENDIX C.

WATER SUPPLY AND DEVELOPMENT.[1]

COLORADO BASIN.

1. The Colorado Basin is estimated to contain a total of almost 5,000,000 acres of irrigable land, of which about one-third was irrigated in 1915, which year furnishes the latest authentic data for the entire basin. Since then possibly 500,000 acres more have been reclaimed and in general all parts of the basin have reached a stage where storage is necessary for further increase, although at present storage development is negligible.

2. The total area of the basin is 251,000 square miles divided between States and between Mexico and the United States, as follows:

TABLE No. 1.

	Square miles.
Wyoming	18,000
Colorado	39,000
New Mexico	23,000
Arizona	113,000
Utah	40,000
Nevada	12,000
California	4,000
Total, United States	249,000
Total, Mexico	2,000
	251,000

3. Its main tributaries occupy the following areas:

TABLE No. 2.

	Square miles.
Green River	44,000
Grand River	26,000
San Juan River	26,000
Fremont	4,600
Paria	1,400
Escalante	1,800
Kanab	2,200
Little Colorado	26,000
Virgin	51,000
Miscellaneous	11,000
Gila	57,000
	251,000

Area:

(*a*) Green, Grand, and San Juan	96,000
(*b*) Above Boulder Canyon and below mouth of San Juan River	93,000
(*c*) Above Gila and below Boulder Canyon	5,000

[1] Study by Harold Conkling, engineer.

TABLE No. 3.—*Average discharges.*

	Per cent of total discharge.	Discharge in acre-feet.	Square miles.	Per cent of total square miles.	Acre-feet per square mile.
Green River	32	5,510,000	44,000	18	125
Grand River	40	6,940,000	26,000	10	267
San Juan River	14	2,350,000	26,000	10	90
Other areas except Gila	8	1,560,000	98,000	39	16
Gila	6	1,070,000	57,000	23	19
Total	100	17,430,000	251,000	100	70

While technically the drainage area is as given, yet a large part has a climate so arid that it contributes practically no water. All the area in Mexico and California and a large part of that in Arizona is of such character.

4. In discussing the Colorado Basin it is convenient to divide it into three parts. The Gila River enters the Colorado so far down and its flow is so flashy that it can not be used for irrigation of lands along the Colorado. Therefore the Gila Basin may be excluded from a discussion of the Colorado except in discussing flood protection. The Colorado itself is conveniently divided into the Upper and Lower Basins. The former designates all that portion lying above Boulder Canyon and the latter all that below. In the former practically all irrigation is on tributaries; in the latter, on the main river and Imperial and Gila Valleys.

TABLE No. 4.—*Upper basin—Acreage irrigated and irrigable in future—Summary by river basins.*

	Irrigated, 1915.	Additional possible to irrigate.	Total.
	Acres.	*Acres.*	*Acres.*
Green River Basin—Wyoming, Utah, and Colorado	662,000	921,000	1,583,000
Grand River Basin—Colorado	297,000	293,000	590,000
San Juan Basin—New Mexico	107,000	250,000	357,000
Fremont River Basin—Utah	15,000	40,000	55,000
Escalante River Basin—Utah	2,000	12,000	14,000
Paria River Basin—Utah	2,000	10,000	12,000
Little Colorado River Basin—Arizona	20,000	40,000	60,000
Kanab Creek—Arizona	2,000	2,000	4,000
Virgin River—Utah, Arizona, and Nevada	25,000	50,000	75,000
Total	1,132,000	1,618,000	2,750,000

TABLE No. 5.—*Irrigable area—Lower Colorado River.*

Tract.	Gravity.	Pump.	Total.
United States:			
Above Laguna Dam—	*Acres.*	*Acres.*	*Acres.*
Cottonwood Island, Nev. and Calif.	1,000	3,000	4,000
Mohave Valley, Ariz.	24,000	3,000	27,000
Chemehuevis Valley, Calif.	4,000	.....	4,000
Parker project, Ariz.	104,000	6,000	110,000
Palo Verde Valley, Calif.	78,000	.....	78,000
Palo Verde Mesa, Calif.	.....	18,000	18,000
Chucawalla Valley, Calif.	.....	44,000	44,000
Gibola Valley, Ariz.	16,000	.....	16,000
Isolated tracts, Arizona	1,000	2,000	3,000
Total above Laguna Dam	228,000	76,000	304,000

TABLE No. 5.—*Irrigable area—Lower Colorado River*—Continued.

Tract.	Gravity.	Pump.	Total.
United States—Continued.	*Acres.*	*Acres.*	*Acres.*
Yuma project, Arizona and California	69,000	61,000	130,000
Imperial Irrigation District	515,000	.....	515,000
Imperial Valley extensions—			
East Side Mesa, Calif.	120,000	33,000	153,000
Dos Palmas, Calif.	10,000	.....	10,000
Coachella Valley, Calif.	80,000	10,000	90,000
West Side, Calif.	10,000	30,000	40,000
Total Imperial Valley extensions	220,000	73,000	293,000
Total in United States	1,032,000	210,000	1,242,000
Mexican lands:			
Under Imperial Canal	275,000	.....	275,000
Under All-American Canal	22,000	8,000	30,000
Delta south of Volcano Lake and Bee River	250,000	.....	250,000
Sonora	210,000	55,000	265,000
Total in Mexico	757,000	63,000	820,000
Grand total	1,789,000	273,000	2,062,000

TABLE No. 6.—*Summary of irrigated and irrigable acreage, Upper Basin above Boulder Canyon, by States.*

	Irrigated, 1916.	Additional possible.	Total.
	Acres.	*Acres.*	*Acres.*
Wyoming	393,000	344,000	737,000
Colorado	452,000	536,000	988,000
Utah	215,000	434,000	649,000
New Mexico	47,000	250,000	297,000
Arizona	20,000	44,000	64,000
Nevada	5,000	10,000	15,000
Total	1,132,000	1,618,000	2,750,000

TABLE No. 7.—*Summary of irrigated and irrigable acreage, lower basin, except Gila, by States and countries.*

	Irrigated, 1915.	Additional, possible.	Total.
United States:	*Acres.*	*Acres.*	*Acres.*
Nevada	300	1,700	2,000
Arizona	29,300	250,700	280,000
California	358,400	601,600	960,000
Total, United States	388,000	854,000	1,242,000
Mexico	75,000	745,000	820,000
Grand total	463,000	1,599,000	2,062,000

TABLE No. 8.—*Summary of estimated ultimate irrigation—Entire basin, except Gila.*

	Acreage.	Per cent of total.
United States:		
Wyoming	737,000	15
Colorado	988,000	21
Utah	649,000	14
New Mexico	297,000	6
Arizona	344,000	7

TABLE No. 8.—*Summary of estimated ultimate irrigation, etc.*—Continued.

	Acreage.	Per cent of total.
United States—Continued.		
Nevada	17,000	
California	960,000	20
	3,992,000	83
Mexico	820,000	17
Total	4,812,000	100
Summarized:		
Upper basin	2,750,000	56
Lower basin	2,062,000	44
	4,812,000	100

5. The foregoing tables present the statistics as to the Colorado Basin. In what follows these questions are discussed:

(*a*) Is the water supply sufficient for reclamation of all the irrigable lands in the basin?

(*b*) What storage capacity is necessary so that, when the upper basin is developed to the ultimate, the lower basin will still have a water supply, and are there reservoirs of sufficient capacity to provide such storage?

(*c*) What storage is necessary for the lands in Imperial Valley, both in Mexico and the United States, so that development above both in the near and distant future will not jeopardize the water supply of Imperial Valley?

(*d*) Can the lands of the lower basin be protected from floods by means of reservoirs?

(*e*) What development of hydroelectric power can be made and relative desirability of such development to irrigation development in the lower basin?

(*f*) To what extent is it desirable at the present time to provide storage for all the lands in Mexico and such lands in the United States in the lower basin which are so expensive to irrigate that they can not be expected to be developed for many years to come?

6. It may be said at the outset that, based on the estimated demands for water used in this study, water supply is more than sufficient for all the lands in the entire Colorado Basin. In referring to the Colorado Basin in this the Gila is not considered.

7. It may also be said that reservoir sites exist in the Green and Grand River Basins which are large enough to furnish an approximately sufficient supply for all the lands in the lower basin after the upper basin has developed to the ultimate. The foundations for dams on these tributaries have been explored and are believed to be satisfactory. However, for many reasons, a reservoir on the main stream nearer to the lower basin is desirable. Here several have been surveyed, and one, the Boulder Canyon, is of sufficient capacity not only for irrigation but for complete control of the entire average run-off, except possibly excessive floods. At the present time exploration of the foundation of the dam sites for this reservoir is in

progress, and at this time it can not be stated that this reservoir can be used.

8. It can be further said that the reservoir sites on the tributaries previously referred to will impound sufficient water to give a full supply for all lands in Imperial Valley, both in Mexico and the United States, and for other feasible areas in the United States in the lower basin even after full development in the upper basin.

9. The other questions can not be answered so definitely, but depend on possible financing and results shown by present drilling at dam sites. However, possibilities are shown in the following discussion:

UPPER BASIN.

10. Past and future development in the upper basin has been studied in order to estimate the depletion already caused thereby on the water supply for the lower basin and also the probable future depletion. Records of discharge of the Colorado River at Yuma started in 1903, and these form the basis for estimates of supply for the lower basin. The development in the upper basin since that year is used in the estimates of past depletion.

UPPER BASIN.

Irrigated in 1902	665,000
Irrigated in 1915	1,127,000
Increase	462,000

11. Another item is diversion from the tributaries to other drainage basins. Starting in 1910, an average of 60,000 acre-feet annually is estimated to have been thus diverted and in 1914 this increased to 150,000 acre-feet.

12. It is assumed that the increase of irrigation took place gradually and it is known that most of it was for wild hay land, the water consumption of which is small. Altogether an average depletion from 1902 to 1916 of 440,000 acre-feet annually is estimated, starting with 615,000 acre-feet in 1903, and gradually decreasing until the year 1916.

13. Future development above will be for higher class crops and should produce a heavier consumption of water. It will also be attended with the construction of storage reservoirs to serve local areas. Knowledge of conditions on the Colorado is not very exact, but it is assumed that reservoir sites exist, rightly located to serve the lands of the upper basin. Sufficient stream records exist to make rough estimates of storage needed.

14. While reservoirs in the upper basin will not appreciably affect the consumption of water, they will concentrate the diversion into the months of flood discharge, thus causing a heavy depletion during flood period and a probable increase in discharge to the lower basin during the winters because of return flow.

15. The estimated demand and return flow for the different streams of the upper basin is:

TABLE No. 9.—*Diversion, consumption, and return flow per acre.*

	Diversion.	Consumption.	Return flow.
Green River	2.50	1.50	1.00
Grand River	3.00	2.00	1.00
San Juan River	3.00	2.00	1.00
Other streams above Virgin River	3.50	2.50	1.00

16. Based on comparison of average stream discharges with these demands multiplied by the irrigable acreage the estimated storage needs are as follows:

TABLE No. 10.—*Acre-feet per acre.*

Green River Basin	0.75
Grand River Basin	.20
San Juan River Basin	.80
Other streams	(1)

17. The estimated future depletion based on the foregoing is as follows:

TABLE No. 11.—*Total future demands, upper basin.*

[A minus sign (—) signifies gain.]

	Acre-feet.		Acre-feet.
January	—10,000	August	190,000
February	20,000	September	80,000
March	40,000	October	—30,000
April	190,000	November	—90,000
May	960,000	December	—70,000
June	1,190,000		
July	380,000	Total	2,850,000

LOWER BASIN.

18. Records in the Imperial Valley indicate that consumption of water there is less than 3 acre-feet per acre. The return flow from all irrigation below Boulder Canyon and above Laguna Dam can be diverted at Laguna Dam; hence the demand for the 305,000 acres above Laguna Dam is only the consumptive use—here estimated at 3 acre-feet per acre.

Entire lower basin: Estimated diversion—gravity, 5 acre-feet per acre; pumping, 3.50 acre-feet per acre.

19. This is believed to be sufficient if a reservoir can be constructed at Boulder Canyon. If it can not be and reservoirs must be constructed on upper tributaries, it is believed an addition should be made for regulation loss.

[1] Unknown, but possibly 4 or 5 acre-feet because of erratic discharge.

TABLE No. 12.—*Ultimate irrigation demand, entire Colorado Basin, except acreage in upper basin prior to 1916 (acre-feet).*

	Additional above Boulder Canyon, 1,618,000 acres.	Total below Boulder Canyon, 2,062,000 acres.	Grand total, 3,680,000 acres.
January	−10,000	340,000	330,000
February	20,000	230,000	250,000
March	40,000	760,000	800,000
April	190,000	850,000	1,040,000
May	960,000	850,000	1,810,000
June	1,190,000	1,100,000	2,290,000
July	380,000	1,100,000	1,480,000
August	190,000	1,020,000	1,210,000
September	80,000	930,000	1,010,000
October	−30,000	590,000	560,000
November	−90,000	510,000	420,000
December	−70,000	180,000	110,000
Total	2,850,000	8,460,000	11,310,000
Acre-feet per acre	1.76	4.10	3.08

WATER SUPPLY.

20. As previously stated, the discharge of the Colorado has been measured at Yuma since and including 1903. Since 1878 gauge heights have been recorded, but because of the shifting channel no trustworthy estimates of discharge can be made from the earlier records.

21. The critical period in recent years on the Colorado embraces the four extremely dry years 1901 to 1904, and therefore it is desirable to make estimates of the discharge as far back as 1899 to determine the probable discharge during the critical period and immediately preceding.

22. The record at Yuma does not directly determine the discharge available for irrigation. What is wanted is the discharge at Laguna Dam above the Gila. This latter discharge is practically the same as that at Boulder Canyon, and may be considered as measuring the supply for the lower basin.

23. Between Boulder Canyon and Laguna Dam there are 200,000 acres of land subject to annual overflow, which would be partially irrigated in the ultimate development of the river. Probably in high years the evaporation loss from this overflow land is as great as the consumption if it were irrigated, and in those years the discharge at Boulder Canyon was probably more than at Laguna Dam.

24. In dry years, however, it is believed only a small portion of this land was overflowed and the loss small.

25. As the dry years are the ones used in estimating storage needs, no allowance has been made to reduce storage because of overflow.

26. Also, there are to-day about 80,000 acres irrigated between Boulder Canyon and Laguna Dam, but in 1915 there was only 24,000 acres irrigated, and back in 1902 irrigation must have been insignificant, so that no allowance has been made for that item.

27. The recorded discharge at Yuma is 17,430,000 acre-feet annually. After deducting the Gila River discharge, and also the depletion caused by increased demand in the upper basin, and adding

the canal diversions of the Yuma project, the average is reduced to 15,710,000 acre-feet. The annuals are shown in the graph and also in the following table. The years 1899 to 1902, inclusive, are estimated by comparison with the principal tributaries which were recorded in those years:

TABLE No. 13.—*Acre-feet discharge at Laguna Dam.*

Year.	Discharge.	Per cent of average.	Year.	Discharge.	Per cent of average.
1899	22,010,000	140	1911	17,340,000	110
1900	16,020,000	102	1912	17,970,000	114
1901	14,360,000	91	1913	11,620,000	74
1902	8,240,000	52	1914	20,210,000	129
1903	10,040,000	66	1915	12,950,000	82
1904	9,160,000	58	1916	18,700,000	119
1905	15,380,000	98	1917	19,910,000	127
1906	17,090,000	108	1918	13,280,000	84
1907	24,270,000	154	1919	10,480,000	67
1908	12,110,000	77			
1909	24,890,000	158		15,710,000	.....
1910	13,800,000	88			

	Acre-feet.
Estimated supply	15,710,000
Estimated demand	11,310,000

That is, the supply is estimated to average 40 per cent more than the demand.

STORAGE.

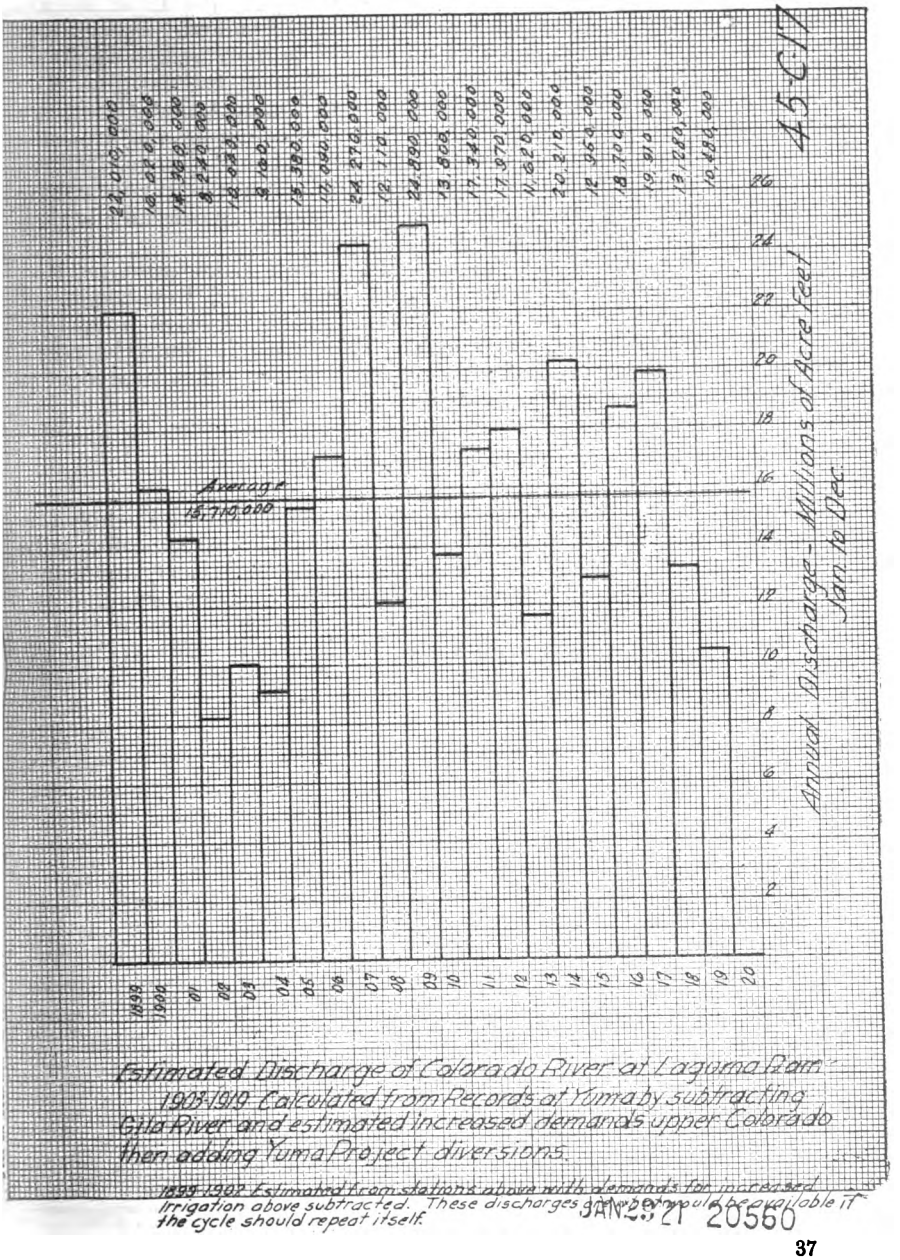
28. To give these estimated demands a full supply during the dry years and provide for 5 feet evaporation from the reservoir requires 10,000,000 acre-feet of storage. It is desirable to give a full supply when water is so plentiful as in the Colorado Basin, but it is not obligatory, and whether it should be done depends on the cost of the storage reservoirs.

