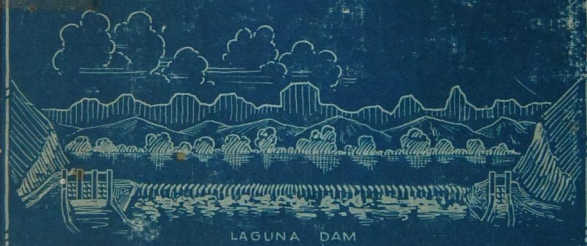
Frederick H. Newell
Director U.S. Reclamation Service.

United States Reclamation Service
YUMA PROJECT
ARIZONA-CALIFORNIA

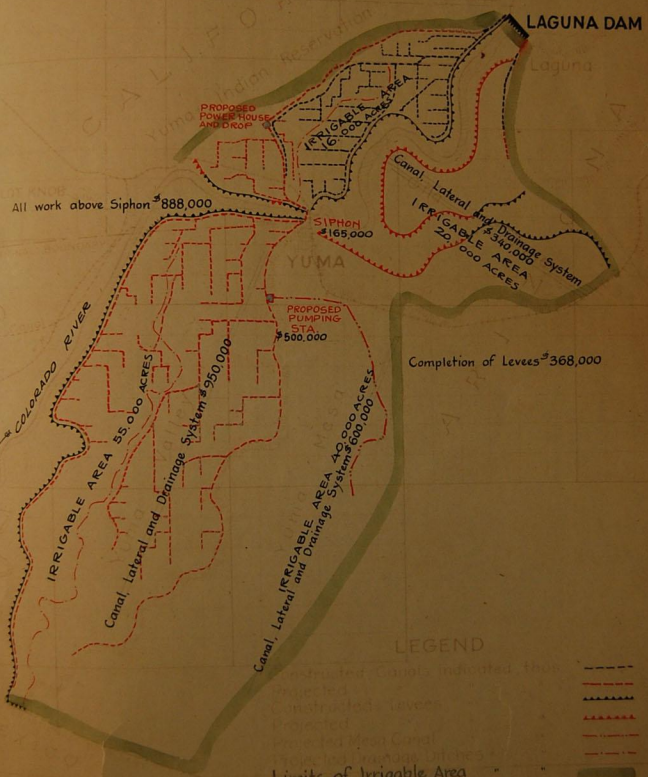
Data prepared for Board of Engineers
U.S.A.

SEPTEMBER 1910



LAGUNA DAM

"When river and desert join hands in
Arizona nothing is left but imagination."


LAGUNA DAM
PROPOSED POWER HOUSE AND DROP
IRRIGABLE AREA 6,000 ACRES
Canal, Lateral and Drainage System $340,000
IRRIGABLE AREA 20,000 ACRES
All work above Siphon $888,000
SIPHON $165,000
YUMA
PROPOSED PUMPING STA. $500,000
Completion of Levees $368,000
COLORADO RIVER
IRRIGABLE AREA 55,000 ACRES
Canal, Lateral and Drainage System $950,000
IRRIGABLE AREA 40,000 ACRES
Canal, Lateral and Drainage System $600,000
Limits of Irrigable Area

UNITED STATES RECLAMATION SERVICE.

YUMA PROJECT.

==========

=======

-o-

DATA PREPARED FOR BOARD OF ENGINEERS,

U. S. A.

****

SEPTEMBER, 1910.

THE YUMA PROJECT.

INFORMATION COMPILED FOR BOARD OF ARMY ENGINEERS, SEPTEMBER, 1910.

--*--*--*--

LOCATION AND EXTENT.

The area now being prepared for irrigation by the U. S. Reclamation Service and known as the Yuma Project lies along the Colorado River, between the Mexican Boundary and a point about 40 miles north. The land to be reclaimed, comprising an ultimate area of about 130,000 acres, of which 75,000 acres is public land and 55,000 acres private ownership, lies in both California and Arizona: that in California is in Imperial County, in the extreme southeastern part of the State and consists of about 16,000 acres of bottom lands on the Yuma Indian Reservation: the Arizona lands are all in Yuma County, in the southwesterern corner of the Territory and consists of about 55,000 acres of bottom lands, between the Town

of Yuma and the International Boundry: 20,000 acres of land in the lower Gila Valley, immediately above Yuma: and a future extension by pumps to include 40,000 acres of mesa land, south and east of Yuma: these mesa lands are above frost and are probably so situated that their development will make them the most attractive citrus area of this country.

INAUGURATION OF PROJECT.

The Reclamation Act was passed by Congress in June, 1902, and in the following October investigations along the Colorado River were commenced. The area under consideration reached from the Mexican Boundary to a point about 100 miles above Needles, a total distance of over 300 miles.

These preliminary examinations contunued until June, 1903, during which time levels were extended from the Pacific Ocean to Yuma, a distance of 275 miles: others lines of levels were

run on both sides of the river north and south of this point, to include all the territory under consideration: gauging stations were established and suggested sites for high dams explored with the diamond drill. These examinations indicated that there were along this portion of the river six projects worthy of further consideration, the most promising for immediate work being that with a high dam at the so-called Yuma damsite, a point about 22 miles above Yuma: here the river passes through the first rocky gorge, and as the rock walls approach each other to within 1500 feet, it was at first supposed to be a favorable location for a high overflow dam. The maps showed that the construction here of a dam 70 feet in height would render feasible the irrigation of large areas in Arizona and in California, and also the possibility of extending the California canal to cover lands in Salton sink.

Further examinations of this proposition showed that there was no bed rock at this point upon which to found a high masonry dam and this project was abandoned in favor of constructing a low diversion weir of the Indian type.

Further investigation led to moving the site of the headworks about 7 miles nearer Yuma, at a point known as Laguna, on the Arizona side and Pot Holes, on the California side.

SOURCE OF WATER SUPPLY.

Water for irrigation will be taken from the Colorado River, which has a never failing supply. This stream is formed ~~in the~~ southeastern part of Utah, by the union of the Grand and the Green rivers. The Green is the larger of the two and in reality the upward continuation of the Colorado. Including the Green, the length of the Colorado is 2000 miles: its drainage ground is 800 miles long, varying in width from 300 to 500 miles and containing approximately 300,000 square miles, ranking in

extent as the second drainage area of arid America. This area includes the southwestern part of Wyoming, the western part of Colorado, the eastern half of Utah, practically all of Arizona and some portions of California, Nevada, New Mexico and Old Mexico.

The rivers comprising the Colorado system receive their main supply from the melting snows on the mountains of Wyoming, Utah and Colorado and flowing through canons of practically inaccessible depth in their upper reaches, the fertile waters are preserved for the irrigation of the rich bottom lands below.

The flow during the low season is from 3000 to 4000 second feet and in flood it may rise, as in 1909, to 150,000 second feet. The river begins to rise in March or April, when the melting snows are first in evidence, and it generally crests in June: following the crest there is a somewhat rapid decline in gage height and comparitively low stages are reached in August and September. In November, 1902, a gauging station was established at Yuma by the Reclamation Service and since that date meter measurements have been made of the stream three times each

week. The following table gives the minimum run-off for each month during the period covered by the observations, the duty of water for the different months and the area possible to irrigate if the entire flow had been diverted:

Fig. 1. Colorado River During Low Stage.

TABLE 1. - SEPTEMBER 5, 1910.

MINIMUM MONTHLY FLOW OF COLORADO RIVER AT YUMA, FOR YEARS 1903 to 1908, INC.

MONTH	MINIMUM MONTHLY RUN-OFF IN ACRE FEET.	MONTHLY DUTY DEPTH IN FT	AREA POSSIBLE TO IRRIGATE ACRES
January	185,407	0.20	927,000
February	182,531	0.25	730,000
March	367,702	0.30	1,220,000
April	479,663	0.41	1,170,000
May	1,670,000	0.52	3,200,000
June	2,550,000	0.70	3,650,000
July	1,411,995	0.90	1,570,000
August	598,366	0.80	750,000
September	386,456	0.56	690,000
October	494,160	0.38	1,300,000
November	321,271	0.26	1,230,000
December	266,598	0.22	1,210,000

5.50

The above is not a minimum year, but a year made up of the minimum run-off in the various months between 1903 and 1908, inclusive.

Fig. 2. Colorado River during moderate flood.

Fig. 3. Canal Heading Abandonment by River.

