Lode Highway from El Dorado to Plymouth traverses the reservoir site and the road is paralleled by a power line (single circuit, 60,000-volt, wood pole). Relocation of ten miles of highway and nine miles of power line would be necessary.

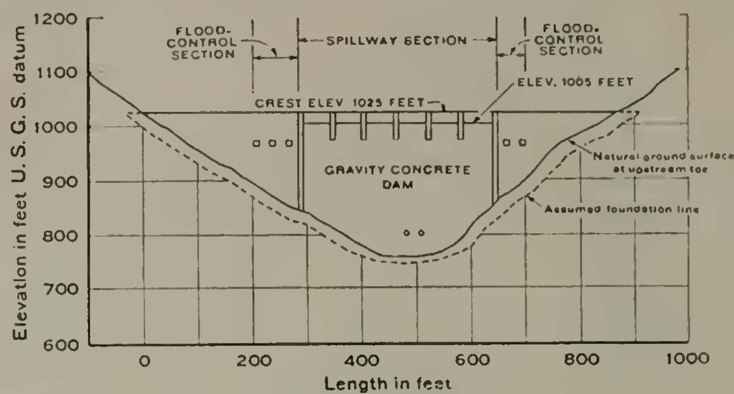
The water supply which could be made available from Nashville Reservoir is not sufficient for the requirements of the lands to be served in the service area (Hydrographic Division 13) of the Cosumnes River. It is proposed to obtain required supplemental supplies from the American River. Accordingly, under the ultimate State Water Plan, Nashville Reservoir would be operated coordinately with the supply imported from the American River. With such coordinate operation, the mean annual irrigation yield of Nashville Reservoir, for the 11-year period 1918–1929, would have been 163,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—The dam site is a narrow "V" shaped gorge. A geological examination (see Appendix C) shows it to be suitable for a high concrete structure. Solid bed rock (diabase) is exposed in the stream bed. The same formation follows a cliff profile to 125 feet above stream bed. On the higher slopes there is a considerable overburden of earth and jointing which has weakened the massive rock near the surface so that large blocks have been loosened from the mass. No borings or test pits have been made at the site, but from field examination, it is estimated that the removal of surface and underlying loose blocks would necessitate an average depth of stripping of 20 feet on the right abutment and 25 feet on the left. In the stream bed, which consists of fresh bedrock with tight joints, an average stripping depth of ten feet would be necessary to produce an even surface and properly key the structure.

PLATE XXVII

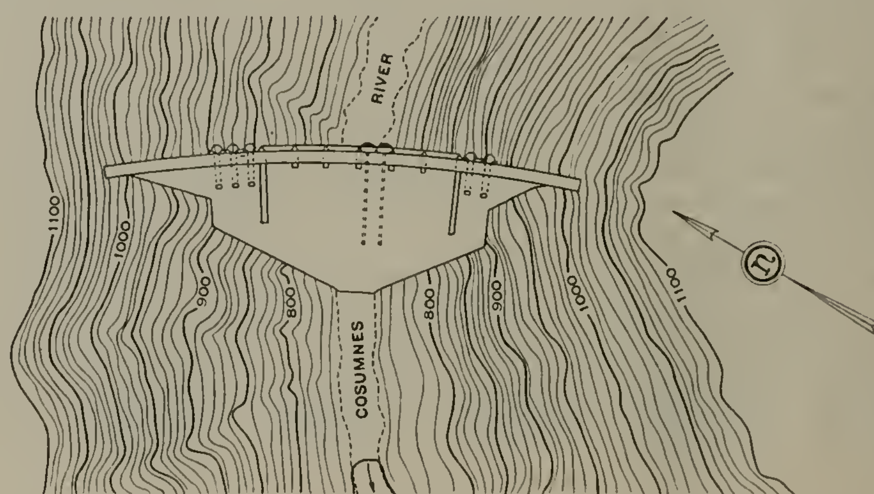
NASHVILLE DAM SITE ON COSUMNES RIVER

PLATE XXVIII



PROFILE OF DAM

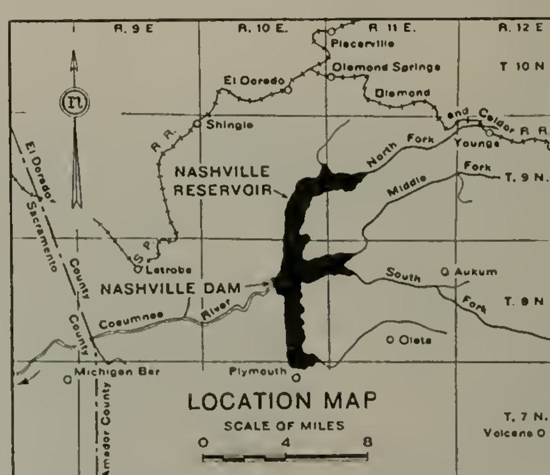
LOOKING UPSTREAM



GENERAL PLAN OF DAM

FEET

0 200 400



NASHVILLE RESERVOIR

ON

COSUMNES RIVER

Dam and Appurtenances—The topography of the dam site and general layout of the dam and appurtenances required are shown on Plate XXVIII, "Nashville Reservoir on Cosumnes River." The height of the proposed dam is 270 feet above stream bed, including a five-foot freeboard. It is of the gravity-concrete type slightly curved to fit the topography, and has an overflow type of spillway in its center of 60,000 cubic feet per second capacity, controlled by six steel drum gates 50 feet long by 15 feet high. Reserve storage space of 56,000 acre-feet would be used for flood control. This would require a maximum drawdown of 20 feet, and would result in a regulated flow, exceeded once in one hundred years on the average, of 15,000 second-feet. For the purpose of flood regulation, the plans provide for five ten-foot by ten-foot openings through the dam, located at elevation 975 feet and controlled by gates of the caterpillar type at the upstream face of the dam. Two 48-inch diameter pipes with a discharging capacity of 1200 second feet, when operating under a minimum head of 50 feet, are provided for release of irrigation supplies. The inlet ends of these irrigation outlets are located at elevation 780 feet, and are controlled by two 48-inch needle valves and two four-foot emergency slide gates. No hydroelectric power installation is contemplated at this site.

Cost of Nashville Reservoir—The capital and annual costs of Nashville Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 68.

TABLE 68

COST OF NASHVILLE RESERVOIR

Height of dam, 270 feet. Capacity of reservoir, 281,000 acre-feet.
Capacity of spillway, 60,000 second-feet.
Capacity of irrigation outlets, 1,200 second-feet.
Capacity of flood control outlets, 15,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		760,000
Excavation for dam, 97,000 cubic yards at $3.00 to $5.00	$314,000	
Mass concrete, 465,000 cubic yards at $7.85	3,650,000	
Reinforced concrete, 2,000 cubic yards at $18.00 to $30.00	45,000	
Spillway gates	120,000	
Irrigation outlets and sluiceways	54,000	
Flood control outlets	40,000	
Drilling, grouting, drains and contraction seals	50,000	
		4,273,000
Miscellaneous		472,000
Subtotal, dam and reservoir		$5,535,000
Administration and engineering, at 10 per cent		553,000
Contingencies at 15 per cent		830,000
Interest during construction, based on an interest rate of 4.5 per annum		482,000
Total capital cost of dam and reservoir		$7,400,000
Total annual cost of dam and reservoir		$441,000

Ione Reservoir on Dry Creek, a Tributary of Mokelumne River.

The main dam site for the Ione or Arroyo Seco Reservoir on Dry Creek, a tributary of the Mokelumne River, is located in the Arroyo Seco Ranch near what would be the west line of sections 7 and 18, Township 5 North, Range 9 East, M.D.B. and M., if the rancho were sectionized, and in Sacramento and San Joaquin counties about one mile west of the Amador County line. Two auxiliary dam sites are located in saddles northerly from the main site.

The Dry Creek basin, situated between the Cosumnes watershed on the north and the lower Mokelumne on the south, drains the lower slopes and foothills of the Sierra Nevada. It comprises an area of about 270 square miles above the dam site and rises to a maximum elevation of about 4300 feet. The total length of the watershed above the dam site is about 33 miles and the maximum width is about thirteen miles. The reservoir site is so situated that, in addition to the run-off naturally tributary from the Dry Creek basin, excess waters of the Mokelumne River after Pardee Reservoir has filled could be diverted into Ione Reservoir through the constructed Jackson Creek spillway located on the ridge between the two watersheds. As such water spilled from the Pardee Reservoir would occur in wet years only, cyclic storage would be necessary for its utilization.

Water Supply—The water supply considered available for regulation at this site would comprise the run-off of Dry Creek above the Ione Dam site less the net diversions for lands to be irrigated ultimately above the reservoir, and the excess Mokelumne River water spilled from Pardee Reservoir. The net reservoir evaporation loss is estimated as four feet in depth per season on the reservoir surface. The average seasonal ultimate net run-off, which would have been available for regulation at this site for the 40-year period 1889–1929, is 68,700 acre-feet, excluding spill from Pardee Reservoir. In addition, water spilled from Pardee Reservoir would have been available for regulation, amounting to 280,000 acre-feet, average seasonal for the 40-year period.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, and one of the main dam site, scale one inch equals 200 feet, were prepared from surveys made in 1925 by Stephen E. Kieffer. The State made surveys and prepared maps of the auxiliary dam sites in the same year. Table 69 sets forth areas and capacities for various heights of dam.

TABLE 69

AREAS AND CAPACITIES OF IONE RESERVOIR

Height of dam, in feet (10-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
40	190	1,400	20,000
60	210	3,700	75,000
80	230	6,800	181,000
100	250	10,700	360,000
120	270	14,800	610,000
140	290	18,700	930,000

The capacity selected for the reservoir, 610,000 acre-feet, is the amount of storage that would have been required to regulate without waste the ultimate net run-off of Dry Creek and the additional water spilled from Pardee Reservoir for the 11-year period, 1918–1929. This reservoir, with a flow line elevation of 270 feet, would back water up Jackson and Dry creeks about eight miles. It would have an average width of about four miles and a surface area of 14,800 acres.

The lands which would be included in the reservoir are mostly agricultural and range in quality from poor pasture land to that which is suitable for orchards. Several roads cross the reservoir site and would require relocation. The main road from Clements to Ione has an oiled or asphalt surface. The construction of 10 miles of new roads, 18 miles of reconstructed road and one highway bridge about 100 feet in length would be required if the dam were constructed. The Ione Branch of the Southern Pacific Railroad would be flooded for a portion of its length and the construction of 4.5 miles of new roadbed, together with three bridges having an aggregate length of 300 feet, would be required for its relocation.

Under the ultimate State Water Plan, Ione Reservoir would be operated coordinately with Pardee and Valley Springs reservoirs, on the Mokelumne and Calaveras rivers, respectively, together with imported supplies from the American River to furnish the water requirements of the lands to be served in hydrographic divisions 12 and 12A. With such coordinate operation, the mean annual irrigation yield from Ione Reservoir for the 11-year period, 1918–1929, would have been 150,000 acre-feet, including Mokelumne River water obtained by regulation of spill averaging 92,500 acre-feet annually, from Pardee Reservoir. This spill would have been the supply contributed from Mokelumne River after operating the Pardee Reservoir to yield a municipal supply of 200,000,000 gallons per day and an average annual irrigation supply of 294,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—The dam site is a relatively wide "U" shaped gap cut by the stream through a long rounded ridge. A geological examination of the site (See Appendix C) shows the formation to be sedimentary, consisting of nearly horizontally stratified fine to coarse grained tuffaceous sandstone beds, interbedded with siliceous shale members and conglomerate. The stream bed has an alluvial covering with an average thickness of 35 feet. The formation is considered inadequate to support a masonry dam but entirely satisfactory for an earth fill dam. The auxiliary dam sites are in saddles just northerly from the main site and the formations are of the same rock series as the upper 50 feet of the main site. Stripping might be limited to the removal of the top soil and vegetation only. A cut-off for the dam would be keyed into the rock which, though porous to a certain degree, is believed from available information to be sufficiently fine textured in the sandstone and conglomerate matrix to be practically impervious.

Dams and Appurtenances—The topography of the dam site and general layout of the proposed dam, auxiliary dams and appurtenances are shown on Plate XXX, "Ione Reservoir on Dry Creek." The main dam is an earth fill section with a length along the crest of 3750 feet and a maximum height of 120 feet. There are two auxiliary dams, designated on the plans as Dam "A" and Dam "B." Dam "A" has a crest length of 2580 feet and a maximum height of 40 feet. Dam "B" is 300 feet long with a maximum height of 15 feet. All three dams have a theoretical cross section with a crest width of 20 feet and upstream and downstream slopes of 3 to 1 and 2½ to 1 respectively. The spillway is located on the left abutment of auxiliary Dam "A".

This is a concrete structure consisting partly of a section controlled by five steel drum gates 15 feet high by 45 feet long and partly of an uncontrolled overpour weir section. The capacity of the spillway is 42,000 second-feet with a reservoir level at elevation 270 feet or 10 feet below the crest level of the dams.

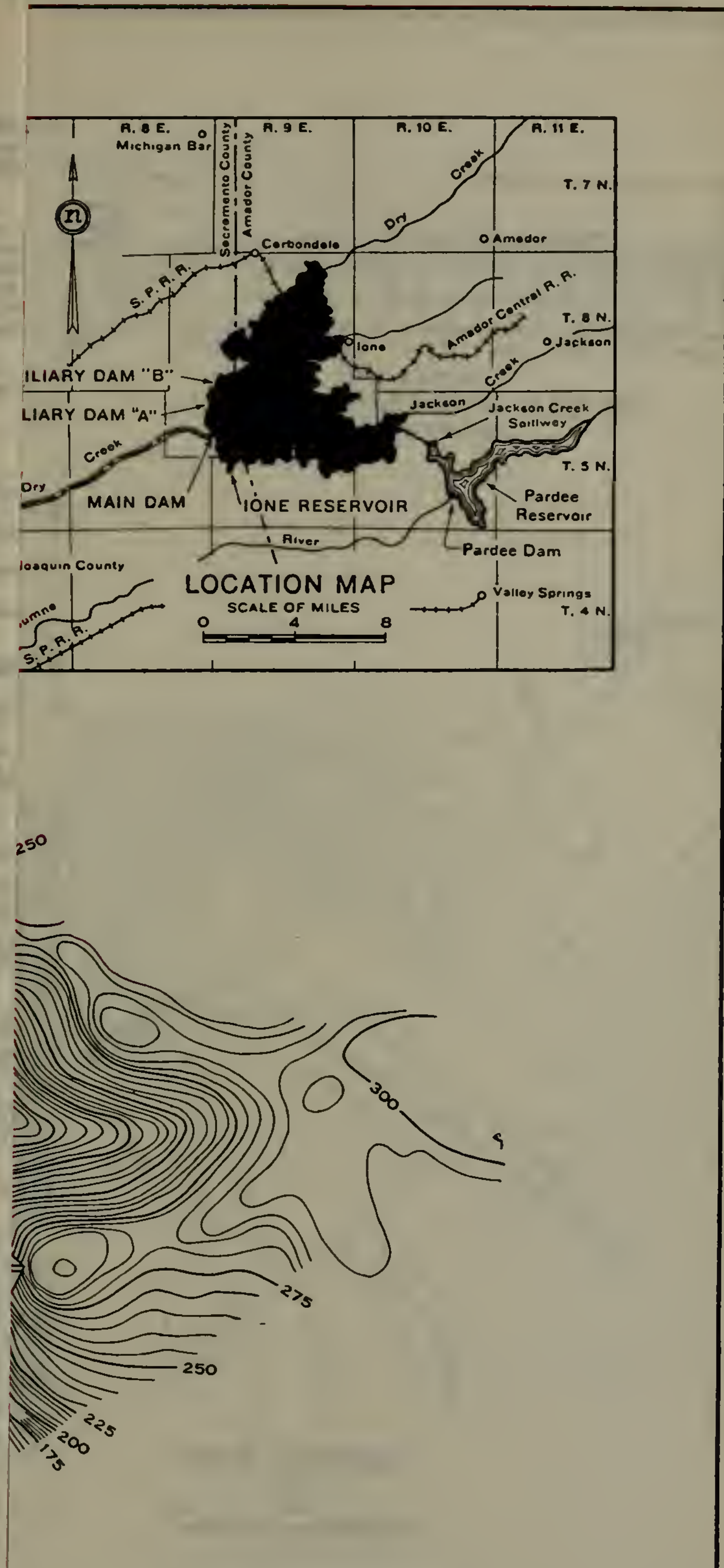
A reinforced concrete conduit is provided under the right abutment of the main dam for the release of irrigation supplies. The capacity of this conduit is 750 second-feet under a minimum head of eight feet. The conduit, 10 feet in diameter and 700 feet in length, is controlled by two, 5 feet by 5 feet, caterpillar type gates on the outer

PLATE XXIX

IONE DAM SITE ON DRY CREEK, A TRIBUTARY OF MOKELUMNE RIVER

side of a reinforced concrete gate tower, and one, 7 feet by 7 feet, emergency gate of the same type on the inside of the tower. Reserve storage space of 121,000 acre-feet requiring a maximum drawdown of 9 feet would be used for the control of floods, including flood diversions through the Jackson Creek Spillway from the Pardee Reservoir. This would result in a regulated flow of 5000 second-feet exceeded once in 100 years on the average. Flood control regulation is secured through the operation of the drum gates in the spillway section, which have a capacity of twice the regulated flow of 5000 second-feet with the reservoir level at elevation 261 feet. No hydroelectric power development is proposed at this site.

Cost of Ione Reservoir—The capital and annual costs of Ione Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 70.