29. The following table shows the storage required in all years of record:

TABLE No. 14.—*Storage required for lower basin.*

Year.	With reservoir at Boulder Canyon.	Lower basin per cent short with 2,250,000 acre-feet storage.	Year.	With reservoir at Boulder Canyon.	Lower basin per cent short with 2,250,000 acre-feet storage.
	Acre-feet.			*Acre-feet.*	
1899	630,000	.....	1910	2,080,000	.....
1900	2,120,000	.....	1911	600,000	.....
1901	2,170,000	.....	1912	444,000	.....
1902	3,180,000	38	1913	1,310,000	.....
1903	1,500,000	18	1914	420,000	.....
1904	1,190,000	14	1915	1,380,000	.....
1905	1,300,000	.....	1916	320,000	.....
1906	480,000	.....	1917	490,000	.....
1907	0	0	1918	1,080,000	.....
1908	410,000	.....	1919	1,850,000	.....
1909	0	0			

30. The third column in the preceding table shows that after allowing 80,000 acre-feet for evaporation from the reservoir surface a



Estimated Discharge of Colorado River at Laguna Dam 1903-1919 Calculated from Records at Yuma by subtracting Gila River and estimated increased demands upper Colorado then adding Yuma Project diversions.

1899-1902 Estimated from stations above with demands for increased irrigation above subtracted. These discharges can be computed if the cycle should repeat itself.

storage capacity of 2,250,000 acre-feet will supply full demands for the cycle of years under discussion except 1902, 1903, and 1904. The best place to secure such an amount of storage capacity is on the Green or the Grand River, as is subsequently discussed. But if it is secured on the tributaries, the amount should be increased to approximately 2,700,000 acre-feet to provide for loss in regulation. The shortages in 1902, 1903, and 1904 are due to the fact that the entire annual run-off for each one of those years was less by the amounts shown in the table than the demands for irrigation. Hence, if these years are provided for it must be by building enough reservoir capacity to hold water over from previous high years. As already stated, this will require 10,000,000 acre-feet of storage.

31. La Rue's study of the rise and fall of Salt Lake indicates that periods approximately like the 1901 to 1904 period have occurred four times between 1850 and 1900; that is, in the 70 years since 1850 there have been five periods of drought. This would indicate the possible recurrence of shortages for 2 or 3 consecutive years in every 14 unless holdover storage is provided.

IMPERIAL VALLEY.

32. To provide a full storage supply for the Imperial Valley it is necessary to anticipate probable depletion of the stream not only from development in the upper basin but from such areas lying below Boulder Canyon as now seem able to finance the cost of storage.

33. The total depletion from the upper basin will be as estimated in the foregoing discussion of ultimate development. The following table gives all the acreage in the lower basin believed to be financially feasible in the near future.

TABLE No. 15.—*Acreage financially possible in near future—Lower basin.*

	Gravity.	Pump.	Total.
United States:			
Above Laguna Dam—			
Parker project	104,000	6,000	110,000
Palo Verde Valley	78,000	.....	78,000
Cibola Valley	16,000	.....	16,000
Isolated tracts	1,000	2,000	3,000
Total	199,000	8,000	207,000
Yuma project	69,000	51,000	120,000
Imperial irrigation district	515,000	.....	515,000
Imperial Valley extensions—			
East side mesa	120,000	33,000	153,000
Dos Palmas	10,000	.....	10,000
Coachella Valley	80,000	10,000	90,000
West side	10,000	30,000	40,000
Total	220,000	73,000	293,000
Total, United States	1,003,000	132,000	1,135,000
Mexico:			
Under Imperial Canal	255,000	.....	255,000
Under All-American Canal	22,000	8,000	30,000
Total, Mexico	277,000	8,000	285,000
Grand total	1,280,000	140,000	1,420,000

34. The estimated total demand for this plan is as follows:

TABLE NO. 16.—*Estimated demands (acre-feet), Colorado Basin, except acreage irrigated before 1916, and except Gila.*

Month.	Upper basin.	Lower basin.	Total.	Month.	Upper basin.	Lower basin.	Total.
January	−10,000	280,000	270,000	August	190,000	860,000	1,050,000
February	20,000	220,000	240,000	September	80,000	780,000	860,000
March	40,000	660,000	700,000	October	−30,000	490,000	460,000
April	190,000	730,000	920,000	November	−90,000	420,000	330,000
May	960,000	740,000	1,700,000	December	−70,000	120,000	50,000
June	1,190,000	930,000	2,120,000				
July	380,000	930,000	1,310,000	Total	2,850,000	7,160,000	10,010,000

35. To fill the foregoing demand during the dry years 1901 to 1904, 3,800,000 acre-feet of storage is required at Boulder Canyon, as the supply for 1904 must be held over from 1901.

36. For other years the storage required is as follows:

TABLE NO. 17.—*Storage required for lower basin, present feasible acreage.*

Year.	Acre-feet.	Lower basin per cent short with 1,600,000 acre-feet storage.	Year.	Acre-feet.	Lower basin per cent short with 1,600,000 acre-feet storage.
1899	380,000		1910	1,500,000	
1900	1,470,000		1911	260,000	
1901	1,560,000		1912	210,000	
1902	1,800,000	25	1913	830,000	
1903	200,000	3	1914	270,000	
1904	760,000	11	1915	730,000	
1905	890,000		1916	90,000	
1906	210,000		1917	200,000	
1907	0		1918	460,000	
1908	260,000		1919	1,100,000	
1909	0				

37. As with the previous computations, the shortage in 1902, 1903, and 1904 could only be reduced by carrying over storage from prior years. As previously stated, to provide for this will require 3,800,000 acre-feet of storage at Boulder Canyon, but if this storage were in the upper basin on the tributaries it is believed it should be increased to 4,500,000 acre-feet. To provide for all other years requires 1,600,000 acre-feet, but if this were placed on the tributaries it should be increased to 1,900,000 acre-feet.

38. What was said as to recurrence of periods of drought in discussing previous plan of development applies equally to this.

FLOOD CONTROL.

39. Floods in the lower Colorado come from three sources: (*a*) The Gila Basin; (*b*) the intermediate area between the San Juan and the Gila; (*c*) the headwaters of the Green, Grand, and San Juan.

40. The first gives floods in January and February, as a rule, but they are very erratic. They are also heavier than floods from other

sources, but are of short duration. The second area gives floods of similar nature and they are possibly as severe as from the Gila, but the sharp peaks are so smoothed out by storage in the Colorado that they rarely reach Yuma in destructive size. In the period of record, there was one flood of about 70,000 second-feet in February, 1920, most of which probably came from this source, but to date, records are not available from the upper streams by which the source can be determined. Floods from the third area, the upper tributaries, occur practically every spring, and are of long duration. They start with the melting snow on the slopes of the Continental Divide and its spurs in Colorado, Utah, and Wyoming.

41. Floods from the first source can be controlled only by a reservoir near the mouth of the Gila, from the second by a reservoir below Virgin River, and from the third by reservoirs either on the three major tributaries or lower down on the main river. A reservoir below the Virgin would control floods from both areas 2 and 3.

42. Flood control by storage will have to be supplemented by levees. It is estimated that if the floods could be controlled to a maximum of 50,000 second-feet, a satisfactory levee system could be maintained. Estimates of flood control storage which follow are based on that figure.

TABLE No. 18.—*Flood control on the Colorado River, exclusive of Gila.*

Year.	Period above 50,000 second-feet.	Days.	Total discharge (acre-feet).	Storage to reduce to 50,000 second-feet.
1905	May 24 to June 30	37	5,603,000	900,000
1906	May 11 to July 5	55	9,430,000	3,900,000
1907	May 24 to Aug. 9	77	12,765,000	5,065,000
1909	May 15 to July 20	67	12,426,000	5,726,000
1910	May 4 to May 28	25	2,838,000	338,000
	June 6 to June 16	10	1,379,000	379,000
1911	May 16 to July 12	58	6,960,000	1,100,000
1912	May 25 to July 13	50	8,839,000	3,839,000
1913	June 4 to June 15	12	1,365,000	165,000
1914	May 18 to July 13	57	10,513,000	4,813,000
1917	May 25 to July 25	78	11,498,000	3,698,000
1920	May 16 to July 12	57	11,155,000	5,455,000

43. The estimate of storage needed is based on a draft of 50,000 second-feet. When ultimate development takes place the floods will be reduced by storage for irrigation in the upper basin.

44. In round figures the flood control necessary in the worst year of record, 1909, is:

	Acre-feet.
Present conditions	6,000,000
Ultimate conditions	4,000,000

45. There is likelihood that more severe floods occur. So far as gauge records give information, exceptionally high water occurred in 1884, 1905, 1906, 1907, and 1909, with 1909 the highest during the spring floods. Gauge heights at Yuma are not entirely conclusive, as there is some evidence that the river bed raised 3 feet at Yuma between 1884 and 1909, which, if true, would indicate a very heavy flood in 1884. This would corroborate other evidence bearing on 1884, which is as follows:

46. (*a*) Grand River (principal tributary to Colorado): Gauge in 1884 read at peak was 18.5; highest since, in 1909, was 15, indicating a flood with possibly twice as high a peak as the 1909.

(*b*) Cache La Poudre River (heading on opposite side of Rockies from the Grand): 1884 was highest year ever recorded. The next highest was 1909. In May and June of 1884 total discharge was 68 per cent greater than in 1909.

(*c*) Columbia River and San Joaquin were both higher in 1884 than in 1909, although the difference for entire year was only 7 per cent and 9 per cent, respectively.

47. The inference from the foregoing is that there was surely a high flood on the Grand, that it may have continued through May and June, and that probably heavy discharge occurred throughout the West, making it possible that the Green and San Juan both were in flood.

48. A 50 per cent greater flood continued as long as that of 1909 would require for control to 50,000 second-feet storage capacity of 12,000,000 acre-feet for present conditions on the river and 7,000,000 acre-feet for ultimate conditions.

49. A baffling feature of estimate of flood control necessary is the great variation in discharge with the same gauge. It would be conservative, however, to estimate that 5,000,000 acre-foot capacity for flood control would bring the largest flood down to 50,000 second-feet.

50. Necessity for building capacity specifically for flood control decreases as reservoirs approach that capacity necessary for complete control of the discharge.

FLOOD CONTROL ON THE GILA.

51. Control of the Gila for floods can be accomplished only at Sentinel reservoir site. The worst flood of record occurred from January 20 to February 3, 1916, during which time the peak reached almost 200,000 second-feet and the entire discharge was 2,373,000 acre-feet.

52. The following shows the storage necessary to reduce the discharge to various figures:

Discharge (in second-feet):	Storage necessary.
10,000	2,100,000
20,000	1,800,000
30,000	1,500,000
40,000	1,200,000
50,000	900,000

53. With control of the Colorado River by reservoirs on the tributaries, and with floods from the Gila probably occurring at the same time that floods occur from the intermediate basin below the San Juan, there would be necessity for reducing the floods of the Gila perhaps to as low as 10,000 second-feet in order to avoid simultaneous floods. But with the Colorado River Reservoir at Boulder Canyon such necessity would not exist, and the discharge could be permitted to average during the filling period probably 40,000 second-feet with safety, reducing the necessary size of the reservoir by 900,000 acre-feet for the year 1916.

54. However, if the Sentinel Reservoir is constructed, it is believed it should be built to full capacity (2,200,000 acre-feet) regardless of computations.

55. The possibility of financing the Sentinel Reservoir seems remote, and its feasibility is doubtful from an engineering standpoint. Without it to control the Gila, control of the Colorado River alone will not be fully effective, although desirable. That is, if the Sentinel Reservoir is not built large expenditure for levees to protect against extraordinary floods below the Gila must still continue, whether the Colorado River itself is controlled or not.

SILT.

TABLE No. 19.—*Silt-deposit data.*

	Annual water.	Annual silt.	Per cent silt by volume @ 85 pounds per cu. ft.
	Acre-feet.	*Acre-feet.*	
Colorado below Gila	17,740,000	113,000	0.65
Gila	1,070,000	15,000	1.40
San Juan	2,350,000	29,000	1.23
Green	5,510,000	10,000	.18
Grand	6,940,000	10,000	.14

56. The difference between the first item and the sum of the last four items should represent the silt discharge of the tributaries below the San Juan, the water discharge of which is estimated to average 1,560,000 acre-feet annually. This would give a silt content by volume of over 3 per cent, which is probably impossible. It is not improbable that silt in the Green and Grand, or the Gila, has been underestimated. The basis for the estimates is poor on the Grand and Green but good on the Colorado at Yuma.

57. The discharge at Boulder Canyon with present conditions above is estimated at 15,710,000 acre-feet annually. The silt content of the Colorado with the Gila not in flood has averaged 0.5 per cent, giving a silt content at the reservoir at present of approximately 80,000 acre-feet per year.

RESERVOIRS.

TABLE No. 20.—*Major storage sites in Colorado Basin for use of lower basin.*

Reservoir site.	Stream.	Height water storage above river.	Acre-feet capacity.	Greatest depth to bedrock.
On tributaries:				
Flaming Gorge	Green River	230	3,120,000	73 feet.
Browns Park	do	200	2,500,000	Unsatisfactory bedrock.
Ouray	do	210	16,000,000	121 feet.
Juniper	Yampa River	200	1,500,000	24 feet.
Kremling	Grand River	230	2,200,000	104 feet.
Dewey	do	215	2,270,000	44 feet.
Bedrock	Dolores River	210	800,000	Not drilled.
Bluff	San Juan River	206	1,350,000	Do.
On main stream:				
Junction	Colorado River	250	7,450,000	None at 120 feet.
Boulder Canyon—				
Dam at Boulder Canyon.	do	560	26,000,000	Now exploring.
Dam at Black Canoyn	do	(1)		
Bulls Head	do	70	400,000	37 feet.

[1] Not yet determined.

58. Of the foregoing the following are of doubtful availability:

Browns Park.—Because it is only a short distance below Flaming Gorge, would control the same water and has unsatisfactory foundation.

Ouray.—Because of large cost in getting to bedrock, and also because it would flood the location of the Moffatt Railroad, which is now partially built and which is expected at some time to be built into this region.

Kremling.—Because it is now occupied by the Moffatt Railroad, which has built through the reservoir dam site.

Bluff.—Site would not be satisfactory for irrigation because of large silt discharge compared to size. Furthermore, the entire flow of the San Juan, except in extremely high floods, can be used for irrigation in the lower basin. The Bluff could be used as a detention reservoir.

Junction.—Because of lack of foundation.

Bulls Head.—Because the great volume of silt makes any small reservoir in the main river unsuitable. It could be used, however, to create head for power.

59. Summing up, the following reservoirs have either been found to be suitable or investigations have not been carried far enough to determine their suitability:

	Capacity, in acre-feet.
Explored:	
Flaming Gorge	3,120,000
Juniper	1,500,000
Dewey	2,270,000
Not explored, Dolores	800,000
Now exploring, Boulder Canyon	26,000,000

Irrigation Control.

RESERVOIRS ON TRIBUTARIES.

60. The average past annual run-off at these sites and estimated future run-off after ultimate development above is shown in the following table:

Table No. 21.—*Acre-feet data.*

	Past.			Future.		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Flaming Gorge	2,300,000	3,900,000	1,400,000	1,800,000	3,400,000	900,000
Juniper	1,200,000	2,200,000	800,000	900,000	1,900,000	500,000
Dewey	6,800,000	9,000,000	3,800,000	6,200,000	8,400,000	3,200,000

61. In paragraphs 30 and 37 it was estimated that storage on tributaries was required as follows:

Table No. 22.—*Water supply.*

	Full supply, all years.	Disregarding 1902, 1903, and 1904.
	Acre-feet.	*Acre-feet.*
(1) All lands in Colorado Basin developed	12,500,000	2,700,000
(2) All lands upper basin developed, also present financially feasible acreage in lower basin	4,500,000	1,900,000

62. For the second plan and disregarding the years 1902, 1903, and 1904, the Dewey would be sufficient and the Juniper approximately so. For a full supply of 4,500,000 acre-feet the Dewey, supplemented by the Flaming Gorge, would suffice.

63. For the first plan and disregarding the years 1902, 1903, and 1904, the Dewey would not be quite sufficient nor the Juniper. While the Flaming Gorge is large enough, yet the run-off is small, and it would not be possible to store so much water in a great many years. For this plan the Dolores might prove a satisfactory supplement to the Dewey if its foundation is found to be satisfactory. Otherwise the Juniper or the Flaming Gorge could be used to supplement the Dewey.

64. For ultimate full development some calculations are necessary. The estimated supply at Laguna Dam will be 15,700,000 acre-feet, but it may be assumed that all the tributary inflow below the San Juan will be lost because of its flashy nature, leaving approximately 14,000,000 acre-feet subject to more or less regulation. The 2,700,000 acre-feet of storage necessary could be supplied each year by the Dewey and Juniper Reservoirs—a total capacity of 3,800,000 acre-feet—and there would be margin enough in supply over demands so that the Green River at Flaming Gorge could be practically entirely stored most years and the reservoir could enter the period 1902 to 1904 full. That is, to supply the estimated storage requirement of 12,500,000 acre-feet there would be approximately 7,000,000 acre-feet of storage. While this is subject to revision with more detail estimates, yet it would seem justifiable to say that the severe shortage of 1902 can be eliminated, leaving only the shortages of 18 per cent and 14 per cent, respectively, in 1903 and 1904.

65. There are some other smaller sites in the upper tributaries which could be used to supplement the three reservoirs mentioned, but their effect would be small. It is evident that estimated needs for ultimate development assumed herein can not be completely filled by reservoirs on the upper tributaries and also that complete flood control by this method is not possible. It is, however, probable that a fair degree of regulation will be given, which will secure a supply approximately as complete as most irrigation projects have.

COMPARISON OF RESERVOIRS.

66. While the foregoing indicates that the reservoirs on the tributaries can be used to secure an approximately complete supply for irrigation of the lower basin, yet there are various reasons why they are less desirable than a reservoir at Boulder Canyon.

(1) Particularly for full development the value of power sites would be impaired below the reservoirs on both the Green and the Grand. In the operation of the reservoirs for irrigation the winter discharge of the Grand would all be impounded. On the Green no discharge would pass through Flaming Gorge for several consecutive years. On the main river winter discharge would be decreased and later summer discharge increased.

(2) While most irrigation in the upper basin is above these reservoirs, yet on the Yampa, and particularly on the Green, there is some

development below at present and more possible, making some difficulty in regulation likely. This is not true of the Dewey on the Grand River.

(3) Without a reservoir at Boulder Canyon it is estimated that practically 2,500,000 acre-feet annually will be lost.

(4) A reservoir at Boulder Canyon would provide an opportunity for power development in a locality where a market for power exists now and which should develop rapidly—southern California. The 2,500,000 acre-feet wasted without this reservoir could be used for power development and also all irrigation water.

(5) With Boulder Canyon reservoir built, the development of the lower and upper basins is entirely separated and each can proceed in accordance with its economic needs.

67. While Boulder Canyon is apparently the most desirable development if satisfactory foundation is discovered, yet the difficulty of financing so great an undertaking will be large. The previous estimates of storage needed and where it can be obtained throw some light on the portion of the cost of storage which could and should be borne by irrigation.

68. It was concluded that Dewey Reservoir would be sufficient for many years to come and that all the lands in the lower basin which could finance reservoir development at present would require less than 4,000,000 acre-feet of storage at Boulder Canyon.

69. In order to determine what power development is possible at Boulder Canyon and how it would fit in with irrigation, the proposition of building the dam with power development in mind has been investigated.

Power Development.

BOULDER CANYON.

70. Assumptions: Minimum head, 320 feet; load factor, 50 per cent; river discharge regulated to a continuous-flow efficiency at turbines, 86 per cent.

71. A minimum head of 320 feet will create a dead storage of 5,000,000 acre-feet, which will provide silt storage for many years.

Table No. 23.—*Power possible to generate at Boulder Canyon.*

Continuous flow.	Annual draft.	Storage, regular, plus 5,000,000 dead storage.	Kilowatts generated, 320-foot head.	Raise in water surface above stream.
Second-feet.	*Acre-feet.*			
16,700	12,000,000	28,700,000	745,000	585
15,300	11,000,000	23,600,000	684,000	543
13,900	10,000,000	19,800,000	621,000	510
12,500	9,000,000	15,900,000	559,000	470
13,500	9,700,000	18,700,000	600,000	500

72. The following table shows the flows estimated necessary for irrigation compared to the steady flows which can be maintained for power alone.

TABLE No. 24.