One peculiarity of this flood, as observed at Yuma, is that while the rise indicated on the gauge from low water to flood height is in the vicinity of 10 or 12 feet; there is also a lowering of the bed, due to scour, which may reach as much as 30 or 35 feet - thus the gage reading of the river gives not even an approximate idea of the volume flowing.

The Colorado is a silt bearing stream of considerable magnitude and in the course of centuries has built a delta extending from the Gulf of California to near Laguna Dam. This delta is made up of alluvial deposits, whose depths have never been approximately established, except by borings in the river bed near Yuma, where it appears that sandstone occurs at a depth of about 100 feet. The river valley above Yuma is from one to six miles wide, while the channel of the river is from 1000 to 4000 feet in width and the slope is approximately 1.2 feet per mile. Velocities, as measured at Yuma, range

from two feet per second at extreme low water to 12 feet per second during the highest floods. Figure 1 is a view of the river at the Southern Pacific bridge, at Yuma, during an extreme low stage, when the bases of the bridge piers are exposed. Figure 2 is a view of the same bridge during a moderate flood. At half flood stage, the stream overflows its banks and inundates considerable areas on both sides: in fact all of the bottom land, which it is proposed to irrigate under the Yuma Project, has been subject to overflow at one time or another and these lands are all to be defended by levees. The stream, along its lower reaches, is continually cutting its banks and changing its course, which action greatly augments the volume of silt carried and has also meant death and destruction to the private canals which attempted to take out its waters below Yuma. Figure 3 shows a portion of the intake of one of these canals, after it had been abandoned by the river. All of the above conditions, which had to be amply provided for, made the Yuma Project one

of the most difficult pieces of construction undertaken by the Reclamation Service and the absence of rock foundation at Laguna Dam and the necessity for providing for partial silt removal before allowing the water to enter the canals places the work in a class by itself.

OUTLINE OF ENGINEERING FEATURES.

The works here described are all indicated on the Project map which forms the fronticepiece of this report:

The general scheme is to divert from the Colorado river, at a point about 15 miles above Yuma, by means of an Indian Weir, a maximum amount of 1900 second feet: 1700 second feet will enter the main canal in California and the balance will be distributed by a smaller main canal on the Arizona side. At each end of the weir are controlling works for regulating the canal supply, partially removing the sediment before allowing the water to enter the canals and for returning the sediment to

the river below the weir. While most of the water will be diverted on the California side, the main body of irrigable land is in Arizona, and the water will be carried across the Colorado through an inverted siphon under the river, a short distance below the railroad bridge at Yuma. Levees extending along the river margins of all the bottom lands will be constructed to insure against flooding and drainage systems will be provided for the removal of waste water and the control of the ground water plane.

DESCRIPTION OF THE VARIOUS FEATURES.

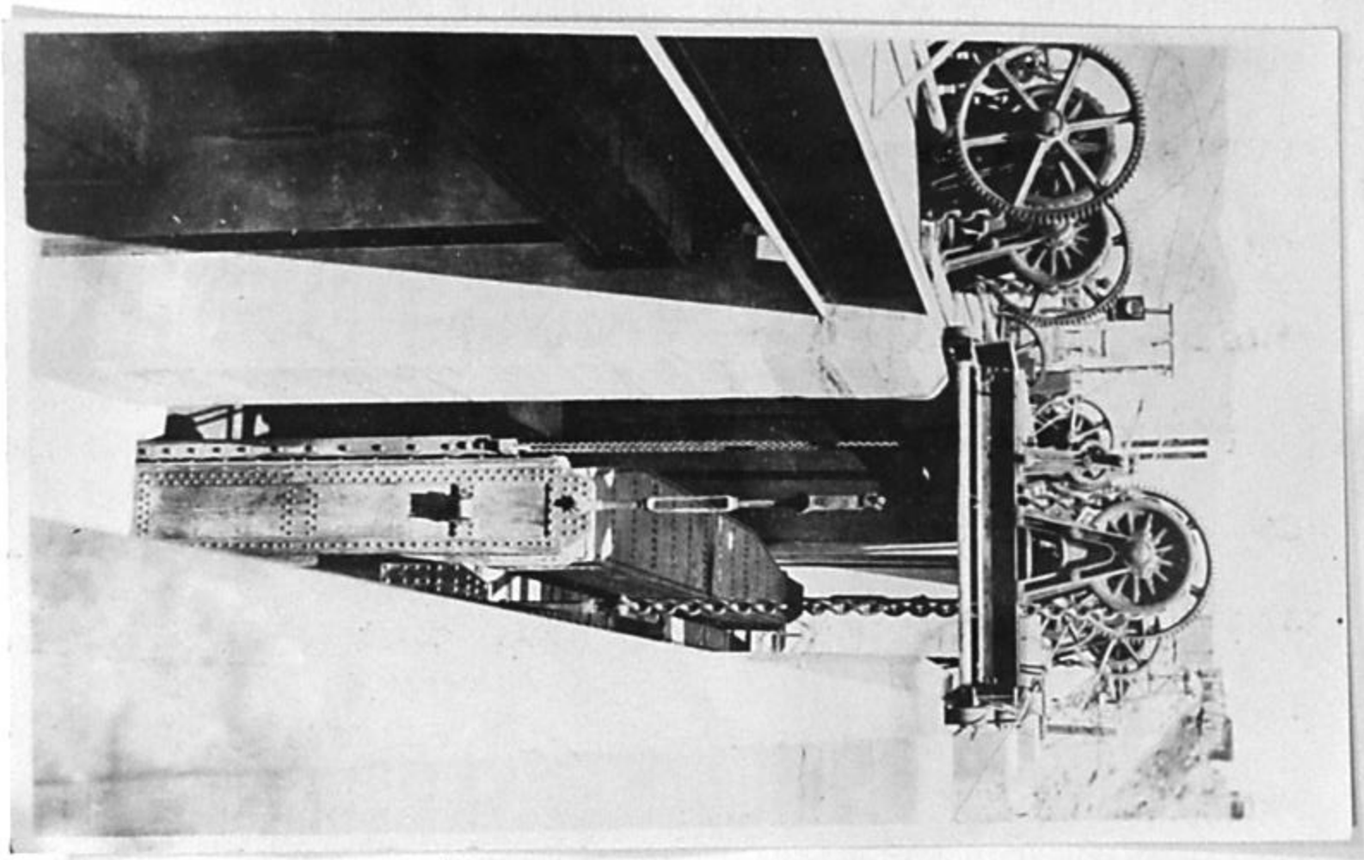
LAGUNA DAM:

The problem before the engineers was to build a structure founded on the alluvial deposit of the valley that would fully control the river and at the same time divert water to canals at each end of the structure in such a manner that it would be possible to eliminate a good deal of the silt before the water was allowed to pass to the canals. Nothing of the kind had been built in this country,

and before a decision was reached as to the type of structure to put in a careful examination was made of foreign works, principally those of Egypt and India. This resulted in a design fashioned after that of the Okla Weir, across the Jumna, in India, and following somewhat the lines of another weir across the Nile below Cairo..

The structure is about 4,780 feet in length, is known as the Indian Weir type of diversion dam, and raises the general river surface about 10 feet. Its maximum bottom width is practically 250 feet. The structure is traversed longitudinally by three concrete walls extending from the top of the dam to well below the river bed. These walls are 5 feet thick; one is placed at the crest of the dam with a top elevation of 151 feet above sea level; the next one is 57-1/2 feet downstream from

the first; and the third 93-1/2 feet downstream from the second. The top of the dam slopes from the crest elevation of 151 feet mentioned above at the rate of one foot in 12. Between these walls is a loose rock fill made from stone of the ordinary run of the quarries. Below the downstream wall is an apron composed of derrick stone, the top width of the apron being 40 to 50 feet. This is to protect the structure against any cut-back from the river. The crest wall rests upon a row of 6-inch sheet piling from 12 to 32 feet long, which was driven throughout its entire length for the purpose of cutting off seepage. Considerable sheet piling was also placed under the middle wall, on account of the excessive seepage, and some piling under the lower wall, but the latter provision was to supply a foundation over the soft bottom. The entire top of the dam is covered with concrete pavement about 18 inches



thick, except a very small portion near the Arizona end, which was paved with rough stone from 2 to 3-1/2 feet in thickness. This latter method was intended for the entire dam, but abandoned because sufficient suitable rock was not available in the quarries. The lower wall of the dam is placed with its top at elevation 138, or three feet below ordinary low water. During the flood season of 1909, the plane of the river was lowered by excessive scouring, until the top of this wall was 3 feet above low water, but no injury to the structure occurred. On the upstream side of the weir, the crest wall is protected by rock, of varying top width from 10 to 30 feet and slope of about 3 to 1. Only the ends of the dam are built on rock; the remainder of the structure is resting on alluvial deposit of the valley, which was dredged to a depth of about 12 feet. This dredging was carried on to the completion of the work, which leaves practically two-thirds of the bulk below the ordinary low water stages.