IONE RESERVOIR

ON

DRY CREEK

A TRIBUTARY OF MOKELUMNE RIVER

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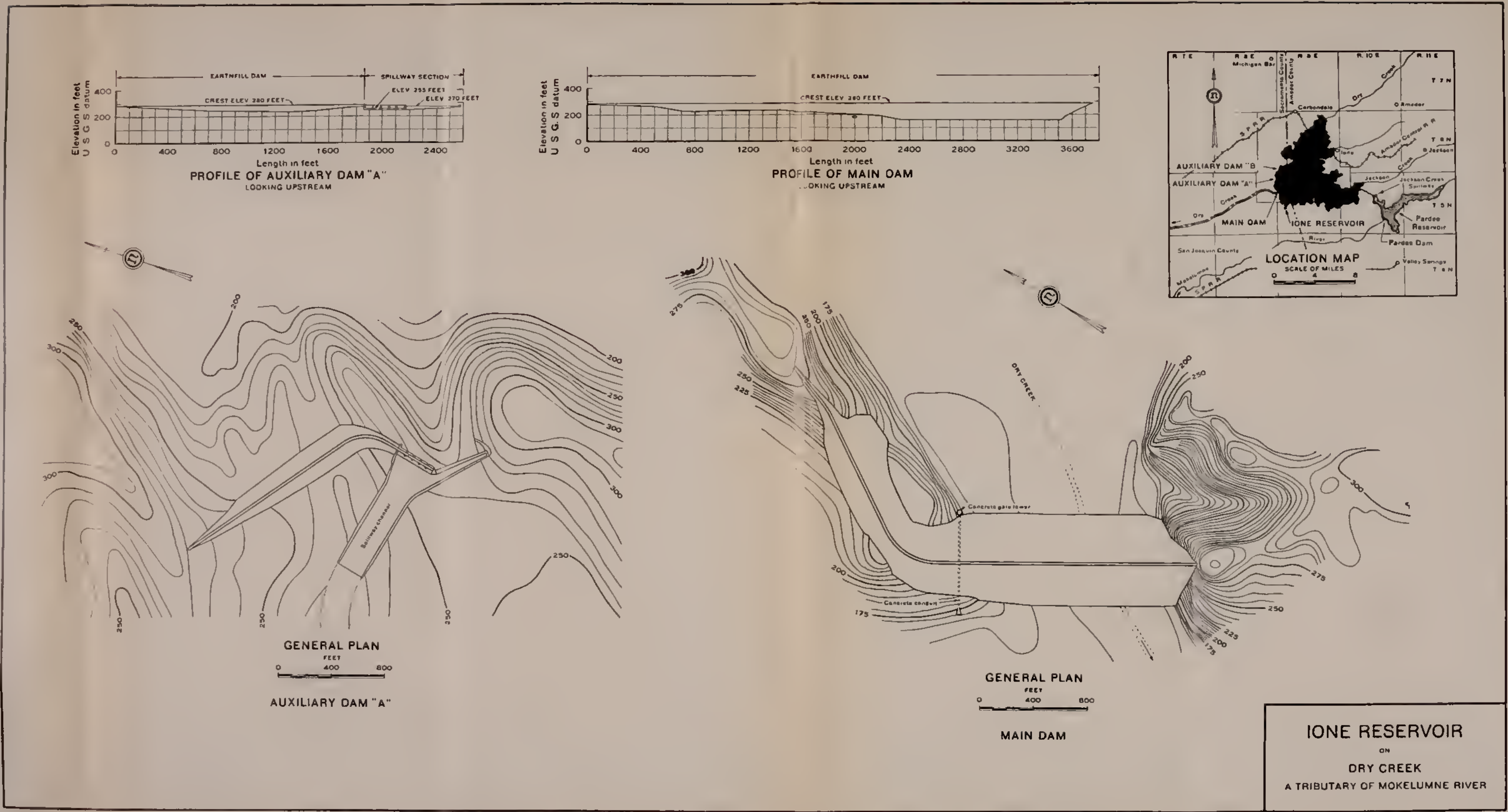
PLATE XXIX

IONE DAM SITE ON DRY CREEK, A TRIBUTARY OF MOKELUMNE RIVER

side of a reinforced concrete gate tower, and one, 7 feet by 7 feet, emergency gate of the same type on the inside of the tower. Reserve storage space of 121,000 acre-feet requiring a maximum drawdown of 9 feet would be used for the control of floods, including flood diversions through the Jackson Creek Spillway from the Pardee Reservoir. This would result in a regulated flow of 5000 second-feet exceeded once in 100 years on the average. Flood control regulation is secured through the operation of the drum gates in the spillway section, which have a capacity of twice the regulated flow of 5000 second-feet with the reservoir level at elevation 261 feet. No hydroelectric power development is proposed at this site.

Cost of Ione Reservoir—The capital and annual costs of Ione Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 70.


EARTHFILL DAM
SPILLWAY SECTION
CREST ELEV 280 FEET
ELEV 295 FEET
ELEV 270 FEET
Elevation in feet U S G S datum
Length in feet
PROFILE OF AUXILIARY DAM "A"
LOOKING UPSTREAM
EARTHFILL DAM
CREST ELEV 280 FEET
PROFILE OF MAIN DAM
LOOKING UPSTREAM
LOCATION MAP
SCALE OF MILES
AUXILIARY DAM "B"
AUXILIARY DAM "A"
MAIN DAM
IONE RESERVOIR
Carbondale
Michigan Bar
Ione
Amador
Jackson
Pardee Reservoir
Pardee Dam
Valley Springs
San Joaquin County
Spillway channel
DRY CREEK
Concrete gate tower
Concrete conduit
GENERAL PLAN
FEET
AUXILIARY DAM "A"
GENERAL PLAN
FEET
MAIN DAM
IONE RESERVOIR
ON
DRY CREEK
A TRIBUTARY OF MOKELUMNE RIVER


GENERAL PLAN

TABLE 70

COST OF IONE RESERVOIR

Height of dam, 120 feet. Capacity of reservoir, 610,000 acre-feet.
Capacity of spillway, 42,000 second-feet.
Capacity of irrigation outlet, 750 second-feet.

Exploration		$10,000
Diversion of river during construction		60,000
Lands and improvements flooded and clearing		2,528,000
Excavation for dams, 152,000 cubic yards at $0.35 to $2.00	$103,000	
Earth fill in dams, 3,167,000 cubic yards at $0.75	2,375,000	
Reinforced concrete face, 21,000 cubic yards at $15.00	315,000	
Miscellaneous reinforced concrete cut-off walls, 6,000 cubic yards at $15.00 to $28.00	95,000	
Spillway gates	93,000	
Spillway channel	543,000	
Irrigation outlet tower, conduit and gates	70,000	
		3,594,000
Miscellaneous		168,000
Subtotal, dam and reservoir		$6,360,000
Administration and engineering at 10 per cent		636,000
Contingencies at 15 per cent		954,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		650,000
Total capital cost of dam and reservoir		$8,600,000
Total annual cost of dam and reservoir		$517,000

Pardee Reservoir on Mokelumne River.

The Pardee Reservoir is located on the Mokelumne River in Amador and Calaveras counties in Township 5 North, Ranges 10 and 11 East, M.D.B. and M., about five miles northerly from the town of Valley Springs. It is already developed by the East Bay Municipal Utility District to a capacity of 222,000 acre-feet which it is estimated by the district will furnish a supply of two hundred million gallons daily. The Jackson Creek Spillway, located and designed to discharge surplus waters of the Mokelumne River into the Dry Creek watershed, also is constructed.

The drainage areas on the Mokelumne River watershed, above the Pardee Dam are segregated by zones of elevation as follows:

Area above elevation 5000 feet	317 square miles
Area between elevations 2500 and 5000 feet	194 square miles
Area below elevation 2500 feet	64 square miles
Total area above Pardee Dam	575 square miles

A contour map of the reservoir site, scale one inch equals 2000 feet, was prepared by Stephen E. Kieffer from surveys made in 1925. The East Bay Municipal Utility District prepared a contour map of the dam site, scale one inch equals 50 feet, in 1926. Table 71 sets forth areas and capacities for various heights of dam. These data were obtained from the East Bay Municipal Utility District.

The reservoir when filled to its present constructed capacity at flow line elevation 567.5 feet will be capable of diverting water through the Jackson Creek spillway. A larger storage capacity at this site is unnecessary as all spill therefrom probably can be conserved more economically in the Ione Reservoir.

The area included in the reservoir was undeveloped and without improvements. It consisted mostly of characteristic mountain land, steep, rocky and, in its natural state, partially covered with brush and small timber. All land below the flow line has been cleared. A full reservoir submerges an area of 2134 acres. The location of the existing dam and reservoir is shown on the location map on Plate XXX.

TABLE 71

AREAS AND CAPACITIES OF PARDEE RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
55	280	38	500
75	300	75	1,620
95	320	115	3,470
115	340	173	6,300
135	360	250	10,500
155	380	350	16,400
175	400	464	24,500
195	420	611	35,200
215	440	758	48,800
235	460	920	65,500
255	480	1,097	85,600
275	500	1,294	109,500
295	520	1,490	137,200
315	540	1,722	169,300
335	560	2,005	206,500
342.5	567.5	2,134	222,000

The dam is located in Section 26, Township 5 South, Range 10 East. It is of the arched gravity type, 343 feet in height from stream bed to crest and curved in plan to a radius of 1200 feet measured from the upstream or back line of the dam. The crest length is 1337 feet and the maximum thickness at stream bed 241 feet. A spillway with a capacity of 100,000 cubic feet per second is provided in a natural gap about 1000 feet south of the dam and has a total length of overflow of 800 feet. It discharges upon a broad apron of reinforced concrete and is gradually contracted by training walls into a canyon which leads back into the Mokelumne River about 1000 feet below the dam. The sluiceways consist of two 42-inch and two 72-inch diameter cast iron pipes. At the downstream end of each a Larner-Johnson discharge regulator and a butterfly valve of the same size as the sluiceway pipe are installed. A two-mile tunnel leads from an outlet tower in the reservoir to the main East Bay Municipal Utility District pipe line.

A power plant with an installed capacity of 18,750 kilovolt amperes located at the downstream toe of the dam is included in the project. It has two generators with a normal output capacity of 7500 kilowatts each. The maximum head on the power plant is 327.5 feet. The annual output was estimated by the district at from 70,000,000 to 125,000,000 kilowatt hours. From July 1, 1931, to June 30, 1932, the output was 58,966,300 kilowatt hours. The penstocks consist of two cast-iron pipes, 72 inches in diameter. A 72-inch butterfly valve is provided between each penstock and the water wheels of the power plant.

The Jackson Creek spillway is located at the head of Jackson Creek in a topographic saddle on the divide between the Mokelumne River and Dry Creek watersheds. It is a concrete structure of 16,000 second-feet capacity, consisting of a battery of sixteen siphons, each having throat dimensions of four by twelve feet. The siphons are provided with gates which are sealed at present. The structure was built with the idea of discharging surplus waters into the proposed storage reservoir on Dry Creek and will not be permitted to function until such time as the Ione Reservoir is constructed.

The following summary of costs of the Pardee development has been furnished by the East Bay Municipal Utility District.

Construction item	*Contract cost*	*Non-contract cost*
Pardee Reservoir	$337 35	$1,005,860 33
Pardee Dam	5,850,724 86	147,884 95
Pardee Power House	568,100 90	83,970 50
South Spillway	545,939 77	22,994 40
Jackson Creek Spillway	235,496 20	6,779 82
Reservoir roads	50,703 57	6,090 00
Reservoir fencing	----------	14,364 20
Railroad right of ways	----------	5,230 01
Pardee Outlet Tower	192,412 49	7,297 44
Pardee Tunnel	878,953 94	23,228 40
Camp Pardee	74,994 85	51,295 24
Patrolmen's houses	----------	12,250 17
Other items	----------	47,500 79
Direct costs	$8,397,663 93	$1,434,746 25
Total direct cost		9,832,410 18
Overhead (engineering, administration, etc.)		785,987 61
Interest during construction		409,979 80
Operating charges		7,512 38
Total Pardee development		$11,035,889 97

Water Supply and Yield—The average seasonal ultimate net run-off above Pardee Dam for the 40-year period, 1889–1929, is estimated at 820,000 acre-feet per season. Details of ultimate net run-off have been presented in Chapter II. In the State Plan, the present constructed reservoir would be operated in conjunction with the proposed Valley Springs Reservoir on Calaveras River, the Ione Reservoir on Dry Creek and the importation of water from the American River to furnish a surface supply with a maximum deficiency of 35 per cent, in an exceptionally dry year, to the irrigable areas in hydrographic divisions 12 and 12A. The combined yields and deficiencies are set forth in Chapter VII. With such coordinate operation, the estimated average annual irrigation yield for the 11-year period 1918–1929 from Pardee Reservoir alone would have been 294,000 acre-feet in addition to furnishing the East Bay Municipal Utility District a full supply of 200,000,000 gallons per day and an average annual spill into Ione Reservoir of about 92,500 acre-feet. In making these yield studies it was estimated that the net depth of evaporation loss from the reservoir surface would be 3.5 feet per season.

Other Developments on Mokelumne River—Above the Pardee reservoir, the North Fork of the Mokelumne River has been developed for hydroelectric power by the Pacific Gas and Electric Company. The system includes six storage reservoirs, three forebay reservoirs, one afterbay, three canals and three power houses. The principal physical features of the larger reservoirs are as follows:

Reservoir	*Drainage area, in square miles*	*Water surface elevation, in feet*	*Height of dam above streambed, in feet*	*Capacity, in acre-feet*
Salt Springs	160.0	3,947	300	130,000
Twin Lakes	0.8	8,172	22	1,309
Upper Blue Lake	2.7	8,131	31	7,106
Lower Blue Lake	4.8	8,040	48	4,190
Meadow Lake	5.5	7,773	73	6,021
Bear River Reservoir	28.5	5,875	80	6,712
Tabeaud Forebay	2.0	1,960	120	1,200
Tiger Creek Afterbay	360.0	2,331	105	3,800
Total				160,338

The power plants have a total installed generating capacity of 91,000 kilovolt-amperes, segregated as follows:

Power plant	*Installation in kilovolt amperes*
Salt Springs	11,000
Tiger Creek	60,000
Electra	20,000
Total	91,000

PLATE XXXI

PARDEE DAM ON MOKELUMNE RIVER

Further storage development is projected on Bear River and additional power installations are contemplated at Salt Springs, Electra and West Point. These developments would result in additional installed capacities of 30,000 kilovolt amperes at Salt Springs, 15,000 kilovolt amperes at West Point and 40,000 kilovolt amperes at Electra.

Small diversions are made through power company ditches for domestic use in the town of Jackson. Many diversions have been made through ditches on the headwaters of the stream for mining use. Records as to amounts diverted are not available. Most of these ditches have been abandoned and the amounts taken by those still operating are believed to be relatively small.

Diversion from the Mokelumne River below the Pardee Dam is made by the Woodbridge Irrigation District, containing a gross area of 13,851 acres, of which 6184 acres were irrigated in 1929. Approximately 4000 acres of riparian lands are irrigated by pumping plants located along the river between Pardee Dam and the mouth of Dry Creek.

Valley Springs Reservoir on Calaveras River.

The dam site for the Valley Springs Reservoir is located in a narrow canyon just below the confluence of Bear Creek and the main river in the southwest quarter of Section 31, Township 4 North, Range 11 East, M.D.B. and M., about three miles southerly from the town of Valley Springs, in Calaveras County. Immediately above the dam site the canyon widens out into a broad basin. The reservoir site extends to the forks of the Calaveras River about two miles west of San Andreas.

The Hogan Dam recently has been completed by the City of Stockton at the Valley Springs dam site for the purpose of controlling floods on the Calaveras River to afford flood protection to Stockton and adjacent areas. The completed structure is a concrete variable radius arch dam with concrete gravity type abutments. The spillway, with an overall length of 616.25 feet, extends for the entire length of the arch. The spillway crest is at two elevations, the central portion, 375 feet long, having its crest at elevation 637.5 and adjoining portions on either side having a crest elevation of 649 feet. The maximum height of the arch dam in the center of the spillway is 107.5 feet above stream-bed. The capacity of the reservoir at elevation 637.5 feet is 76,000 acre-feet. The crests of the gravity abutments are at elevation 655.5 feet. An earth embankment 227 feet in length is constructed at the extreme end of the right abutment. Nine flood control outlets, $5\frac{1}{2}$ feet in diameter, are provided through the dam. Four of these outlets are at elevation 557 feet, three at elevation 584 feet and one each at elevation 600 feet and 614 feet. These flood openings have no gate controls. The discharge capacity of these flood openings, with a reservoir level at elevation 655.5, is approximately 12,800 second-feet. The capacity of the spillway with this same reservoir level is approximately 96,000 second-feet, making the combined capacity of the spillway and flood outlets approximately 108,800 second-feet. The cost of the structure is reported as $1,189,157. Tentative plans are proposed for raising the dam sometime in the future to increase the reservoir capacity to 165,000 acre-feet for the purpose of obtaining a greater degree of flood protection than that afforded by the present structure.

Preliminary investigations were made of several other sites. The principal ones are the North Branch site on the main river, the Kentucky House site on the South Fork and the McCarthy site on the North Fork. These investigations showed the Valley Springs site to be the most suitable for the purpose desired.

The drainage areas on the Calaveras River watershed, above the Valley Springs dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	3 square miles
Area between elevations 2500 and 5000 feet	90 square miles
Area below elevation 2500 feet	270 square miles
Total area above Valley Springs dam site	363 square miles

Present Developments on Calaveras River—There are no important diversions above the Valley Springs dam site. Below the site, from Jenny Lind to Stockton, a number of pumping plants divert water from the river for agricultural purposes. No information is at hand to indicate the extent and amount of these diversions. The recently organized Linden Irrigation District of 13,700 acres proposes to secure water from the Calaveras River. About 6000 acres in this district were irrigated from wells in 1929.

Water Supply—The water supply which would be regulated in the Valley Springs reservoir is the ultimate net run-off of the Calaveras River, averaging 189,000 acre-feet per season for the 40-year period 1889–1929.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 500 feet, was prepared by Galloway and Markwart from a survey made in 1910. The city of Stockton prepared a contour map of the dam site, scale one inch equals 50 feet, in 1925. Table 72 sets forth areas and capacities for various heights of dam based on those surveys.

TABLE 72

AREAS AND CAPACITIES OF VALLEY SPRINGS RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
15	540	23	100
35	560	184	1,900
55	580	482	8,500
75	600	872	22,000
95	620	1,354	44,200
115	640	1,837	76,200
135	660	2,342	117,900
155	680	2,904	170,300
175	700	3,489	234,200
195	720	4,167	310,600
200	725	4,300	325,000
205	730	4,545	354,100

The capacity of the reservoir proposed for ultimate development is 325,000 acre-feet. It would have a flow line elevation of 725 feet. Water would be backed up to the junction of the North and South forks, a distance of about eight miles, submerging an area of 4300 acres. A reservoir capacity of 160,000 acre-feet is required, in addition to the projected capacity of 165,000 acre-feet for flood control, for the purpose of equalizing the flow to meet irrigation demands. This additional capacity would have regulated the entire available stream flow of the Calaveras River for the 11-year period, 1918–1929. This would have been accomplished without infringing on the flood regulation capacity of 165,000 acre-feet desired and partially developed by the city of Stockton to control flood flows to a maximum of 25,000 second-feet which would be exceeded once in 100 years on the average. This amount of flood control capacity was added to give the total selected reservoir capacity. The Calaveras Reservoir would be operated coordinately with the Pardee and Ione reservoirs and imported water supplies from the American River to provide the water requirements in hydrographic divisions 12 and 12A. With such coordinate operation, the capacity proposed for irrigation alone would have furnished an average seasonal yield for the 11-year period 1918–1929 of 98,000 acre-feet. In making the yield studies at this site, it was estimated that the net seasonal evaporation loss would be 3.5 feet in depth on the reservoir surface. Details of reservoir yield and utilization are given in Chapter VII.

There is some agricultural land within the proposed reservoir, but most of the area to be flooded, above the present city of Stockton reservoir, is grazing land. There are few county roads traversing the reservoir site which are not flooded by the existing development. The flow line of the proposed reservoir may come sufficiently close to the roadbed and bridge floors of the Lodi-San Andreas highway to necessitate construction of new bridges over the North Fork and North Branch Creek, and relocation of about one and one-quarter miles of highway. The flow line also may be sufficiently high on the grade of the Southern Pacific-Calaveras Cement Company Railway to require relocation of about three miles of that line, together with the construction of a bridge over the North Fork. For this reason both the highway and railroad relocations have been included in the reservoir cost estimate.