Month.	Full supply to lower basin from Table 12.		Full supply to part of lower basin from Table 16.		
	Irrigation demand.	Storage, 28,700,000 acre-feet; power, 745,000 kilowatts.	Irrigation demand.	Storage, 24,100,000 acre-feet; power, 690,000 kilowatts.	Storage, 18,700,000 acre-feet; power, 603,000 kilowatts.
		Second-feet.	*Second-feet.*		
April	14,100	16,700			
May	14,100	16,700	12,350	15,500	13,500
June	18,300	16,700	15,500	15,500	13,500
July	18,300	16,700	15,500	15,500	13,500
August	17,000	16,700	14,300	15,500	13,500
September	15,500	16,700	13,000	15,500	13,500

73. To give a continuous flow of 13,500 acre-feet requires 13,700,000 acre-feet of storage, and the addition of 5,000,000 acre-feet below outlets gives a total of 18,700,000 acre-feet. The peak irrigation demands are 2,000 second-feet greater than this discharge, and the demand for the peak irrigation requires an annual discharge of 300,000 acre-feet in excess of power. To provide for the carry over during the low period 1901 to 1904 requires 1,100,000 acre-feet of storage in addition to that for power alone, a total of 19,800,000 acre-feet.

74. On the other hand, if it is desired to limit storage to 18,700,000 acre-feet and provide for full estimated irrigation supply, this can be accomplished by reducing the continuous flow to 13,000 second-feet, which will give 580,000 kilowatts.

Appendix D.

SOIL RECONNOISSANCE—ALL-AMERICAN CANAL PROJECT.

PROGRESS.

The soil examination of the areas of land that might possibly be supplied with irrigation water by the construction of branches from the All-American Canal was begun on October 1. Time has not been available for a complete examination of the several districts.

About 90 per cent of the east side mesa has been given a rather detailed examination, and a short reconnoissance trip has been made over the remainder.

A short trip of inspection has been made through the Dos Palmas district, but no regular field work has been started.

No field work has been carried on in the Coachella Valley, but that district was given a brief visit in the latter part of October.

In the west side gravity district the detailed soil examination has covered all of the area excepting a very small part in the vicinity of Dixieland.

On the west side mesa the larger part of that district has been given a soil examination and the balance has been gone over in a hasty trip.

The soil examinations on the east and west side mesas and the west side gravity district should be completed about December 1, that of the Dos Palmas district about the middle of December, and that of the Coachella Valley in the latter part of January.

MAP.

Upon the map accompanying this report, the several districts into which this area has been divided have been outlined and numbered to correspond with maps in other portions of the report.

On the east-side mesa, where the soil examination has been carried northward to the third standard parallel, the larger bodies of nonirrigable soil have been left uncolored, but on account of the small scale of the map the size of those bodies has been somewhat exaggerated in order that they might stand out more effectively. The northern portion of the mesa, which has not yet been examined, has been left uncolored.

In the Dos Palmas district the approximate area of the only known body of irrigable soil has been shown, and the final examination of this district may either increase or decrease the size of that area.

As no field work has been carried on in the Coachella Valley, that area has been left uncolored, and it is merely shown by the colored outline around its boundaries.

With the exception of some very small possible areas of irrigable land in the extreme southern portion of the west-side gravity dis-

trict, the areas of irrigable land have been outlined and colored as well as the scale of the map will permit.

On the west-side mesa the boundaries of the areas of irrigable land have been largely determined, but there may be some slight changes in the region west of Dixieland when the field examination has been completed.

EAST-SIDE MESA.

The examination of the soil conditions on the east-side mesa at the present time includes all of the lands from the Mexican boundary northward to the third standard parallel—a distance of about 25 miles. This area includes about 206,000 acres, or about 90 per cent of the gross area of the mesa.

For the purpose of this report the soils are divided into irrigable and nonirrigable lands. There is possibly about 5 per cent of the area so far examined where the soil and alkali conditions are not favorable for irrigation; but, aside from that small amount, the only feature involved in the determination of the irrigable acreage is that of the topography.

The irrigable lands consist of light-brown fine sands and light-textured sandy and fine sandy loams, that are commonly underlaid at about 24 inches by brownish gray, porous and uncompacted fine sands to a depth of 6 or more feet. The surface of these soils occasionally carries a thin pavement of small concretionary fragments, or of dark-colored, water-worn gravel, or is covered by varying amounts of wind-blown sand. The upper 12 or 18 inches of the soil is usually very slightly compacted, but this condition is so little developed that it offers practically no resistance to the movement of the soil with agricultural implements; and when this structure is once broken down the soil becomes an incoherent mass and does not resume the compacted form. This condition will entirely disappear for all time when the land is placed under cultivation. The soils are free from alkali and possess excellent drainage conditions. The coarser materials are not present in sufficient amounts to have any effect upon the value of the land for irrigation, and the presence of the fine wind-blown material, while it will not materially affect the value of the land for crop production, will often require a large amount of leveling to adequately place the land in condition for cultivation.

The nonirrigable soil consists almost entirely of large masses of wind-blown sand and fine sand that occasionally form isolated dunes of large size, but which more frequently occur as areas of dune sand of several thousand acres in extent. These dunes are in part stationary, being held by growths of desert vegetation, and in part are slowly moving across the floor of the mesa in a direction a little south of east. The movable portions of these dunes will be of some detriment to the lands which lie in their path. The smaller dunes can be readily handled by spreading the material as it encroaches upon the cultivated fields, but the larger ones will destroy the value of the land for many years, as they move but slowly, unless the material can be moved to some other location. Such an expense would be practically prohibitive to the land owner.

Under irrigation the larger part of the soils will have satisfactory drainage conditions for many years to come. Excessive moisture

conditions may be expected to develop, however, shortly after the mesa is placed under irrigation in the narrow area between the ancient beach line and the east side high-line canal. Conditions relative to the local topography and the shape of the body of land are such that the reclamation of those lands could be satisfactorily handled only in connection with drainage operations to the west of the present canal.

That part of the mesa not yet covered by the examination is known to have the same general soil characteristics as the portion already covered, but it is quite certain that the percentage of nonirrigable land will be considerably higher.

DOS PALMAS DISTRICT.

Beyond a single brief reconnaissance trip no examination of the soil conditions has been made in this district.

This district is a long narrow body of land lying to the north of Salton Sea and the northern boundaries of the Imperial irrigation district and below the steeper foot slopes of the Chocolate Range of mountains. It extends in a northwesterly direction from near Iris station for a distance of about 35 miles. With the exception of a large ridge near the shore line of Salton Sea, in the northern part of the district, the topography is a pronounced slope that is crossed by a number of well-defined arroyos and by almost numberless smaller ones that have no well-established channels. The stream discharge depends upon the duration and intensity of the storms in the adjacent mountains, and while the water courses are dry for the larger part of the time, they are subject to occasional violent floods which they can not carry, and practically the entire area becomes covered with a moving sheet of water.

The soils consist, for the larger part, of strata of very compact clays that are often so indurated as to approach a shale in structure. Practically all of these materials carry large amounts of alkali. Over extensive areas these clays are exposed upon the surface, are practically barren of vegetation, and usually show signs of alkali either by the presence of crusts upon the surface or by a pronounced puffy structure of the surface soil. For a distance of several miles northwest of Iris, and in bodies of lesser extent elsewhere, these clays are covered by a thin overwash of sandy material. This rather effectively masks the presence of the clay in the subsoil and tends to create an impression of favorable soil conditions.

In the vicinity of Salt Creek, in township 8 south, ranges 11 and 12 east, a well-defined alluvial fan has been developed to the eastward of the present channel of the stream. This fan has a pronounced but quite regular slope in a southerly direction and is traversed by a number of small meandering washes. The soil upon this fan is largely light-brown, uncompacted sandy loam that often carries small deposits of wind-blown sand upon the surface. The drainage conditions are excellent and the soil appears to be entirely free from alkali. It should be well adapted to irrigation when the danger of occasional flooding is removed.

As a result of the brief inspection trip given to this district the entire area of clays, and of sandy surface soils that are underlaid by

clays at shallow depth, is considered as nonirrigable, and only the alluvial fan in the vicinity of Salt Creek is considered as being adapted to irrigation. The detailed examination that is to follow may possibly result in the finding of small detached areas of agricultural land, but the combined areas will be small and will have but little effect upon the irrigable area of this district.

COACHELLA VALLEY.

This district is a valley from 6 to 10 miles in width which extends in a northwesterly direction from Salton Sea for a distance of about 45 miles. The upper limits of the soil examination will extend about 10 miles above the town of Indio, or about 30 miles from the lower end of the valley. The northerly and southerly limits of the valley are formed by the Chocolate and Santa Rosa ranges of mountains.

Throughout the central portions of the valley the general slope is quite uniform, but along the sides the effects of the mountain drainage has been to build up rather steep, short slopes that are traversed by the shifting channels of the water courses. To the west of Indio and extending for several miles beyond the limits of this work there is an extensive area of large sand dunes, and a similar topography exists in a number of restricted localities throughout the valley, particularly along the southern edge.

There are no permanent streams within the valley, but there are a very large number of washes which drain the surrounding mountain region. These usually possess no well-defined channels after emerging from the mountains, and the storm waters are discharged onto the lower lands and eventually reach the Salton Sea. Considerable areas of the valley lands are at times subject to severe overflows, with considerable damage resulting to property lying within the course of the waters.

The larger part of the soils have been formed of materials deposited by streams entering the valley and apparently consist largely of grayish micaceous silts and clays. Along the margins of the valleys the soils become more sandy and gravelly. Sand dunes occupy a considerable area in the northern end of the valley and dunes of wind-blown silt are of local occurrence in the region west and southwest of Mecca. From Indio southward the indications are that a large part of the soils contain considerable amounts of alkali. The distribution of the alkali seems to be very irregular, and no estimate can be made at the present time of the amount of land that is nonirrigable because of the presence of excessive amounts of that material.

The drainage conditions of the soils, except in an area bordering Salton Sea, seem to be satisfactory, and, if such is the case, the reclamation of the larger part of the soils may be possible through the installation of drains.

The floods which come down the mountain sides are often violent and destructive, and a large part of the valley can not be brought under a permanent and satisfactory development until means have been taken for controlling the discharges from the higher slopes.

WEST SIDE GRAVITY.

The west side gravity district includes a long narrow area on the west side of the Imperial Valley lying above the western boundaries of the Imperial Valley irrigation district and below the surveyed line of the B branch of the All-American canal. From the Mexican boundary northward to about the third standard parallel the area will average about 1 mile in width. Northward from that parallel the upper boundary of the district turns westerly to cross the valley of San Felipe Creek, and the district gains a maximum width of about 10 miles. From San Felipe Creek, the western boundary, the district lies roughly parallel to the present shore line of Salton Sea.

From the Mexican boundary to a short distance beyond Dixieland the surface is uniform to quite hummocky and there are a number of small areas where the surface is dotted with sand dunes ranging up to 15 or 18 feet in height. A few small indistinct washes occasionally carry flood waters across this part of the district, and the control of those waters would be necessary before the land could be brought under irrigation. Within this body the soils are largely porous uncompacted sands and sandy loams to a depth of several feet, with smaller areas of heavier textured soils in the vicinity of the present canal. The lighter textured soils are, and will probably continue to be, well drained and free from alkali, but the heavier textured soils carry some alkali, and because of their proximity to the canal they can be expected to develop an unfavorably high water table soon after having been placed under irrigation.

Northward from about the center of township 15 south to the northern boundary of township 14 south the surface is rather flat in the southern portion, and in the northern part there is a pronounced surface slope from the base of the Superstition Mountains toward the lower valley lands. Portions of this body are subject to local overflow, and means for some flood control would be necessary before the lands could be maintained in a state of cultivation. In this portion of the district the soils range from sands to clays, and these materials form large numbers of small bodies of soil of widely varying textures. The lighter textured members are adapted to irrigation, and also some of the heavier bodies, but the latter materials sometimes carry excessive amounts of alkali, and continued irrigation would eventually require rather extensive drainage operations for the reclamation of the land. Time has not been available for the examination of but a small part of this body, but it is estimated that about 50 per cent of the area is either nonirrigable or will become so within a short time following the application of irrigation water.

From the northern boundary of township 14 south northwesterly to in the vicinity of Harpers Well the surface is largely formed by slopes that extend easterly and northerly from the base of Superstition Mountain and in part by a very flat plain bordering the shore line of Salton Sea. The upper slopes are moderate and are traversed by numbers of more or less well-defined channels that carry the run-off from the higher lands. As these slopes flatten out the channels lose their identity and the storm waters flood the larger part of the lower plain. In this portion of the gravity district the soils

are very largely old sediments ranging from compact clays to sands and in part are more recent sediments on the lower plain adjacent to the shore line of Salton Sea. The clays and sands are very compact. the latter often approaching a sandstone in structure. These strata are badly faulted and folded. Local areas carry a veneer of wind-blown sand, and some sand dunes occur at intervals. All of the older sediments carry some alkali, the amount in the clays commonly exceeding 1 per cent. The lower lands along the sea are both clays and sands in texture, the latter predominating, and are always excessively alkaline. This body is subject to overflow by washes from the higher slopes, and it could not be placed under irrigation until means had been taken for the control of the flood waters and for the removal of the alkali. Because of the compact structure of the larger part of the soils, the almost universal presence of alkali, and the necessity of extensive works for flood control this part of the gravity district is not considered to be irrigable.

West of Harpers Well this district includes a part of the valley of San Felipe Creek. Here the surface slopes from the north and south toward the axis of the valley. The slopes are, as a rule, moderate, but the surface is traversed by a number of large permanent arroyos, and is often very irregular because of bodies of dune sand. The channels of the water courses are often inadequate to handle the volume of the run-off from heavy storms, and practically all of the valley is subject to occasional overflows. In the flood plain of San Felipe Creek the soils are largely heavy textured, occasionally very compact, and always carry large amounts of alkali. The reclamation of these lands from alkali and the protection from floods would be both difficult and expensive, and this part of the gravity district is considered to be nonirrigable.

From San Felipe Creek northward to the end of the district the surface has a pronounced slope in a northeasterly direction and extends well outward toward Salton Sea, but is separated from that body of water by a long, narrow, very flat plain. The surface of the higher plain is uniform to moderately rolling and is locally irregular on account of considerable numbers of sand dunes and rocky knolls. A considerable number of prominent arroyos and their smaller tributaries maintain definite channels from the higher lands to the lower plain, but are not of sufficient size to carry all of the water resulting from the heavier storms. and the larger part of the area is subject to occasional floodings. The drainage channels terminate upon reaching the lower lands and their waters pass over the surface as a sheet flood. The lower plain seldom has any evident slope, and is quite uniform except for local areas of small dunes.

The soils in this part of the district consist of heavy and light textured materials along Salton Sea, and upon the higher slopes of great masses of very compact clays and of sandy materials that often carry considerable amounts of fragmentary sandstone upon the surface. The soils of the lower plain along Salton Sea are always excessively alkaline and poorly drained. The clays on the higher plain are very compact, the strata are sharply folded, and, with very few exceptions, excessive amounts of alkali are always present. This body of soils occasionally carries a thin veneer of sandy material, but in the main the surface is very hard and compact, and over large

areas either entirely devoid of vegetation or plants are present only as solitary widely scattered individuals. A significant feature in indicating the possible behavior of these soils under irrigation is the presence of occasional small seepage areas. Many of the clay strata are impervious to water, and water is carried for unknown distances to the surface at the line of the outcrop. With a general application of irrigation water and the accumulation of waste waters in the subsoil, there would undoubtedly result a speedy waterlogging of large areas of soil, and the complex folding of the clay strata indicates that it would be practically impossible to secure satisfactory drainage facilities. All of these clays, as well as the lighter textured soils along Salton Sea, are considered as nonirrigable.

The sandy areas of soil are brownish sands and sandy loams that are porous, well drained, and free from alkali. In probably somewhat more than 50 per cent of the area of these soils the surface is thickly covered with an accumulation of hard brown sandstone fragments of varying size. This material does not affect the productive power of the soil, but, since it would require considerable time and expense to clear the land, this soil would be generally regarded as less desirable by prospective settlers, and the larger part of it would not be developed until the supply of other land had been fully exhausted. These sandy soils constitute the only irrigable soils in the northern part of this district.

WEST SIDE MESA.

The west side mesa covers an area lying above the survey of the B branch of the all-American canal. The eastern boundary of the district follows the line of the survey of that branch, while the western boundary is an irregular line from 1 to 15 miles distant. The outline of the district is shown upon the accompanying map.

From the third standard parallel southward the general topography is that of a broad plain with a very uniform surface, the major relief being afforded by the uplift of the Superstition Mountains. The drainage is partly to the north, by the way of Carrizo Creek and its tributaries, into San Felipe Creek, and in the southern portion of the run-off from the mountains is carried by Coyote Creek and a number of smaller washes. All of the slopes are very gradual, and the watershed divide between Carrizo Creek and the Arroyos to the south is so slight as not to be evident to the eye. In the vicinity of the ancient beach line and south of the San Diego, Arizona & Eastern Railroad the surface becomes more uneven, and there are considerable areas where the surface is not adapted to irrigation.

Carrizo Creek maintains a well-defined channel from its entrance onto the plain, near the southwestern corner of township 14 south, range 10 east, to about the northern line of that township. At that point the stream loses its identity in a maze of smaller channels, and the area northward to San Felipe Creek is subject to extensive overflows at irregular intervals. During periods of high water in Carrizo Creek a portion of the discharge follows an irregular course eastward across the plain and accumulates in the old lake bed in the southern part of township 14 south, range 11 east. In the southern part of this district the smaller washes disappear shortly after reaching the plain, but the larger arroyos maintain their chan-

nels as far as the beach line and then discharge their flow onto the lower land.

Along San Felipe Creek the soils are predominantly silt loams or heavier in texture, are often very compact, and usually carry excessive amounts of alkali. Some sandy textured materials occur near the western boundary of this district, and an area of about 16,000 acres of land in the western part of township 12 south, range 9 east, is considered as irrigable land. This body is shown upon the accompanying map.

North of San Felipe Creek a long, narrow range of low hills extends easterly through townships 11 and 12 south to about the eastern line of range 10 east. Below these hills the surface is an extensive series of moderately steep slopes, descending southward toward San Felipe Creek and in a northerly direction toward Salton Sea. These slopes are traversed by a large number of well-defined drainage channels. The larger number of these channels are inadequate to handle the flood waters, and the larger part of the surface is subject to occasional overflows.

Between San Felipe Creek and extending nearly to Palm Creek the larger part of the soil material consists of stratified clays that are very compact and locally indurated. These materials almost invariably carry very excessive amounts of alkali, and because of that condition, the unusually compact structure of the materials, the soils are considered as nonirrigable. A small area of alkali-free, sandy-textured soils occurs just below the extreme eastern end of the low range of hills. The topography, drainage, and soil conditions of this body render it favorable for irrigation. From Palm Creek northward to the limits of this district the soil of the upper slopes is a very gravelly and stony material to a depth of several feet. The topography is a series of rather rolling ridges, descending toward Salton Sea, which are traversed laterally by a large number of unusually large washes and by a number of poorly defined shallow drainage channels. Nearly all of this body is subject to severe floods that at times cover the larger part of the surface. In its present condition the larger part of this body is too stony for cultivation, and considerable expense would be necessary to prepare the land for cultivation. Because of none too favorable topography, the presence of a large amount of coarse material on the surface, and the necessity for expensive flood control, this body is considered as nonirrigable.

Southward from San Felipe Creek to about the southern boundary of township 14 south the soils are largely materials approaching a silt loam in texture, with minor areas of both lighter and heavier textured soils. Some of these soils are very compact and carry large amounts of alkali, but the larger part are free from alkali and adapted to irrigation.

Throughout townships 15 and 16 south and above the ancient beach line the larger part of the soils are sandy loams that are well drained and free from alkali and well adapted to irrigation.

The irrigable land indicated upon the map in this part of the district shows the boundaries of that class of soil so far as they are known at the present time. The soil examination is not quite complete in the vicinity of Dixieland and to the southward, and the results of that work may result in a slight extension of the boundaries inclosing the irrigable land.

SUMMARY.

Over the larger part of the east side mesa the soil conditions are well adapted to irrigation, wherever the topography is not so irregular that the land can not be leveled.

The only known area of irrigable land in the Dos Palmas district is a body in the northern portion, in the vicinity of Salt Creek, and the completed examination will probably not develop more than a very few small isolated additional bodies.

An examination of the soils in the Coachella Valley has not yet been made. The indications are that the larger area of the soils have a topography favorable for irrigation. The unfavorable conditions are the presence of alkali and the danger of occasional floods, but no estimate can be made at the present time of the area that may be nonirrigable.