The sluiceways at each end of the dam, through which the canals will take their supply, were built through the native rock, which was so seamy and disintegrated that the bottom and sides had to be paved throughout with concrete. The bottoms of these sluiceways are at elevation 138, or 13 feet below the crest of the dam. That in California has a bottom width of 116 feet. It is controlled at its lower end by three sluicing gates of the Stoney type of iron roller, each 18 feet by 34 feet 9-1/2 inches, and supported between piers that rise to a height of 41 feet above the floor. They are operated electrically and are controlled at present by a 25 k. w. generator. On the Arizona side, the sluiceway is 40 feet in width on the bottom and controlled by one Stoney gate, the electrical mechanism for which has not yet been installed. The lifting mechanism for these gates is well illustrated by Figure 4. Figure 5 gives a general view of the California sluice gates, a portion of the canal regulator and the entire length of the

weir, as it appeared during the flood of the present season, when about 65,000 second feet were passing. In the background, may be seen the piers of the Arizona sluice gates. Figure 6 shows the Laguna Dam at the crest of the flood of 1909, when a volume of 150,000 second feet was passing over. The view is looking toward the Arizona side: the telephone poles at the left mark the crest of the dam: particular attention is directed to the position of the standing wave, which lies about half way between the middle and lower walls, the water passing off the toe of the dam with practically no erosive action.

The water approaches the canal heads through the sluiceways at as low a velocity as a foot a second: all of the sand and a great deal of the silt held in suspension is dropped: the clarified water in the sluiceway is them skimmed off for irrigation purposes, the top 15 or 18 inches only being allowed to enter the canals. When the clearing of the silt from the sluiceway is desirable, the gates controlling the canal supply are

closed and the sluicegates previously mentioned are suddenly opened and a velocity as high as 20 feet per second may be generated for dragging the silt from the sluiceways to the river below. The California heading will supply about 1700 second feet to the canals and the Arizona heading about 200.

The contract for this work was let to J. G. White & Co., on July 6, 1905, and operations were commenced under their direction July 19, 1905.

In August, 1906, the contractors petitioned for relief from their contract, claiming that they were meeting with excessive losses. A conference was held between the contractors' representatives and a board of engineers in Los Angeles, during the month above stated, and the board decided not to relieve them of their contract, but recognized their claim as to the character of the material available for the construction of the dam being somewhat different from that which both parties had reason to anticipate, and consequently a supplemental

contract was drawn and subsequently approved by the Secretary of the Interior, whereby compensating prices were allowed for certain portions of the work. There was also an allowance for the construction of a temporary bridge across the Colorado to be used principally by the contractor. The result of these changes was the advancing of the contract price from $797,650.00 to $1,129,135.00 and extending the contract time from July 19, 1907, to January 19, 1908. During the latter part of 1906, the contractors again petitioned for relief and after a conference between the Engineers of the Reclamation Service and representatives of the Contractors at Washington, D. C., the work was ordered taken over and was assumed by the Service on January 23, 1907. It was carried to completion on March 20, 1909, by force account, under the immediate direction of the Engineers of the Reclamation Service.

The rock, which forms the main portion of the dam, was found in the abutments at either end of

the structure. This rock, however, went to pieces under powder and sometimes the waste from the quarries was as high as 50%: this waste represents only the rock that was too small for the crusher.

The cement used in the work was obtained at various points near the Pacific Coast and from Iola, Kansas. The price has ranged from $2.84 per barrel to $3.53 f.o.b. at the dam.

During the time the contractor had charge, the material for the work was delivered by railroad at Yuma and then shipped either by steamboat, or sent by teams to the site of the work. When the Service took charge, the levee on the California side of the river, between Yuma and Laguna Dam, was constructed and through cooperation of the Southern Pacific Company, a railroad was laid on this levee, and after March, 1908, supplies for the dam were delivered by rail immediately on the site of the work on the California side, where connections could be made with the construction tracks in use on the dam.

The method of operation consisted of opening quarries in the rock at either end of the dam, where derricks were placed, which loaded the output onto cars hauled by dinky locomotives, which completely covered the area of operations. On entering the river, cofferdams were built above and below the work by dumping spoil from the quarry operations. Inside these cofferdams large pumps were operated, mainly by gas engines using distillate for fuel. The distillate was obtained on the Pacific Coast, usually in the vicinity of Los Angeles, and the average cost per gallon, f o.b. at the works was 10 cents. When the area inside the cofferdams had been partially unwatered, some of the material in the river bed, which had to be removed to clear away for the foundations of the work, was taken out by scraper teams. The balance was handled by suction dredges and pumps. This method of cofferdamming from each side of the river was carried on until there was finally left a gap in the river channel of approximately 800 feet. Work was then pushed at the shore ends and the sluice-

ways were prepared to carry the low-water flow of the stream during the closure and construction of the channel section. These sluiceways were completed and ready to by-pass the water early in December, 1908. On the 11th of the month, the work of building the closure cofferdams commenced. Previous to this date, however, trestles carrying railroad tracks of standard gauge had been built above and below the line of the dam, entirely across the closure, and were connected with quarries on both sides of the river. The bottom of the river, under these trestles, which was composed of fine river silt, had been well blanketed with spoil from the quarries. The problem then presented was to dump from these trestles quarry spoil, filled with enough large rock to give it stability, faster than the river could take it away, and carry these fills high enough to force the water above the dam into the sluiceways at either end, and to continue these fills sufficiently high to protect the cofferdam against a sudden rise in the stream. Before

the water was flowing freely through the sluice-ways, the river level above the dam had been raised about 11 feet. This was accomplished in 14 days, working two 10-hour shifts per day, the balance of the time being required for making repairs to equipment. In this cofferdam, a total volume of 81,794 cubic yards was dumped from the trestles. The total cost of the closure cofferdam, including trestles and incidental work, was $90,816.66.

The concrete used in the construction was made from rock obtained at the quarries and delivered to crushers situated at each end of the dam. The product of the crushers was delivered by ordinary bucket elevators to bins and from these bins directly into the hopper of the mixer, the mixers discharging into cars handled by dinky engines and run to various parts of the work.

Below are tabulated the approximate quantities for the dam and first class excavation at the time of letting the contract and also the final amounts


YUMA PROJECT LAGUNA ARIZ.
UPPER COFFER-DAM.
SMYTHE-PHOTO.
U.S.R.S.NO.157

on its completion:

	CONTRACT.	* ACTUAL.
Excavation, Class 1, (rock) - - -	305,000 cu yds	444,640 cu yds
Excavation, Class 2, (earth) - - -	282,000 " "	346,930 " "
Placing Rock in Dam -	305,000 " "	375,018 " "
Rock Paving, - - - -	80,000 sq "	5,300 sq "
Concrete, - - - - - - -	27,150 cu "	76,066 cu "
Sheet Piling, - - - -	53,000 lin ft.	82,779 lin ft.

* Exclusive of quantities used in flood protection, cofferdamming of river, etc.

The large difference between the estimated and the actual figures on first class excavation is caused by the fact that after closing up to the river section, the material remaining in the sluiceways had to be wasted in order to prepare a channel for the by-passing of water during the closing of the river, and after that the amount of rock necessary to complete the dam had to be borrowed beyond the sluiceway lines. The second class excavation was very likely estimated upon the neat lines; but in practice, much additional earth came to the pumps and suction dredges, which had to be taken out before the bottom could be reached and maintained. Concrete quantities were originally


UMA PROJECT-LAGUNA-COFFER DAM DEC, 1908.
U.S.R.S. NO.130
SMYTHE PHOTO.

estimated, covering only the core walls, but on account of the disintegrated material encountered in the quarries, it was necessary to pave the top of the entire dam, and the uncertain nature of the rock in the sluiceways made the pavement of their bottoms and sides also imperitive. Considerable scour in the river section of the stream, just prior to the closure, so deepened the channel that a considerable increase in rock fill in the dam was necessitated. In sheet piling, only the crest wall was considered; but this method of construction was afterwards found necessary in other features. Figure 7 shows the upper trestle at the beginning of dumping operations: Figure 8 is a view of the work partially finished and Figure 9 shows the completed cofferdam.