Dam Site—Previous to the construction of the present dam by the city of Stockton, the site was tested by diamond drill borings, and much additional information was secured during construction as to the adequacy of the foundations and probable depth of stripping required for the proposed structure. Sound rock is found at shallow depths at and near the stream bed, at depths ranging from 15 to 50 feet on the right abutment and from 10 to 40 feet on the left. The character of the bedrock is entirely satisfactory for supporting the proposed structure.

Dam and Appurtenances—Topography of the dam site and general layout of the proposed dam and appurtenances required to effect the desired irrigation storage and flood control are shown on Plate

PLATE XXXII

HOGAN DAM ON CALAVERAS RIVER

XXXIII, "Valley Springs Reservoir on Calaveras River." The dam is a concrete gravity type structure, having a maximum height of 200 feet above streambed, and slightly curved in plan to follow a ridge on either side of the canyon. The overflow spillway, located at the left abutment of the dam and controlled by nine steel drum gates 20 feet high by 50 feet long, would discharge into a natural draw that joins the river about a quarter of a mile below the dam site. The spillway capacity with 5 feet of freeboard on the dam is estimated at 140,000 second-feet or about two and one-half times the once-in-25-year flood.

The reserve space of 165,000 acre-feet proposed for flood control, would require a maximum drawdown of 48 feet. Regulation would be obtained by ten 9-foot by 9-foot openings through the dam with a center line elevation of 652 feet, controlled by sluice gates of the caterpillar type. Floods could be controlled to a maximum value of 25,000 second-feet, exceeded once in one hundred years on the average. Irrigation water would be released through two 42-inch diameter pipes having a combined discharging capacity of 800 second-feet, under a minimum head of 50 feet. The elevation of outlets is 540 feet. The releases would be controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Valley Springs Reservoir—The capital and annual costs of Valley Springs Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 73. Since the proposed dam would provide equivalent flood protection to that proposed by the city of Stockton, the cost estimate does not include any amount for the value of the present dam.

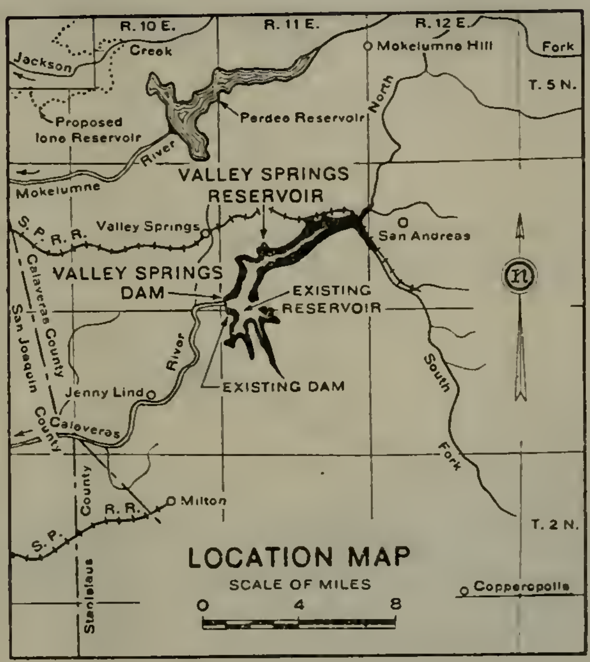
TABLE 73

COST OF VALLEY SPRINGS RESERVOIR

Height of dam, 200 feet. Capacity of reservoir, 325,000 acre-feet.
Capacity of spillway, 140,000 second-feet.
Capacity of irrigation outlets, 800 second-feet.
Capacity of flood control outlets, 25,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		830,000
Excavation for dam, 339,000 cubic yards at $1.00 to $5.00	$860,000	
Mass concrete, 490,000 cubic yards at $6.30	3,087,000	
Reinforced concrete, 5,700 cubic yards at $18 to $30	120,000	
Spillway gates	270,000	
Spillway channel	220,000	
Irrigation outlets and sluiceways	50,000	
Flood control outlets	76,000	
Drilling, grouting, drains and contraction seals	100,000	
		4,783,000
Miscellaneous		41,000
Subtotal		$5,684,000
Administration and engineering at 10 per cent		568,000
Contingencies at 15 per cent		853,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		495,000
Total capital cost of dam and reservoir		$7,600,000
Total annual cost of dam and reservoir		$452,000

In calculating the annual cost, it was assumed that the city of Stockton would pay the cost of the bonded indebtedness on the present development since it would receive at least equivalent service under the State Plan. Therefore, the figure for annual cost does not include any amount for the annual cost of the present dam and reservoir but does



VALLEY SPRINGS RESERVOIR

ON

CALAVERAS RIVER

80997

XXXIII, "Valley Springs Reservoir on Calaveras River." The dam is a concrete gravity type structure, having a maximum height of 200 feet above streambed, and slightly curved in plan to follow a ridge on either side of the canyon. The overflow spillway, located at the left abutment of the dam and controlled by nine steel drum gates 20 feet high by 50 feet long, would discharge into a natural draw that joins the river about a quarter of a mile below the dam site. The spillway capacity with 5 feet of freeboard on the dam is estimated at 140,000 second-feet or about two and one-half times the once-in-25-year flood.

The reserve space of 165,000 acre-feet proposed for flood control, would require a maximum drawdown of 48 feet. Regulation would be obtained by ten 9-foot by 9-foot openings through the dam with a center line elevation of 652 feet, controlled by sluice gates of the caterpillar type. Floods could be controlled to a maximum value of 25,000 second-feet, exceeded once in one hundred years on the average. Irrigation water would be released through two 42-inch diameter pipes having a combined discharging capacity of 800 second-feet, under a minimum head of 50 feet. The elevation of outlets is 540 feet. The releases would be controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Valley Springs Reservoir—The capital and annual costs of Valley Springs Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 73. Since the proposed dam would provide equivalent flood protection to that proposed by the city of Stockton, the cost estimate does not include any amount for the value of the present dam.

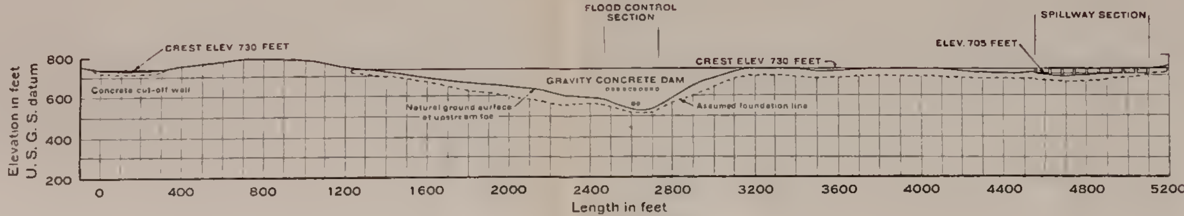
TABLE 73

COST OF VALLEY SPRINGS RESERVOIR

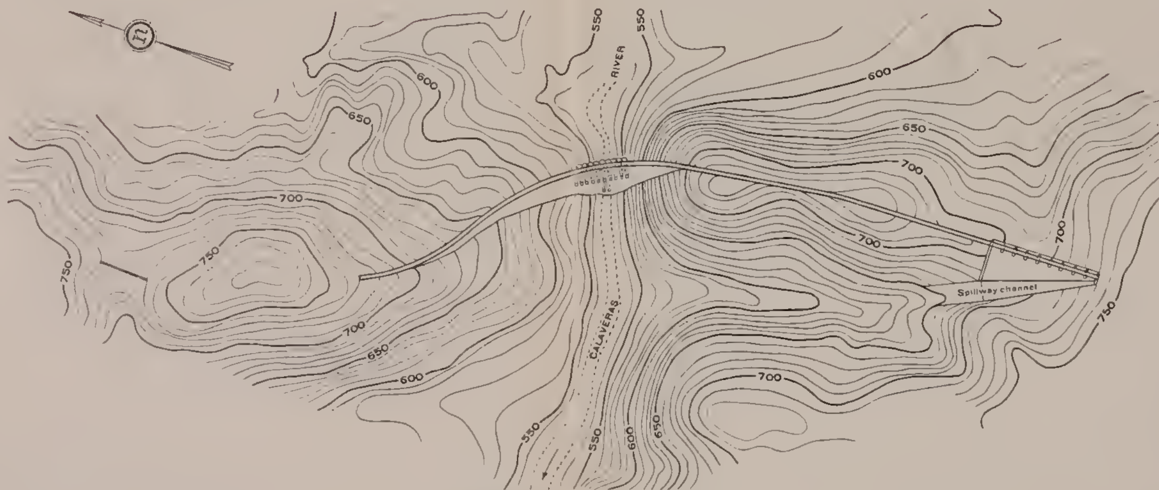
Height of dam, 200 feet. Capacity of reservoir, 325,000 acre-feet.
Capacity of spillway, 140,000 second-feet.
Capacity of irrigation outlets, 800 second-feet.
Capacity of flood control outlets, 25,000 second-feet.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		830,000
Excavation for dam, 339,000 cubic yards at $1.00 to $5.00	$860,000	
Mass concrete, 490,000 cubic yards at $6.30	3,087,000	
Reinforced concrete, 5,700 cubic yards at $18 to $30	120,000	
Spillway gates	270,000	
Spillway channel	220,000	
Irrigation outlets and sluiceways	50,000	
Flood control outlets	76,000	
Drilling, grouting, drains and contraction seals	100,000	
		4,783,000
Miscellaneous		41,000
Subtotal		$5,684,000
Administration and engineering at 10 per cent		568,000
Contingencies at 15 per cent		853,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		495,000
Total capital cost of dam and reservoir		$7,600,000
Total annual cost of dam and reservoir		$452,000

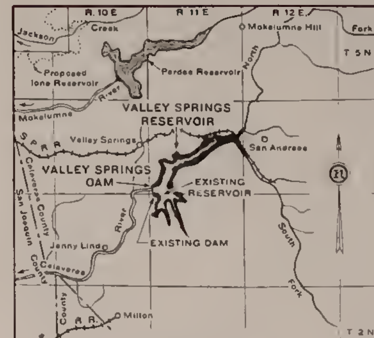
In calculating the annual cost, it was assumed that the city of Stockton would pay the cost of the bonded indebtedness on the present development since it would receive at least equivalent service under the State Plan. Therefore, the figure for annual cost does not include any amount for the annual cost of the present dam and reservoir but does



PROFILE OF DAM
LOOKING UPSTREAM



GENERAL PLAN OF DAM
FEET
0 400 800



LOCATION MAP

VALLEY SPRINGS RESERVOIR
ON
CALAVERAS RIVER

include the cost of furnishing the service now rendered by the present development by means of the proposed works.

Melones Reservoir on Stanislaus River.

The dam site for the Melones reservoir on the Stanislaus River is located about 1000 feet upstream from the existing Melones Power Plant and about 3600 feet downstream from the constructed Melones dam of the South San Joaquin and Oakdale irrigation districts. It is situated in what is known locally as Iron Canyon in the southeast quarter of Section 10 and the southwest quarter of Section 11, Township 1 North, Range 13 East, M.D.B. and M., about six miles westerly from the town of Jamestown, in Calaveras and Tuolumne counties.

Two other reservoir sites, one with a dam at the Black Creek dam site about eight miles below the Melones site and the other with a dam at the Robinson's Ferry dam site about 11.5 miles above the Melones site, were investigated, but it was found that their potential capacities were inadequate to give the desired regulation of the run-off of the Stanislaus River. The Melones site is the only one capable of being developed to the required capacity.

The drainage areas on the Stanislaus River watershed, above the Melones dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	555 square miles
Area between elevations 2500 and 5000 feet	205 square miles
Area below elevation 2500 feet	140 square miles
Total area above Melones dam site	900 square miles

Present Developments on Stanislaus River—Above the Melones site, the conduit of the Utica Mining Company, with a capacity of 88 second-feet, diverts water from the North Fork about seven miles above its junction with Middle Fork. The water is carried a distance of 23 miles to the vicinity of Murphy where it is dropped 527 feet to a power plant on Angels Creek. Part of the water is then used for irrigation, mining and domestic purposes near the towns of Murphy, Vallecito and Angels. A total of 1400 acres is irrigated by the system. About three miles below the power plant, water is rediverted from Angels Creek to the forebay of Angels Power Plant. Here it is dropped 450 feet and, after passing through the plant, flows down the creek to the Stanislaus River above the Melones site. The electrical installation at Murphy is 1500 kilovolt amperes and at Angels 650 kilovolt amperes. The Pacific Gas and Electric Company has an extensive power development on the Middle and South Forks. The Spring Gap Plant, with an installed capacity of 7500 kilovolt amperes, and the Stanislaus Power Plant, with an installed capacity of 34,000 kilovolt amperes, are located on the Middle Fork. Water also is diverted from the South Fork to the latter plant. The Phoenix Plant, with an installed capacity of 1875 kilovolt amperes, is located on Sullivan Creek in the Tuolumne River watershed, but receives its water through the old Main Tuolumne Ditch which heads at an altitude of 4000 feet at Lyons Dam Reservoir on the South Fork of Stanislaus River. The Melones Mining Company Power Plant (now owned by the South San Joaquin and Oakdale irrigation districts and leased to the Pacific Gas and Electric Company), with an installed capacity of 1000 kilovolt amperes, is located about seven miles upstream from the existing Melones Dam and diverts water from the main Stanislaus River.

In connection with the foregoing power developments, many reservoirs have been constructed. The larger of these have a combined storage capacity of 55,900 acre-feet, distributed as follows:

Relief Reservoir on Relief Creek	15,100 acre-feet
Utica Reservoir on North Fork	2,400 acre-feet
Union Reservoir on North Fork	2,000 acre-feet
Silver Valley Reservoir on North Fork	4,600 acre-feet
Upper Strawberry Reservoir on South Fork	1,200 acre-feet
Lower Strawberry Reservoir on South Fork	17,900 acre-feet
Lyons Dam Reservoir on South Fork	5,500 acre-feet
Spicer Meadows Reservoir on Highland Creek	7,200 acre-feet

The South San Joaquin and Oakdale irrigation districts jointly have constructed a reservoir at the Melones site, with a storage capacity of 112,500 acre-feet. The dam is located about 3600 feet upstream from the dam site proposed for ultimate development. It is arched in plan, has a height of 183 feet above stream bed and a crest length of 590 feet. The center section, 450 feet in length, has a constant radius of 238 feet on the upstream face. The wings are of the gravity type, with a combined length of 140 feet. The spillway extends across the top of the dam, and is divided by piers into nine sections, each containing a steel drum gate. An outlet tunnel equipped with large needle valves enters the reservoir beneath the south abutment. This tunnel extends downstream below the irrigation outlet valves to supply a power plant of the Pacific Gas and Electric Company having an installed capacity of 27,000 kilovolt amperes.

The project was constructed under an agreement, dated January 2, 1925, between the two districts and the Pacific Gas and Electric Company. Under the terms of this agreement, the maximum capacity of Melones Reservoir is fixed at 112,500 acre-feet, with 103,500 acre-feet available for withdrawal each year, to be shared equally between the two districts. The cost of Melones Dam and Reservoir, amounting to $2,351,000, is divided equally between the two districts. The power company constructed and bore the cost of the power plant below the dam. From March 1 to October 31 of each year the control of the stored water is in the hands of the districts, with the maximum withdrawal from stored water to be at the rate of 1500 second-feet. All inflows less than 1000 second-feet must be released through the power plant. The releases for irrigation pass through the power plant when needed. From November 1 to March 1 operation of the reservoir is placed under the direction of the power company, which must release sufficient water to fill a lower reservoir as well as any additional water needed by the districts for irrigation or domestic use. For the use of water passing through Melones Reservoir, the power company pays to the two districts, jointly, the sum of $5,175,000 in semiannual installments of $64,687.50, these payments to be used by the districts to cover interest and principal of the bonds issued for the construction of Melones Dam. When the bonds have been fully paid, this income is to be available to the districts for other purposes. Other provisions of the contract cover storage rights of the power company above Melones Reservoir, release of the water so stored to the districts, maintenance and upkeep of the reservoir and other related matters.

The Oakdale Irrigation District has a gross area of 74,240 acres of which 23,321 acres were irrigated in 1929, and the South San Joaquin Irrigation District a gross area of 71,112 acres of which 54,340 acres were irrigated in the same year.

Water Supply—The water supply available for regulation at the Melones site would be the ultimate net run-off of the Stanislaus River for which the mean seasonal value for the 40-year period, 1889–1929, is estimated at 1,239,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the proposed dam site, scale one inch equals 100 feet, was made by the State in 1930. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 74, have been obtained up to elevation 740 feet from the contour map for the existing reservoir, scale one inch equals 200 feet, prepared by the South San Joaquin and Oakdale irrigation districts in 1921. For areas and capacities above that elevation, the U. S. G. S. topographic maps were used.

TABLE 74

AREAS AND CAPACITIES OF MELONES RESERVOIR

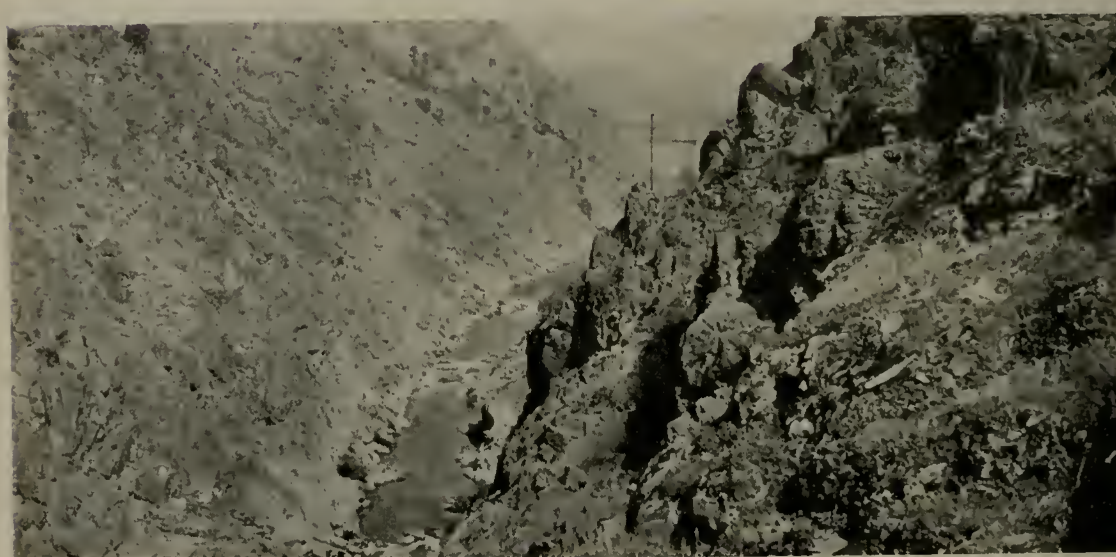
Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
115	620	220	4,500
135	640	420	10,700
155	660	680	21,500
175	680	930	37,600
195	700	1,220	59,000
215	720	1,560	87,000
235	740	1,940	122,000
255	760	2,300	165,000
275	780	2,650	215,000
295	800	3,070	272,000
315	820	3,550	336,000
335	840	4,050	409,000
355	860	4,550	492,000
375	880	5,000	590,000
395	900	5,540	702,000
415	920	6,200	808,000
435	940	6,850	927,000
455	960	7,500	1,059,000
460	965	7,700	1,090,000
475	980	8,150	1,203,000
495	1,000	8,770	1,368,000

The capacity selected for the proposed Melones Reservoir is 1,090,000 acre-feet. This size of reservoir is required to furnish a dependable surface irrigation supply to the lands which are and would be dependent naturally on the Stanislaus River for such supply. This supply could have been made available by this reservoir during the 40-year period, 1889–1929, without resort to ground water storage with an average deficiency of less than two per cent per year. It would have a flow line elevation of 965 feet. At this elevation the reservoir basin would have a length of ten miles and a maximum width of one and one-quarter miles. The area flooded would be 7700 acres.