The larger part of the soil within the west side gravity district is nonirrigable, either by reason of excessive amounts of alkali or on account of unfavorable soil-texture conditions, which would largely prevent satisfactory drainage operations. Only two small irrigable areas of soil have been found in the northern part of this district. The soil examination has not been completed in the southern portion of the district, but a considerable part of the soils are known to be nonirrigable, and the added area of irrigable land will be small.

On the west side mesa the larger part of the area covered by the soil examination is nonirrigable because of unfavorable topography, alkali, and soil conditions. A large area of excellent land has been developed in the region west and southwest of Superstition Mountain. The examination, when completed, will add but very little to the area of irrigable land as it is now outlined upon the accompanying map.

33

2

Appendix E.

PARKER PROJECT, COLORADO RIVER INDIAN RESERVATION.

LOCATION AND DESCRIPTION.

The Parker Valley, or what is called by the United States Indian Service the Colorado River Indian Reservation project, lies on the east side of the Colorado River in Yuma County, Ariz. A small portion of the valley is on the west side of the river in Riverside County, Calif. The principal town, Parker, at the head of the valley, with a population of 500, is located on the Atchison, Topeka & Santa Fe Railroad.

The Parker Valley has a total length of about 37 miles, extending from Parker on the north to near Ehrenburg on the south. The maximum width of the valley is about 7 miles on the east side of the river. The river channel in this valley is somewhat more stable than in the Mohave Valley, though it is also subject to erosion and to shifting of its bed. The river is said to overflow the lower bottom lands with a flood exceeding 40,000 second-feet, and that 95,000 acres are subject to overflow during periods of maximum flood. It would appear, therefore, that for anything less than complete flood control by storage, a levee system will be necessary, although, with partial control, the section of the levee and the riprapping could probably be reduced accordingly.

On the west side of the river there are several separate small areas of bottom land aggregating about 4,000 acres; but, owing to its small area and to the narrowness of the valley, it could not be protected from overflow within reasonable cost by levees, and it will, therefore, not be considered as a part of the project. With complete flood control by storage, it would probably become attractive to individuals, either by irrigation through direct diversion or low lift pumps.

The bench lands considered as a part of the project consist of the Parker Mesa at the head of the valley, surrounding the town of Parker. This is an attractive stretch of land, being quite smooth and level, with a gravelly and sandy soil. The bench is from 75 to 150 feet above the bottom lands.

There is also a mesa on the west side of the river, namely, the Dalzona Mesa. There has been no survey of this mesa, so no detail can be given of it. It is said, however, to be rather rough and unattractive. It is not here considered as a part of the project.

Lands of the Parker project are all in the Colorado River Indian Reservation.

HISTORICAL.

A detailed survey and estimate of the Colorado River Indian Reservation project consisting of the gravity system of the project proposed herein, was made by the United States Indian Service in

1918 and 1919. Topography was taken on a scale of 400 feet to 1 inch covering the entire reservation, with a contour interval on the bottom lands of from 1 to 2 feet. Detailed estimates were prepared and the final report written by Mr. C. A. Engle, engineer in charge, under date of June 30, 1920. A soil report was also made by Mr. A. T. Strahorn, United States Department of Agriculture, dated 1920, which report is made a part of the Engle report.

Topography and soil.—The bottom lands are flat and subject to overflow and are considerably cut with sloughs and very heavily covered with mesquite, arrowweed, and other brush. The soil is river silt and sandy loam and is very fertile. The Parker bench is smooth and gently sloping toward the river. The soil is gravelly and sandy loam.

Drainage.—The bottom lands are lowest next to the mesa, or away from the river, and are subject to seepage from the river during normal high water and by backing up from the sloughs. Artificial drainage will be necessary.

Ownership.—All the lands in the proposed Parker project lie within the United States Indian reservation. Fifteen thousand acres is the maximum that will be needed for allotment to the Indians; the balance may be thrown open to settlement.

Area:

	Acres.
Gross	121,000
Irrigable—	
Gravity	104,000
Pumping, lift approximately 135 feet	6,000
Total irrigable	110,000

WATER SUPPLY.

Appropriations.—No water filings have been made for this project to the knowledge of the engineer in charge. The area irrigated in 1920, which is the maximum to date, is 4,100 acres, and it is estimated by the engineer in charge that 7,000 acres will be in cultivation in 1921. The present pumping plant, with the installation of another boiler which is planned in the near future, will be sufficient to cover about 7,500 acres.

The right to divert water from the Colorado River (a navigable stream) was authorized by act of Congress entitled "An act making appropriations for the current and contingent expenses of the Indian Department and for fulfilling treaty stipulations with various Indian tribes for the fiscal year ending June 30, 1905, and for other purposes" (act Apr. 21, 1904, ch. 1402, 33 Stat., 189). The portion authorizing the diversion of water reads as follows:

> That in carrying out any irrigation enterprise which may be undertaken under the provisions of the reclamation act of June 17, 1902, and which may make possible and provide for, in connection with the reclamation of other lands, the reclamation of all or any portion of the irrigable lands on the Yuma and Colorado River Indian Reservations in California and Arizona, the Secretary of the Interior is hereby authorized to divert the waters of the Colorado River and to reclaim, utilize, and dispose of any lands in said reservations which may be irrigable by such works in like manner as though the same were a part of the public domain.

287

Storage required.—On assumption of complete development of lower Colorado River lands storage will be required for the use of the Parker project for the undeveloped area of, say, 103,000 acres.

PRESENT STATUS.

There is a pumping plant installed by the United States Indian Service, as above described, with a capacity for the irrigation of about 7,500 acres. This pump is located on the bank of the river at the head of the valley. The water is pumped from a sump, into which the water enters from the river through five 7-foot gateways equipped with flashboards to keep out all but the top water. The lift of this plant is about 21 feet. Near the pumphouse a large settling basin has recently been constructed, with provision for sluicing the silt back into the river by means of a by-pass.

The canal system consists of about 10 miles of canal of more than 50 second-feet capacity and 43 miles of laterals. The area under the present canal system is about 6,000 acres.

Nine miles of drainage canals have also been constructed.

IRRIGATION PLAN.

Plan of C. A. Engle, engineer in charge, for gravity system (Report of June 30, 1920).—A diversion weir is planned at a point locally known as Headgate Rock, which is a short distance above the railroad crossing of the river. This weir is of the floating type on a sand foundation. The length is 1,600 feet, with a height of 14 feet above mean low water. At the end of the weir a by-pass or diversion channel is planned, to have a clear width of 200 feet and a depth of 22 feet below the weir crest. There will be five by-pass gates (Stony type) 23 feet by 41½ feet. A desilting basin and sluiceway similar to the one at Laguna Dam is planned on the land side of the by-pass structure. The clear width of this basin is 160 feet, and depth 14 feet.

The main canal to the head of the valley where the first division is made is 2¼ miles in length. This will be mainly in a rather porous gravel, and it is planned to be concrete lined. It has a capacity of 1,600 second-feet. The total length of canals, including the principal branches, is 46 miles, and the total length of distributaries is 184 miles.

A protective levee is provided. This is planned to be constructed near the bank of the river, with a section consisting of a 12-foot crown and a height of 5 to 6 feet above mean high water. A coarse gravel blanket 12 inches thick is to be placed on the entire surface of the levee, and the river slope is to be provided with a rock revetment containing an average of 7½ cubic yards per linear foot. The total length of levee planned is 45 miles.

A drainage system is provided with a main drain running the length of the valley and with a system of lateral drains connecting therewith. A pumping plant will be required at the lower end of the main drain.

Pumping system.—The pumping portion of the project, which covers the area of the Parker bench, has not been worked out in detail, and therefore the plan and estimate herein are very rough.

A pumping plant will be required to pump from the main canal near its head, and, as the bench slopes toward the river, a long pipe line will be required with probably a second lift. The average lift will be approximately 135 feet. The distribution system of the mesa lands is to be concrete lined.

Power requirement:		
Irrigable area	acres	6,000
Pump capacity	second-feet	60
Mean lift	feet	135
Theoretic horsepower		920
Requirement, horsepower (60 per cent efficiency)		1,500

COSTS.

Cost to date.—The cost of the present pumping plant and canal system of the United States Indian Service, according to the Engle report of 1920, is approximately $140,000. The pumping plant will have no value as a part of the larger project though the distribution system can be incorporated by an enlargement into the new system and will probably have a value equal to the cost of its construction.

Estimated cost to complete (exclusive of storage for flood control).

Gravity project data from Engle report of June 30, 1920:	
Diversion weir	$753,300
By-pass or diversion channel	601,590
Desilting basin and sluiceway	698,410
Main canal and distributary system	2,059,400
Levee system and river improvement	2,271,500
Drainage system	849,400
Total (Engle estimate)	7,234,600
Pumping system (no detailed estimate available):	
Pumping plant, 1,500 horsepower, at $100	150,000
Distribution system (concrete lined), 6,000 acres at $70	420,000
Grand total	7,804,600

One hundred thousand acres, exclusive of storage, flood control, and power.

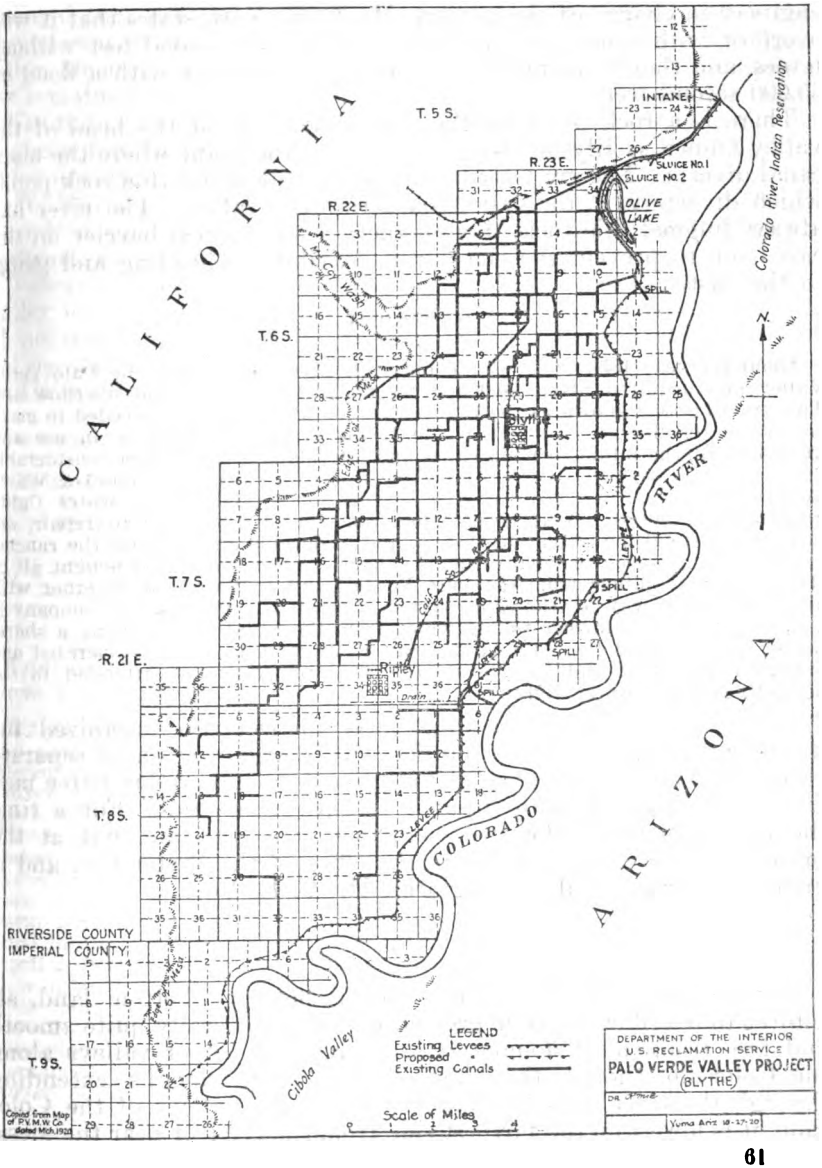
Palo Verde Valley (Blythe Project).

LOCATION AND DESCRIPTION.

The Palo Verde Valley is located on the west side of the Colorado River, in Riverside and Imperial Counties, Calif.

The principal town is Blythe, with a population of 2,000 people, situated in the north-central part of the valley. Ripley is a new town just starting, and is at the terminus of the California Southern Railroad, a branch of the Atchison, Topeka & Santa Fe from Blythe Junction. The distance from Blythe Junction to Blythe is 42 miles.

The valley is 25 miles in length with an average width of about 6 miles. It lies in a compact body and is well adapted to irrigation development. The river skirts the east side of the valley except near the north end, where the Palo Verde Valley overlaps the Parker Valley, and at the south end where it overlaps the Cibola Valley. These three valleys, in fact, constitute one large valley, being broken



only by the river channel at the two points where it crosses the valley. The Palo Verde mesa lies adjacent to and west of the valley, and the Chucawalla Valley lies west of this, over a small divide.

The general elevation of the valley is 250 feet above sea level. The engineer in charge of the project, Mr. C. E. Yost, states that it will overflow with a flood of from 50,000 to 60,000 second-feet without levees, and that bank protection would be necessary with a flood of 35,000 second-feet.

There is a rock point on the west river bank at the head of the valley known as Blythe Heading, which is the point where the main canal diverts. The river strikes the west bank about this rock point, which diverts it to the east bank across the valley. The river has always hugged this rock, though there is no natural barrier on the east bank to prevent the river from leaving the heading and going to the east.

HISTORICAL.

About the year 1856 * * * Thomas H. Blythe came into the Palo Verde Valley and acquired about 40,000 acres under the swamp and overflow act. This tract became known as the Blythe rancho. Blythe then proceeded to make certain water filings. * * * He built the gravity intake now in use and known as Blythe intake, a main canal and laterals and irrigated a considerable area. In 1905 or 1906 a corporation known as the Palo Verde Land & Water Co. was organized and acquired the Blythe rancho and all the water rights appertaining thereto. This corporation immediately proceeded to repair, enlarge, and extend the irrigation system, and to develop and colonize the rancho.

In 1908 the present company was organized in the valley and bought all of the water-right filings from the Palo Verde Land & Water Co. together with all the rights of way for the canal system extensions. The present company is a mutual one, each farmer taking water from the canal system being a shareholder. It is called the Palo Verde Mutual Water Co., and has operated and extended the canal and levee systems. This company also attended to the perfecting of the water rights.

In 1918 the Palo Verde joint levee district was organized for the purpose that its name implies. This organization is separate from the Water Co., though at the present time there are three men who hold the position of director in both companies. For a time the management of the two companies was separate, but at the present time it is all handled in the office of the Water Co., and is under the direction of one engineer, Mr. C. E. Yost.

LAND.

Topography and soils.—The valley is flat river-bottom land, all subject to overflow without protection. It is generally quite smooth and free from small sloughs as compared with other valleys along the Colorado, though there are a few large sloughs extending through the tract. As is characteristic of the valleys of the Colorado, it is lowest on the farthest side from the river or near the mesa, the fall being about 15 feet.

The lower end of the valley is a fine, rather heavy, silt. The middle and upper portion is a light sandy silt. The soil is very fertile, as is evidenced by the land in cultivation, and generally it seems quite free from alkali, except in some of the lower portions in the old irrigated sections where it has become alkalied by the rise of the ground water.

Drainage.—There is fairly good surface drainage throughout the valley except during the high-water period, the water being carried off through the large sloughs above mentioned, which empty into the river near the lower end of the valley, but due to irrigation it found that during a period of about 10 years prior to 1918 the ground water had risen about 7 feet, and at that time was also within about 7 feet of the surface. Since that time the water table has remained about the same, though it fluctuates to some extent, due to the rise and fall of the river. The need of artificial drainage has been felt for some years in the irrigated portion of the valley, and a drainage estimate and plan of work were made in report by D. W. Murphy, drainage engineer, under date of November 18, 1918. Since that time some progress has been made in the way of drainage construction.

Ownership and area.—Practically all of the land in the Palo Verde Valley is in private ownership. The Blythe rancho has been sold off into small tracts averaging about 60 acres. The area of the project and the status of land as of October, 1920, as shown by the records of the United States Land Office, are as follows:

	Square miles.
Gross area of valley	95,000
Irrigable area—	
Private	72,000
Entered	6,600
Total	78,600

WATER SUPPLY.

Appropriations.—The various water-right filings for the Palo Verde Valley project are listed as follows:

July 17, 1877: By Thomas H. Blythe, 95,000 inches to be diverted at Black Point, approximately 1¼ miles above the Blythe intake.

December 15, 1878: By Thomas H. Blythe and O. T. Calloway, 90,000 inches to be diverted at a point in sec. 30, T. 5 S., R. 24 E. In this notice is described a main canal then being constructed.

February 20, 1883: Recorded in the records of San Diego County on an undated notice of filing. By Thomas H. Blythe, 100,000 miner's inches to be diverted at a point approximately midway between the north and south lines of sec. 18, T. 5 S., R. 24 E. This point was very probably intended for the present Blythe intake and was doubtless the filing on the water to be diverted at that intake into the canal system as built by Blythe.

April 2, 1904: By Florence Blythe Moore and A. A. Moore, jr., 300,000 miner's inches to be diverted at Black Point.

1905–1908: It was understood that the Palo Verde Land & Water Co. made some water filings during this period, but the records of these filings are not obtainable at Blythe.

September 14, 1908: By C. W. Petit, 200,000 miner's inches of water to be diverted at Blythe intake. In this filing all of Petit's interests were assigned to the Palo Verde Mutual Water Co.

March 18, 1911: On this date the Palo Verde Mutual Water Co. purchased from the Palo Verde Land & Water Co. the intake point known as Black Point.

August 5, 1911: By the Palo Verde Mutual Water Co., 200,000 miner's inches of water to be diverted at Black Point.

The above record copied from the report of N. B. Conway, dated June 10, 1916.

Storage required.—It is the opinion of the engineer in charge of the project that the water rights of the company are sufficient for the irrigation of the entire valley, and that no storage will be re-

quired. The question of the water rights of the company is a matter to be eventually determined by adjudication.

PRESENT STATUS.

The present works of the Palo Verde Mutual Water Co. consist of 181 miles of irrigation canals and laterals, of which approximately 8 miles are main canals, 26 miles of submains, and 147 miles of laterals. The company has also constructed 28½ miles of main levee, 6 miles of auxiliary levee, 7¼ miles of wasteway canals, and 5½ miles of drainage canals, in addition to the borrow-pit drain which extends the full length of the levee. The intake of the main canal is constructed in a granite rock cut at the Blythe heading above mentioned. A new concrete structure has been installed at this point sufficient in capacity to irrigate the entire valley. The structure is controlled by wooden emergency gates, with steel-stem screw-lifting devices. Ordinarily it is controlled by flashboards, over which the water enters the canal, permitting the skimming process. As the main current of the river strikes the Blythe heading it is free from silting up above the intake.

Two and one-half miles below the intake is sluiceway No. 1, and at mile 4 is sluiceway No. 2, which are large wooden structures. The skimming process is repeated at these points over flashboard into the canal, and the silt is sluiced out into the river. Excess water is run to these points for this purpose.

At 7¾ miles below the intake are located the controlling gates of the three submains, at the lower end of the main canal proper.

The engineer in charge, Mr. Yost, states that the canals are sufficient in capacity for the irrigation of the entire valley on condition of proper cleaning.

The main levee as constructed at present extends from the head of the valley to the county line near the lower end of the valley, a length of 28½ miles. The section of the levee is: Crown 12 feet, river slope 3:1, land slope 2:1, average height 10 feet. A borrow pit has been constructed continuously on the land side, with a berm of 50 feet between the pit and the levee. This borrow pit is intended as a shallow drain and has been fairly successful for this purpose, though deep drains are planned some distance back from the levee; 3,500 feet only of the levee have been riprapped. Two miles of railroad are constructed on the levee, and 3 miles leading from the levee to the quarry. There are several cross levees extending from the main levee out into the valley. The area protected by levees at present is said by the engineer in charge to be 70,000 acres, which is also the area under the present constructed canal system.

The area irrigated in the present season (1920) is approximately 35,000 acres.