Messes were maintained for those employees who desired to take advantage of them, and well-stocked commissaries were carried on for the accommodation of the men and their families. The labor employed was mostly Mexican, with a few Indians, while in the cooler months of the year a fair percentage of wandering white men were carried on the

rolls. The skilled labor, consisting of engineers, firemen, derrick runners, pipe fitters, etc., were principally white mechanics. From October to June, little trouble was experienced in maintaining a full force of men, but during the remainder of the year, when the temperatures were very high, sometimes reaching 115 degrees in the shade, it was impossible to keep an efficient working force.

CALIFORNIA MAIN CANAL.

The main canal of the Project leaves Laguna Dam on the California side and passes in a generally southwesterly direction along the foot of the mesa, which flanks the westerly edge of the bottom lands of the Yuma Indian Reservation, to a point about three miles due north of Yuma. Here the main canal will run nearly south to the California end of the Colorado Siphon, through which the water will be crossed under the river to the Arizona side. The first mile and-a-half of this canal below Laguna Dam has a bottom width of 65 feet, a slope of .000175 feet, a mean velocity of 3.5 feet, and a water depth of 7.2 feet. The remainder of this portion

has a bottom width of 107 feet, a slope of .00005 feet, a velocity of 2.5 feet and a water depth of 7 feet. Its maximum capacity is 1,700 second feet. Diversions are made at various points, for the irrigation of bottom lands in the Indian Reservation, and the water delivered to the Colorado Siphon will be 1,400 second feet.

At the point where the canal leaves the mesa, and runs south toward the Siphon, is a favorable location for a power house, and here a drop of about 12 feet is made, from which 1,000 net horsepower may be developed. This power can be used for various operations, connected with the maintenance of the Project, such as operating the drainage pumps and gates, and in the future, when the mesa land is taken in, will be available for pumping to a portion of this higher area.

After passing the Siphon, the canal will traverse the upper portion of Yuma Valley, In Arizona, for a short distance, when it will be separated into two channels. That on the west side of the valley

will be located along the high ground, near the levee, and the one on the east side will follow along the high areas near the foot of the mesa. Both of these canals will reach southward to the vicinity of the Mexican boundary, and are so placed as to command all the irrigable bottom land of this portion of the Project. The east branch will be of sufficient capacity to carry water for the future mesa extension and the pumping station for this feature will probably lie near this canal, a short distance below Yuma. All the canals will have such dimensions and inclinations as will allow them to properly perform their functions and maintain throughout the system a uniform mean velocity of about 2-1/2 feet per second. In addition to these canals, a comprehensive lateral system, supplying water to each farm unit, will be constructed.

On the Yuma Indian Reservation, some 60 miles of this lateral system has been put in.

The supply for this system, which leaves the main canal about a mile and-a-half below Laguna Dam, has a maximum capacity of 250 second feet. The smallest lateral on this portion of the work has a capacity of 10 second feet. Since the middle of March, 1910, water has been distributed through the lateral system on the Reservation, to prime the canals and to supply water to such settlers occupying the area opened on March 1st as have prepared their land for it. This is the first unit opened for settlers on the Project and comprises about 6500 acres, divided into 173 farms. The applicants averaged about 16 per farm. At the end of August, 71 entrymen were on their holdings: over one-sixth of the area entered had been cleared, and 425 acres were under crop and receiving water. Many entrymen remained throughout the hot weather, and the development has been steady since April 1st. All checks, gates, bridges and turn-outs on this distribution system are of reinforced concrete, of which

Figures 10 and 11 are typical views. Figure 12 shows the development accomplished by one settler within one month after his arrival on the land, and many others have made showings equally good.

The main canal has been constructed from Laguna Dam to a point a mile and-a-half below, where the Indian lateral system takes out. This canal passes through the foothills, which at this location encroach closely upon the river, and the excavation was accomplished by means of steam shovels, served by dinky engines and cars. The material removed in excavating was used for blanketing the levee to a point about 7 miles below the Dam and some of it was used in bank protection immediately below the California sluicegates. Operations were commenced on this portion of the canal in April, 1909, and were completed in March, 1910. The total yardage removed was 228,597.

Although no construction has been done on the main canal below this point, the line has been

located on the ground to the upper end of the Colorado Siphon: below that structure, the line has been studied on topographical maps and the profile, alignment and cross section determined for the system covering nearly all the 55,000 acres in Lower Yuma Valley.

Most of the silt is expected to be removed by the sluiceways before entering the main canal, but the probability is that in the first half or three quarters of a mile of this channel, there will be more or less deposit, and in order to remove this, provision will be made at a point about a half mile below Laguna Dam for a wasteway and sluicegates into the river, so that the upper portion of the canal may be periodically sluiced.

ARIZONA MAIN CANAL.

This canal will leave Laguna Dam at the Arizona end and pass along the foot of the mesa in a generally southerly direction, to the vicinity of the Gila River. Future observations of the effect, which the storage works now building, and contemplated,

upon the upper Gila and its tributaries will have upon the floods in the lower Gila, will determine the feasibility of extending this canal across the Gila to water the bottom lands on the south side. From December, 1908, to March, 1909, about 2 miles of this canal were constructed. As the building of a canal immediately adjacent to the Dam would have interfered with the construction operations then in progress on the Dam itself, the first mile of this canal was omitted, and the construction, beginning one mile below the Arizona diversion point, continued towards the south for about 2 miles. The total yardage moved on this portion of the work was 65,325. All work in connection with the canal system has been done by force account.

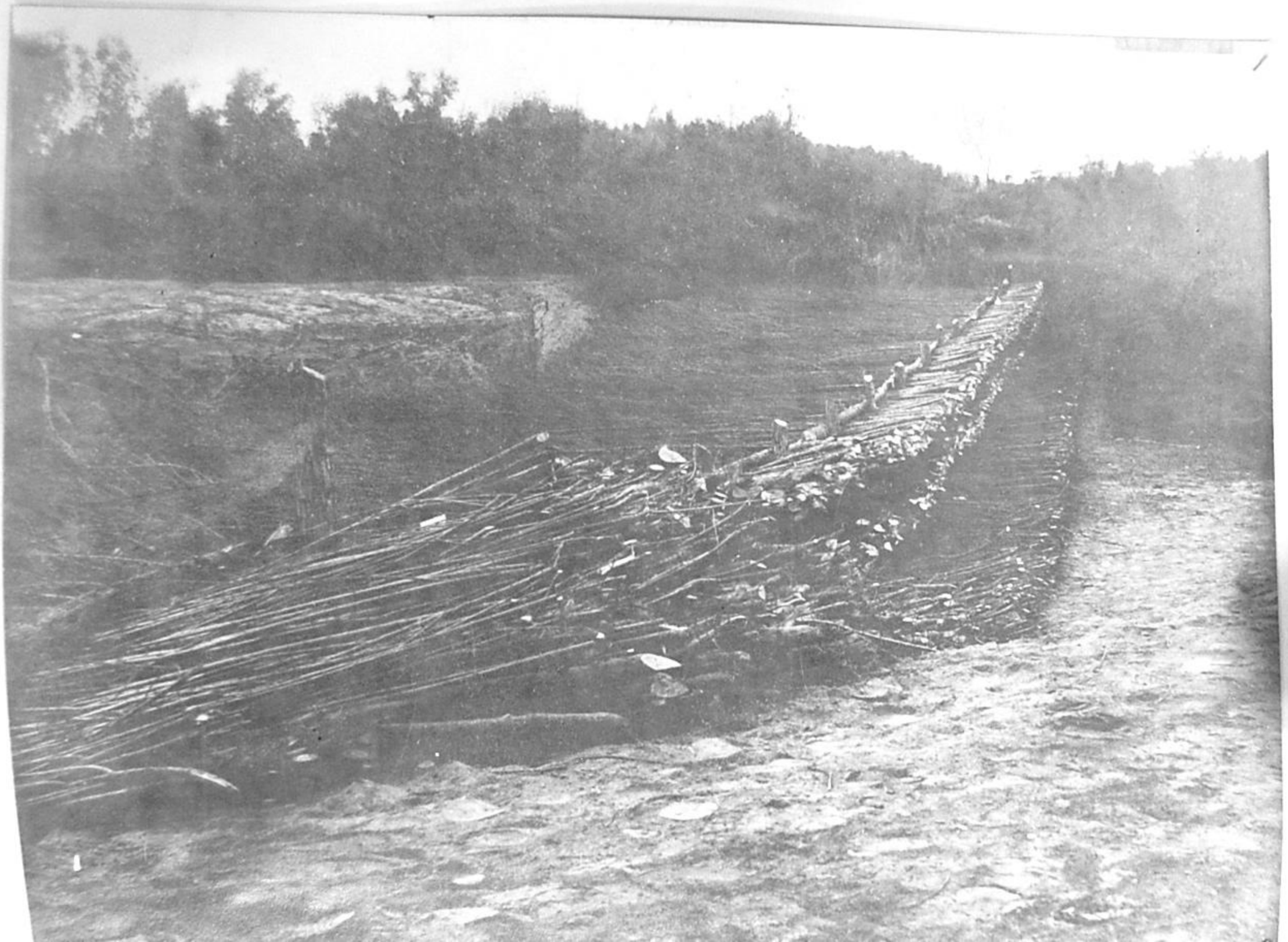
LEVEES.