The flooded area, exclusive of that now included in the present Melones Reservoir, consists of 5880 acres of rough mountainous land.

PLATE XXXIV

Present Melones Dam Completed in 1926



Site of Proposed Dam Below Existing Structure

Present Melones Powerhouse Below Site of Proposed Dam

MELONES DAM SITE ON STANISLAUS RIVER

The Mother Lode, embracing valuable mines and mining claims, crosses the site. The most important of these mines is Carson Hill Mine of Carson Hill group. The workings, mill, cyanide plant and other structures of the mine would be flooded. The small power plant of 1000 kilovolt amperes installation, owned by the South San Joaquin and Oakdale irrigation districts and leased to the Pacific Gas and Electric Company, also is below the proposed flow line. The Mother Lode Highway, between Sonora and Angels, the Robinson's Ferry County Road and the Angels branch of the Sierra Railway also would be flooded and would require relocation.

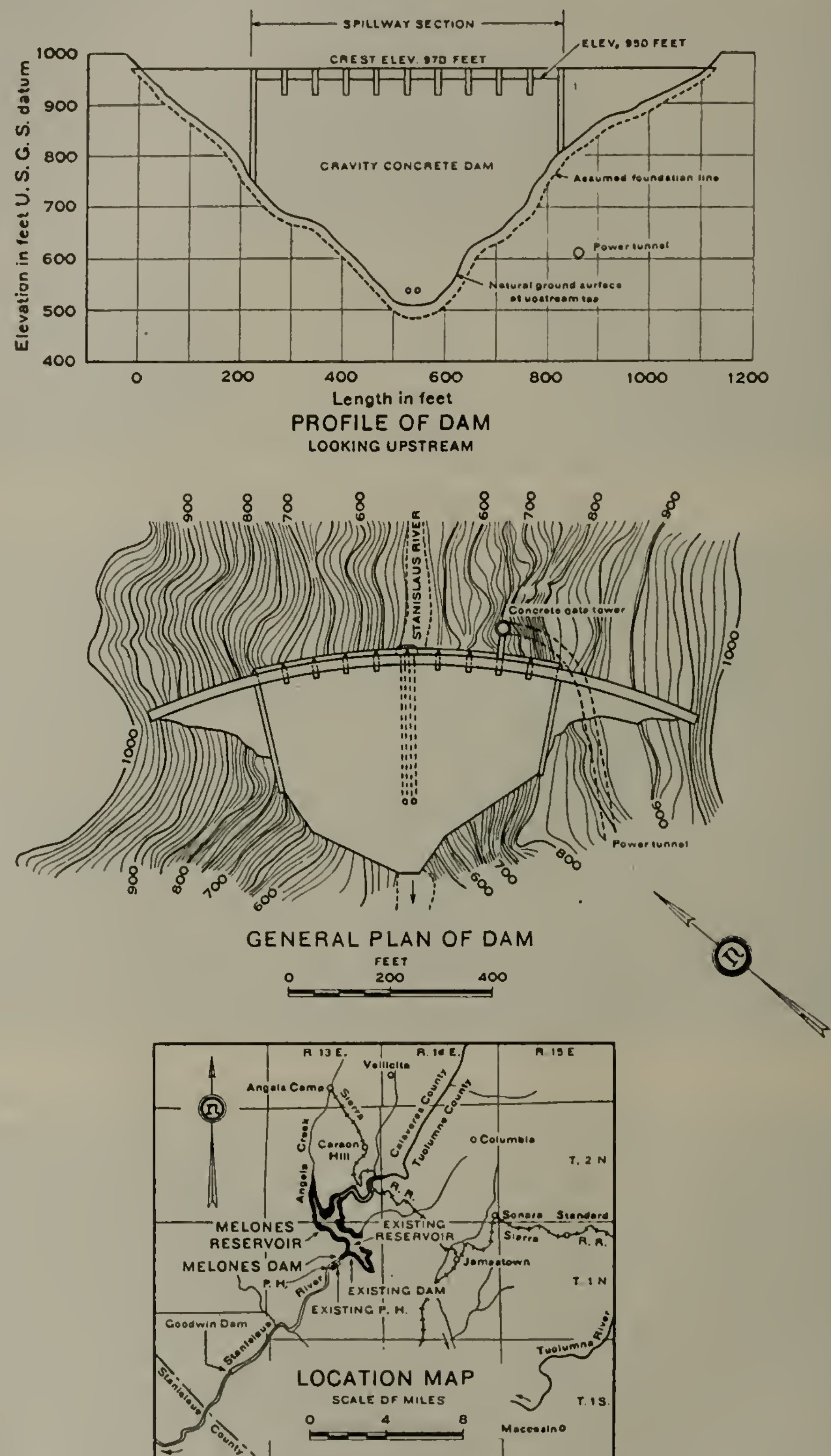
The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceptionally dry year, would have been 905,000 acre-feet. The mean seasonal irrigation yield for the 40-year period would have been 887,000 acre-feet. A net seasonal evaporation loss of 3.5 feet depth on the reservoir surface was used in making yield studies at this site. Details of reservoir yields and utilization are given in Chapter VII.

Dam Site—A geological examination shows the site to be suitable for a high concrete structure. The topographic and geologic features of this site are similar to those of the Nashville site on the Cosumnes River. The stream has developed a deep ''V'' shaped gorge with cliff profile at the dam site through a dike-like rock mass, consisting of a fine grained dark green diabase. No exploration has been made at this site, but from field examination it is estimated that stripping to average depths of fifteen feet normal to the slope on the right abutment and 20 feet normal to the slope on the left abutment will remove all loose material and reveal rock which, although jointed, could be rendered sound by pressure grouting. The width of the stream bed varies from 30 to 50 feet and it is believed that a good foundation can be secured therein by excavating to depths of from 15 to 20 feet.

Dam and Appurtenances—Topography of the dam site and general layout of the proposed dam and appurtenances are shown on Plate XXXV, ''Melones Reservoir on Stanislaus River.'' The height of dam above stream bed is 460 feet, including five feet of freeboard. It is a concrete gravity type dam with a centrally located overflow spillway section controlled by ten steel drum gates 15 feet high by 50 feet long. The estimated discharging capacity of the spillway is 120,000 second-feet or two and four-tenths times the estimated once-in-25-year-flood.

Reserve storage space of 204,000 acre-feet, with a maximum draw-down of 34 feet, is proposed for flood control. The utilization of this space would result in a controlled flow of 15,000 second-feet, exceeded once in one hundred years on the average. The required outlet capacity for flood regulation is provided by the irrigation and power plant outlets, with reservoir surface at elevation 930 feet, assuming that turbine by-passes are provided in the power plant. Irrigation outlets are provided for a discharging capacity of 2700 second-feet by means of two 78-inch diameter pipes through the dam, controlled by needle valves and also emergency slide gates.

PLATE XXXV



MELONES RESERVOIR

ON

STANISLAUS RIVER

Power Plant—The economic power plant installation has been determined as 68,000 kilovolt amperes, based on a value of power of $0.003 per kilowatt hour. The power plant is located about one-quarter mile downstream from the dam on the left bank of the stream. It would be supplied through an outlet pressure tunnel, located under the dam on the left bank. The intake of the tunnel consists of a cylindrical reinforced concrete tower having a balanced cylinder valve to be used for unwatering the tunnel and for emergency closures. Adits lead from the main tunnel to the face of the hill where they would discharge into steel pipes leading to each turbine. These pipes are equipped with needle valves at each turbine inlet. A surge tank and shaft carried to a point slightly above the flow line elevation of the reservoir is located at the downstream end of the main tunnel. The power plant consists of four 17,000 kilovolt ampere units, equipped with turbine by-passes. It would replace the present Melones Power Plant which has an installed capacity of 27,000 kilovolt amperes. The cost of the power development is estimated at approximately $60 per kilovolt ampere.

Cost of Melones Reservoir—The capital and annual costs of Melones reservoir and power plant, estimated in accord with bases previously presented in this chapter, are shown in Table 75. Estimates also are shown of revenue from sale of electric energy and the net annual cost after deducting power revenue. The tabulated costs do not include any amounts for the destruction of the present Melones Dam of the South San Joaquin and Oakdale irrigation districts or for any possible interference with the existing power development in connection therewith. It is contemplated that interests and lands now receiving service, both irrigation and power, from the present development would continue to receive the same service with no additional cost under the larger development as proposed herein for the State Water Plan. Therefore, in accord with such assumption, the commitments and obligations of the parties now interested in the present development would be maintained without modification. The figure for annual cost includes no amount for present development, but does include amounts for equivalent service which would be rendered with the larger State proposal. It is not possible to foretell the conditions under which, or when or by whom, the proposed development would be constructed. Neither is it possible to state whether or not the present development would be entirely amortized and depreciated at the time the proposed development is undertaken. Therefore, the entire anticipated power revenue has been credited to the proposed unit and deducted from the gross annual cost to obtain the net annual cost.

TABLE 75

COST OF MELONES RESERVOIR

Height of dam, 460 feet. Capacity of reservoir, 1,090,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 2,700 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing		4,660,000
Excavation for dam, 185,000 cubic yards at $3.00 to $5.00	$761,000	
Mass concrete, 1,318,000 cubic yards at $7.90	10,412,000	
Reinforced concrete, 3,500 cubic yards at $18.00 to $30.00	72,000	
Spillway gates	200,000	
Irrigation outlets and sluiceways	185,000	
(Power plant outlets and tunnels included in cost of power plant).		
Drilling, grouting, drains and contraction seals	88,000	
		11,718,000
Miscellaneous		196,000
Subtotal		$16,604,000
Administration and engineering at 10 per cent		1,660,000
Contingencies at 15 per cent		2,491,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,445,000
Total capital cost of dam and reservoir		$22,200,000

Cost of Power Plant for Melones Reservoir

Installed capacity, 68,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total cost of power plant, including all appurtenances	$4,000,000

Annual Cost of Melones Reservoir and Power Plant

Gross annual cost of dam and reservoir	$1,334,000
Gross annual cost of power plant	323,000
Total gross annual cost	1,657,000
Average annual revenue from sale of electric energy, 240,000,000 kilowatt hours at $0.003	720,000
Average net annual cost, not covered by revenue from sale of electric energy	937,000

Don Pedro Reservoir on Tuolumne River.

Two reservoir sites on the lower reaches of the Tuolumne River were investigated as possibilities for units in the State Water Plan, namely: Don Pedro and Jacksonville sites. The dam site for the Don Pedro Reservoir is on the main river about one-half mile downstream from the existing dam of the Modesto and Turlock irrigation districts in the southeast quarter of Section 34, Township 2 South, Range 14 East, M.D.B. and M., and about four miles northeasterly from the town of La Grange. Upstream from the Don Pedro site is the Jacksonville dam site in Section 24, Township 1 South, Range 14 East, M.D.B. and M. It is on the main river below the mouth of Woods Creek at a stream bed elevation of about 536 feet. These two sites are the only ones located on the lower reaches of Tuolumne River capable of adequately regulating the run-off of the stream. The drainage area above the Don Pedro site is 1536 square miles and above the Jacksonville site, 1451 square miles. The Don Pedro site is capable of being developed to larger capacity than the Jacksonville site. Both reservoirs are limited, in the practicable height to which a dam can be constructed, by the Moccasin Creek Power Plant, the tail race of which is 920 feet. The capacity of the Don Pedro Reservoir constructed to that elevation would be 2,580,000 acre-feet and for the Jacksonville Reservoir 493,000 acre-feet. The height of dams would be 604 feet and 394 feet respectively. From geological examinations it has been determined that the Don Pedro site is satisfactory for a masonry dam or any other type of dam. The Jacksonville site is uncertain, even for a rockfill dam, because of unsuitable foundation conditions. A fault passes through this latter site. Cost estimates reveal that the cost per acre-foot of storage at the Jacksonville site would be several times that at the Don Pedro site. Because of its greater available potential storage capacity, more favorable dam foundation, greater tributary drainage and lower unit cost of storage, the Don Pedro site was chosen over the Jacksonville site.

The drainage areas on the Tuolumne River watershed, above the Don Pedro dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	920 square miles
Area between elevations 2500 and 5000 feet	375 square miles
Area below elevation 2500 feet	241 square miles
Total area above Don Pedro dam site	1536 square miles

Present Developments on Tuolumne River—The water developments above the Don Pedro dam site of the State Water Plan comprise those for the municipal water supply of the city of San Francisco and the irrigation supply of the Turlock and Modesto irrigation districts. The Hetch Hetchy and Lake Eleanor reservoirs of the city of San Francisco are in the upper part of the watershed. The O'Shaughnessy Dam of the Hetch Hetchy Reservoir is located in Section 16, Township 1 North, Range 20 East, M.D.B. and M., on the main stream at stream bed elevation 3500 feet. The initial reservoir impounds 206,000 acre-feet. With the dam raised 85 feet to its proposed ultimate height, the capacity would be 348,500 acre-feet. The drainage area above the dam is 459 square miles. The dam of Lake Eleanor Reservoir is located in Section 3, Township 1 North, Range 19 East, M.D.B. and M., on Eleanor Creek at stream bed elevation of 4600 feet. It has been constructed to a capacity of 27,800 acre-feet and the plans of the city of San Francisco call for the construction of a dam at this site to an ultimate height of 225 feet, which would impound 218,000 acre-feet. The drainage area above the dam is 79 square miles, which would be increased to 193 square miles if the drainage area above a proposed diversion from the Cherry Creek watershed be included. The ultimate plans of the city of San Francisco include storage development at five other reservoir sites, namely: Poopenant Valley, Cherry Valley, Lake Vernon, Huckleberry Lake and Emigrant Lake with a total storage capacity of about 205,000 acre-feet. If these plans are fully executed a total storage capacity of about 770,000 acre-feet, including Hetch Hetchy and Lake Eleanor reservoirs, will be developed for the regulation of the run-off from a total tributary drainage area of 666 square miles on the upper Tuolumne River watershed. In addition to the run-off from that area there would still remain the run-off from 877 square miles of watershed above the valley floor to be regulated. The total drainage area above the valley floor is 1543 square miles. In connection with the foregoing development the city of San Francisco has constructed the Moccasin Creek and Cherry Creek power plants with capacities of 80,000 and 3000 kilovolt amperes, respectively. Plans for ultimate municipal water supply development include extensive additional power installations.

The present Don Pedro Reservoir and Power Plant, constructed jointly by the Modesto and Turlock irrigation districts at a cost of more than $5,000,000, has a storage capacity of 290,000 acre-feet. The dam has a height of 270 feet, a crest length of 1020 feet and a maximum base thickness of 177 feet. It is a concrete gravity-type dam, curved in plan with a constant radius. An overflow wing-type spillway and spillway channel located on the right abutment of the dam was designed for an estimated discharging capacity of 125,000 second-feet. The discharge is controlled by ten steel drum-type gates, nine feet high by 57 feet long, installed on the spillway crest. Three 60-inch sluiceways extend through the dam, 254 feet below its crest, controlled by slide gates at the upstream face of the dam. Two batteries of irrigation outlets are placed 98 and 188 feet, respectively, below the crest of the dam. Each battery consists of six 52-inch diameter outlets. The power plant is located at the downstream toe of the dam on the left bank of the stream. It is equipped with five turbine and generator units having an aggregate installed capacity of 33,740 kilovolt amperes. Water is supplied to the turbines through 72-inch penstocks. Each penstock is located in the base of the dam for part of its length, but the downstream portions are excavated in solid rock. Slide gates are installed near the upstream end of each penstock for emergency control. The turbines discharge vertically downward into a tunnel outlet. The diversion of the irrigation supply from the river is accomplished at the La Grange Dam, four miles below Don Pedro Dam. The La Grange Dam, at the time of its construction in 1893, was one of the highest overpour structures in existence. It is built of masonry, has a height of 131 feet above stream bed and cost a little more than $500,000. Below the La Grange Dam, the Turlock Irrigation District has constructed the La Grange Power Plant, with an installed capacity of 4750 kilovolt amperes, which is used chiefly for stand-by purposes.

The Modesto Irrigation District paid 31.54 per cent and the Turlock Irrigation District 68.46 per cent of the cost of the Don Pedro Project. The storage and power releases are owned in the same proportion. The Modesto District owns and operates its own power distribution system and retails all of its power for agricultural, domestic and industrial uses.

The Turlock District, on June 21, 1922, voted to distribute its share of the Don Pedro power output and, on October 23, 1923, approved a bond issue for power distribution. On March 11, 1924, it entered into a contract with the San Joaquin Light and Power Company under which the district agreed not to sell power outside of certain boundaries, and the company agreed to take the entire surplus power of the district, provided that the rate of delivery should be not less than 6500 kilowatts from June 1 to December 31, nor more than 2500 kilowatts from January 1 to May 31 of each year. The power company also agreed to take all future surplus output that might be developed by the district. In years in which the run-off of Tuolumne River is less than 1,900,000 acre-feet from January 1 to July 31, the district is not obligated to deliver to the company more than 65 per cent of its share of Don Pedro power. The price paid by the company to the district is 4.5 mills per kilowatt hour for energy delivered at the Livingston substation, at not less than 80 per cent load factor. The contract was to remain in force for fifteen years, but may be renewed at the option of the district for an additional fifteen years.

The Turlock Irrigation District includes an area of 181,498 acres between the Tuolumne and Merced rivers, of which 133,750 acres were irrigated in 1929. The Modesto Irrigation District contains a gross area of 81,183 acres on the north side of Tuolumne River, of which 66,372 acres were irrigated in 1929. The Waterford Irrigation District includes an area of 14,110 acres on the same side of the river and above the Modesto District, of which 5272 acres were irrigated in 1929. This district diverts through the Modesto Canal from LaGrange Dam but does not share in Don Pedro storage rights.