The shares of water stock issued by the company represent water sufficient for one acre to the share. To the present date, October 20, 1920, 40,700 shares have been sold. These shares are valued at $35 per share.

IRRIGATION PLAN.

The Palo Verde project is entirely a gravity system. The water is diverted direct from the river at the Blythe intake, as above de-

scribed, without a diversion dam. There is no plan on the part of the management for the construction of a dam at this point, first, for the reason that it is not needed, as at practically all times there is sufficient head against the intake for the required diversion, and in the second place, for the reason that there is no dam site at the head of the Palo Verde Valley. As stated previously, there is no physical reason why the river should not leave the Blythe heading and go to the east, as there is a wide, flat valley at this point. This, however, has never occurred in the history of the project, though it does not necessarily follow that it will not occur in the future. Such a possibility is realized by the present management, and plans are made to riprap the opposite bank in case it should become necessary.

The desilting question is handled fairly well at the present time, considering that there is no diversion dam with sluiceway, as at Laguna. This is probably the best natural intake on the lower Colorado River, and the project is thus fortunate in being able to enjoy the benefit of reasonably well desilted water without the cost of diversion dam.

The lateral system is now constructed for all but about 9,000 acres in the valley, and the present plan is to extend these laterals as water stock is purchased by new lands and water is called for. The sale of the stock pays for the construction of the laterals.

It is planned to extend the main levee to the lower end of the valley for a distance of 6 miles. A railroad is planned to be constructed on the entire length of the main levee for the purpose of protection in case the river threatens at any point. Riprap, generally, is not planned, except at threatened points, though without flood control the entire length will probably eventually require riprap.

A complete drainage system will be required and is planned, as outlined in the D. W. Murphy report of January 1, 1918.

POWER REQUIREMENT.

As the Palo Verde project is under a gravity system, no power will be required.

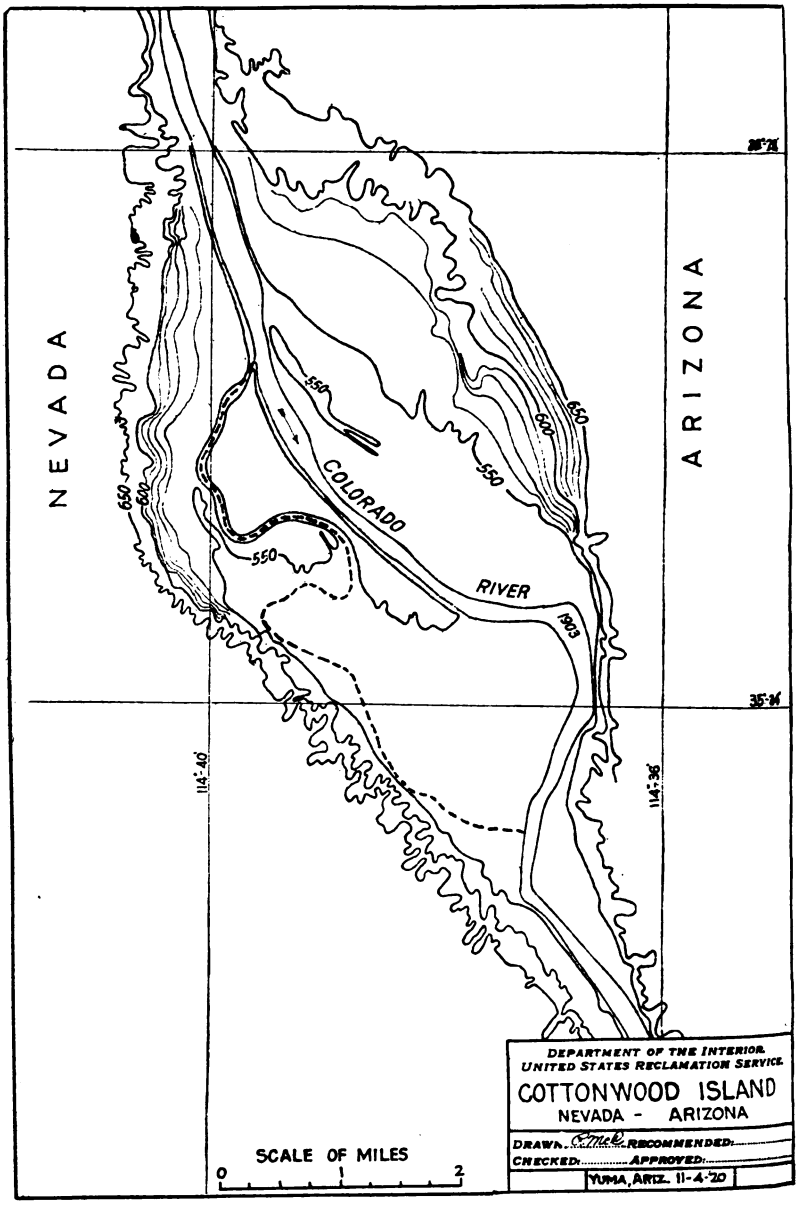
Cottonwood Island Project.

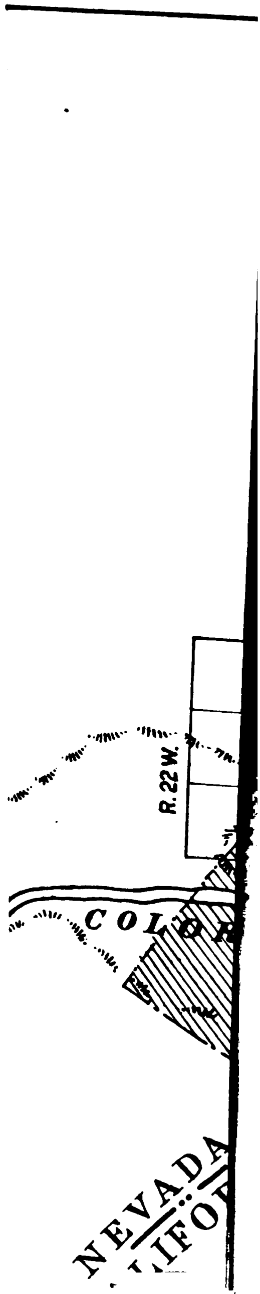
The Cottonwood Valley project, or what is generally known as Cottonwood Island, is located on both sides of the Colorado River in Clark County, Nev., and Mohave County, Ariz. The nearest railroad point is Chloride, which is about 30 miles east.

This tract is a small valley of river-bottom land through which the river meanders, changing its channel from time to time. There are generally two principal channels, which form the island, but the river is now all in the west channel. This tract will be submerged in case the Bulls Head Reservoir is constructed.

Ownership.—There are no patented lands in the valley. The area was withdrawn under the reclamation act in 1903 for the proposed Bulls Head Reservoir.

28722—21——5





	Acres.
ss	6,600
gable—	
Gravity	1,600
Pumping (40-foot lift)	2,800
Total	4,400

Mohave Valley Project.

LOCATION AND GENERAL DESCRIPTION.

ohave Valley is located principally in Mohave County, Ariz., a small area on the west side of the river, in Clark County, ., and in San Bernardino County, Calif.

he principal town, Needles, with a population of 2,500, is located the west bank of the river. The Atchison, Topeka & Santa Fe ilroad crosses the Colorado River at the lower end of the valley.

he main valley extends from Fort Mohave on the north to ock on the south, a distance of about 25 miles, with a maximum th of about 5 miles.

egarding this valley, Mr. Homer Hamlin, in his diary of April 13, 0, states:

> he bottom lands in Needles Valley are very low, and a small rise in the river cause extensive overflow. The river is evidently changing its course at y points. The low bottom lands and rapidly changing river channel will e the irrigation of these lands extremely difficult if not impossible.

he valley is subject to overflow, at least to some extent, for floods 5,000 second-feet. It would appear, therefore, that even with age for flood control a levee system will be required in order to aim these lands.

ll odd-numbered sections in the Mohave Valley on the east side he river and outside of the reservation were granted by the ted States to the Atlantic & Pacific Railroad, now the Atchison, eka & Santa Fe. In 1904 these lands were sold and are now by the Cotton Land Co., which planned to reclaim 30,000 s.

ll even-numbered sections in Mohave Valley east of the river—t 18,000 acres—were made a part of the Indian reservation by cutive order of February 2, 1911.

n 1912 and 1913 the Indian Service constructed 5 miles of levee. s levee failed in 1914, as also did the levee of the Cotton Land Co. ce that date neither of these levees has been repaired.

and classification and topographic surveys were made of the have Valley in 1903.

Tract.	Ownership.				Area.			
	Indian lands.	Public lands.	Private lands.	Total.	Gross.	Irrigable.		
						Gravity.	Pumping.	Total.
have Valley, east side	20,000	.....	19,000	39,000	39,000	22,500	2,400	24,900
th of Fort Mohave, east side	.....	1,000	2,000	3,000	3,000	.....	800	800
st side	2,500	1,700	1,800	6,000	6,000	1,000	.....	1,000
Total, gross	22,500	2,700	22,800	48,000	48,000	23,500	3,200	26,700
Total, net irrigable	12,500	1,500	12,700	26,700	.....	.....	.....	.....

PRESENT STATUS.

The only irrigation development in the Mohave Valley has been done by the Cotton Land Co. and the United States Indian Service. The Cotton Land Co. system comprises about 19½ miles of canal, with a capacity of about 100 second-feet. A concrete intake is installed about 2 miles below Fort Mohave, which is at a point well protected from river action by a jutting point of mesa. No silting works or diversion structure other than an intake has been provided.

The Cotton Land Co. has also constructed about 10 miles of levee, with a crown width of about 6 feet and an average height of 4 feet. No riprap or slope protection has been done. This levee, as previously stated, was partly destroyed in 1914.

The United States Indian Service afterwards constructed a levee running south from near the head gate of the Cotton Land Co.'s canal. This levee was also partly destroyed in 1914, and has not since been repaired.

Chemehuevis Valley Project.

LOCATION AND DESCRIPTION.

The Chemehuevis Valley is located on both sides of the Colorado River, with the larger area on the west side. The portion on the east side is in Mohave County, Ariz. The portion on the west side of the river is in San Bernardino County, Calif.

The nearest town and railroad station is the little station of Powell, on the Atchison, Topeka & Santa Fe Railroad, about 10 miles from the valley.

The length of the valley north and south is about 6 miles and the maximum width 2 miles. The elevation is about 400 feet above sea level. The valley is all subject to overflow during normal high water. For this reason it is not feasible for irrigation development without the construction of levees on both sides of the river. Such levee construction may be reduced in cost by a partial flood control and possibly could be eliminated with complete flood control by storage. The valley is small and is not attractive as an irrigation project.

The valley on the west side of the river is in the Chemehuevis Indian Reservation. A few Indians (approximately 200) live on the reservation. Tentative allotments of 10 acres each have been made to these Indians, aggregating a total of about 2,000 acres.

There is no irrigation at the present time nor has there ever been in the valley. The Indians living here do some farming on a small scale on the overflow lands, the crops being planted after the receding of the high water.

Land classification and a topographic survey on a scale of 2 inches to the mile were made in 1902 and 1903.

OWNERSHIP.

There are no private lands in the valley. The lands were all withdrawn under the reclamation act in 1903. The west side of the river is Indian reservation lands and the east side is public lands.

	Area.	
	Gross.	Net.
Indian lands	2,900	2,300
Public lands	1,700	1,400
Total	4,600	3,700

Cibola Valley Project.

LOCATION AND DESCRIPTION.

The Cibola Valley lies on the east side of the Colorado River in Yuma County, Ariz. It is about 20 miles south of the lower end of the Parker Valley and is adjacent to the lower end of the Palo Verde Valley, being separated from the latter only by the river.

The nearest railroad point is the new town site of Ripley in the Palo Verde Valley, about 12 miles north.

The valley lies north and south, with a length of 12 miles and a mean width of 3 miles.

The general elevation of the valley is about 230 feet above sea level.

The Cibola Valley is but little above the bed of the stream, and the entire area is subject to overflow during normal high water. The valley could not be developed without complete storage control or without a levee for the full length of the river bordering the valley. There is no diversion dam site in the vicinity of the Cibola Valley.

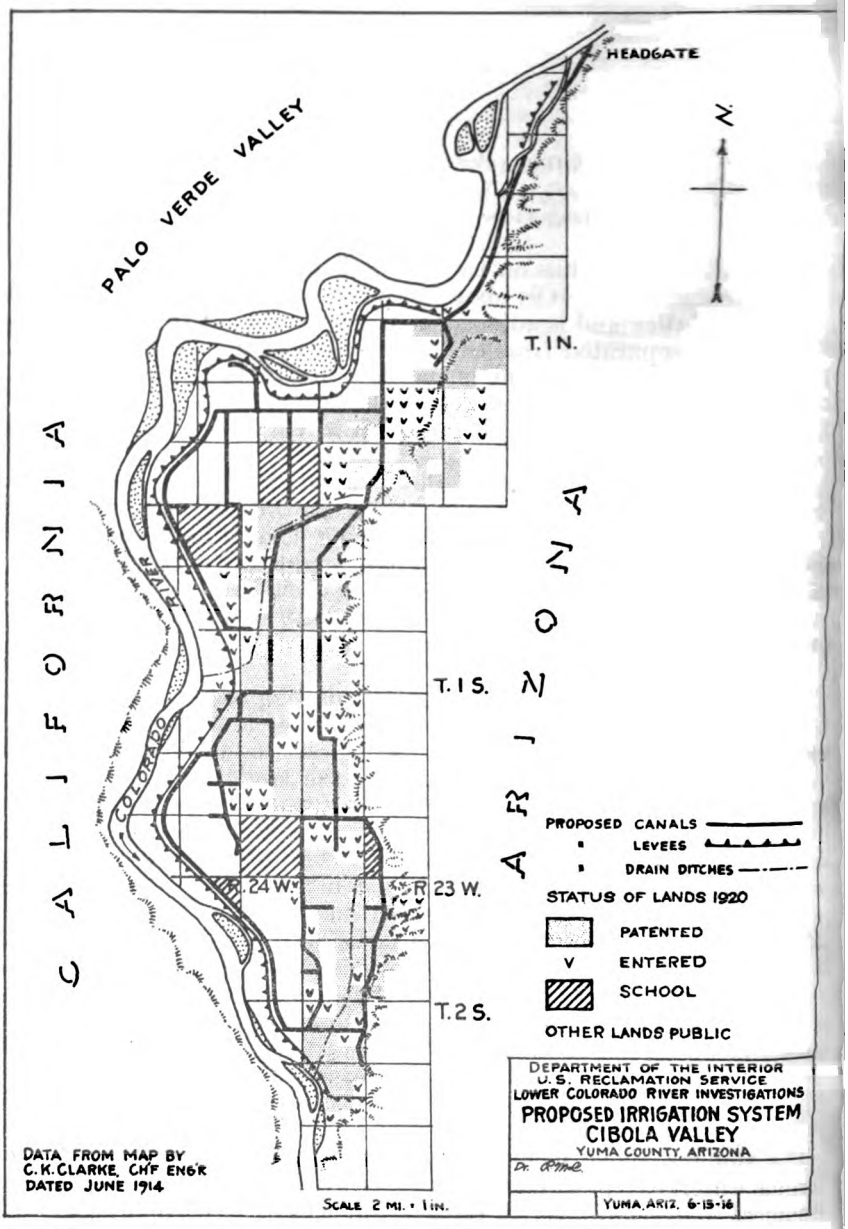
A topographic survey was made on the scale of 2 inches per mile in 1902 and 1903.

There has never been any irrigation development in this valley except a few attempts on a very small scale of individual pumping. Some farming on a small scale has been practiced on overflow lands.

An irrigation district was formed by the landowners in 1913 for the purpose of developing an irrigation project. Detailed surveys of an irrigation and levee system were made for the district by R. L. Morton in 1914. From these surveys a complete system of canals, levees, and drains was designed and quantities computed, and a report and estimate were made covering the same by C. K. Clarke in 1914. The plan as laid out by Mr. Clarke is shown on the index map herewith, which was copied from a large scale map prepared by him. The irrigation district voted bonds for the construction of the project as outlined and estimated by Mr. Clarke, but to the present date no market has been found for them.

DRAINAGE.

The sloughs above mentioned are sufficient for carrying off the surplus water, except during high water of the river, when the valley is subject to overflow. With the development of irrigation, however, artificial drains will be necessary. These sloughs can be used to a large extent in the construction of a drainage system.



OWNERSHIP AND AREA.

The area of the project and the status of the lands, as of October, [illegible], as shown by the records of the United States land office, is as follows:

	Gross.	Net.
[illegible]ed	3,000	2,550
[illegible]ted	8,000	6,800
[illegible]	5,500	4,650
[illegible]	2,000	1,700
Total	18,500	15,700

Palo Verde Mesa and Chucawalla Valley Project.

[Data mainly from report of Koebig & Koebig, consulting hydraulic engineers, Los Angeles, Calif., dated Jan. 1, 1917.]

LOCATION AND DESCRIPTION.

The Palo Verde Mesa and Chucawalla Valley project is located in Riverside County, Calif.

The Palo Verde Mesa lies adjacent to, and west of, the Palo Verde Valley or Blythe project. The elevation of the mesa is from 320 to 450 feet above sea level, and from 70 to 200 feet above the adjacent valley.

West of the Palo Verde Mesa is a low pass between Mule and McCoy Mountains, at an elevation of 460 feet above sea level. Through this pass is the Chucawalla Valley, extending northwesterly for a distance of about 30 miles, and with a maximum width of about 12 miles. The valley is a large inland basin or sink, with no surface drainage outlet. There are two dry lake beds in the bottom of the basin: Pelan Lake, elevation 450 feet, near the west end of the basin, and Ford Lake, the lowest point of the basin, elevation 360 feet, near the east end.

HISTORICAL.

On November 9, 1908, the Chucawalla Development Co. was organized for the purpose of supplying water from the Colorado River to an extensive area of desert land. * * * The lands to be covered by this irrigation project are known as the Palo Verde Mesa and the Chucawalla Valley and embrace an area of, collectively, 177,550 acres. * * * The land has been filed upon in the United States Land Office, under the desert land act, these filings having been made under the encouragement offered by the Chucawalla Development Co. * * *

* * * The company made preliminary surveys of the canal lines. Investigations of and borings at the dam sites, situated 8 miles above Parker, Ariz., below Bill Williams Fork and at Pyramid Canyon, 30 miles above Needles, Calif., also surveys of the reservoir sites were made in connection with the dam sites herein mentioned. * * * Further preliminary surveys were made for a transmission line for conveying electric power to the pumping plants near the diversion dam and reservoir at Black Point.

The report of Koebig & Koebig, from which the above is quoted, outlines a general plan of the project, including a diversion dam, pumping plants and canal systems, and includes estimates of cost of the same.

An act of Congress was passed and approved February 15, 1911, entitled "An act to authorize the Chucawalla Development Company to build a dam across the Colorado River at or near the mouth of Pyramid Canyon, Arizona, also a diversion intake dam at or near Black Point, Arizona, and Blythe, Calif." (Public, No. 374, H. R. 31859). The following provisions are made in this act:

Provided, That the actual construction of said dams shall be begun within two years and completed within five years from the date of the passage of this act; *And provided further*, That the actual construction of said dams shall not be commenced until the plans and specifications therefor shall have been presented to and approved by the Secretary of the Interior in addition to the requirements of the act approved June twenty-third, nineteen hundred and ten, entitled "An act to amend an act entitled 'An act to regulate the construction of dams across navigable waters,' approved June twenty-first, nineteen hundred and six," and in approving the plans and specifications, the Secretary of the Interior may impose such conditions as to him shall seem proper for the protection of the public interests of Indians and the United States.

LAND.

Soil.—A soil reconnaissance survey of this project was made in April, 1920, by A. T. Strahorn, of the United States Bureau of Soils, and another soil reconnaissance was made in November, 1920, by Charles F. Shaw, professor of soil technology, University of California. The reports of these men are quoted in full, as follows:

The Chucawalla Valley is an inclosed depression on the desert west of the Blythe Mesa, and is nearly inclosed by the Ironwood and Chucawalla Mountains. The valley varies from about 3 miles to upward of 12 miles in width, and is about 35 miles in length.