While the bottom lands to be irrigated are above the normal and low-water stages of the river, they are subject to inundation during floods. In May, June, and July the annual freshet of the Colorado puts large areas under water, and the erratic

rises of the Gila at various portions of the year are likely to cause considerable inconvenience and damage. To guard against such a contingency, an elaborate system of levees for flood protection has been designed. These levees are distributed, as follows:- Along the west bank of the Colorado, from Laguna Dam to a point on the Southern Pacific Railroad, known as Araz, which lies about four miles west of Yuma: along the east bank of the Colorado, from Laguna Dam to the confluence of the Colorado and Gila rivers, thence below this confluence to the Mexican boundary: also along both banks of the Gila, from its junction with the Colorado, to a point which will furnish ample protection to the irrigable lands along the stream. The levees vary in height, from 4 to 15 feet, and are generally 4 feet above high-water line. The slopes on the river side are generally three to one, and those on the land side, 2-1/2 to 1, the crown width being from 8 to 10 feet. Substantial muck ditches under the river slopes,

are provided on all the levees, except the first 14 miles below Yuma and what small amount of work has been done on the Gila. The total length of levees contemplated is about 75 miles, of which about 40 miles have been completed.

Construction work on the Yuma Valley levee, which extends from Yuma to the Mexican boundary, was begun in September, 1905, by contract, and approximately 14 miles built during the season 1905-6. The following year, the work was continued by force account and was prosecuted at intervals until March, 1909. Since that time, no further work has been done on this portion of the levee. At the present time, this levee is completed for 24-1/2 miles west and south of Yuma, with the exception of about 2 miles, which was left at a somewhat lower grade, but sufficiently high to protect the land from ordinary floods. The dike system in the Gila Valley was located by the first of 1906, and in March of the same year construction was begun by force account. Work continued on



this feature for about eight months, in which time 5.6 miles of the south levee and 2.2 miles of the north levee were completed. No further work has been done in the Gila Valley since that time, as a further study of the meanders of the stream showed clearly that it was advisable to note the effect upon its floods of the works now in progress on the upper reaches of the stream, before going further with the matter of flood control.

The levee on the west bank of the Colorado, between Laguna Dam and Araz, is known as the Reservation levee. Work on this was performed by force account during the years, 1907, 1908 and 1909, and the levee is now completed from the Dam to a point about three miles west of Yuma, with the exception of three-quarters of a mile across private property, through which a right-of-way had not been acquired at the time operations were in progress. This right-of-way has since been obtained.

The total volume of earth moved in levee constructed has amounted to 2,150,402 cubic yards, of which 450,000 cubic yards was done by contract and the remainder by force account.

Abattis dikes are constructed at frequent intervals along the river slopes of the levees, to break up erosive currents during floods. Figure 13 is a view of a Fresno scraper outfit, engaged in levee construction. Figure 14 shows a typical abattis dike and Figure 15 shows the drift lodged behind one of these dikes after a flood. end-

DRAINAGE.

While drainage of the irrigated lands may not be necessary in the early history of the Project, no irrigation can be continuously successful without proper channels to control the ground-water level and to remove the surplus water from the irrigated lands. In Yuma Valley, and also in the Indian Reservation, nature has pointed the

way for such a system of drains in the large sloughs, which exist and traverse nearly the median lines of these tracts from one end to the other. The branches of these sloughs greatly aid in the problem of local drainage channels connecting with the main drains. A comparitively small amount of inexpensive work in straightening and deepening these channels will convert them into a most admirable drainage system for the removal of surplus water. During low stages of the river, these drains can discharge by gravity at their lower ends into the river, through gates in the levee, and during high stages, the levee gates may be closed and the elevation of the water in the drains controlled by means of pumps. It is proposed to build only the main arteries of this system, leaving the small local drainage channels to be provided by the settlers themselves. No work has yet been done upon this system, but on

the Indian Reservation rights-of-way through the sloughs have been reserved for this purpose, and the matter will be given proper attention in the design of the irrigating system in the Yuma Valley, so that if desirable work may be prosecuted on it during the later days of the completion of the Project.

COLORADO SIPHON.

As stated above, the main canal from Laguna Dam, on the California side, will cross under the Colorado river by means of a depressed structure, known as an inverted siphon. Borings made along the line of the proposed tunnel have demonstrated that the river is underlaid by sandstone at such reasonable depth that tunnel operations through it may readily be conducted. The sandstone, which appears to be of the same general character as the bluff that now flanks the eastern border of the river, near Yuma, is about 50 feet below river bed in midstream and some 80 feet below the surface on the site of the shaft on the Cali-