Water Supply—The water supply available for regulation is that allotted to the existing irrigation rights on the stream under the terms of the Raker Act (U. S. Congress 1913). Under these rights, the mean seasonal ultimate net run-off available for regulation at the Don Pedro site for the 40-year period, 1889–1929, would have been 1,634,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the proposed dam site, scale one inch equals 400 feet, was made by the State in 1925. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 76, have been obtained up to elevation 650 feet from the contour map for the existing reservoir, scale one inch equals 500 feet, prepared by the Modesto and Turlock irrigation districts in 1913. For areas and capacities above that elevation, the U. S. G. S. topographic maps were used.

TABLE 76

AREAS AND CAPACITIES OF DON PEDRO RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
110	425	270	5,700
135	450	470	15,200
160	475	740	30,000
185	500	1,120	52,000
210	525	1,610	86,000
235	550	2,340	137,000
260	575	2,730	200,000
285	600	3,120	271,000
310	625	3,360	348,000
335	650	3,610	431,000
360	675	3,860	522,000
385	700	4,100	623,000
410	725	5,170	738,000
435	750	6,250	875,000
455	770	7,100	1,000,000
460	775	7,320	1,044,000
485	800	8,390	1,247,000
510	825	9,800	1,496,000
535	850	11,200	1,768,000
560	875	12,600	2,060,000
585	900	14,000	2,370,000

The capacity selected for the proposed Don Pedro Reservoir of 1,000,000 acre-feet is required to furnish a dependable irrigation supply to the lands which are or would be naturally dependent upon the Tuolumne River for such supply. The required supply could have been made available by a reservoir of this capacity during the 40-year period, 1889–1929, without resort to ground water storage, with an average seasonal deficiency of less than 2 per cent. With a flow line elevation of 770 feet, the reservoir basin would have a length of sixteen miles, an average width of nearly three-quarters of a mile and a submerged area of 7100 acres. Of the total submerged area, 3182 acres lie within the flow line of the existing reservoir at elevation 605.5 feet.

The present Don Pedro Reservoir floods the only lands that were of any appreciable extent and value for farming purposes below elevation 900 feet. A small area of bottom land along Woods Creek would be flooded by the proposed reservoir. The remaining area is practically all characteristic mountain land covered with scattering timber and brush, and used mostly for grazing. The Big Oak Flat road extending from Oakdale to the Yosemite Valley would be flooded from Woods Creek to where it crosses Moccasin Creek. The town of Jacksonville, consisting of about 20 frame houses, would be submerged. The Hetch Hetchy Railroad, built by the city of San Francisco from Hetch Hetchy Junction on the Sierra Railroad to the O'Shaughnessy Dam on the Tuolumne River, traverses the proposed reservoir site from about one-half mile below the mouth of Woods Creek to Moccasin Creek. The Mother Lode crosses areas that would be submerged and several gold mines and mining claims would be flooded. The Eagle-Shawmut, Tarantula, Clio-Vindicator and Harriman are the most important properties.

In irrigation yield studies of this reservoir, a net seasonal reservoir evaporation loss of 3.5 feet in depth on the reservoir surface has been used. The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per annum on the average and 35 per cent as a possible maximum in an exceptionally dry year such as 1924, would have been 1,330,000 acre-feet. The average seasonal irrigation yield for the 40-year period would have been 1,303,000 acre-feet. In obtaining this yield, ultimate diversions by the city of San Francisco for municipal purposes were deducted from the run-off of the Tuolumne River. These diversions were considered as being limited by the provisions of the "Raker Act" and the operation of the physical works proposed by the city for ultimate development, for an attempted draft of four hundred million gallons per day. Further details as to yield and utilization of water supplies developed by this reservoir are presented in Chapter VII.

Dam Site—A geological examination of the site of the present dam (See Appendix C) showed that the topographic conditions and geologic structure were not favorable for the construction of a higher dam at that site. However, at a point about one-half mile downstream from the present dam, there is a site which is favorable, both topographically and geologically, for a high dam. Here, a series of thick-bedded or banded rock formations resembling diabase strike across the stream. In order to best conform to the topography and the rock structure at this site, the center line of the dam has been located across the strike of the rock bands where these bands are relatively thick.

PLATE XXXVI

Present Don Pedro Dam Completed in 1922

Site of Proposed Dam Below Existing Structure

DON PEDRO DAM SITE ON TUOLUMNE RIVER

The stream bed and right abutment to the top of the cliff profile, 150 feet above stream bed, probably would require stripping to an average depth of 10 feet. From that point to the crest, an average depth of 20 feet probably would be required in order to remove loose joint blocks and reach reasonably sound rock in which the joints could be pressure grouted. The left abutment carries a heavier soil cover and is somewhat wooded. Stripping allowance should be 15 feet to an elevation of 150 feet above stream bed and 25 feet from this elevation to the crest of the ridge.

Dam and Appurtenances—The topography of the dam site and layout of the proposed dam and appurtenances are shown on Plate XXXVII, "Don Pedro Reservoir on Tuolumne River." The dam is a gravity type concrete structure, straight in plan and located at an an angle of about 20 degrees from normal to the axis of the stream bed. Its height above stream bed is 455 feet, including five feet of freeboard.

A spillway of the wing type, located at the left abutment of the dam, is controlled by 11 drum gates, 15 feet high by 50 feet long. The spillway channel is carried about 350 feet beyond the crest of the dam and past a bend in the canyon, so that the discharge would drop into the main stream channel about 1000 feet downstream from the dam.

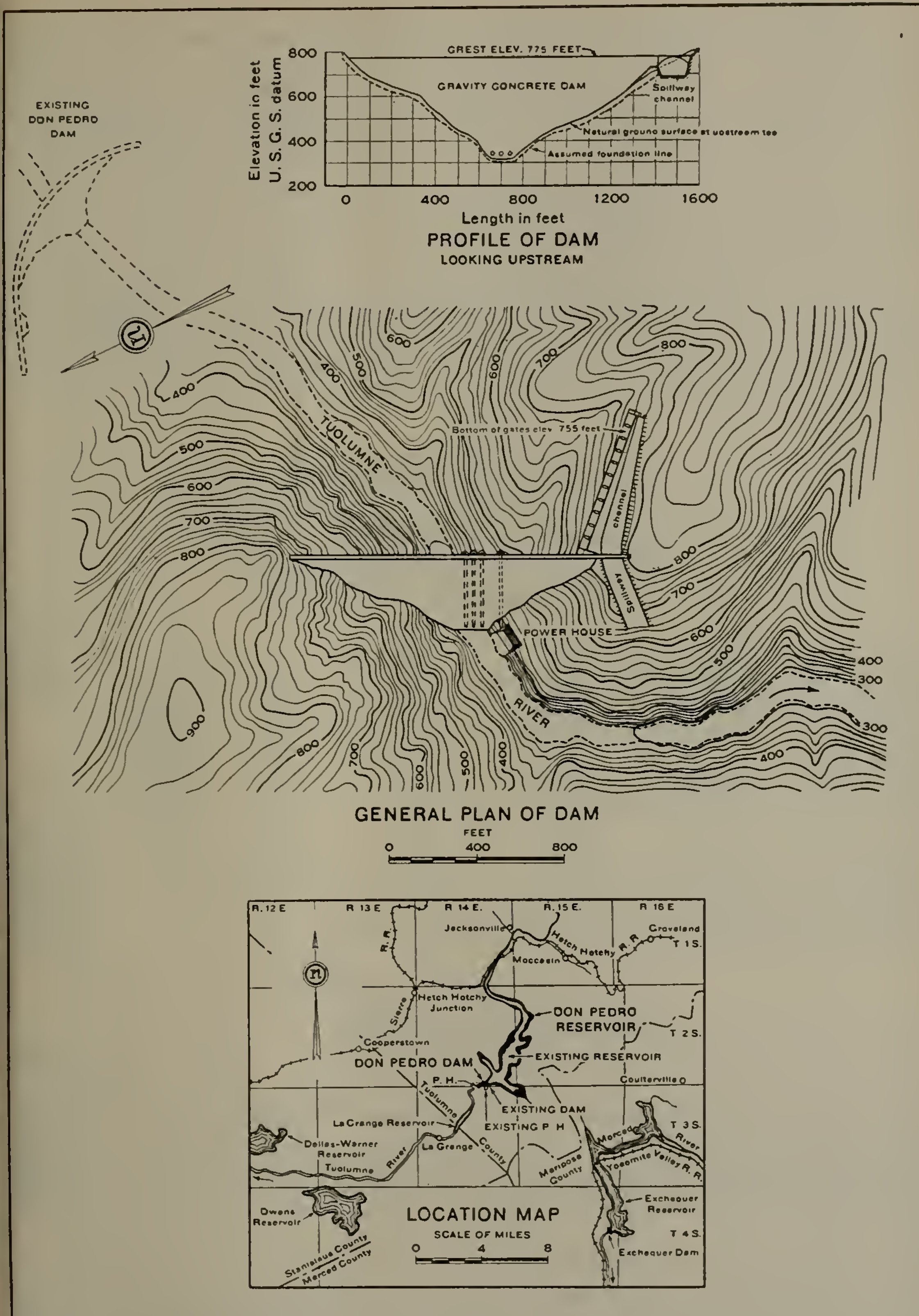
Reserve space of 214,000 acre-feet, involving a maximum drawdown of 32 feet, would be provided for regulation of the stream to a maximum flood flow of 15,000 second-feet, exceeded once in 100 years on the average. The required capacity for flood regulation is provided by the outlets for irrigation and power releases, assuming the power plant to be equipped with turbine by-passes.

The irrigation outlets consist of three 78-inch pipes through the dam, with a combined discharging capacity of 4000 second-feet under a minimum head of 50 feet. These outlets are controlled by needle valves and emergency slide gates. The inlets are at elevation 340 feet.

Power Plant—The economic size of installation for the proposed power plant has been determined as 120,000 kilovolt amperes, based on a value for power of $0.003 per kilowatt hour. The power plant is located on the right bank of the stream at the downstream toe of the dam. It would be supplied by steel penstocks through the dam, equipped with needle valves at the inlet of each turbine and emergency slide gates near the upstream face of the dam. The installation includes six 20,000 kilovolt ampere units equipped with turbine by-passes. It would replace the present Don Pedro Power Plant, which has an installed capacity of 33,740 kilovolt amperes.

Cost of Don Pedro Reservoir—The capital and annual costs of Don Pedro Reservoir and Power Plant, estimated in accord with bases previously presented in this chapter, are shown in Table 77. Estimates are also shown of revenue from sale of electric energy and the net annual cost after deducting power revenue. The tabulated costs do not include any amounts for the destruction of the present Don Pedro Reservoir and Power Plant of the Modesto and Turlock irrigation districts. It is contemplated that interests and lands now receiving service, both irrigation and power, from the present development would continue to receive the same service with no additional

PLATE XXXVII



DON PEDRO RESERVOIR
ON
TUOLUMNE RIVER

cost under the larger development as proposed herein for the State Water Plan. Therefore, in accord with such assumption, the commitments and obligations of the parties now interested in the present development would be maintained without modification. The figure for annual cost includes no amount for present development but does include amounts for equivalent service which would be rendered with the larger State proposal. It is not possible to foretell the conditions under which, or when or by whom, the proposed development would be constructed. Neither is it possible to state whether or not the present development would be entirely amortized and depreciated at the time the proposed development is undertaken. Therefore, the entire anticipated power revenue has been credited to the proposed unit and deducted from the gross annual cost to obtain the net annual cost.

TABLE 77

COST OF DON PEDRO RESERVOIR

Height of dam, 455 feet. Capacity of reservoir, 1,000,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 4,000 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		65,000
Lands and improvements flooded and clearing		2,050,000
Excavation for dam, 272,000 cubic yards at $3.00 to $5.00	$856,000	
Mass concrete, 2,030,000 cubic yards at $7.20	14,616,000	
Reinforced concrete, 1,400 cubic yards at $18.00 to $45.00	40,000	
Spillway gates	220,000	
Spillway channel	1,430,000	
Irrigation outlets and sluiceways	282,000	
(Power outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	108,000	
		17,552,000
Miscellaneous		144,000
Subtotal		19,821,000
Administration and engineering at 10 per cent		1,982,000
Contingencies at 15 per cent		2,973,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,724,000
Total capital cost of dam and reservoir		26,500,000

Cost of Power Plant For Don Pedro Reservoir

Installed capacity, 120,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total cost of power plant, including all appurtenances	$6,000,000

Annual Cost of Don Pedro Reservoir and Power Plant

Gross annual cost of dam and reservoir	$1,590,000
Gross annual cost of power plant	484,000
Total gross annual cost	2,074,000
Average annual revenue from sale of electric energy, 365,000,000 kilowatt hours at $0.003	1,095,000
Average net annual cost not covered from sale of electric energy	979,000

Exchequer Reservoir on Merced River.

The Exchequer Reservoir is located in Townships 3 and 4 South, Ranges 15 and 16 East, M.D.B. and M., in Mariposa County about 20 miles northeast from the city of Merced. It is already developed by the Merced Irrigation District to a capacity of 279,000 acre-feet. It supplies water for lands in the district with a gross area of 189,682 acres, of which 134,379 acres were irrigated in 1929. The recently organized El Nido Irrigation District with a gross area of 9450 acres also obtains water from the Merced Irrigation District.

The drainage areas on the Merced River watershed, above the Exchequer Dam, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	52 square miles
Area between elevations 5000 and 10,000 feet	494 square miles
Area between elevations 2500 and 5000 feet	317 square miles
Area below elevation 2500 feet	171 square miles
Total area above Exchequer Dam	1034 square miles

A contour map of the dam site, for elevations above the existing dam, scale one inch equals 100 feet, was made by the State in 1925. The areas and capacities of reservoirs for various heights of dam, as set forth in Table 78, have been obtained up to elevation 750 feet from the contour map for this site, scale one inch equals 400 feet, prepared by J. D. Galloway in 1920. For areas and capacities above that elevation the U. S. G. S. topographic maps were used.

TABLE 78

AREAS AND CAPACITIES OF EXCHEQUER RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
102	500	240	6,500
127	525	440	15,500
152	550	690	30,500
177	575	950	51,000
202	600	1,190	79,000
227	625	1,460	112,000
252	650	1,750	153,000
277	675	2,090	202,000
302	700	2,470	262,000
*307	707	2,600	279,000
327	725	2,910	329,000
352	750	3,410	412,000
377	775	3,730	500,000
402	800	4,050	599,000
427	825	4,720	709,000
452	850	5,400	833,000
477	875	6,080	977,000
502	900	6,750	1,140,000

*Existing dam has only a 3-foot freeboard.

The present Exchequer Reservoir and Power Plant were constructed in 1925 by the Merced Irrigation District at a cost of $10,725,000. The dam is located below the mouth of Cotton Creek in the southwest quarter of Section 13, Township 4 South, Range 15 East, about seven miles upstream from the town of Merced Falls. It is a concrete gravity type dam, arched in plan with a constant radius of 674 feet on the upstream face. Its height is 307 feet above stream bed and it has a crest length of 960 feet. The reservoir, when filled to the flow line elevation of 707 feet, submerges an area of 2600 acres with a length of 13 miles and an average width of one-third of a mile. Two overflow spillways are provided—one at each end of the dam. The crest of each spillway, at elevation 693 feet, is 168 feet long and allows a depth of water of 14 feet to flow over the crests to concrete-lined channels excavated in solid rock and leading from the abutments. These spillways were designed for an estimated discharging capacity of 70,000 second-feet. The water level in the reservoir can be maintained at elevation 707 feet by means of 14 plate steel butterfly gates on the spillway crests. The power plant at the base of the dam has two

15,625 kilovolt ampere vertical turbo-generator units designed to operate under heads of from 140 to 300 feet. The units are supplied by steel penstocks, through the dam, 96 inches in diameter. The flow through each penstock is controlled by a needle valve at the turbine inlet. The penstocks also are equipped with emergency slide gates. Two sluice pipes, 60 inches in diameter, extend through the dam and past the power house walls. Each is provided with a regulating needle valve at the downstream end and an emergency slide valve above the needle valve.

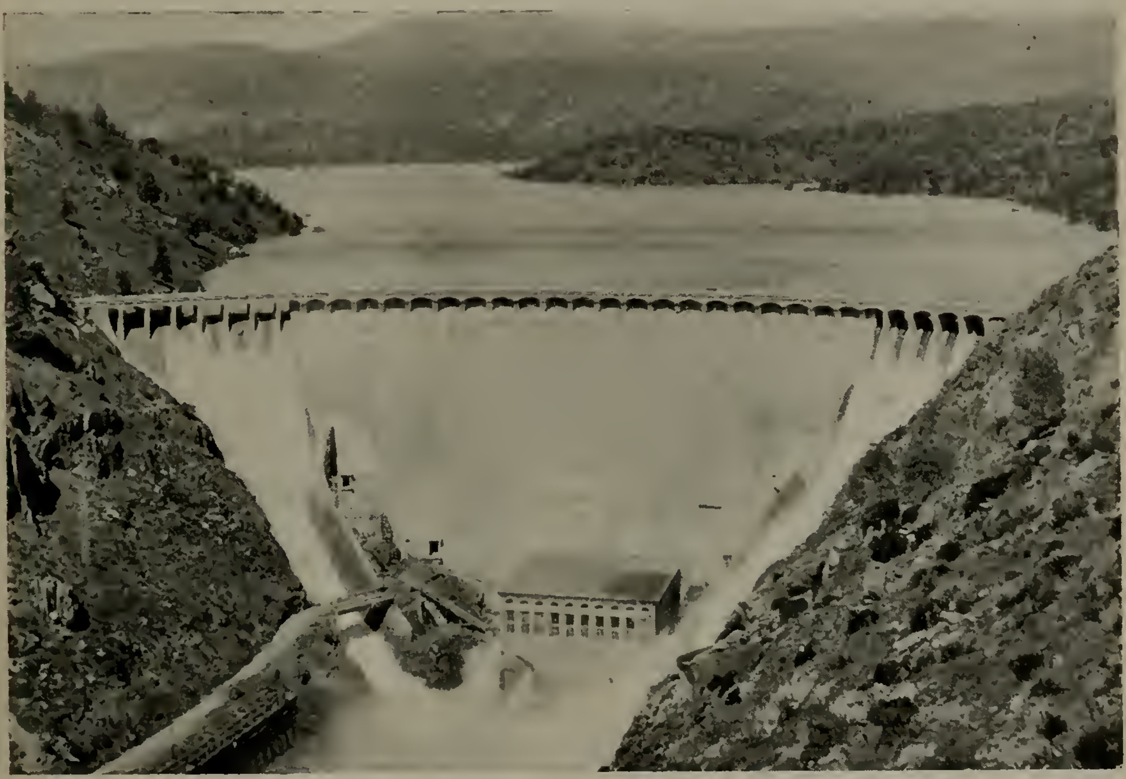
The Merced Irrigation District wholesales the power output to the San Joaquin Light and Power Company under a contract dated February 21, 1924, which runs for a period of 20 years with option to the district to continue for a second 20-year period. Power is delivered to the company at the Exchequer plant. Deliveries of water to the power plant are goverened chiefly by irrigation requirements, but the district agrees to deliver energy on a daily load factor ranging from unity to eight-tenths, as demanded by the company. The contract also provides for some delivery at less than eight-tenths daily load factor. The price paid by the power company is 4.5 mills per kilowatt-hour at the power plant switchboard.