The soils in this valley exist in three well-defined groups. One, which is characterized by small gravel pavements, often devoid of vegetation, has strongly cemented and alkaline subsoils. This condition occupies all of the north side of the valley from the western end of the sink to the east end of the valley, and in the south of the sink it extends westerly for about a third of the length of the valley.

The second condition consists of grayish, gravelly sands and sandy loams, with subsoils that are porous and unconsolidated. This soil occurs in the southwestern portion of the valley. The third condition includes the soils within the sink. These consist largely of clay loams and clays, having similarly textured, cemented, and alkaline subsoils. This body occupies the lowest portion of the valley and receives all the surface waters from the surrounding slopes.

For irrigation the first and third groups are entirely worthless, the first because of the cemented and alkaline conditions of the subsoil, and the second for the reason that it is also heavily alkaline and has no possibilities of being drained. The second group is exceedingly porous and coarse textured, and while it would undoubtedly produce well under irrigation, the duty of water would be so low as to render satisfactory irrigation almost impossible.

The cost of providing irrigation water for this valley would be expensive, because of the lift and because all the canal sections would require an impervious lining to prevent excessive seepage and the accumulations of alkali salts; also, rather extensive works to control the summer floods would be a necessity. If the entire area, or even the larger part of the valley, were adapted to irrigation the costs would probably not prove excessive, but, as probably not even one-quarter of the area has any possible value, the acreage is not sufficient to justify the cost of the necessary works.

A. T. STRAHORN.

SOIL RECONNOISANCE OF THE CHUCAWALLA VALLEY AND PALO VERDE MESA, CALIF.

A reconnoissance of the Chucawalla Valley was made on November 15 by the writer, accompanied by Mr. A. T. Strahorn of the United States Bureau of Soils. The valley was crossed from west to east, with side trips as seemed

necessary. Conditions will be described from the east toward the west, as this would be the direction of development.

From the divide between the Palo Verde Mesa toward the Chucawalla, the soils for several miles are of rather poor quality, being remnants of old alluvial deposits in which the subsoil has become very thoroughly compacted and which would probably be more or less impervious to the penetration of water. The surface has been eroded considerably with sloping, gravel-strewn plains, cut by washes of more recent material. About halfway from the divide to Ford Dry Lake the conditions begin to improve, the soils being less compact and of better quality. There are, however, numerous indications of alkali, and as the dry lake bed is approached the evidences of alkali materially increase. The sink, which occupies the bottom of the valley, is very much larger than is shown on most of the maps. Most of the land is heavy, ranging from clay loam to clay, and is evidently strongly impregnated with alkali. On the north side of this sink wind-blown sands have drifted in, making numerous low mounds or dunes. We did not penetrate beyond these sandy areas, but apparently the soils become of better quality and farther to the north were probably reasonably free from alkali. South of the valley trough the soils consist of broad alluvial fans, sloping down from the Chucawalla and Little Chucawalla Mountains. These soils consist of gravelly sands and gravelly sandy loams and apparently are of good quality. Soil of this character occupies the slopes to the west end of the valley beyond Palen Dry Lake. No doubt good results could be obtained from this soil provided water could be lifted high enough to cover them. The gradient is rather steep, and they are somewhat irregular in topography.

The soils along the trough of the valley, from Palen Dry Lake east to Ford Lake, carry considerable quantities of alkali. The area of the affected soils is large near Palen Dry Lake, but to the southeast the area of low, alkali land becomes very narrow, almost pinching out opposite Palen Mountain, to broaden out again toward the Ford Dry Lake already mentioned.

Summarizing: The south side, and particularly the upper slopes of the broad alluvial fans, are made up of good soils. The trough of the valley is made up of heavy soils containing considerable alkali. With irrigation the alkali land would become worse, due to seepage, and possibly the dry lakes would become true lakes or bogs. The area of good land lies rather high, and would probably call for a considerable lift for irrigation.

A brief examination was made of the northern portion of the Palo Verde Mesa. This land varies considerably in character, with large areas of questionable soils. There are considerable areas of deep, sandy soils that would undoubtedly prove to be of excellent quality. There are also areas that show indications of alkali and have a compacted, partially cemented subsoil. It would be necessary to make a much more detailed examination to determine the relative extent and proportion of good and poor soils on this mesa.

CHAS. F. SHAW,
Professor of Soil Technology, University of California.

YUMA, ARIZ., *November 17, 1920.*

Ownership and area.—The status of the project lands as of October, 1920, as determined from the records of the United States land office, is as follows:

Tract.	Gross acreage.				Total.	
	Public	Entered.	Private.	State.	Revised area.	Koebig & Koebig report.
Palo Verde Mesa:						
Low level	600	12,700	5,000	1,400	19,700	20,000
Intermediate level	1,200	12,100	2,000	1,200	16,500	15,850
High level	600	7,200	500	700	9,000	10,500
Chucawalla Valley:						
North side	13,000	28,000	300	1,700	43,000	43,000
South side	4,000	37,000	500	2,500	44,000	42,800
High level	8,000	38,500	350	2,150	49,000	45,400
Total	27,400	135,500	8,650	9,650	181,200	177,550

Net irrigable area, assuming 50 per cent waste on account of soil (see soil report), also omitting the two high level lifts, as ad by Koebig & Koebig in letter of October 27, 1920:

Public	
Entered	
Private	
State	
Total	

PRESENT STATUS.

No construction has been undertaken to date on this projec no plan has been presented for financing its construction.

There are no improvements on the project except a few well

Most of the land is held under desert entry, and is unpat The status of these entries is defined in the act of Congress en "An act to exempt from cancellation certain desert-land entr Riverside County, Calif. (Public, No. 49), approved April 11, which reads in part as follows:

> That no desert-land entry heretofore made in good faith under the land laws for lands, townships * * * in Riverside County, State o fornia, shall be canceled prior to May 1, 1919, because of failure on the the entrymen to make any annual or final proof falling due upon an entry prior to said date. * * * If the said entrymen are unable to p water to irrigate the said lands above described through no fault of * * * the Secretary of the Interior is hereby authorized to grant a fu extension for an additional period of not exceeding two years.

YUMA PROJECT.

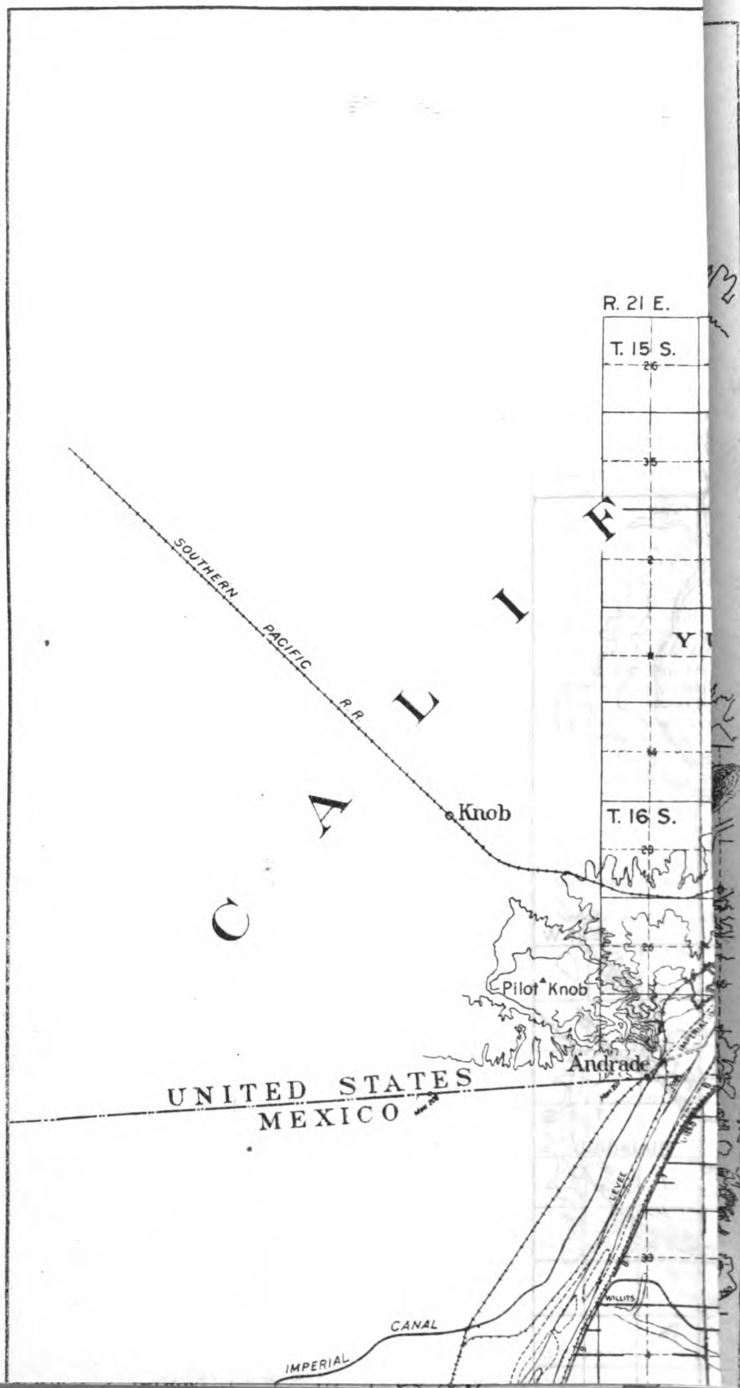
LOCATION AND DESCRIPTION.

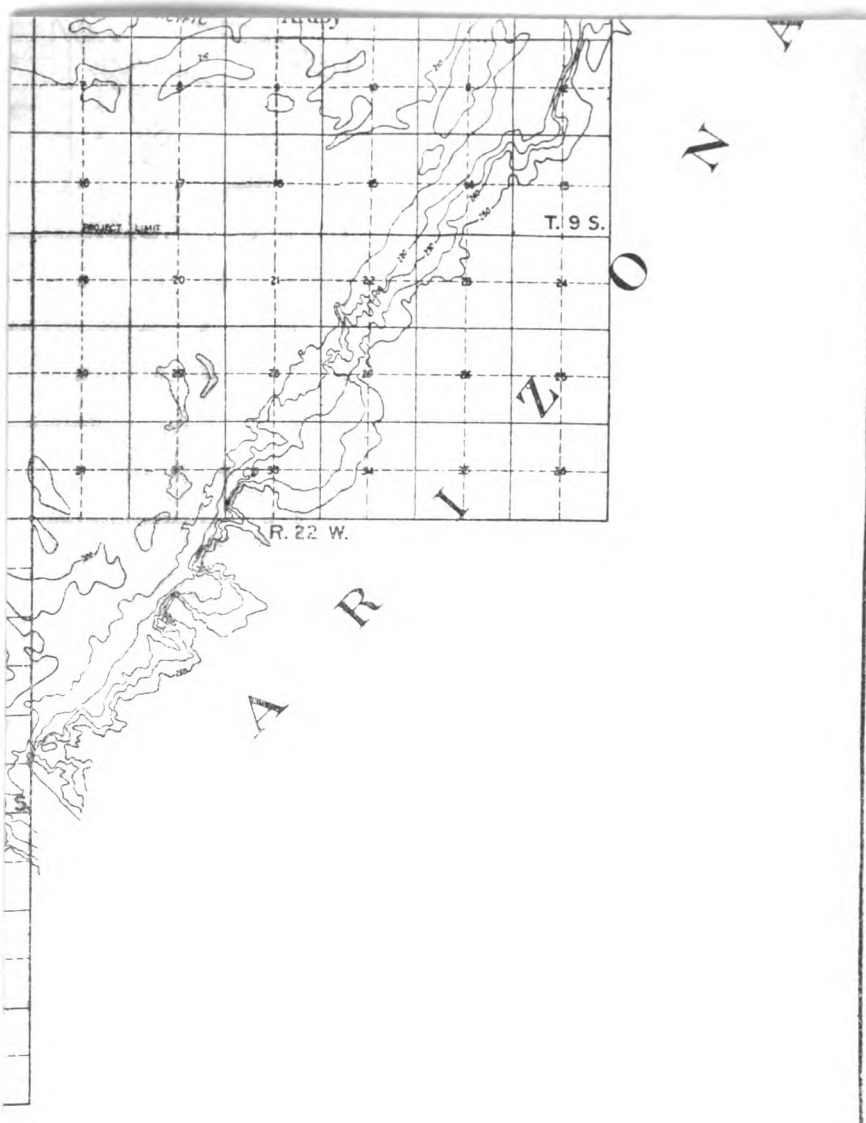
The Yuma project is located in Yuma County, Ariz., and in I perial County, Calif. The principal town of the project is Yu with a population of 5,000. It is located on the Colorado River the point of crossing of the Southern Pacific Railroad. The oth principal towns of the project are Somerton and Gadsden, in A zona, and the town of Winterhaven, in California.

The railroads of the project are the main line of the Southern P cific; the San Diego & Arizona Railroad, recently completed, fr Yuma to San Diego, Calif.; and the Yuma Valley (Governmen Railroad, which runs south from Yuma to the Mexican border distance of 24 miles.

The present constructed portion of the Yuma project compris the valley lands of the Yuma Indian Reservation on the Californ side, extending from Yuma northeast about 10 miles to near t Laguna Dam, at which point the river flows between two rock hi On the Arizona side the present constructed project comprises t Yuma Valley lands, extending from Yuma to the Mexican border distance of about 17 miles. The average width of the Yuma Val is about 6 miles, and that of the reservation about 3 miles.

The valley lands of the project were practically all subject to ov flow in extreme high water, and it has been necessary to constr levees for their protection.





DEPARTMENT OF THE INTERIOR
NITED STATES RECLAMATION SERVICE
[A PROJECT ARIZONA-CALIFORNIA

SCALE OF MILES
0 1 2 3 4 5

MAP NO. 17671

REPRINT 1918 — 500

The pumping unit of the project, or what is known as the Yuma xiliary project, comprises the bench lands lying adjacent to and st of the Yuma Valley, at a general elevation of about 190 feet ove sea level and about 80 feet above the valley lands. The first nit of this project is now under construction.

HISTORICAL.

Reconnoissance made and preliminary surveys begun in 1902.
Construction recommended by board of engineers April 8, 1904.
Construction authorized by Secretary, May 10, 1904.
First irrigation by Reclamation Service, season of 1907.
Laguna Dam completed March, 1909.
Colorado River siphon completed June 29, 1912.
Gravity water from Laguna Dam furnished to Yuma Valley hrough siphon June 29, 1912.
Yuma Mesa auxiliary reclamation project act passed January 25, 1917.
Construction of first mesa unit approved June 8, 1920.
Yuma project 95 per cent completed and first mesa unit of auxiliary project 20 per cent completed June 30, 1920.

LAND.

Topography and soil.—The valley lands of the project are flat river bottom lands, formerly covered with brush, and cut to some extent with sloughs, as is characteristic of other valleys of the Colorado River. There are also some sand dunes in portions of the project. The soil is alluvium, or river silt, and especially near the river is quite sandy.

The mesa lands are uniformly smooth, with a gentle slope to the southwest. The soil is sandy loam.

Drainage.—The valley lands are generally lower near the mesa than adjacent to the river, and, in general, are lower than the high-water level of the river. Due to these conditions, artificial drainage has been found necessary for the greater portion of the valley lands, and the construction of open drains is actively under way.

The drainage conditions of the mesa lands are good.

Ownership and area.—The status of the irrigable lands of the project as of June 30, 1920, is as follows:

	Acres.
Public land entered	19,000
Public land open	300
Public land withdrawn	37,900
State land unsold	1,800
Indian land	9,000
Private land	62,000
Total irrigable area	130,000

WATER SUPPLY.

Right to divert water from Colorado River.—The right to divert water from the Colorado River (a navigable stream) was authorized by act of Congress entitled "An act making appropriations for the

current and contingent expenses of the Indian Department and for fulfilling treaty stipulations with various Indian tribes for the fiscal year ending June 30, 1905, and for other purposes" (act Apr. 21, 1904, ch. 1402, 33 Stat., 189). The portion authorizing the diversion of water reads as follows:

> That in carrying out any irrigation enterprise which may be undertaken under the provisions of the reclamation act of June 17, 1902, and which may make possible and provide for, in connection with the reclamation of other lands, the reclamation of all or any portion of the irrigable lands on the Yuma and Colorado River Indian Reservations in California and Arizona, the Secretary of the Interior is hereby authorized to divert the waters of the Colorado River and to reclaim, utilize, and dispose of any lands in said reservations which may be irrigable by such works in like manner as though the same were a part of the public domain.

Appropriations.—Appropriations of water for diversion from the Colorado River to be used on the Yuma project are listed as follows:

	Second-feet.
Appropriated July 8, 1905, to be diverted from the left side of Colorado River at Laguna Dam, to be used on lands in Yuma County, Ariz., recorded July 10, 1905, at Yuma County recorder's office, Yuma, Ariz. (book 5, miscellaneous, p. 99)	3,000
Appropriated July 8, 1905, to be diverted from right bank of Colorado River at Laguna Dam, to be used on lands in Imperial County, Calif., recorded July 13, 1905, at Imperial County recorder's office at El Centro, Calif. (book 1, p. 106)	6,000

Also, in 1907 and 1908 the United States purchased for the benefit of the Yuma project the property and rights of the following old canals in the Yuma Valley:

Farmers' Pump Canal.—Purchased from the Colorado Valley Pumping & Irrigation Co., March 15, 1907. This company was incorporated March 4, 1901. There was under irrigation in 1907 from 2,000 to 3,000 acres from this system.

Farmers' Gravity Canal.—Purchased from the Yuma Valley Union Land & Water Co., February 3, 1908. This company (originally the Yuma Canal Co.) was incorporated June 26, 1897. Its plans involved practically all lands in the Yuma Valley.

Rollins Ditch (including Ives heading, pumps, and ditches).—Purchased from the Greene Land & Cattle Co., July 23, 1908. This system was constructed in 1892, and on January 20, 1893, an act of Congress was approved granting right of way for two ditch lines for the company.

Storage required.—It is assumed that the water rights of the Yuma project, as stated above, are of sufficient priority to furnish an ample supply from the natural flow of the Colorado River for the completed project, and therefore it is not estimated that any storage will be required.

IRRIGATION PLAN.

The irrigation plan of the Yuma project provides for the diversion of water from the Colorado River at the Laguna Dam, 10 miles northeast of Yuma, Ariz., into a canal system heading on the California side, conveying water to the irrigable lands on that side of the river, including those in the Yuma Indian Reservation, crossing the river at Yuma through an inverted siphon and serving lands in the Yuma Valley below the town of Yuma. The plan also provides for large pumping plants below Yuma on the east main canal for rais-

g water to irrigate 45,000 acres of mesa land. The lands adjacent the Colorado River are protected from overflow by means of ees. In addition, a drainage system is under construction and is ing extended to areas in which the ground water is rising to such extent as to threaten the lands with seepage. At the lower end of e project a large pumping plant is provided for pumping the drain-ge waters across the levee.

Power requirement, in theoretic horsepower.

uma mesa pumping:	
162 second-feet, lift 80 feet	1,473
185 second-feet, lift 68½ feet	1,440
103 second-feet, lift 54.6 feet	640
50 second-feet, lift 10 feet	57
Total mesa pumping	3,610
Drainage pumping	300
Total for project	3,910
Required horsepower (40 per cent loss in pump and motor)	6,500

It is planned to develop some of the power required for the Yuma project on the project, a small plant to be developed at the siphon drop on the main canal, where there is a head of about 12 feet, and a larger plant near Araz, or as an alternative power will be secured from the power plants which it is proposed to construct at the drops of the All-American High Line Canal.

Imperial Irrigation District, California, and Imperial Valley, Mexico.