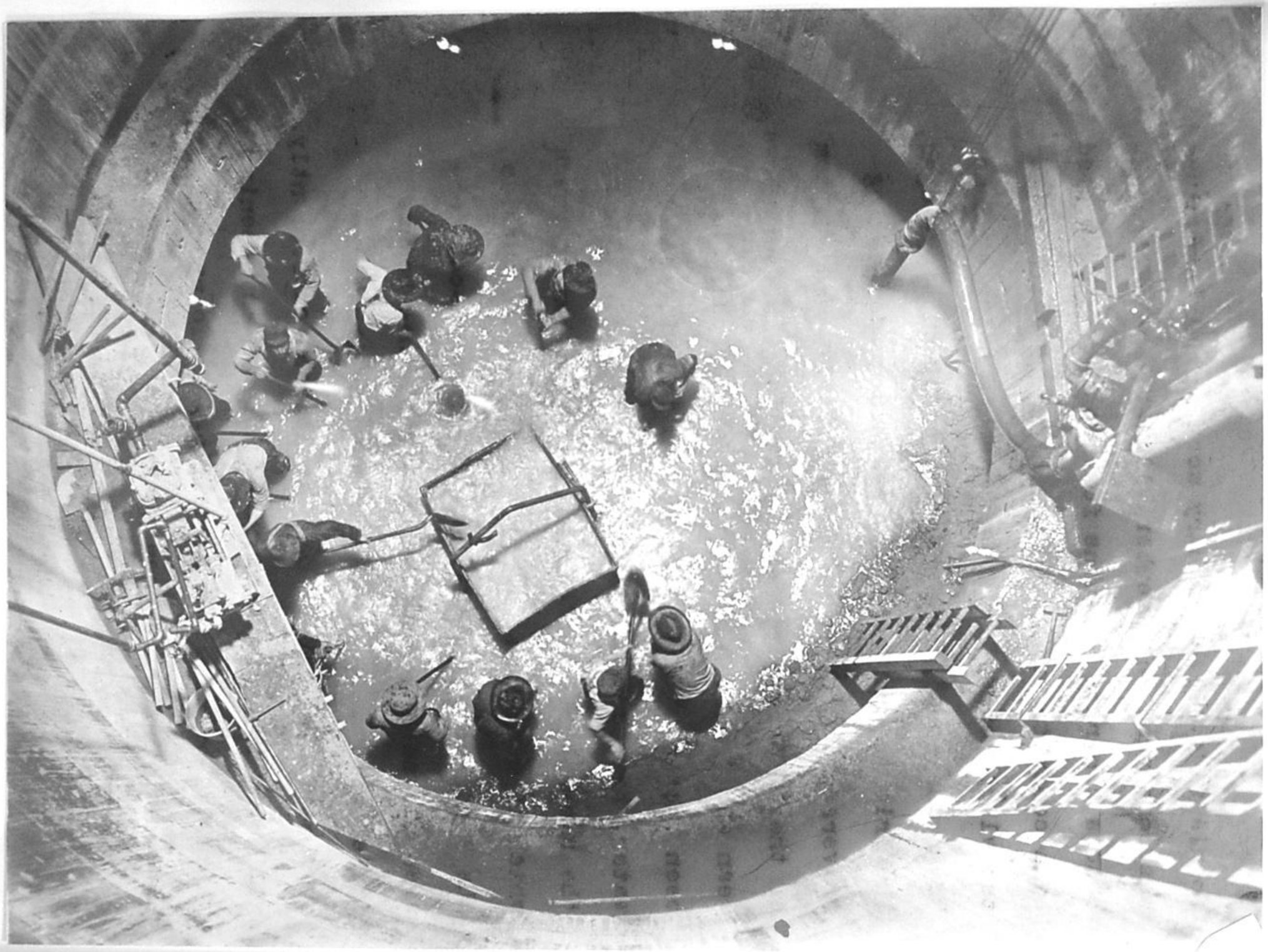


Fig. 17. Arizona Shaft at Fifty Foot Level.

fornia side. Preliminary work on this structure was commenced in November, 1909. The design embraces concrete caissons for two shafts connected by a concrete tube under the river of 14 foot internal diameter. The shafts are being sunk as "open caissons", supported on steel cutting-edges. The Arizona shaft has now reached grade, having traversed a total depth of 140 feet. The bottom of the cutting-edge is at elevation 8.3 feet above mean sea level. The bottom of the shaft has been closed by concrete, placed in 112 feet of water, by means of a bottom dump bucket. During the sinking of the caisson, the sandstone through which it passed was sheared off somewhat outside the lines of the structure, and this space, between the caisson and the hard rock, has become filled with sand, which, as soon as the water surface inside the caisson is lowered sufficiently, will blow into the structure, through any opening which may be made for tunnelling. To prevent this, 4" pipes have been driven into the area,

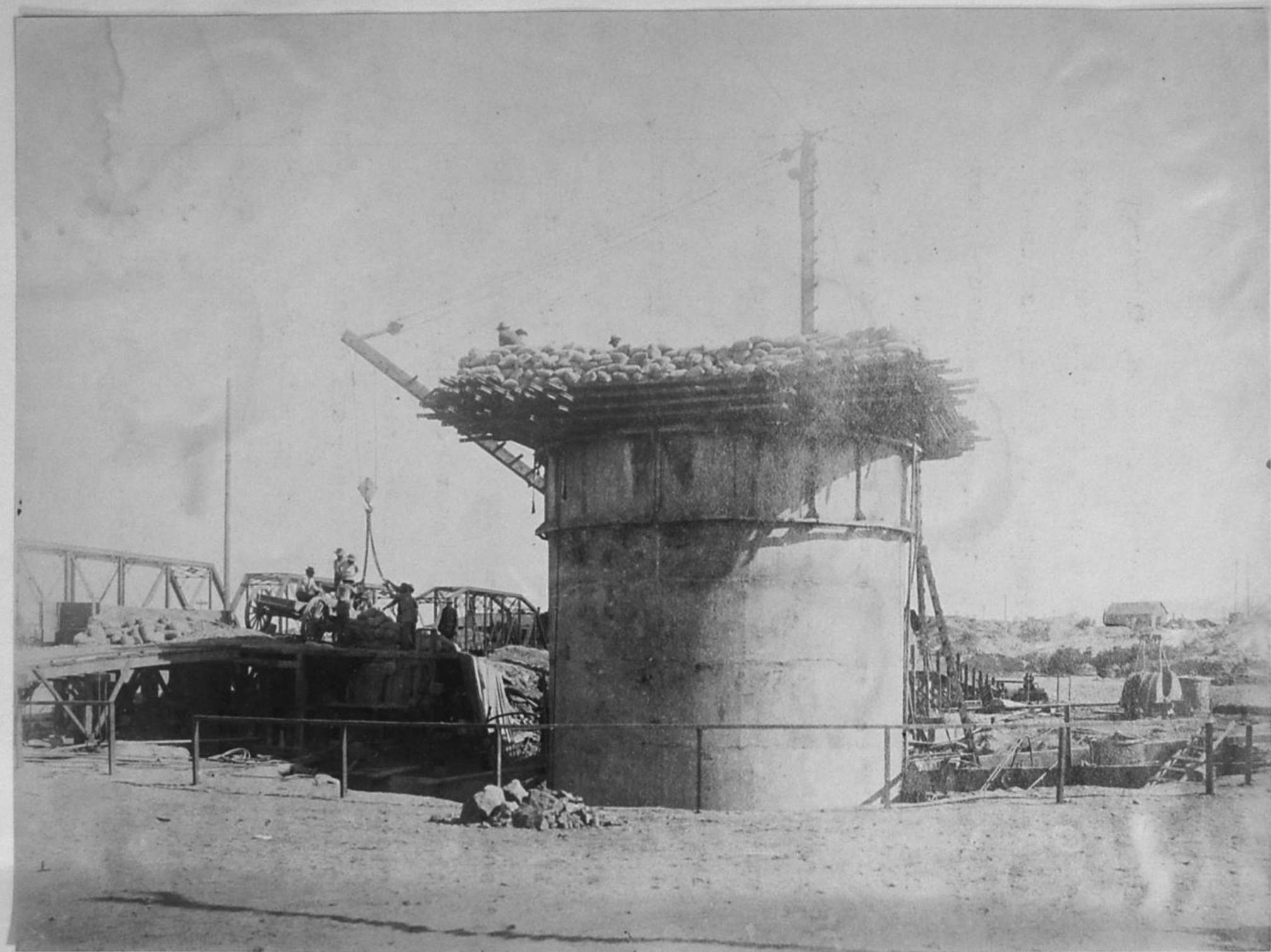


Fig. 18. California Caisson - 300 Tons Additional Load.

near the outer skin of the caisson, through which the tunnel must pass, and the sandy material is being consolidated by the injection of grout through these pipes, under pressure varying from 100 to 175 lbs. per sq. inch.

The cutting-edge of the caisson at the California shaft, is now about 100 feet below the surface, or at elevation 30 above mean sea level. The cutting-edge has penetrated the rock about 7 feet: the material above the rock is quicksand, which has a tendency to flow into the structure if it is pumped out, and consequently it is necessary to obtain considerable penetration into the rock before the structure will seal sufficiently to be unwatered. This is being accomplished by the use of divers and dynamite. This caisson has about 30 feet more to go. Figure 16 is a profile of the Siphon, showing canal connections at either end: Figure 17, a view of the Arizona caisson at 50 feet depth and Figure 18

the California Shaft, with 300 tons additional load to cause penetration.

The upstream end of the Siphon will be controlled by a cylinder gate and a short distance above this gate there will be a screen across the canal, fully protecting the Siphon from any large floating object. Just above the screen, an overflow will be constructed into a wasteway leading to the river, in order to by-pass the water around the Siphon in case of emergency, or during an inspection of the Siphon, when water must necessarily be shut out of it, this by-pass would provide for the flow of water if it was desirable to operate the power house, situated about 3 miles upstream.

On the basis of the probable excavation of this feature, about 35 per cent of the work has been completed to date. The work has been carried on by force account.

MESA LANDS.

Situated south of Yuma is a fine body of land, practically devoid of vegetation, at an average elevation of about 80 feet above river level and practically frostless. The land is fairly smooth, sloping gently towards the southwest, and has been pronounced by experts, largely on account of the absence of frost, to be probably the best citrus land in the United States. The Project embraces the ultimate cultivation of these lands, by means of a pumping station on the bank of the main canal near Yuma, feeding through force mains leading to the mesa a system of laterals which will properly control this elevated area. No detailed studies have been made of the proposition, other than to outline approximately the area which it is practicable to reach - being in the neighborhood of 40,000 acres. In order to provide for this future work, however, the main canal from Laguna Dam and the Siphon are given such dimensions as

will pass the water required.