There is no other reservoir site of adequate capacity on the stream and the dam site now occupied is the only one suitable for use in developing additional storage, which could be secured by increasing the height of the existing dam. A geological examination of the site (See Appendix C) reveals that so far as the foundation conditions are concerned such an increase in height would be possible. A study was made to determine the costs and additional yields obtainable by enlarging the present reservoir to various capacities up to 882,000 acre-feet. The relocation of the Yosemite Valley Railroad rendered the present development relatively expensive. The cost of this item alone was $5,566,000, or more than half the total cost of reservoir and power plant. With an additional increase in water surface elevation, the problem of relocation of this railroad would be even more difficult and costly. The geologic structure above the present dam on the right abutment would require excessive stripping from the crest of the present dam to the top of the ridge. These factors, together with the relatively small increase in yield which could be secured through additional storage, indicate that no increase in storage development can be economically justified.

Water Supply and Yield—The water supply available for regulation at this site under conditions of ultimate development would be the run-off of the Merced River impaired by such diversions above the reservoir as would be required for the ultimate development of all irrigable mountain and foothill lands dependent on the Merced River for their water supply. The mean seasonal ultimate net run-off for the 40-year period 1889–1929 would have been 989,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II. In making yield studies, a net seasonal reservoir evaporation loss of 3.5 feet in depth on the reservoir surface has been used.

The safe surface irrigation yield of the existing reservoir for the 40-year period 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceedingly dry year such as 1924, would have been 440,000 acre-feet. The average seasonal surface irrigation yield for the 40-year period would have been 434,000 acre-feet. In addition, an average seasonal supply of 294,000 acre-feet of reservoir spill would have been utilizable through ground water storage and pumping in absorptive areas. Further details pertaining to yield and utilization of water supply are presented in Chapter VII.

PLATE XXXVIII



EXCHEQUER DAM ON MERCED RIVER

Other Developments on Merced River—The only diversion of any importance from Merced River above the Exchequer Reservoir is that from Big Creek, a tributary of the South Fork of Merced River, to the Fresno River watershed for irrigation and lumbering purposes. The diversion ditch has a capacity of 35 second-feet, and the average seasonal exportation is estimated to be about 4600 acre-feet. Immediately below Yosemite Valley, the National Park Service has installed a power plant with a capacity of 2500 kilovolt amperes. The San Joaquin Light and Power Corporation has a small power plant, called the Mountain King, about two miles above the mouth of North Fork. It has an installed capacity of 350 kilovolt amperes. Below Merced Falls the same company has recently constructed a power plant with an installed capacity of 4000 kilovolt amperes.

Buchanan Reservoir on Chowchilla River.

The dam site for the Buchanan Reservoir on Chowchilla River is located in the southeast quarter of Section 22, Township 8 South, Range 18 East, M. D. B. and M., in Madera County, about 20 miles northerly from the city of Madera. There are no other reservoir sites of any importance on Chowchilla River.

The drainage areas on the Chowchilla River watershed, above the Buchanan dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	5 square miles
Area between elevations 2000 feet and 5000 feet	104 square miles
Area below elevation 2000 feet	129 square miles
Total area above Buchanan dam site	238 square miles

Water Supply—There is no existing or projected development of any consequence on the upper reaches of the stream. The water supply available for regulation at the Buchanan site would be the full natural run-off. The mean seasonal full natural run-off for the 40-year period, 1889 to 1929, is estimated as 70,900 acre-feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 400 feet, was prepared by C. M. Carter from a survey made in 1919. The State made a survey and prepared a contour map of the dam site, scale one inch equals 200 feet, in 1922. Table 79 sets forth areas and capacities for various heights of dam.

TABLE 79

AREAS AND CAPACITIES OF BUCHANAN RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
35	440	140	1,500
55	460	330	6,500
75	480	550	15,500
95	500	780	29,000
115	520	970	47,000
135	540	1,140	69,000
147	552	1,250	84,000
155	560	1,310	94,000

The reservoir basin is situated among rolling foothills, sparsely timbered and used chiefly for cattle range. Trial yield studies on this reservoir determined the season of maximum deficiency for the 40-year period 1889–1929 to be that of 1919–1920. The selected capacity of 84,000 acre-feet was found to be necessary to regulate the run-off without waste and to obtain the yield required to serve the tributary service area. At flow line elevation 552 feet, the flooded area would be 1250 acres, with a length of 3.5 miles and a maximum width of 1.2 miles. In making yield studies a net seasonal reservoir evaporation loss of 4.0 feet depth on the reservoir surface was used.

The safe surface irrigation yield of the proposed reservoir for the 40-year period 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per annum on the average and 35 per cent as a possible maximum in an exceptionally dry year, would have been 54,000 acre-feet. The mean seasonal irrigation yield for the 40-year period would have been 53,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

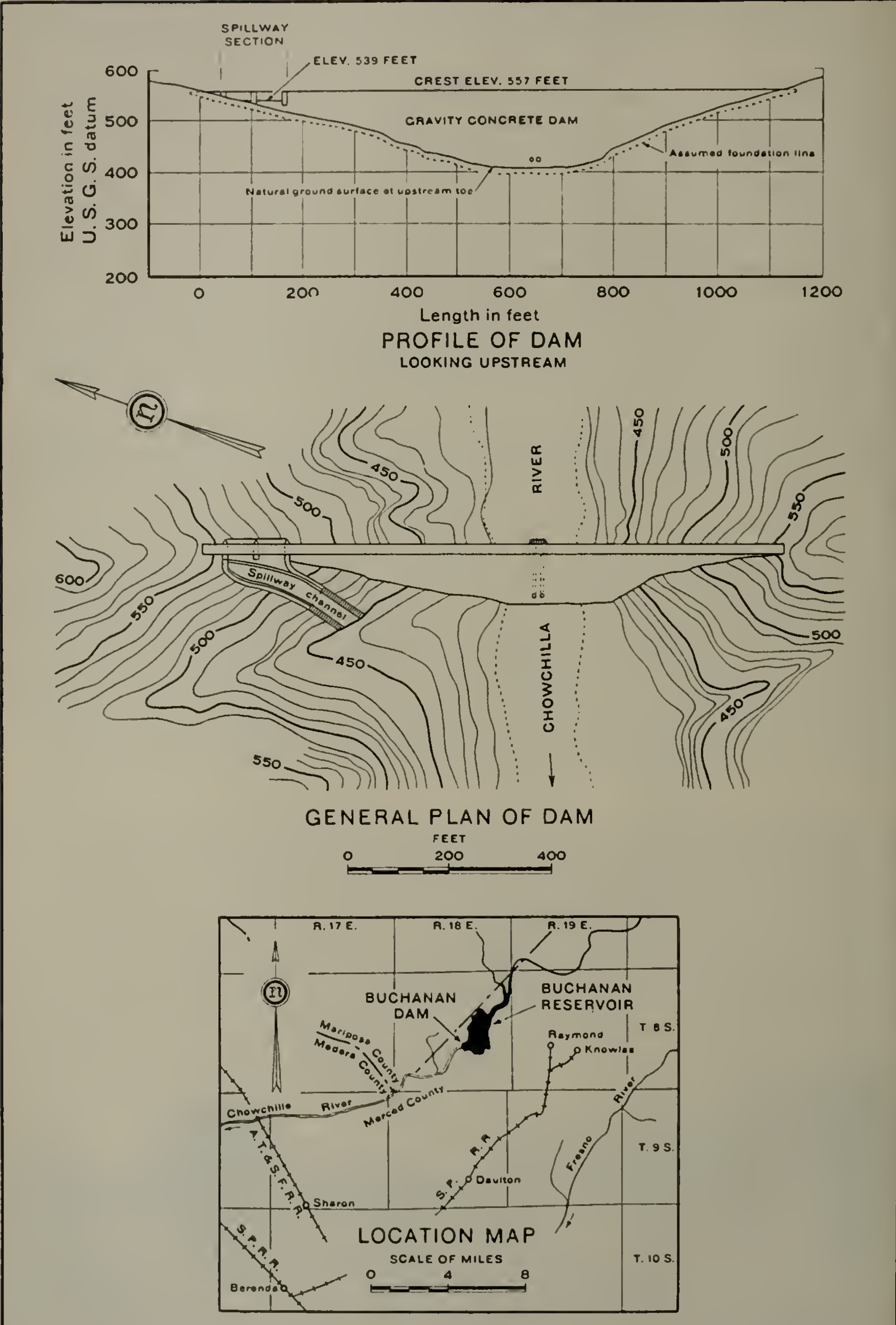
Dam Site—The Buchanan dam site is situated at a point where the Chowchilla River has cut its way through a rock ridge of mica schist in a direction across the planes of schistosity. A geological examination (see Appendix C) shows that the schistose texture is fully developed and makes up a hard crystalline rock mass, containing lines of weakness or parting planes which strike across the channel and dip north 35 degrees east, 75 to 80 degrees from the horizontal upstream. The site was partially excavated over 30 years ago, revealing the same bands of rock carrying from one abutment across the stream bed and up the opposing abutment. At fresh exposures in the stream bed, the schistosity planes and joints are closed features. The condition of these lines of weakness below ground surface is revealed by diamond drill borings made for the Madera Irrigation District. The planes and joints appear from the logs of the drill holes to be closed features, except in a limited zone from 45 to 60 feet below the stream bed where water was lost. The rock type is such as to contain no joint openings that could not be closed by pressure grouting. It is estimated that an average of ten feet of additional stripping would be required to secure a sound foundation.

Dam and Appurtenances—The topography at the site and the general layout of the proposed dam and appurtenances are shown on Plate XL, "Buchanan Reservoir on Chowchilla River." The dam is a concrete gravity type structure, straight in plan, 147 feet in maximum height above stream bed. An overflow type of spillway, located at the right abutment, is controlled by two drum gates 13 feet high by 50 feet long. The spillway has an estimated discharging capacity of 16,000 second-feet. Two 30-inch diameter pipes, with inlets at elevation 425 feet, are provided for release of irrigation supplies. These have a combined discharging capacity of 200 second-feet under a minimum head of 12 feet and are controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

PLATE XXXIX

BUCHANAN DAM SITE ON CHOWCHILLA RIVER

PLATE XL



BUCHANAN RESERVOIR

ON

CHOWCHILLA RIVER

Cost of Buchanan Reservoir—The capital and annual costs of Buchanan Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 80.

TABLE 80

COST OF BUCHANAN RESERVOIR

Height of dam, 147 feet. Capacity of reservoir, 84,000 acre-feet.
Capacity of spillway, 16,000 second-feet.
Capacity of irrigation outlets, 200 second-feet.

Exploration		$10,000
Diversion of river during construction		5,000
Lands and improvements flooded and clearing		125,000
Excavation for dam, 29,000 cubic yards at $4.50	$131,000	
Mass concrete, 178,000 cubic yards at $8.25	1,468,000	
Reinforced concrete, 1,000 cubic yards at $18.00 to $30.00	20,000	
Spillway gates	34,000	
Spillway channel	34,000	
Irrigation outlets and sluiceways	10,000	
Drilling, grouting, drains and contraction seals	30,000	
		1,727,000
Miscellaneous		77,000
Subtotal, dam and reservoir		1,944,000
Administration and engineering at 10 per cent		195,000
Contingencies at 15 per cent		292,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		169,000
Total capital cost of dam and reservoir		2,600,000
Total annual cost of dam and reservoir		$155,000

Windy Gap Reservoir on Fresno River.

The dam site for the Windy Gap Reservoir on Fresno River is located in the southeast quarter of Section 2, Township 7 South, Range 20 East, M.D.B. and M., in Madera County, about 32 miles northeasterly from the city of Madera. A lower site, called Hidden Reservoir, located near the valley floor, also was investigated, but its potential capacity was found to be inadequate for desired purposes.

The drainage areas on the Fresno River watershed, above the Windy Gap dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	14 square miles
Area between elevations 2000 and 5000 feet	88 square miles
Area below elevation 2000 feet	0
Total area above Windy Gap dam site	102 square miles

Water Supply—There is no existing or projected development of any consequence on the upper reaches of the stream. The water supply available for regulation at this site is the run-off of Fresno River, augmented by the importation of some water by ditches of the Madera Sugar Pine Lumber Company and Madera Canal and Irrigation Company from the adjacent drainage areas of the Merced and San Joaquin rivers. The mean seasonal run-off for the 40-year period, 1889–1929, is estimated as 55,200 acre-feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 1000 feet, and one of the dam site, scale one inch equals 200 feet, were prepared from surveys made by the State in August 1922. The areas and capacities set forth in Table 81 were obtained from a more detailed survey made by Madera Irrigation District in November 1922.

The critical period on the Fresno River covers the seasons from 1925 to 1929. The selected reservoir capacity of 62,000 acre-feet is the amount of storage that would have been required to regulate the water

TABLE 81

AREAS AND CAPACITIES OF WINDY GAP RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
85	1,960	110	2,500
105	1,980	180	5,000
125	2,000	290	10,000
145	2,020	430	17,000
165	2,040	600	27,500
185	2,060	830	42,000
205	2,080	1,100	60,500
206	2,081	1,110	62,000
225	2,100	1,440	86,000

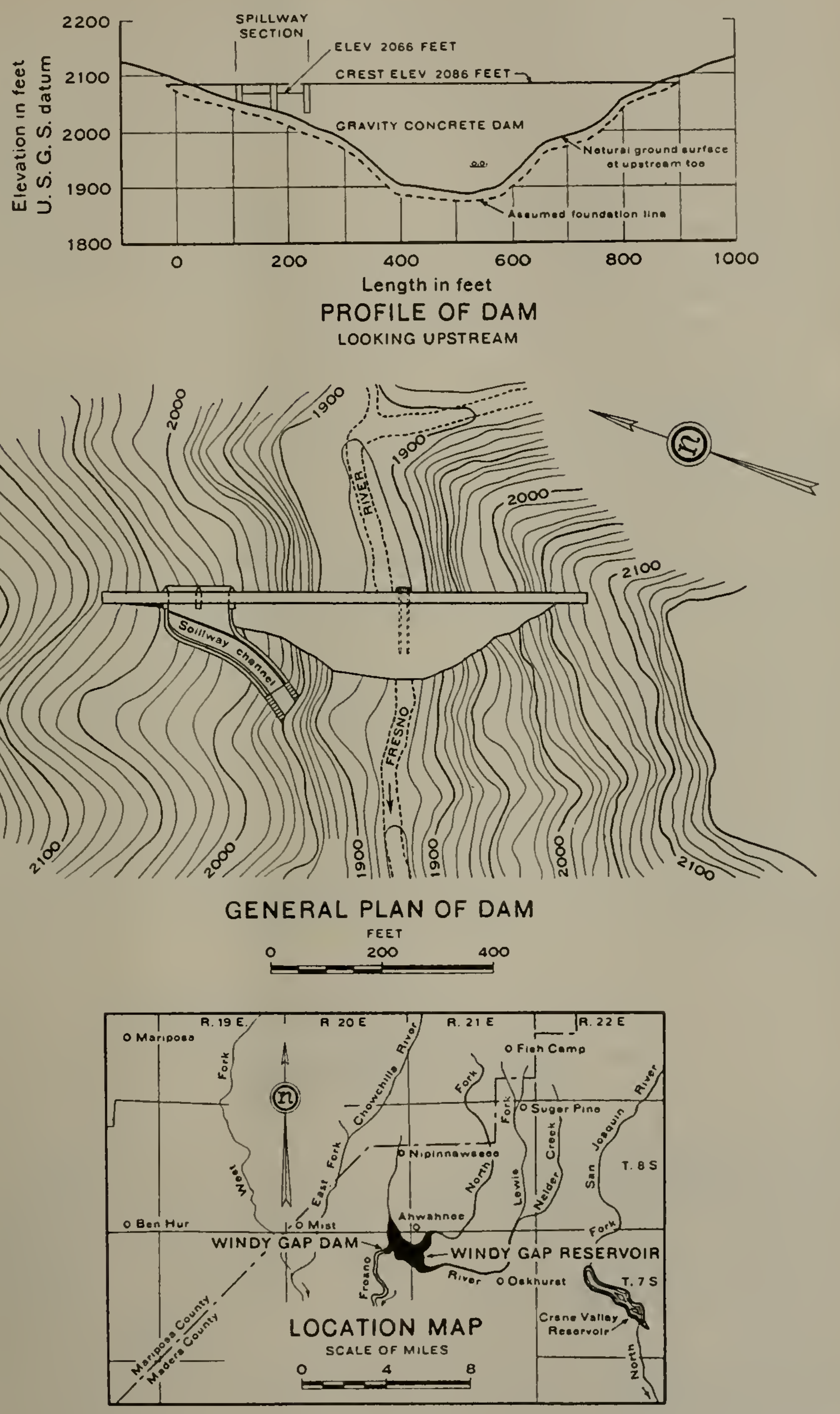
supply without waste for this period. With a flow line elevation of 2081 feet, the reservoir would flood an area of 1110 acres, with a length of four miles and a maximum width of 0.8 miles. The only improvements to be flooded are six miles of the Madera Sugar Pine Lumber Company's timber flume and four miles of county road, both of which would require relocation.

In making yield studies at this site, a net seasonal reservoir evaporation loss of 4.0 feet in depth in the reservoir was used. The safe surface irrigation yield of the proposed reservoir for the 40-year period, 1889–1929, based upon an allowable deficiency not exceeding 2 per cent per season on the average and 35 per cent as a possible maximum in an exceedingly dry year, would have been 46,000 acre-feet. The mean seasonal yield for the 40-year period would have been 45,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

PLATE XLI

WINDY GAP DAM SITE ON FRESNO RIVER

PLATE XLII



WINDY GAP RESERVOIR

ON

FRESNO RIVER

Dam Site—The Windy Gap dam site is located at the point where the Fresno River leaves Fresno Flats through a gorge cut across the topographically prominent Crook Mountain-Potter Ridge. The rock formation at this site comprises black micaceous slate, converted in part into a mica schist. The bands of rock strike across the stream bed continuously from the crest of one abutment to the other and dip nearly vertically. The joint planes are closed-tight features over fresh stream bed exposures and probably would refuse grout at relatively short distances below ground surface. It is estimated that an average depth of stripping of fifteen feet on the abutments would suffice to reach sound rock and that an average depth of ten feet of stripping would provide a sound rock foundation in the stream bed.