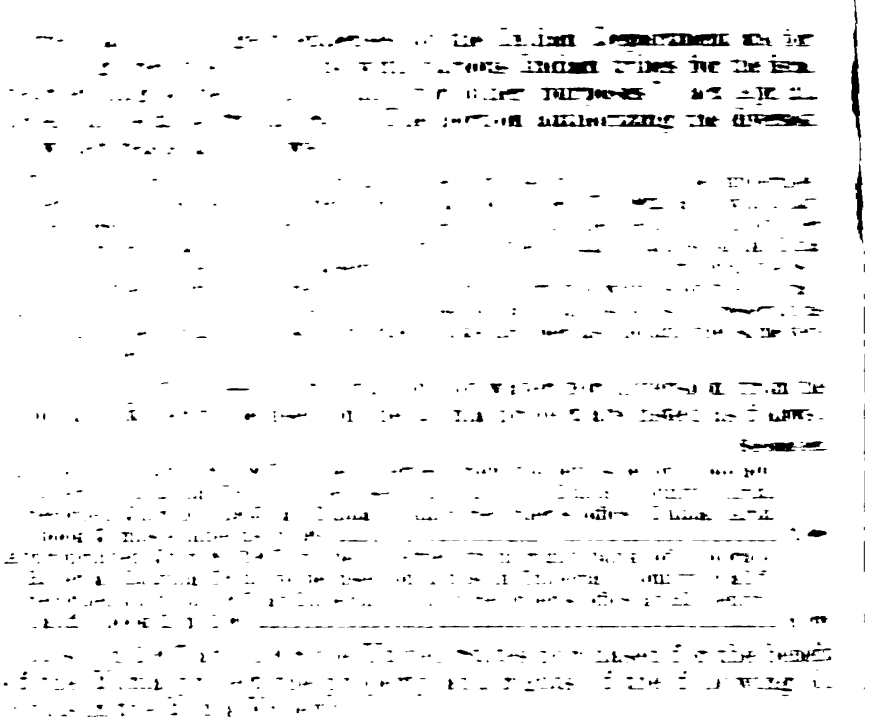
LOCATION AND DESCRIPTION.

The Imperial irrigation district is located in Imperial County, Calif., in townships 9 to 17 south, ranges 12 to 16 east. The district comprises the bottom of the south portion of what is known as Salton Basin, the district extending from the center of the east side of Salton Sea on the north to the Mexican border on the south, a distance of about 48 miles, and with a maximum width of 30 miles.

The Imperial Valley of Mexico lies south of and adjacent to the Imperial district in California, extending a maximum distance south of the boundary line of about 20 miles and having a length parallel to the boundary of about 50 miles.

The Imperial Valley, both of California and Mexico, comprises the north slope of the Colorado River delta, which has been built across the north end of the Gulf of California during past ages. The crest of the delta is in Mexico, about 20 miles south of the border, in the vicinity of Volcano Lake and along the line of the Bee River, which is the present channel of the Colorado River. The valley ranges in elevation from about 100 feet above sea level in the eastern portion of the Mexican lands to about sea level on the California-Mexican border and to 250 feet below sea level at Salton Sea.

The principal towns of the project in California are Calexico, near the boundary; El Centro, in the south-center; Brawley, in the north-center; and Niland, near the north end. The principal Mexican town is Mexicali, near the west end of the Mexican tract and just south of



IRRIGATION PLAN.

The irrigation plan of the Yuma project provides for the diversion of water from the Colorado River at the Laguna Dam, 10 miles northeast of Yuma, Ariz., into a canal system heading on the California side, conveying water to the irrigable lands on that side of the river, including those in the Yuma Indian Reservation, crossing the river at Yuma through an inverted siphon and serving lands in the Yuma Valley below the town of Yuma. The plan also provides for large pumping plants below Yuma on the east main canal for rais-

ing water to irrigate 45,000 acres of mesa land. The lands adjacent to the Colorado River are protected from overflow by means of levees. In addition, a drainage system is under construction and is being extended to areas in which the ground water is rising to such an extent as to threaten the lands with seepage. At the lower end of the project a large pumping plant is provided for pumping the drainage waters across the levee.

Power requirement, in theoretic horsepower.

Yuma mesa pumping:	
162 second-feet, lift 80 feet	1,473
185 second-feet, lift 68½ feet	1,440
106 second-feet, lift 54.6 feet	640
50 second-feet, lift 10 feet	57
Total mesa pumping	3,610
Drainage pumping	300
Total for project	3,910
Required horsepower (40 per cent loss in pump and motor)	6,500

It is planned to develop some of the power required for the Yuma project on the project, a small plant to be developed at the siphon drop on the main canal, where there is a head of about 12 feet, and a larger plant near Araz, or as an alternative power will be secured from the power plants which it is proposed to construct at the drops of the All-American High Line Canal.

Imperial Irrigation District, California, and Imperial Valley, Mexico.

LOCATION AND DESCRIPTION.

The Imperial irrigation district is located in Imperial County, Calif., in townships 9 to 17 south, ranges 12 to 16 east. The district comprises the bottom of the south portion of what is known as Salton Basin, the district extending from the center of the east side of Salton Sea on the north to the Mexican border on the south, a distance of about 48 miles, and with a maximum width of 30 miles.

The Imperial Valley of Mexico lies south of and adjacent to the Imperial district in California, extending a maximum distance south of the boundary line of about 20 miles and having a length parallel to the boundary of about 50 miles.

The Imperial Valley, both of California and Mexico, comprises the north slope of the Colorado River delta, which has been built across the north end of the Gulf of California during past ages. The crest of the delta is in Mexico, about 20 miles south of the border, in the vicinity of Volcano Lake and along the line of the Bee River, which is the present channel of the Colorado River. The valley ranges in elevation from about 100 feet above sea level in the eastern portion of the Mexican lands to about sea level on the California-Mexican border and to 250 feet below sea level at Salton Sea.

The principal towns of the project in California are Calexico, near the boundary; El Centro, in the south-center; Brawley, in the north-center; and Niland, near the north end. The principal Mexican town is Mexicali, near the west end of the Mexican tract and just south of

the border, and the other important railroad stations are Hechicera, near the center, and Paradones, near the east end.

The railroads of the project are the main line of the Southern Pacific, touching the north end of the Imperial district in California, a branch of the Southern Pacific extending south from Niland through the center of the district to Calexico on the border line, and the San Diego & Arizona (in Mexico called the Inter-California) Railway, running west from Yuma through the Mexican lands and north into the Imperial district at Calexico and to El Centro and west to San Diego.

HISTORICAL.

* * * Dr. O. M. Wozencraft, as principal promoter, with Ebenezer Hadley, the county surveyor of San Diego County, as his engineer, worked out a project some 60 years ago for the colonization and development of lands in California under irrigation with Colorado River water. Their proposition involved a diversion of water from the river toward the west into the region drained by the Alamo River, which would then carry it, substantially as under the later scheme, to the points in California from which it could be distributed by a canal system.

This project involved a grant of Government land to California amounting to about 3,000,000 acres. It was approved by the Legislature of California, but the necessary bill failed to pass Congress. Subsequently an examination was made under Government direction to determine whether or not it would be feasible to reach the Imperial Valley without following a route through Mexico. This examination was made in 1876 by Lieut. Eric Bergland, Corps of Engineers, United States Army, who acted under the direction of Lieut. George M. Wheeler. He reported unfavorably upon a canal location entirely in the United States, but again called attention to the natural route across Mexican territory.

Despite this report, which was discouraging to those who desired to have water supplied to the desert in a canal located throughout its entire length on United States territory, the efforts to get water into the Imperial Valley did not cease. But no proposition gave promise of success until Mr. C. R. Rockwood and his associates organized the Colorado River Irrigation Co. in 1892. Surveys were made and works were planned to deliver water from Colorado River in California across the boundary into a short canal in Mexico, which would discharge into the Alamo River, down which it would then flow to a reentry into California. This company failed, however, and was succeeded in 1896 by the California Development Co. At the head of this company, except for two years—1900–1902—was the late Mr. A. H. Heber. Mr. Rockwood remained in charge of engineering and construction. A reorganization of the company in 1905 put the control of its affairs into the hands of the Southern Pacific Co. From 1910 until 1916 the property of the canal company was in the hands of a receiver. In 1914 the Imperial irrigation district was organized and two years later took over the canal properties, which included all the shares of stock of the Mexican corporation through which the properties in Mexico are managed.

The canal of the California Development Co., as originally constructed, had its head in California at Hanlons or Hanlons Crossing, about 100 yards north of the international boundary. The canal was cut from the river at an oblique angle, and its flow was controlled by a timber structure. On a falling river the head of the canal and the headgate were obstructed by silt deposit, and it became difficult to keep the water flowing from the river into the canal. The water shortages due to this cause in 1903 and 1904 and the failure of various remedial measures prompted the application to Mexico for a concession under which a diversion would be allowed on Mexican territory. This concession was granted in 1904, and operating thereunder the dredger cut was made about 4 miles below the boundary line in Mexico, which caused the river a year later to turn for a time inland away from its course to the Gulf.

The concrete headgate of the Imperial Canal at Hanlon, which was constructed in 1906, has a sill at elevation 100.7 feet above mean sea level. (U. S. Geol. Survey datum.) This was at that time believed to be low enough to accomplish di-

version of the desired amount of water at any stage of the river. The large amount of sand which has annually been carried into the canal and the depression of the water surface in the river below the assumed minimum elevation have combined to make the diversion of an adequate quantity of water at the river's low stages impossible. This is true despite the fact that a few years ago a 25-foot section of the headgate sill was lowered 5 feet. Imperial irrigation district has, therefore, found it necessary to construct temporary weirs across the river of rock and brush. Such a weir was constructed in 1910 and annually since 1915.

There is some water obtained for the irrigation of lands in the Imperial irrigation district and in Mexico from Volcano Lake through the Cerro Prieto Canal. This is only a temporary expedient. The connection of the Cerro Prieto Canal with Volcano Lake was made in 1916. Water has thus been made obtainable from the Volcano Lake region while the river is high. As this water is drawn from an extensive ponded area it is comparatively clear, and its use has materially reduced the difficulty with silt in the west side canal system. The maximum amount of water obtained from this source has exceeded 800 second-feet. This source of supply will be available only so long as the river is allowed to send its flood waters against the Volcano Lake Levee. The time will come when the river is put back upon a direct course to the Gulf, and thereupon this source of supply will no longer be available. (All-American Canal Report.)

Regarding flood protection problems of the Imperial Valley, the following is from report of Mead, Henny, and Jacobs on "Irrigation and flood protection problems of Imperial Valley, Calif.," March, 1917:

* * * In 1891 so much water flowed over the western bank that it found its way through the dense bordering growth of brush and weeds and reached the lowest part of the Salton Sink, not, however, for a long enough time or in sufficient volume to effect a permanent channel change.

Concentrated flow, carrying the entire Colorado River, occurred, however, in 1905 and again in 1906, when the river left its normal course by breaking through the lower Mexican heading of the Imperial Canal, gathered in the Alamo and New River channels an,d flowed then to the Salton Sink which it transformed into a great inland sea. The cost of closing these breaks and restoring the river to its old channel was in excess of $2,000,000.

No doubt many diversions of the Colorado River to the Salton Sink mark the past history of that stream, but in recent times we have only the record of 1891, when a lake of 100,000 acres, and of 1905 and 1906, when a lake of 285,000 acres, was formed.

In order to insure against a recurrence of such a channel change in the Colorado River, levees have been constructed as shown on Exhibit B. These levees are necessary for the protection of Imperial Valley lands both in Mexico and in the United States, although their location is entirely on Mexican soil. They include the following:

(*a*) The C. D. Levee, built by the California Development Co., extending from the present Imperial Canal intake, southerly along the right bank of the Colorado River, a distance of 10 miles; thence southwesterly an additional distance of 17 miles.

(*b*) The Volcano Lake Levee, extending from Cerro Prieto, a rock mountain at the northwesterly corner of Volcano Lake, a distance of 16½ miles to a connection with the Inter-California Railroad embankment; thence north 1½ miles to a connection with the south embankment of the Imperial Main Canal.

(*c*) The Ockerson Levee, constructed in 1911 by the United States, for the primary purpose of returning the flow of the Colorado from the Bee River channel, which it had assumed two years before, back into its previous and more easterly channel along the base of the Sonora Mesa. During the summer flood of 1911 it was breached at numerous points, the largest breach occurring at the Bee River channel, which widened until the entire river flowed down this channel to Volcano Lake, which continues to be its course to the present time. Due to the lack of maintenance a few additional breaches have occurred, but the major part of the levee is intact.

The total expenditure incurred to date in the above levee construction, including closures, has been estimated at about $5,000,000. (See Exhibit F.) Aside from the Ockerson Levee, these levees have thus far fairly accomplished

their object, but not without actual and threatened breaks that might have precipitated a calamity at any time.

The political obstacles encountered in constructing and operating the system have been almost as serious as the physical difficulties and have at times jeopardized the integrity of the enterprise. From its inception the project has been financed by American capital and built with American equipment, although practically all of the main canal and the flood protection works and about one-third of the irrigable area are in Mexican territory. The customs and other regulations of Mexico governing movement of persons and materials across the border often cause serious and costly delays which, in cases of emergency, might be disastrous. The situation is at times so critical and the ability to act promptly is so vital to the safety of the enterprise, that these restrictions should be abolished. The present Mexican concession is unsatisfactory because inadequate in several respects. It does not establish equality of irrigation charges on the two sides of the boundary; it does not authorize enlargement of the main canal or construction of any higher canal; it does not provide for any flood-protection works. The unstable political conditions in Mexico add to the gravity of this situation.

Drainage.—As the district stands to-day, there is very little provision made for drainage. The need of proper drainage facilities is being felt in different sections where the underground water is bringing the salt to the surface. In these sections it is impossible to raise a crop to-day on land that was giving a heavy yield five years ago.

Imperial Mutual Water Co. No. 3 has a few surface drainage ditches. The usual method is to run a double system of canals with a road between.

Imperial Mutual Water Co. No. 8 has a few surface drainage ditches, but they are for the most part owned by private individuals and are not kept in very good condition.

Imperial Mutual Water Co. No. 5 has an elaborate system of surface drainage ditches. Practically every feed canal in the system is paralleled by a drainage ditch. The usual method of placing a road between every feed and drainage ditch is followed. In all of the other companies little or no provision has been made for surface drainage.

The New, Alamo, and the Greeson River channels are ideally located for the main drainage channels of the district. At the present time they are used for wasteways by the several water companies. A dam has been thrown across the Alamo River channel at a point opposite Calipatria, and the Imperial Northend and Northside Mutual Water Cos. divert the waste water for irrigation purposes.

Ownership and area.

Tract and ownership.	Gross area.	Irrigable area.
Imperial irrigation district, California (practically all private land)	603,800	515,000
Mexican lands:		
Lower California Land & Water Co.	72,000	54,000
Small tracts, private owners	10,000	8,000
Mexican lands—Continued.		
International Co.	12,000	9,000
Imperial Development Co.	15,000	11,000
E. Easton (owner)	15,000	11,000
Colorado River Land Co.	208,000	156,000
Government land	8,000	6,000
Total Mexican	340,000	255,000
Grand total	943,800	770,000

Appropriations—Water supply.

[Joseph Jacob's report, April, 1917.]

Claimant.	Date of filing.	Amount claimed.	Remarks.
		Sq. ft.	
E. I. Rockwell	May 16, 1895	10,000	Diversion point, 1¼ miles north of boundary.
California Development Co	Dec. 15, 1895	10,000	Do.
E. I. Rockwell to the California Development Co.	Aug. 15, 1911	10,000	Rockwell conveys to California Development Co. all his interests in his original filing of May 16, 1895.
W. T. Gonder	July 15, 1895	10,000	Diversion point, 1¼ miles north of boundary.
[illegible] T. Heffernen	Sept. 13, 1895	10,000	Do.
[illegible] T. Gonder	Nov. 12, 1895	10,000	Do.
Do	Jan. 14, 1896	10,000	Diversion point 1¼ miles north of boundary.
[illegible] T. Heffernen	Mar. 18, 1896	10,000	Do.
Do	May 18, 1896	10,000	Do.
Do	Jan. 23, 1897	10,000	Do.
[illegible] T. Gonder	Mar. 27, 1897	10,000	Do.
[illegible] T. Heffernen	July 24, 1897	10,000	Do.
[illegible]lifornia Development Co	Dec. 15, 1898	10,000	Do.
[illegible] N. Perry, for himself and California Development Co.	Dec. 21, 1898	10,000	Do.
[illegible] T. Heffernen	Jan. 18, 1899	.....	Assigns all his claims to California Development Co.
W. T. Gonder	Jan. 25, 1899	.....	Do.
Do	Apr. 25, 1899	10,000	Diversion point 1¼ miles north of boundary.
C. N. Perry, for himself and California Development Co.	Feb. 20, 1899	10,000	Do.
Do	Apr. 25, 1899	10,000	Do.
Do	.....do.....	10,000	Diversion point, 3,000 feet north of boundary.

Mexican use of water.—A concession was granted by Mexico in 1904 for rights of way for the Imperial Canal. Regarding water for Mexican lands, this concession provides as follows:

The Sociedad de Reigo y Terrenos de la Baja California, S. A., is authorized to carry through the canal which it has built in Mexican territory, and through other canals that it may build, if convenient, water to an amount of 284 cubic meters per second from the waters taken from the Colorado River in territory of the United States by the California Development Co., and which waters this company has ceded to the Sociedad de Riego y Terrenos de la Baja California, S. A. It is also authorized to carry to the lands of the United States the water, with the exception of that mentioned in the following article.

From the water mentioned in the foregoing article, enough shall be used to irrigate the lands susceptible of irrigation in Lower California with the water carried through the canal or canals, without in any case the amount of water used exceeding one-half of the volume of water passing through said canals. (All-American Canal Board report, p. 20.)

Storage required.—It is expected that some storage will be required for full development of the lands under the Imperial Canal in California and Mexico. The question of water supply and storage requirements of this project must be considered in conjunction with the subject as a whole on the Colorado River, and it is being so considered in the general water-supply report being prepared on the Lower Colorado River in connection with the investigations required under the Kinkaid Act.

PRESENT STATUS.

The present constructed works of the Imperial project are briefly as follows:

There is a new heading, known as the Rockwood gate, about 6,000 feet above the old or Hanlon heading, constructed in 1918. This is

a concrete structure, with its face parallel to the river bank. It consists of 75 gates 8 feet center to center, 27 of which have a sill elevation of 98.6 feet above sea level and 48 have a sill elevation of 106.7 feet. The height of the structure above the higher-sill gates is 21 feet. The piers are 18 inches thick, and there is a 24-foot pier between the high and the low sill gates.

The main canal, from the Rockwood heading through Mexico, is about 55 miles long and mainly follows an old channel of the river known as Alamo River. Portions of the channel have been straightened by constructing cut-offs, and especially these portions will require enlarging for the carrying of sufficient water for the entire project. Also the old channel, due to silting, has in places spread out over considerable areas and will require dredging or reconstruction for full development of the project. The maximum amount carried in the canal to date has been about 6,000 second-feet. There are about 70 miles of distributaries operated by the district in Mexico and about 61 miles constructed and operated by the district in the United States. Other distributing canals and laterals in the United States, where built, are operated by 14 separate water companies, the distributaries of these companies aggregating approximately 2,300 miles in length. The total canals and laterals of the Imperial project in both California and Mexico aggregate approximately 2,570 miles. The distribution system of the project is estimated to be 75 per cent completed. The area irrigated in the Imperial district in 1920 was 415,000 acres, or 80 per cent of the net irrigable area, and in Mexico there was irrigated, in 1920, 190,000 acres, or 75 per cent of the net irrigable area.

Levees constructed.—C. D. Company and Saiz Levee, built by C. D. Company, 1906 to 1909, length 27 miles, with 10 miles enrocked.

Volcano Lake Levee, built by C. D. Company and United States, 1908 to 1912, and later raised 3½ feet and extended to connect with the Inter-California Railroad and with the bank of the main Imperial Canal, length 18 miles, with 8 miles enrocked.

Ockerson Levee, built by United States in 1911, length 24½ miles. This was partly destroyed shortly after its construction and has not since been repaired.

Operation difficulties.—A great deal of difficulty is being experienced by the Imperial project in its operation, due to the fact that there is no permanent diversion dam and sluicing basin at the inlet, which condition requires the construction of a temporary diversion dam, which is needed to enable the diversion of sufficient water through the low period; and on account of the insufficient desilting at the diversion point a large expense is incurred in dredging canals. Also on account of the silting up of the channel of the river below the Imperial heading the overtopping of the levee system is threatened each high-water period, and large expenses are required in maintaining and strengthening these levees. The present course of the river is following the Bee River channel to the southwest into Volcano Lake and it is silting up the lake to such an extent as to endanger the Volcano Lake Levee. Plans are now being considered by the district to divert the river to the south and thus keep it out of Volcano Lake.