To aid in forming an opinion regarding the future of these Mesa lands, attention is directed to the following, taken from "The Earth", of August, 1909, page 14:

"The sales sheets of the New York market for the days Arizona oranges were sold during December, 1908 and January, 1909, are herewith produced; in each case, the highest price is quoted. The following figures were furnished us January 10, 1909, by the Fruit Trade Journal, of New York:

	DECEMBER, 1908.		
	California.	Florida.	Arizona.
7	$3.90	$5.10	$9.20
14	3.90	3.10	9.20
16	4.00	4.35	7.40
18	4.15	3.60	7.00
21	4.15	3.90	7.00
23	3.85	3.25	6.80
28	3.75	3.50	6.40
30	3.30	2.65	6.50
	JANUARY, 1909.		
4	2.95	3.50	6.70
5	3.05	3.50	6.00
7	2.60	2.40	3.30
11	3.70	3.55	6.20
13	3.45	2.65	3.70
16	3.60	2.70	8.90 "

This comparison well illustrates the demand in Eastern markets for the products this Mesa can produce.

ANTICIPATED RETURNS FOR THE FARMER.

What has gone before deals almost entirely with the engineering features of the work, its investigation and construction. But no Project, however carefully investigated, designed and constructed can be classed as successful unless the people, who are to make their homes under it, are assured of an adequate return for their labor and the hardships to be endured as pioneers in a new country. This region has a perpetual irrigation season, extremely fertile soil, continually replenished by the silty waters from the canals and an infinite variety of products, which makes the agricultural development inconceivable to the man who is familiar only with farming as conducted in the rainfall sections. The following products have been successfully grown at Yuma, under the temporary system of canals, which are supplied by pumps, operated by the Reclamation Service.

Alfalfa	Dates
Wheat	All small fruits and berries
Barley	Apricots
Corn	Grapes (Malaga, Muscat, Tokay)
Kaffir Corn	Asparagus
Milo Maize	Melons
Cotton (Upland)	Potatoes, white and sweet
Cotton (Egyptian)	All varieties of Beans
Apples	Peas
Pears	Dairy Products
Figs	Livestock
Vegetables	Poultry and Honey.

One grove of 60 acres on the Mesa, supplied with water by the pumps of the Town Water Company, has shown that this elevated area is well adapted to the raising of citrus fruits.

Below are tabulated the average yield per acre of some of the crops and the gross annual returns, obtained at Yuma market prices in 1909:

CROP.	YIELD PER ACRE PER ANNUM.	YUMA MARKET PRICE 1909.	GROSS RETURN PER ACRE.
Barley	36 bushels	1.35	$ 47.25
Corn	35 "	1.12	39.20
Alfalfa	10 tons	13.00	130.00
Wheat	22 bushels	1.20	26.40
Milo Maize	60 "	1.00	60.00
Alfalfa Seed	500 lbs.	0.12	60.00
Potatoes	100 bushels	2¢ lb	120.00
Onions	10 tons	1-1/2¢ lb	300.00
Cantalopes	150 crates	0.50	75.00
Cotton (Egyptian)	1 bale (500 lbs)	0.20 lb	100.00
Cotton (Upland)	1-1/2bales	0.11 lb	82.50

Stock 3 animals to two acres.

Fig. 19. Second Cutting Alfalfa, May 12, 1910.

But the above does not exhibit the gross annual returns to be obtained from an acre of ground, unless various combinations are considered. For instance, with a crop of barley, yielding $47.25 per acre, can be grown in the same year, from the same area, a crop of corn worth $39.20 per acre, giving a gross annual return of $86.45. In the same year, wheat and corn could be combined with a return of $65.60: barley and milo maize with return of $107.25: wheat and milo maize $86.40: potatoes and corn $159.20. There is also a combination of alfalfa and alfalfa seed. If the entire number of crops from the area are devoted to hay, the annual return would be about $130.00. This is based on the supposition that seven cuttings will be made. If two of these cuttings were sacrificed to producing alfalfa seed, we would then have about 7 tons of hay, or a yield of $91.00 per acre, and to this should be added $60.00 per acre for the seed, which would amount to $151.00, as the annual income. There are

Fig. 20. Harvesting Barley in Yuma Valley.

various other combinations that may be worked out as the farmer studies his land, as, for instance, onions might be grown with small truck crops and the same could be worked with cotton. One combination suggested for a farmer on a small tract, is fruit trees, alfalfa, poultry and bees. The list of crops might be extended somewhat, but the above represents the present general condition and will probably not be seriously modified in the early years of the Project.

In 1909, the area under the pump canals, at Yuma, upon which crops were grown, was about 7000 acres. This area produced an estimated value of $608,000.00, which gives a gross annual return per acre, with what may be classed as rather indifferent cultivation, of $87.00. Some idea of the luxurient growth at Yuma may be gained from Figure 19, which shows the harvesting of the second crop of alfalfa hay, on May 12, 1910, and from Figure 20, which shows a field of barley during harvest.

From the estimates, which follow, it appears that this entire project, including the Mesa land, can be completed for about $57.00 per acre, and the above estimate of anticipated returns appears to fully justify the expenditure. It should be understood that the annual returns here given apply to the bottom lands and such crops as can be grown there; the returns from citrus lands will be several times greater.

PROBABILITY OF INVESTMENT BEING RETURNED TO THE GOVERNMENT BY THE SETTLERS.

It is a safe statement that the value of land in Yuma Valley, before operations were begun by the Reclamation Service, was on the average of $30.00 per acre. At present, the selling price ranges from $60.00 for undeveloped wild land near the Mexican Boundary to $250.00 for land in crop under the temporary canals near the Town of Yuma. No land under crop and receiving water sells for less than $100.00. Let us say that the average selling

price today is $100.00 per acre: this shows an increase of $70.00. Good citrus lands in California bring several hundred dollars per acre: in many cases over $1000.00 has been paid, so $70.00 does not in any degree represent the increase which will come to the Mesa when fully developed. The fact that the Mesa is here considered as a pumping proposition, should not stand against it, for it must be remembered that crops grown on this area will have an extremely high value. In the citrus regions of California, the height to which water must be pumped is of slight consequence some areas in Riverside County, I am informed, are irrigated with water pumped in three lifts to an elevation of 500 feet. The question there is "Have we the water", and if that is available, it is placed upon the land regardless of its elevation, provided it is comparitively free from frost. At Yuma, we have the land without frost and an ample supply of water, so there should

be no reasonable doubt regarding its development. Assuming a conservative value for the Mesa land, it would appear that a fair average increase in land values over the entire irrigable area of 130,000 acres would be $100.00 per acre. This gives a total increase of $13,000,000.00, or nearly double the amount shown by the following estimates as necessary for its reclamation. Such an increase should insure the prompt return to the Reclamation Fund of the money spent in its development.

EXPENDITURES TO JUNE 30, 1910, AND ESTIMATED COST OF COMPLETION.

The total amount expended for investigation and construction on the Yuma Project to June 30th, 1910, appears in Table No. 2, following: Here are also exhibited the estimates of the amounts required for the completion of the various features and the total expenditure to complete the entire work, as herein outlined. It appears from this

estimate that the reclamation of the entire 130,000 acres may be accomplished for the sum of $7,700,462.08, equal to about $57.00 per acre.

Table No. 2 also shows that after deducting from the estimated cost of the entire project the total allotments to December 31, 1910, there remains an amount of about $3,580,462.08, which is necessary to carry the work to final completion.

TABLE NO. 2.

EXPENDITURES TO JUNE 30, 1910, AND

ESTIMATED COST TO COMPLETE.

	COST TO JUNE 30, 1910	FUTURE COST.	TOTAL
Siphon Connections, etc. - - - - - - -		$43,000.	$ 43,000. -
Dam and Main Canal to Indian Reserva.	2,135,116.11	230,000.	2,365,116.11
Main Canal to Siphon - - - - - - - - - -	2,899.78	540,000.	542,899.78
Indian Reservation Canal - - - - - - -	271,838.25	75,000.	346,838.25
Colorado Siphon and Wasteways, - - - -	101,391.66	165,000.	266,391.66
Main Canal and Laterals in Yuma Val.	11,625.84	800,000.	811,625.84
Drainage Systems -	780.47	150,000.	150,780.47
Rights and Property	77,062.43	175,000.	252,062.43
Gila Valley Main Canal and Laterals	29,664.87	340,000	369,664.87
Levees - - - - - - -	556,213.13	368,000	924,213.13
Mesa Land Pumping Station, - - - - -		500,000.	500,000.00
Mesa Land Main and Lateral Systems -	581.06	600,000.	600,581.06
Preliminary Surveys and undivided gen.accts.	374,013.05		374,013.05
Temporary Pumping Plants.	153,275.43		153,275.43
	$3,714,462.08	3986000.	7,700,462.08
Allotments to December 31, 1910.			4,120,000.00
Balance required			$3,580,462.08

URGENCY OF COMPLETION.