Dam and Appurtenances—The topography at the dam site and the general layout of the proposed dam and appurtenances are shown on Plate XLII, "Windy Gap Reservoir on Fresno River." The dam is a concrete gravity type structure, straight in plan, with a maximum height of 206 feet above stream bed. An overflow type of spillway, located at the right abutment, is controlled by two drum gates, 15 feet high and 50 feet long, and discharges through a lined channel about 200 feet long into a small draw that drains into the river about 150 feet below the toe of the dam. The discharging capacity of the spillway is estimated as 20,000 second-feet, or 4.3 times the once-in-25-year flood. Two 30-inch diameter pipes, with inlets at elevation 1940 feet, are provided for release of irrigation supplies. These have a combined discharging capacity of 200 second-feet under a minimum head of 12 feet, and are controlled by needle valves and emergency slide gates. No hydroelectric power development is proposed at this site.

Cost of Windy Gap Reservoir—The capital and annual costs of Windy Gap Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 82.

TABLE 82

COST OF WINDY GAP RESERVOIR

Height of dam, 206 feet. Capacity of reservoir, 62,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlets, 200 second-feet.

Exploration		$10,000
Diversion of river during construction		5,000
Lands and improvements flooded and clearing		265,000
Excavation for dam, 40,000 cubic yards at $1.00 to $5.00	$128,000	
Mass concrete, 225,000 cubic yards at $8.25	1,856,000	
Reinforced concrete, 800 cubic yards at $18.00 to $30.00	17,000	
Spillway gates	43,000	
Spillway channel	42,000	
Irrigation outlets and sluiceways	10,000	
Drilling, grouting, drains and contraction seals	28,000	
		2,124,000
Miscellaneous		64,000
Subtotal, dam and reservoir		2,468,000
Administration and engineering at 10 per cent		247,000
Contingencies at 15 per cent		370,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		215,000
Total capital cost of dam and reservoir		3,300,000
Total annual cost of dam and reservoir		$200,000

Friant Reservoir on San Joaquin River.

The dam site for the Friant Reservoir is located about one mile upstream from the town of Friant in the southwest quarter of Section 5, Township 11 South, Range 21 East, M. D. B. and M., at a stream bed elevation of 308 feet. It is situated in Fresno and Madera counties, about 20 miles east of the city of Madera and about 20 miles northerly from the city of Fresno.

In accord with the plan formulated, Friant Reservoir would provide primarily for the conservation and regulation of the tributary run-off of the San Joaquin River and the diversion of San Joaquin River water to the upper San Joaquin Valley to meet the needs therein of imported water supplies. San Joaquin River water now in use on lands in the lower San Joaquin Valley north of Mendota would be replaced by imported water supplies from the Sacramento River basin, conveyed to Mendota by the San Joaquin River pumping system. By means of this exchange, the imported water supplies required in the upper San Joaquin Valley would be furnished by gravity from San Joaquin River water instead of by pumping from the Sacramento River, thus saving about 300 feet in pumping head.

The drainage areas on the San Joaquin River watershed, above the Friant dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	297 square miles
Area between elevations 5000 and 10,000 feet	925 square miles
Area between elevations 2500 and 5000 feet	227 square miles
Area below elevation 2500 feet	182 square miles
Total area above Friant dam site	1631 square miles

Present Developments on San Joaquin River—Present developments on the San Joaquin River above Friant dam site are chiefly for hydroelectric power. The San Joaquin Light and Power Corporation and the Southern California Edison Company have developed four major storage reservoirs, with a combined capacity of about 334,000 acre-feet, for power regulation. The San Joaquin Light and Power Corporation has Crane Valley Reservoir on the North Fork with a capacity of 45,000 acre-feet. The regulated supply from this reservoir passes through a series of power plants, the last and largest of which is the Kerckhoff Plant on the main stream 17 miles above Friant. The Southern California Edison Company has Huntington Lake Reservoir on Big Creek, Florence Lake Reservoir on the South Fork and Shaver Lake Reservoir on Stevenson Creek, with storage capacities of 88,800, 64,400 and 135,300 acre-feet, respectively. Water from Florence Lake is diverted through a tunnel into Huntington Lake. Portions of the flows of Mono and Bear creeks also are delivered into this tunnel through a siphon across the South Fork. From Huntington Lake, the regulated flow may be utilized by the power plant known as Big Creek No. 1 and other plants below it, or it may be diverted to Shaver Lake through another tunnel. The regulated flow from Shaver Lake is utilized successively by the Big Creek Power Plants No. 2A, No. 8 and No. 3, and finally by the Kerckhoff Plant. Data on power storage developments and hydroelectric power plants on San Joaquin River are set forth in Tables 83 and 84, respectively.

TABLE 83

STORAGE RESERVOIRS FOR HYDROELECTRIC POWER DEVELOPMENT ON SAN JOAQUIN RIVER

Name of reservoir	Owner	Location	Height of dam, in feet	Capacity, in acre-feet
Crane Valley	San Joaquin Light and Power Co.	North Fork	145	45,000
Huntington Lake	Southern California Edison Co.	Big Creek	160	88,800
Florence Lake	Southern California Edison Co.	South Fork	162	64,400
Shaver Lake	Southern California Edison Co.	Stevenson Creek	171	135,300
Kerckhoff*	San Joaquin Light and Power Co.	Main river	106	4,200
Total				337,700

*For diversion purposes only.

TABLE 84

HYDROELECTRIC POWER PLANTS ON SAN JOAQUIN RIVER

Name of plant	Owner	Location	Installed capacity in kilovolt-amperes
Crane Valley	San Joaquin Light and Power Co.	North Fork	1,000
San Joaquin No. 3	San Joaquin Light and Power Co.	North Fork	3,750
San Joaquin No. 2	San Joaquin Light and Power Co.	North Fork	3,000
San Joaquin No. 1A	San Joaquin Light and Power Co.	Canal above main river	425
San Joaquin No. 1	San Joaquin Light and Power Co.	Main river	16,000
Kerckhoff	San Joaquin Light and Power Co.	Main river	42,600
Big Creek No. 1	Southern California Edison Co.	Big Creek	80,500
Big Creek No. 2A	Southern California Edison Co.	Big Creek	90,000
Big Creek No. 2	Southern California Edison Co.	Big Creek	70,000
Big Creek No. 8	Southern California Edison Co.	Big Creek	60,000
Big Creek No. 3	Southern California Edison Co.	Main river	84,000
Total			451,275

The Soquel Ditch belonging to the Madera Canal and Irrigation Company diverts water from the North Fork and releases it into Nelder Creek, a tributary of Fresno River. This ditch has a right to 50 second-feet when that amount is flowing in the stream. The average seasonal exportation is estimated to be about 5400 acre-feet. A discussion of present irrigation development and the status of existing water rights below Friant have been presented in Chapter IV.

Water Supply—The water supply available for regulation at the Friant site consists of the natural run-off of the San Joaquin River impaired by the operation of the up-stream developments previously discussed. The average seasonal ultimate net run-off for the 40-year period, 1889–1929, would have been 1,993,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Economic Considerations Governing the Selection of the Friant Site—In order to secure maximum economic regulation of the San Joaquin River and minimum interference with power uses on the upper reaches of the stream, a reservoir located near the valley floor is desirable. However, consideration of the rather unfavorable characteristics of the Friant dam site, which render storage development relatively expensive, namely, the shallow "U" shaped profile of the site, the great length of dam for the required height, and the necessity of having a dead storage volume of 130,000 acre-feet below the gravity diversion level required for serving the areas south of San Joaquin River, resulted in a careful investigation of the entire San Joaquin River to determine the possibility of securing a more economical storage and diversion development.

This investigation included the Temperance Flat dam site, six miles upstream from Friant, and topographic surveys and studies of other possible storage sites on the main San Joaquin River from its junction with Big Creek to several miles above the junction of the Middle and South forks. These surveys were mapped on a scale of one inch equals 400 feet. Consideration of these data and various geological reports eliminated from more detailed study all sites except Temperance Flat and Friant.

A contour map of the Friant Reservoir site, scale one inch equals 200 feet, was prepared from surveys made by Madera Irrigation District in 1921. A map of the dam site, scale one inch equals 100 feet, was prepared from these surveys and supplemental surveys made by the State in 1925. A contour map of the Temperance Flat Reservoir site, scale one inch equals 1000 feet, and one of the dam site, scale one inch equals 100 feet, were prepared from surveys made by the State in 1925 and 1930, respectively.

Table 85 sets forth areas and gross capacities for reservoirs with various heights of dam at the Friant site and Table 86 sets forth corresponding data for the Temperance Flat site.

TABLE 85

AREAS AND CAPACITIES OF FRIANT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Gross capacity of reservoir, in acre-feet
37	340	200	2,000
57	360	420	8,000
77	380	660	19,000
97	400	880	34,000
117	420	1,140	55,000
137	440	1,440	80,000
157	460	1,880	114,000
177	480	2,340	156,000
197	500	2,820	208,000
217	520	3,320	269,000
237	540	3,820	340,000
252	555	4,200	400,000
257	560	4,320	422,000
277	580	4,840	513,000
297	600	5,380	615,000
317	620	5,920	728,000
337	640	6,480	853,000

TABLE 86

AREAS AND CAPACITIES OF TEMPERANCE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
65	450	67	2,000
90	475	114	4,300
115	500	191	8,100
140	525	275	13,900
165	550	376	22,000
190	575	498	32,900
215	600	632	47,100
240	625	822	64,600
265	650	1,042	88,500
290	675	1,270	117,000
315	700	1,520	152,000
340	725	1,790	194,000
365	750	2,048	242,000
390	775	2,334	296,000
415	800	2,642	359,000
440	825	2,981	429,000
465	850	3,338	508,000
490	875	3,728	596,000
515	900	4,070	694,000
540	925	4,469	801,000
565	950	4,856	917,000
590	975	5,251	1,043,000
615	1,000	5,630	1,180,000

After making detailed cost estimates of various heights of dam at each site, comparisons were made of all economic factors of each reservoir for equal net capacities. The results are shown in Table 87 and graphically on Plate XLIII, "Economic Comparison of Friant and Temperance Flat Reservoirs on San Joaquin River." Both sites are situated at low elevations in the watershed area and are in a position to give maximum regulation of the stream flow. The water surface of the Temperance Flat Reservoir with a capacity of 100,000 acre-feet or over would interfere with the operation of the existing Kerckhoff Power Plant of the San Joaquin Light and Power Company.

Curve No. 1 on Plate XLIII shows the cost of rebuilding the Kerckhoff Power Plant plus the capitalized value of the loss in power output that would result from the operation of reservoirs of various capacities at the Temperance Flat site, based on a power value of $0.004 per kilowatt hour capitalized at 10 per cent. Curve No. 2 gives the total cost of Temperance Flat Dam and Reservoir for various capacities, including all lands and improvements flooded with the exception of Kerckhoff Power Plant. Curve No. 3 is the summation of corresponding values in curves No. 1 and No. 2, plus the cost of a 4500 second-foot capacity conveyance channel between Temperance Flat and Friant sites and a 1500 second-foot siphon across the San Joaquin River to connect with the Madera Canal. It shows the total cost of Temperance Flat Reservoir on a basis comparable with Friant, with the exception of credit for power which could be generated at the former site. Curve No. 4 was developed by adding, to corresponding values in Curve 3, the costs of developing sufficient dead storage to give equal capacities in the upper half (water depth) of Temperance Flat Reservoir, the costs of power plants installed for maximum effective heads and 3000 second-feet capacity, and the cost of reinforcing the outlet tunnel for power head, less the value of the power yield at $0.003 per kilowatt hour capitalized at 10 per cent. Curve No. 5 shows the cost

Net storage capacity, in acre-feet	Estimated cost of interference of Temperance Flat Reservoir with Kerckhoff Power Plant[1]	Estimated cost of Temperance Flat Reservoir	(T F vo ( ] p an fro r Fri	Net capital power credit (Value of power, (Col. 12) less total cost of power plant (Col. 10))	Net capital cost of Temperance Flat Reservoir and power plant (Values in Col. 4 less values in Col. 13)	Capital cost of Friant Reservoir	Net capital cost of Temperance Flat project in excess of Friant project
	(1)	(2)		(13)	(14)	(15)	(16)
1,000,000	$8,000,000	$38,200,000		$6,147,000	$50,453,000	--------------	--------------
900,000	8,000,000	34,100,000		5,802,000	46,398,000	--------------	--------------
800,000	8,000,000	30,100,000		5,480,000	42,220,000	--------------	--------------
700,000	7,900,000	26,300,000		5,045,000	38,055,000	$35,000,000	$3,055,000
600,000	7,600,000	22,600,000		4,620,000	33,880,000	29,500,000	4,380,000
500,000	7,000,000	19,000,000		4,136,000	29,764,000	24,400,000	5,364,000
400,000	6,200,000	15,500,000		3,577,000	25,623,000	19,600,000	6,023,000
300,000	5,000,000	12,100,000		2,953,000	21,347,000	15,200,000	6,147,000
200,000	3,600,000	9,000,000		2,308,000	16,892,000	11,300,000	5,592,000
100,000	1,600,000	6,100,000		1,499,000	12,101,000	7,800,000	4,301,000

[1] Includes cost of moving power plant plus ... ead 350 feet.
[2] Conduit comprises 4,500 linear feet of tu... t of $5,000,000.
[3] This assumes dead storage in the lower l... velopment. Dead storage would amount to 20,000 and 120,000 acre-feet respectively for utilizable ne...
[4] Outlet elevation 480 feet.
[5] Capacity 3,000 second-feet; maximum e...
[6] Based on an overall plant efficiency of 7...

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TABLE 86

AREAS AND CAPACITIES OF TEMPERANCE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
65	450	67	2,000
90	475	114	4,300
115	500	191	8,100
140	525	275	13,900
165	550	376	22,000
190	575	498	32,900
215	600	632	47,100
240	625	822	64,600
265	650	1,042	88,500
290	675	1,270	117,000
315	700	1,520	152,000
340	725	1,790	194,000
365	750	2,048	242,000
390	775	2,334	296,000
415	800	2,642	359,000
440	825	2,981	429,000
465	850	3,338	508,000
490	875	3,728	596,000
515	900	4,070	694,000
540	925	4,469	801,000
565	950	4,856	917,000
590	975	5,251	1,043,000
615	1,000	5,630	1,180,000

After making detailed cost estimates of various heights of dam at each site, comparisons were made of all economic factors of each reservoir for equal net capacities. The results are shown in Table 87 and graphically on Plate XLIII, ''Economic Comparison of Friant and Temperance Flat Reservoirs on San Joaquin River.'' Both sites are situated at low elevations in the watershed area and are in a position to give maximum regulation of the stream flow. The water surface of the Temperance Flat Reservoir with a capacity of 100,000 acre-feet or over would interfere with the operation of the existing Kerckhoff Power Plant of the San Joaquin Light and Power Company.

Curve No. 1 on Plate XLIII shows the cost of rebuilding the Kerckhoff Power Plant plus the capitalized value of the loss in power output that would result from the operation of reservoirs of various capacities at the Temperance Flat site, based on a power value of $0.004 per kilowatt hour capitalized at 10 per cent. Curve No. 2 gives the total cost of Temperance Flat Dam and Reservoir for various capacities, including all lands and improvements flooded with the exception of Kerckhoff Power Plant. Curve No. 3 is the summation of corresponding values in curves No. 1 and No. 2, plus the cost of a 4500 second-foot capacity conveyance channel between Temperance Flat and Friant sites and a 1500 second-foot siphon across the San Joaquin River to connect with the Madera Canal. It shows the total cost of Temperance Flat Reservoir on a basis comparable with Friant, with the exception of credit for power which could be generated at the former site. Curve No. 4 was developed by adding, to corresponding values in Curve 3, the costs of developing sufficient dead storage to give equal capacities in the upper half (water depth) of Temperance Flat Reservoir, the costs of power plants installed for maximum effective heads and 3000 second-feet capacity, and the cost of reinforcing the outlet tunnel for power head, less the value of the power yield at $0.003 per kilowatt hour capitalized at 10 per cent. Curve No. 5 shows the cost