IRRIGATION PLAN.

The present plan of the project provides for diversion from the west side of the Colorado River at the Rockwood heading, about 7,000 feet above the Mexican line, and the control of the low-water diversion by temporary rock and brush weirs;

A main canal through the Imperial Valley of Mexico following mainly the old Alamo River Channel;

The division of water into submains and laterals for irrigation of lands in Mexico;

The division of the main canal, a short distance south of where it reenters the United States, into the East Side High Line, East Side Low Line, Central Main, and West Side Main Canals, for the irrigation of the lands of the Imperial irrigation district.

A diversion from the Volcano Lake is also made to supplement the irrigation on the west side in Mexico and the United States.

The present plan of flood control is by a levee extending from Hanlon heading southwesterly to near Volcano Lake and the Volcano Lake Levee, extending from the west mesa, just north of the lake, northeasterly to the Inter-California Railroad embankment and to the bank of the main canal. This forms a double defense except near the west side of the valley. It is planned to strengthen these levees as required and also to repair the Ockerson Levee near its crossing of Bee River and to extend it westerly on the north side of the Bee River, a distance of about 5 miles, and at this point to cut a new river channel southwesterly from the Bee River for a distance of about 4 miles, where it will discharge into an arroyo and onto lower ground and thus to keep it away from Volcano Lake and from threatening the Volcano Lake Levee.

Alternate plan.—It is proposed to divert at Laguna Dam of the United States Reclamation Service, to enlarge the Yuma project main canal to the Siphon Drop and to construct an all-American canal from this point to near the border line of Mexico and thence west on the American side to the Imperial Valley. A contract has been entered into to this effect, dated October 23, 1918, between the United States and the Imperial irrigation district. Details of this plan, including estimate, are outlined in the all-American canal report of June 17, 1919, by Mead, Schlecht, and Grunsky.

Also, storage for irrigation and for flood control is contemplated, if Government aid can be secured.

POWER REQUIREMENT.

The present Imperial project is all a gravity system and no power is required for irrigation pumping.

Imperial Valley Extensions Including Coachella Valley.

LOCATION AND DESCRIPTION.

The mesas east of the Imperial Valley and northeast of Salton Sea and the Coachella Valley can not be supplied by extension of the Imperial district's canal system. These areas have been investigated

with regard to the feasibility of their reclamation by means of branches from the proposed all-American high line canal, both by gravity and by pumping. The canal surveys have not been completed and the results of the soil survey now in progress are available for only a part of the areas considered. However, the data so far obtained by these surveys have been compiled and the remainder have been carefully estimated as the basis of this report.

East mesa, areas 3 and 8.—The east mesa is a gently rolling plain with a small gentle slope toward the center of the valley. As the natural surface drainage from the Chocolate Mountains is intercepted by a range of sand hills extending from beyond the Mexican boundary to a point near Mammoth, the amount of cross drainage to be provided for in the construction of canals on the east mesa is small, except at the north end, where some large washes are encountered. Some parts of the mesa are covered by sand dunes, of which the smaller ones could be leveled for irrigation.

Dos Palmas Mesa, area No. 4.—This area extends along the Southern Pacific Railroad from Iris to Mortmar at the northwestern end of Salton Sea. Practically the entire stretch is crossed by numerous large washes heading in the Chocolate and Crocopia Mountains. In the western part are two isolated tracts of land too high to be reached by gravity canals. Due to the washes and alkali which affect the greater part of this area, only a comparatively small portion is irrigable land. The extension of the surveys may develop a *small* pumpage area in this district.

Coachella Valley, areas Nos. 5 and 9.—The Coachella Valley consists of a central portion, mainly composed of fine alluvial silt, sloping southeast toward Salton Sea, and a bordering zone of a mile or two in width, of sandy mesa land sloping more steeply toward the axis of the valley. About 8,000 acres in the valley have been reclaimed by artesian water and by pumping from wells.

West side under gravity canal, area No. 6.—The west-side main canal of the Imperial irrigation district, as at present constructed, has more fall than is necessary. If built on a lighter slope from the Mexican boundary and extended along the west side of Salton Sea it would be possible to cover by gravity a long, narrow strip of additional land. This area has considerable slope to the northeast and is much cut by washes from the mountains to the west. Large portions are too rocky or too alkaline to be profitably reclaimed, and only some small isolated tracts are considered irrigable.

West mesa, area No. 10.—On the west mesa there are several large areas of good land that can be irrigated only by pumping, if the west main canal is constructed with less fall. Attempts have been made to pump from wells, without financial success.

South of Volcano Lake and Bee River there is a large body of land in Mexico of which the major portion lying above elevation 30 is susceptible of irrigation. Lands lying below elevation 30 are more or less affected by the tides and are generally salty.

Ownership of land in the United States.

District.	United States, public.	Private.	California State.	Southern Pacific R. R.	Entered.	Indian.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*	*Acres.*
No. 8	31,270	.....	1,730	.....	.....	.....	33,000
No. 3	108,560	1,070	5,840	3,560	970	.....	120,000
No. 4	1,280	370	550	5,000	2,800	.....	10,000
No. 5	4,200	13,520	4,860	41,900	3,670	12,750	80,000
No. 9	990	1,970	720	5,380	940	.....	10,000
No. 6	3,530	.....	600	4,430	1,320	120	10,000
No 10	16,000	800	1,640	1,560	10,000	.....	30,000
Total	165,830	17,730	15,940	60,930	19,700	12,870	293,000

NOTE.—The table gives original areas of State and railroad lands. Tracts sold by the State and the railroad company to individuals not segregated.

IRRIGATION PLAN.

All-American High Line Canal.—The All-American High Line Canal is described in the report of the All-American Canal board dated July 22, 1919, printed at the Government Printing Office, Washington, in 1920. This would divert water from the Colorado River at Laguna Dam at elevation 153, and be located entirely within the United States to and across the Imperial Valley of California. It reaches this valley with water surface at elevation 132. Two estimates were prepared for the report, one for a canal of 10,600 second-feet capacity at Laguna Dam and 9,000 second-feet capacity from the siphon drop of the Yuma project to the Imperial Valley, and the second beginning with 7,600 second-feet capacity and delivering 6,000 second-feet to the Imperial Valley. The 1,600 second-feet are for the use of the Yuma project.

An inspection was made of the route of a high line canal which would swing through Mexico around Pilot Knob, the higher portions of the mesa, and the sand-hill area. This indicated that some reduction in cost would result in locating a portion of the canal in Mexico, but this reduction in cost would be small. The small reduction is due to the fact that the sand hills overlap the edge of the mesa, and it will be necessary to cut through sand hills in order to secure holding ground for the canal in the firmer mesa soils.

Cost of All-American (High Line) Canal for 10,600 second-feet canal to siphon drop and then a 9,000 second-feet canal to Imperial Basin.

From report by the All-American Canal board, July, 1919.

Item.		Charge Imperial, Coachella, and extension lands.	Charge Yuma auxiliary project on power account.	Total
From—	To—			
Laguna Dam		$1,900,000	.....	$1,900,000
Do	Siphon drop	2,418,000	$691,000	3,109,000
Siphon drop	Araz	1,057,000	302,000	1,359,000
Araz	Power site	811,000	.....	811,000
Power site	Pilot Knob	1,470,000	.....	1,470,000
Pilot Knob	First east mesa canal	17,067,000	.....	17,067,000
First east mesa canal	Second east mesa canal	[1] 600,000	.....	600,000
Second east mesa canal	West main canal	3,239,000	.....	3,239,000
Total		28,562,000	993,000	29,555,000

[1] Includes drop and check at sites of canal drops, but does not include the cost of developing power.

Alternative.—A concrete-lined section through the sand-hill area, 70,000 feet long, with slope increased from 0.0000862 to 0.00017 and velocity from 3.5 to 6 feet per second, and bottom width reduced from 140 to 70 feet would have no material effect on the cost except that it would result in the requirement of an additional 5.9-foot increase in the height of Laguna Dam or would require an equivalent increase in pump lift for the east side mesa and an equivalent reduction in elevation of the east main canal.

Cost of All-American High Line Canal for 7,600 second-feet canal to Siphon Drop and then a 6,000 second-feet canal to Imperial Valley.

[Par. 12-c of Porter J. Preston's appendix to the Report of the Board of Engineers states: "In this estimate the structures have been estimated of a size and capacity sufficient for the development to 10,600 second-feet. Only such structures as would be required solely for the larger development are omitted. Due to this a reduction in cost of the structures should be made if the costs of canals of various capacities are to be compared.]

Item.		Cost in All-American Canal, report of July, 1919.	Revised cost with structures decreased in size to fit canal.	Charge Imperial Valley.	Charge Yuma auxiliary on account of power.
From—	To—				
Laguna Dam		$1,600,000	$1,600,000	$1,600,000	
Do	Siphon Drop	2,587,000	2,412,000	1,982,000	$430,000
Siphon Drop	Araz	1,200,000	1,158,000	914,000	244,000
Araz	Temporary power site	709,000	617,000	617,000	
Temporary power site	Pilot Knob	1,083,000	1,070,000	1,070,000	
Pilot Knob	West main canal	19,768,000	19,725,000	19,725,000	
Total		27,037,000	26,582,000	25,908,000	674,000

POWER DEVELOPMENT.

The following power plants are to be developed at drops of the All-American High Line Canal.

(*a*) Temporary plant near Hanlon heading, gross cost $705,000, net $323,000. This plant will be used for construction purposes, and its cost is covered by the estimated costs of the work performed in building the canal.

(*b*) Power Plant No. 1, fall 24 feet, with possible increase to 30 feet; 4 units of 4,500 turbine horsepower each.

(*c*) Power Plant No. 2, fall 47 feet; 4 units of 6,500 turbine horsepower each.

Item.	Power plant No. 1.	Power plant No. 2.	Total.
Preparatory work	$49,000	$48,000	$97,000
Building and foundations	152,000	225,000	377,000
Machinery	786,000	1,057,000	1,843,000
Draft tubes, etc	15,000	18,000	33,000
Gates, etc	19,000	22,000	41,000
Switch yard	13,000	13,000	26,000
Settling basin and cooling tower	3,000	3,000	6,000
Quarters	23,000	23,000	46,000
Improvements to grounds	11,000	11,000	22,000
Subtotal	1,071,000	1,420,000	2,491,000
Contingencies, 15 per cent	161,000	213,000	374,000
Total	1,232,000	1,633,000	2,865,000

Siphon spillways and checks included in estimate for canal.

CANAL SYSTEMS, IMPERIAL VALLEY EXTENSIONS, INCLUDING COACHELLA VALLEY.

Preliminary surveys of branch canals from the proposed All-American High Line Canal were made. The data used in designing the canals are as follows:

Capacity, 1 second-foot to 85 acres irrigable land.

Mean velocity, 2.5 to 3 feet per second.

Side slopes, ½ to 1 for capacity and 2 to 1 for excavation and embankments.

Freeboard and top width of embankments.

Capacity.	Free-board.	Top width of banks.
	Feet.	*Feet.*
100 to 500 second-feet	2.5	12
500 to 1,000 second-feet	3	12
1,000 to 2,000 second-feet	4	15
2,000 to 3,000 second-feet	5	20

The largest of the branches, canal "A" (see attached map), would leave the All-American Canal at mile 39 on the east mesa and, running north about 14 miles to the sand hills, thence northwesterly along the base of the sand hills, would supply the greater part of the east mesa by gravity. Continuing, canal "A" would cross the Southern Pacific Railroad about 1 mile east of Iris and follow the slope of the mesa roughly parallel to and 3 to 6 miles from the railroad to a point near Indio, where it would swing southwest, crossing the railroad about one-fourth mile northwest of Indio; thence continuing southeasterly along the southwest side of Coachella Valley to the county line, a total length of about 138.6 miles. This canal would also carry water for the Dos Palmas Mesa, the Coachella Valley, and the pumping area above Indio. The pumping plant for the high land of Coachella Valley would be located about 3 miles northeast of Indio.

For crossing the numerous washes reinforced concrete siphons for the canal are planned, with one or more tubes 9.6 feet in diameter, each tube having a capacity of 434 second-feet. The hydraulic head on these siphons would be small, not exceeding about 10 feet at the top of the tube. The smaller washes that can not be diverted or concentrated may in many cases be carried over the canal in flumes not over 50 feet in width.

A diversion from the south side of the All-American Canal opposite the heading of the "A" line would irrigate by gravity 8,000 acres in the United States and 22,000 acres in Mexico, all of which is mesa land beyond the reach of the Imperial Canal.

Canal "E" is planned to leave the All-American Canal at mile 46, and, running north for 6 miles, would supply the southwestern portion of the east mesa. The canal is designed to irrigate 14,000 acres.

The high land of the east mesa, containing 33,000 acres of irrigable land, is to be supplied by pumping from the All-American

Canal near mile 31 into canal "D," which would follow near the sand hills in a northwesterly direction for 17.5 miles to a junction with canal "A." The total head for the pumping plant would be about 30 feet.

The amount of irrigable land that can be reached by gravity extending the west main canal along the west side of Salton Sea is very small, estimated at not to exceed 10,000 acres. The gross area under the west side main at present is 121,300 acres. The plan on which the cost estimates are based consists in reconstructing the west side main, here called the "B" line, on a lighter grade from the Mexican boundary for a distance of about 21 miles to a point opposite the south end of Superstition Mountain where the pumping plant would be located for the high land of the west mesa, shown as area No. 10. The lift there would be 120 feet. From this point in sec. 4, T. 15 S., R. 12 E., the west high line, canal "R," would run northwesterly on the south side of Superstition Mountain some 10 miles to the mesa lands.

From the boundary to the pumping plant the "B" line is designed large enough to supply all lands now under the west main canal, together with the extensions and the mesa pump lands. Beyond the pumping plant the amount of additional good land possible to reach by gravity is not considered sufficient to warrant new construction and no allowance is estimated for any further extension of the "B" line.

COST OF CANAL SYSTEMS.

"A" and "E" lines for east mesa gravity, 142,000 acres; Dos Palmas, 10,000 acres; Coachella Valley gravity and pumping, 90,000 acres—total 242,000 acres, of which 22,000 are on the mesa in Mexico.

Section.	Miles.	Acres.	Average capacity.	Estimated cost.
			Second-feet.	
1	21.2	[1] 30,000 68,000	1,930	$948,000
2	19.7	30,000	1,353	1,197,000
3	38.6	10,000	1,117	2,084,000
4	31.1	60,000	765	1,248,000
5	28.0	30,000	353	638,000
Canal E	6.0	14,000	165	51,000
Total	144.6	242,000	.....	6,166,000

[1] Mesa lands south of All-American Canal.

Cost per acre, $25.50, including Mexican lands. Cost per acre, $28, excluding Mexican lands.

Cost of "D" line for east mesa pumping, 33,000 acres in United States and 8,000 acres in Mexico:

Cost of canal (including flume across canal for Mexican lands), $250,000; cost per acre (41,000), $6.10.

Cost of "B" and "R" lines for west side mesa (40,000 acres), including capacity for 107,000 acres at present under west main canal:

Cost of "B" line, $1,570,000; cost on basis of 40,000 acres, $39.20. Cost on basis that Imperial district stands 50 per cent of cost for

lands covered by reconstructed canal (area 40,000 acres plus one-half of 107,000=93,000 acres), $17 per acre.

Cost of "R" line, $210,000; cost per acre (30,000), $7.

Cost of pumping plants.

District.	Lift.	Area.	Estimated cost.	Per acre.
	Feet.	*Acres.*		
(8) East mesa	30	[1] 41,000	$324,000	$7.90
(9) Coachella Valley	65	10,000	318,000	31.80
(10) West mesa	120	30,000	1,190,000	40.00

[1] Includes 8,000 acres in Mexico.

APPENDIX F.

COLORADO RIVER STORAGE.

FLAMING GORGE RESERVOIR—JUNIPER RESERVOIR—DEWEY RESERVOIR.

Notes.—The following estimates are the results of an attempt to bring previous estimates up to date by applying new unit costs. The estimates are very preliminary in character.

Flaming Gorge Reservoir—Horseshoe Canyon Dam—Preliminary estimate.

[Crest elevation, 6,050; gross storage, 3,120,000 acre-feet; maximum height, 300 feet.]

Item.	Quantity.	Unit cost.	Total cost.	Summary.
Main dam:				
Excavation—				
Wet	380,000 cubic yards	$3.00	$1,140,000	
Dry	390,000 cubic yards.	1.50	585,000	
Total excavation				$1,725,000
Concrete—				
1; 2½:6:3 mix	493,000 cubic yards.	10.00		4,930,000
Diversion works (lump sum)				100,000
Drainage and grouting (lump sum)				20,000
Outlet works—				
5 by 5 foot hydraulic operated sliding gates and trash racks.	25	20,000.00	500,000	
58-inch Ensign balanced valves	20	20,000.00	400,000	
Total outlet works				900,000
Spillway bridge	1	50,000.00		50,000
Total main dam				7,725,000
Auxiliary dam:				
Embankment—				
6-inch layers moistened and rolled	85,000 cubic yards.	.60		51,000
Paving	5,640 cubic yards.	4.00		22,560
Excavation—				
Class I	12,200 cubic yards.	1.50		18,300
Total auxiliary dam				91,860
Railroad construction and equipment	55 miles	70,000.00		3,850,000
Construction camp				220,000
Finishing and cleaning up				55,000
Total estimated field cost				11,941,860
Contingencies (10 per cent)				1,194,186
Engineering and administration (15 per cent).				1,791,269
Right of way (lump sum)				1,064,000
Grand total estimated cost	3,120,000 acre-feet.	5.12		15,991,315

Juniper Reservoir—Juniper Dam—Preliminary estimate.

[Top of dam elevation, 6.160; spillway crest elevation, 6.150; gross storage, 1,550,000 acre-feet; spillway capacity, 40,000 acre-feet.]

Item.	Quantity.	Unit cost.	Total cost.	Summary.
Excavation:				
Wet	8,750 cubic yards	$3.00	$26,250.00	
Dry	15,400 cubic yards	1.50	23,150.00	
Total excavation				$49,400.00
Concrete:				
1 : 2½ : 6 : 3 mix	153,000 cubic yards	13.00		1,989,000.00
Diversion works (lump sum)				70,000.00
Drainage and grouting (lump sum)				20,000.00
Spillway bridge	8 spans	6,000.00		48,000.00
Outlet works:				
58-inch Ensign balanced valves with trash racks.	20	26,500.00	530,000.00	
5 by 5 foot hydraulic operated sliding gates and trash racks.	5	20,000.00	100,000.00	
Total outlet works				630,000.00
Telephone line	30 miles	400.00		12,000.00
Roads	10 miles	5,000.00		50,000.00
Construction camp				60,000.00
Finishing and cleaning up				15,000.00
Total estimated field cost				2,943,400.00
Contingencies (10 per cent)				294,340.00
Engineering and administration (15 per cent)				441,510.00
Right of way				175,000.00
Grand total estimated cost	1,550,000 acre-feet	2.48		3,854,250.00

Dewey Reservoir—Dewey Dam—Preliminary estimate.

[Maximum height, 285 feet; gross storage, 2,270,000 acre-feet.]

Item.	Quantity.	Unit cost.	Total cost.	Summary.
Dam:				
Excavation—				
Wet	134,200 cubic yards	$3.00	$402,600	
Dry	17,000 cubic yards	1.50	25,500	
Total excavation			428,100	
Concrete—				
1 : 2½ : 6 : 3 mix	563,000 cubic yards	10.00	5,630,000	
Total dam				$6,058,100
Diversion works (lump sum)				100,000
Drainage and grouting (lump sum)				20,000
Outlet works:				
5 by 5 foot hydraulic-operated sliding gates and trash racks	5	20,000.00	100,000	
58-inch Ensign balanced valves with trash racks	10	26,500.00	265,000	
Total outlet works				365,000
Spillway (lump sum)				600,000
Parapets and roadway (lump sum)				25,000
Railroad construction and equipment	20 miles	70,000.00		1,400,000
Construction camp				160,000
Finishing and cleaning up				40,000
Total estimated field cost				8,768,100
Contingencies (10 per cent)				876,810
Administration and engineering (15 per cent)				1,315,215
Right of way (lump sum)				200,000
Grand total estimated cost	2,270,000 acre-feet	4.92		11,160,125