The Yuma County Water Users Association, which is the medium through which the Secretary of the Interior deals with settlers on this Project, now has a membership of 634, representing 75,000 acres of land, all situated in Arizona: this is an average holding of about 120 acres. Most of these land owners joined the Water Users Association, agreeing to pay their pro-rata share of the cost of the works in the early days of the Project and have been waiting for the realization of their hopes ever since. The delay in the completion of the system has embarassed many of them financially and if forced to wait much longer for the water some of them will have to sacrifice their holdings and depart.

About 250 of these water users have been furnished water for 9,600 acres (an average holding of 40 acres) from the temporary system of canals, operated by the Service. This supply,

however, is unsatisfactory, due not only to the small area which can be served, but also to the fact that as the canal supply depends entirely upon pumps during extremely low stages of the river, even this small supply is much curtailed: at the present time, the surface of the river is about four feet lower than it was prior to the flood of 1909, and this lowering of the plane has so reduced the volume discharged by the pumps that the distribution of the water to the fields is over two weeks, and in some cases, three weeks behind the proper schedule. Further than this, on account of the cost of pumping water, and the expense of clearing silt from the canals, due to the necessity of pumping direct from the river without removing any of the sediment, the water costs the irrigator about one dollar per acre foot: the annual duty of water under these canals is about five and one-half acre feet, so the cost of water per acre per year is $5.50: in

some cases, when the land is such as to require a greater amount or more frequent irrigation, the charges are even higher. It is anticipated that with a completed system, the annual charge for maintenance and operation will not exceed one dollar per acre and will probably be even less. So it appears that the small area within reach of our pumps is being charged for maintenance and operation over five times what that charge will be when the contemplated system is delivering water.

The above shows, in a slight degree, the hardships and difficulties under which the settlers at Yuma are working, and it is hoped that means will be found for their relief, which can come only with a speedy completion of the works.

APPENDIX.

ANSWERS TO QUESTIONS PROPOUNDED BY MAJOR BURGESS, CORPS OF ENGINEERS.

Q. 1. - Total expended on project to June 30, 1910?

Ans. - $3,714,462.08.

Q. 2. - Amount and percentage of this for engineering and superintendence on the project?

Ans. - See Table No. 3, attached.

Q. 3. - Amount and percentage of this for clerical charges?

Ans. - See Table No. 3.

Q. 4. - Amount and percentage of this for supervising engineer's office?

Ans. - See Table No. 3.

Q. 5. - Amount and percentage of this for Director's and Chicago offices, expert engineering, et cetera (combined)?

Ans. - See Table No. 3.

Q. 6. - Total allotments to December 31, 1910?

Ans. - $4,120,000.00.

Q. 7. - Estimate for completion (stated by items)?

Ans. - See Table No. 2.

Q. 8. - Number of irrigable acres in each unit?

Ans. - Yuma Indian Reservation - 16,000 acres:

Yuma Valley - - - - - - -	55,000	" :
Gila Valley - - - - - -	20,000	" :
Mesa Land - - - - - - - - -	40,000	" .
	131,000	"

Q. 9 - Number of irrigable acres already opened?

Ans. - 6,500 on Yuma Indian Reservation.

Q. 10 - Show how construction charges for acre for lands already opened were arrived at?

Ans. - The following tabulation shows how the result was reached, on April 30, 1909, based on an ultimate area of 130,000

acres and the expenditures to that date:

Laguna Dam - - - - $\frac{\$2,000,000}{130,000}$ - $15.40 per acre;

Land - - - - - - - - $\frac{100,000}{130,000}$ - .77 " " ;

Preliminary Surveys, etc. $\frac{130,000}{130,000}$ - 1.00 " " ;

General Expense - - $\frac{96,500}{130,000}$ - .74 " " ;

Small canals 13.50 per acre exca.
3.50 " " struct.
17.00 " " ;

Levees, 75 miles at 12,200. per mi.

$\frac{914,000}{130,000}$ - 7.03 " " .

Mesa Pumping Plant:
Pumping Plant 284,000
Pipe - - - - 80,000
Add extras, etc. 400,000, say,
3.08 " " ;

Gila Valley Pumping Plant:
$\frac{30,000}{130,000}$ - 0.25 " " ;

Accounts Payable - - $\frac{224,000}{130,000}$ - 1.72 " " ;

Main Canal, Calif. -	$\frac{475,000}{130,000}$	4.25 per acre;
Structure	$\frac{75,000}{130,000}$	
Arizona Siphon - -	$\frac{175,000}{130,000}$	- - 1.34 " " ;
Power Plant - - -	$\frac{130,000}{130,000}$	- - 1.00 " " ;
Drainage System -	$\frac{130,000}{130.000}$	- - 1.00 " " ;
	Total - -	$54.58 " " .

This total, for purposes of estimate, was taken at $55.00 per acre.

Q. 11 - Show how construction charges per acre for remainder of irrigable land will be determined?

Ans. - As far as can be determined at the present time, the construction charges for lands opened on this Project in the future will be determined in the same manner as that followed in fixing those for the unit opened on the Yuma Indian Reser-

vation. At that time, the work will be further advanced and the cost of the various features will be more definitely known.

Q 12 - How many acres now taken up, including all lands now charged for operation and maintenance, whether actually paying now, or not?

Ans. - 8,500 acres on Yuma Indian Reservation.

Q. 13 - If there is any land under any special agreement, please state conditions of agreement and area?

Ans. - None.

Q. 14 - What was total cost in 1909, for operation and maintenance?

Ans. - No land opened at that time.

Q. 15 - What was charged per acre?

Ans. - No land opened.

Q. 16 - What was total collected (or charged against lands) for operation and mainten-

ance?

Ans. - No collections or charges made.

Q. 17 - How is the difference between No. 14 and No. 16, if any, to be made up?

Ans. - No such difference exists.

Q. 18 - What will be the probable cost per acre for operation and maintenance after the system has been in operation for several years (the canals well seasoned, et cetera)?

Ans. - One dollar per acre.

Q. 19 - Please indicate on any available map acreage of irrigable land in each unit of present work and any proposed extensions.

Ans. - See Fronticepiece.

Table No. 3

Statement showing Building Cost of Yuma Project to June 30, 1910 with elements and percentages thereof.

Feature Accounts	Total Building Cost	Actual Construction		Real Estate		Engineering & Superintendence		Clerical		Legal		Supervising Engineers' office		Director, Expert Engineering Chicago etc.	
		Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%	Amount	%
Laguna Dam & Headworks	2,107,993.26	1,822,384.94	86.4	35,407.83	1.7	134,963.37	6.4	49,717.21	2.3			14,067.03	.7	51,452.88	2.5
Levees	575,232.76	499,527.16	86.9	4,219.60	.7	40,052.15	6.9	13,561.64	2.3			3,837.14	.7	14,035.07	2.5
Main Canal	245,587.86	191,692.84	78.1			40,472.68	* 16.4	5,790.85	2.3			1,638.47	.7	5,993.02	2.5
Distributing Canals	341,989.70	264,214.91	77.2	37,435.00	11.0	21,597.23	6.3	8,086.19	2.3			2,287.91	.7	8,368.46	2.5
Temporary Irrigation Systems	157,317.42	145,318.05	92.3			3,436.20	2.2	3,697.03	2.3			1,046.04	.7	3,826.10	2.5
Preliminary Surveys prior to selection of project and genl proj. constr. chgs.	286,341.08	69,687.03	24.3			200,998.08	70.2	6,754.50	2.3			1,911.13	.7	6,990.34	2.5
TOTALS	3,714,462.08	2,992,824.93	80.6	77,062.43	2.0	441,513.71	11.9	87,607.42	2.3			24,787.72	.7	90,665.87	2.5

* Excessive Percentage due to fact that most of engineering work on feature is done while little construction has been accomplished.

NOTE.. Legal Expenses included in "Supervising Engineers office, and "Director, Expert Engineering, Chicago, etc. amounts.