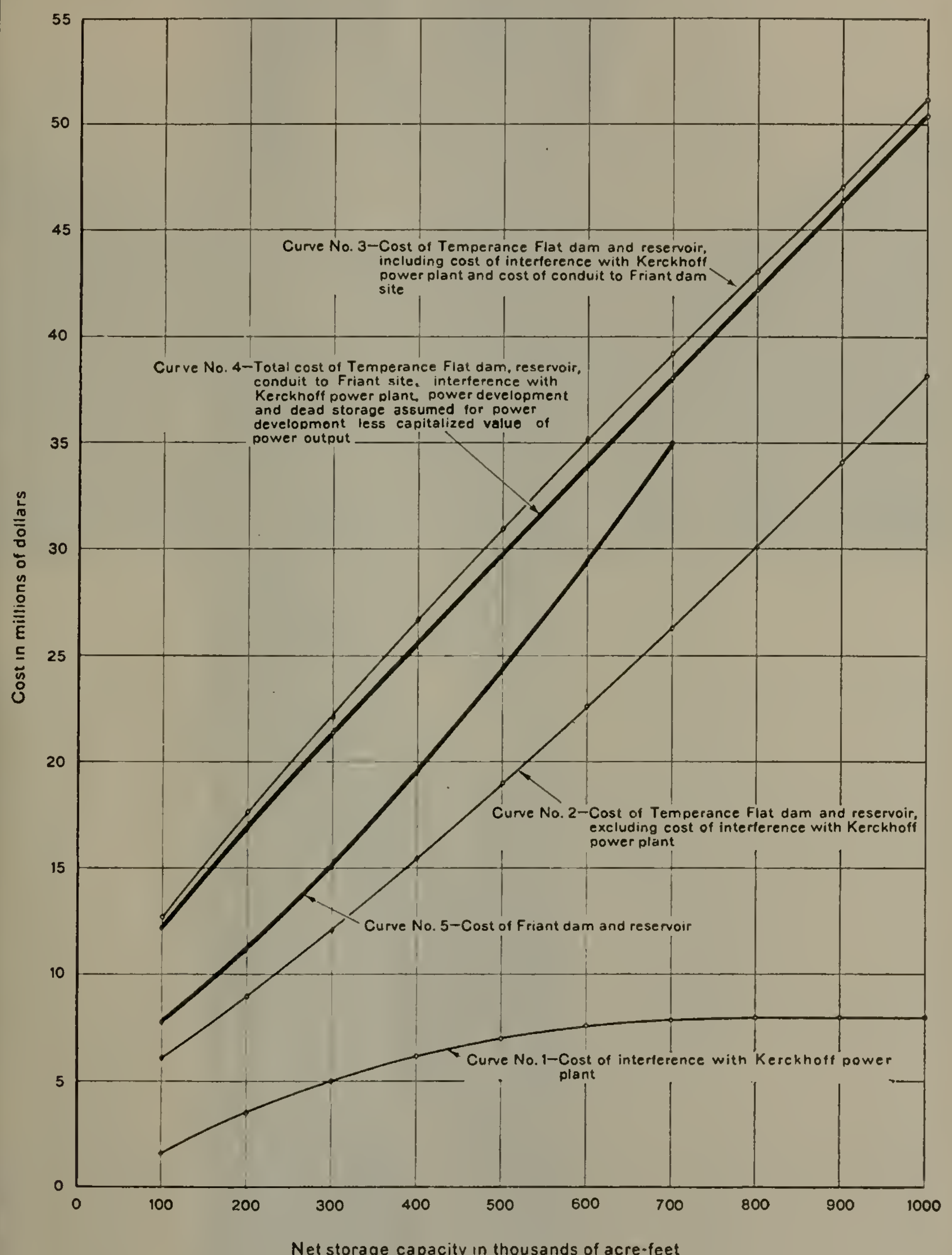
TABLE 87

ECONOMIC COMPARISON OF TEMPERANCE FLAT AND FRIANT RESERVOIRS

Net storage capacity, in acre-feet	Estimated cost of interference of Temperance Flat Reservoir with Kerckhoff Power Plant[1]	Estimated cost of Temperance Flat Reservoir	Combined cost of Temperance Flat Reservoir, interference with Kerckhoff power plant and a conduit from Temperance Flat reservoir to Friant dam site[2]	Cost for same items as column (3) but with utilizable storage in upper half-depth of reservoir[3]	Flow line elevations with utilizable storage in upper half-depth of reservoir, in feet	Temperance Flat Reservoir Power Plant: Maximum power head, in feet[4]	Approximate average operating head, in feet	Cost of power plant, at $50 per kilovolt ampere[5]	Cost of putting outlet tunnel under pressure	Total cost of power plant and pressure outlet tunnel	Average seasonal water supply passing through power plant, in acre-feet	Value of power at $0.003 per kilowatt hour capitalized at 10 per cent[6]	Net capital power credit (Value of power, (Col. 12) less total cost of power plant (Col. 10))	Net capital cost of Temperance Flat Reservoir and power plant (Values in Col. 4 less values in Col. 13)	Capital cost of Friant Reservoir	Net capital cost of Temperance Flat project in excess of Friant project
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1,000,000	$8,000,000	$38,200,000	$51,200,000	$56,600,000	991	511	384	$6,898,000	$675,000	$7,573,000	1,550,000	$13,720,000	$6,147,000	$50,453,000	----------	----------
900,000	8,000,000	34,100,000	47,100,000	52,200,000	972	492	369	6,642,000	655,000	7,297,000	1,540,000	13,099,000	5,802,000	46,398,000	----------	----------
800,000	8,000,000	30,100,000	43,100,000	47,700,000	950	470	353	6,345,000	625,000	6,970,000	1,530,000	12,450,000	5,480,000	42,220,000	----------	----------
700,000	7,900,000	26,300,000	39,200,000	43,100,000	924	444	333	5,994,000	590,000	6,584,000	1,515,000	11,629,000	5,045,000	38,055,000	$35,000,000	$3,055,000
600,000	7,600,000	22,600,000	35,200,000	38,500,000	898	418	313	5,643,000	560,000	6,203,000	1,500,000	10,823,000	4,620,000	33,880,000	29,500,000	4,380,000
500,000	7,000,000	19,000,000	31,000,000	33,900,000	868	388	291	5,238,000	520,000	5,758,000	1,475,000	9,894,000	4,136,000	29,764,000	24,400,000	5,364,000
400,000	6,200,000	15,500,000	26,700,000	29,200,000	836	356	267	4,806,000	480,000	5,286,000	1,440,000	8,863,000	3,577,000	25,623,000	19,600,000	6,023,000
300,000	5,000,000	12,100,000	22,100,000	24,300,000	798	318	238	4,293,000	435,000	4,728,000	1,400,000	7,681,000	2,953,000	21,347,000	15,200,000	6,147,000
200,000	3,600,000	9,000,000	17,600,000	19,200,000	749	269	202	3,631,000	370,000	4,001,000	1,355,000	6,309,000	2,308,000	16,892,000	11,300,000	5,592,000
100,000	1,600,000	6,100,000	12,700,000	13,600,000	679	199	149	2,686,000	280,000	2,966,000	1,300,000	4,465,000	1,499,000	12,101,000	7,800,000	4,301,000

[1] Includes cost of moving power plant plus value of loss in power at $0.004 per kilowatt hour capitalized at 10 per cent. Low water level at present discharge, elevation 635 feet. Present total head 350 feet.
[2] Conduit comprises 4,500 linear feet of tunnel and 30,000 linear feet of open channel of 4,500 second feet capacity and siphon at Friant site of 1,500 second-feet capacity, with estimated cost of $5,000,000.
[3] This assumes dead storage in the lower half-depth of the reservoir with flow line elevations for full reservoir as in Col. (5), for the purpose of obtaining a greater net return from power development. Dead storage would amount to 20,000 and 120,000 acre-feet respectively for utilizable net storage capacities of 100,000 and 1,000,000 acre-feet.
[4] Outlet elevation 480 feet
[5] Capacity 3,000 second-feet; maximum efficiency 85 per cent; power factor 0.80.
[6] Based on an overall plant efficiency of 75 per cent.

PLATE XLIII



ECONOMIC COMPARISON

OF

FRIANT AND TEMPERANCE FLAT RESERVOIRS

ON

SAN JOAQUIN RIVER

PLATE XLIV

FRIANT DAM SITE ON SAN JOAQUIN RIVER

of Friant Reservoir with equivalent net storage capacities above the required diversion elevation. A comparison of curves No. 4 and No. 5 shows that, for any capacity below 700,000 acre-feet, the Friant Reservoir Project would be the more economical.

PLATE XLV

TEMPERANCE FLAT DAM SITE ON SAN JOAQUIN RIVER

Economic Capacities of Friant Reservoir and San Joaquin River-Kern County Canal for Ultimate Development—The function of Friant Reservoir in the ultimate development of the State Water Plan for the San Joaquin River basin is to furnish that portion of the water requirements within the areas on the east side of the upper San Joaquin Valley (included within hydrographic divisions Nos. 1, 2, 3, 4 and 6) which can not be met by the development of all local sources of supply. It is proposed to provide for the fullest practicable regulation of the available ultimate net run-off of the San Joaquin River in the Friant Reservoir and distribute the regulated supplies therefrom through conduits leading north and south from the reservoir. The storage capacity of Friant Reservoir, therefore, should be made sufficient to regulate the available run-off and furnish the water supplies at the rates and in the total amounts required.

The water supply required from Friant Reservoir for the ultimate development within Hydrographic Division No. 6 (Madera Unit) is fixed in accord with the assumed right of the proposed development of the Madera Irrigation District to acquire and divert a total seasonal water supply of 350,000 acre-feet. This water requirement also fixes the capacity of the proposed Madera Canal at 1500 second-feet. The water supply required from Friant Reservoir for the ultimate development of the remaining portion of the east side of the upper San Joaquin Valley to be served from this reservoir depends upon a determination of the amount of water that can be obtained from the fullest practicable development and utilization of the water supplies locally tributary thereto. This has involved a long and complicated analysis with a multiplicity of trial studies including analyses of surface and underground storage regulation and utilization. The results of these studies are presented hereafter in this chapter and in

Chapter VII. In order to arrive at the amount of water required from the San Joaquin River and the most desirable and economical degree of regulation at Friant Reservoir, it was necessary to consider the regulation and utilization of the local water supplies in combination with the supply to be obtained from Friant Reservoir. The studies show that a total average seasonal water supply of about 1,335,000 acre-feet from Friant Reservoir during the 40-year period, 1889–1929, would adequately satisfy the requirements for supplemental supply in the areas of deficiency.

The determination of the economic capacity of Friant Reservoir to furnish this water requirement for ultimate development of the upper San Joaquin Valley involves a consideration of cost of storage, cost of conveyance canals leading from the reservoir and cost of water supply utilization, to ascertain the minimum amount of these combined elements of cost of the water supply to be furnished. The capacity of the Madera Canal is fixed, as previously stated, by the delivery requirements for the Madera unit. However, the capacity the San Joaquin River-Kern County Canal, which is provided in the plan to convey water southerly from Friant Reservoir to the area on the east side of the San Joaquin Valley south of the San Joaquin River, is interrelated to and dependent upon the capacity of the reservoir. Equal yields could be obtained with varying amounts of reservoir and canal capacity operating in combination. It is necessary, therefore, to determine, for the yield required, the size of the reservoir and conduit which would result in the least combined cost. In addition, the cost of utilization by pumping from underground of supplies furnished from Friant Reservoir must be compared with the cost of providing storage to furnish surface irrigation supplies in the irrigation season, in lieu of pumping, to finally determine the minimum combined cost of storage, conveyance and utilization.

Studies pertaining to the determination of the minimum combined cost of Friant Reservoir storage and the San Joaquin River-Kern County Canal are presented in Table 88 and on Plate XLVI, "Curves of Equal Total Annual Cost and of Equal Mean Seasonal Yields for the Operation of Friant Reservoir and San Joaquin River-Kern County Canal for Various Capacities, 1889–1929." Table 88 shows the estimated annual cost for the canal with various capacities, the average seasonal yield in acre-feet for different combinations of reservoir and canal capacity and the estimated combined annual cost of canal and reservoir for different combinations of canal and reservoir capacity, based on the available run-off for the 40-year period, 1889–1929. The estimated reservoir yields are based upon the assumption that surface storage would be provided only as required to permit of maximum utilization of the water supplies furnished to the areas served through the combined means of surface irrigation and ground water storage and pumping. The storage capacities shown in Table 88 are those required to furnish the water supply for the Madera unit as well as the area south of the San Joaquin River. However, the yields shown in the table for various storage capacities are those for the area south of the San Joaquin River only. Plate XLVI has been compiled from the data presented in Table 88. The combinations of reservoir and canal capacities for various yields which would result in obtaining the

TABLE 88

COMBINED ANNUAL COSTS OF FRIANT RESERVOIR AND SAN JOAQUIN RIVER-KERN COUNTY CANAL FOR VARIOUS CAPACITIES WITH AVERAGE SEASONAL YIELDS FOR THE 40-YEAR PERIOD, 1889-1929, FOR AREAS SOUTH OF SAN JOAQUIN RIVER

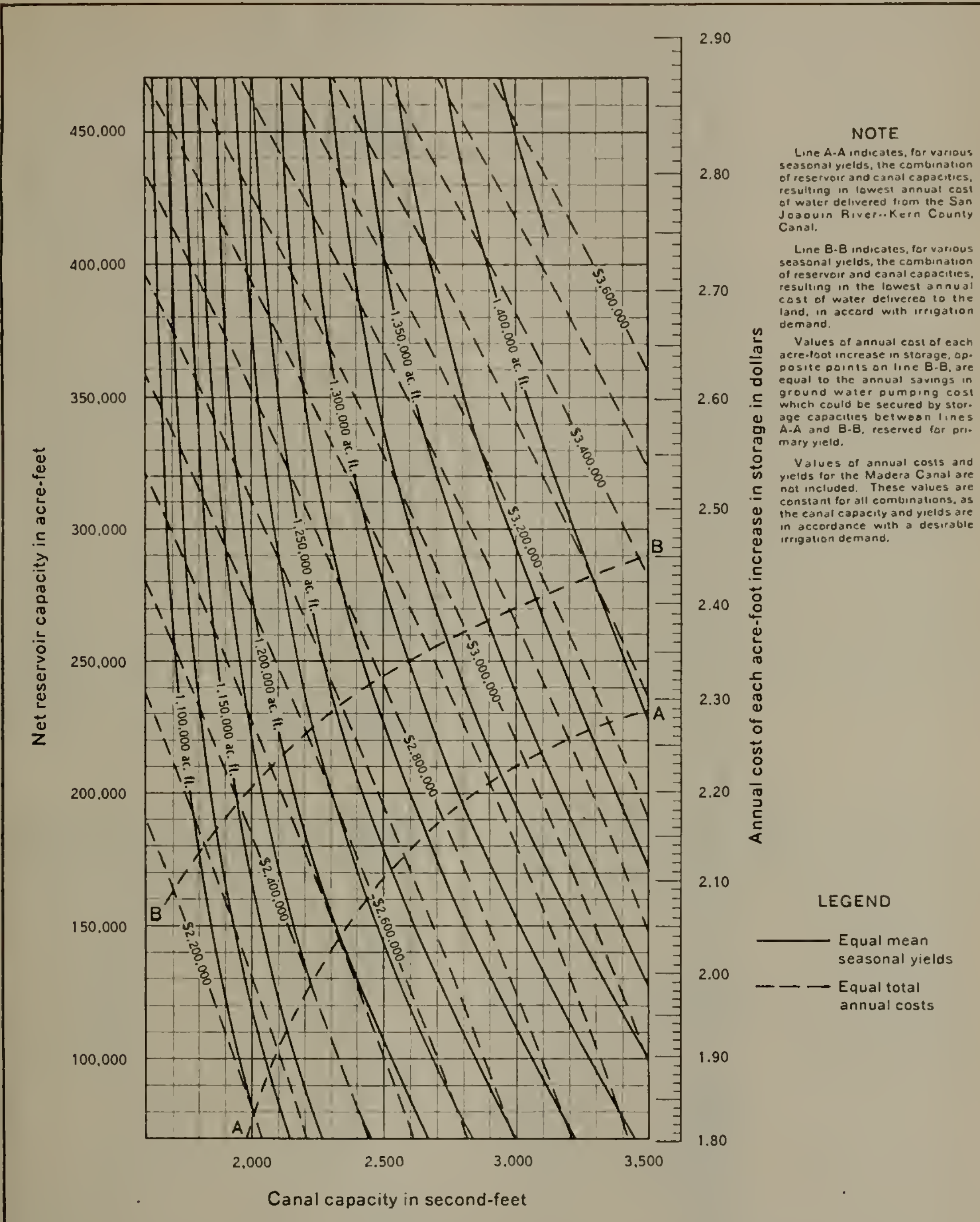
Utilizable storage capacity of reservoir, in acre-feet	Annual cost of reservoir	Canal capacity, 2,000 second-feet. Annual cost of canal, $1,760,000		Canal capacity, 2,500 second-feet. Annual cost of canal, $2,021,000		Canal capacity, 3,000 second-feet. Annual cost of canal, $2,281,000		Canal capacity, 3,500 second-feet. Annual cost of canal $2,535,000,	
		Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir	Average seasonal yield, in acre-feet	Combined annual cost of canal and reservoir
0	$300,000	------	$2,060,000	------	$2,321,000	------	$2,581,000	------	$2,835,000
50,000	385,000	1,075,000	2,145,000	1,175,000	2,406,000	1,245,000	2,666,000	1,295,000	2,920,000
100,000	475,000	1,115,000	2,235,000	1,200,000	2,496,000	1,270,000	2,756,000	1,325,000	3,010,000
150,000	574,000	1,140,000	2,334,000	1,230,000	2,595,000	1,300,000	2,855,000	1,360,000	3,109,000
200,000	678,000	1,165,000	2,438,000	1,260,000	2,699,000	1,330,000	2,959,000	1,385,000	3,213,000
250,000	793,000	1,185,000	2,553,000	1,285,000	2,814,000	1,355,000	3,074,000	1,410,000	3,328,000
300,000	911,000	1,205,000	2,671,000	1,310,000	2,932,000	1,375,000	3,192,000	------	3,446,000
350,000	1,040,000	1,220,000	2,800,000	1,330,000	3,061,000	1,395,000	3,321,000	------	3,575,000
400,000	1,170,000	1,230,000	2,930,000	1,350,000	3,191,000	1,410,000	3,451,000	------	3,705,000
450,000	1,310,000	1,240,000	3,070,000	1,360,000	3,331,000	1,425,000	3,591,000	------	3,845,000

minimum combined annual costs are indicated on Plate XLVI by the dotted curve designated "A-A". For the required average seasonal yield of 1,335,000 acre-feet for the area south of the San Joaquin River, the most economical combination would be a reservoir capacity of 210,000 acre-feet and a canal capacity of 3000 second-feet.

The total average seasonal yield of 1,335,000 acre-feet, obtainable from Friant Reservoir with a capacity of 210,000 acre-feet, for use in the area south of the San Joaquin River would be furnished in part during the irrigation season to directly meet the irrigation demands and in part outside of the irrigation season. The portions of the total supply so delivered are designated, respectively, "in-season" water and "out-of-season" water. "Out-of-season" water would be stored underground and its utilization would require pumping. Consideration has been given to the cost of utilizing by pumping such "out-of-season" water as compared to the cost of providing additional storage in Friant Reservoir to furnish a greater amount of "in-season" water for a surface irrigation supply in place of a pumped supply. The economic limit of additional storage to provide a greater amount of "in-season" water would be arrived at when the annual cost of such additional storage becomes equal to the cost of pumping an equivalent supply from underground. In making this economic study, pumping costs have been segregated into charges for, first, operation and energy estimated at three cents per foot acre-foot of water pumped, and, second, interest and other fixed charges estimated at two cents per foot acre-foot of water pumped. Operation and energy charges are based upon average pumping lifts and the average amount of water pumped over the period considered. However, interest and fixed charges are based upon the required maximum installed pumping capacity which would be fixed by the maximum pumping lift and the maximum amount of water to be pumped in a season of minimum yield such as 1923–1924. For the period 1889–1929 considered, it has been conservatively assumed that the maximum pumping lift, including draw-down, would have been 75 feet and that the average pumping lift, including draw-down, would have been 45 feet.

Table 89 sets forth additional average seasonal yields of "in-season" water that could have been secured during various periods with an assumed additional reservoir capacity of 100,000 acre-feet. The data are compiled for various combinations of reservoir and canal capacities. The net reservoir capacity, exclusive of the additional storage provided for additional "in-season" water, is shown at the head of the columns and the total reservoir capacity, including additional storage for "in-season" water, is shown at the bottom of the columns. The data in this table are presented chiefly for the purpose of showing the effect of additional storage upon the volume of "in-season" water supply obtainable. The data show that the yield of "in-season" water obtained in per cent of the additional storage provided for this purpose varies considerably for different combinations of reservoir and canal capacity and for the different periods of run-off considered. The additional amount of "in-season" water for a given storage capacity increases with greater canal capacity, and, for a given canal capacity, decreases with larger reservoir capacity.

PLATE XLVI



CURVES OF EQUAL TOTAL ANNUAL COSTS

AND OF

EQUAL MEAN SEASONAL YIELDS

FOR THE OPERATION OF

FRIANT RESERVOIR

AND

SAN JOAQUIN RIVER--KERN COUNTY CANAL

1889--1929

TABLE 89

AVERAGE SEASONAL QUANTITIES OF IRRIGATION SUPPLY TRANSFERABLE FROM "OUT-OF-SEASON" TO "IN-SEASON" DELIVERY BY AN ADDITIONAL STORAGE CAPACITY OF 100,000 ACRE-FEET IN FRIANT RESERVOIR

Capacity of San Joaquin River-Kern County Canal, in second-feet	3,500		3,000				2,500			2,000	
Net reservoir capacity, exclusive of additional storage, in acre-feet	75,000	170,000	75,000	170,000	270,000	370,000	75,000	170,000	270,000	75,000	170,000
Period	Average seasonal increase of in-season water, in acre-feet										
1889–1929	91,000	74,000	84,100	59,200	51,500	48,800	72,200	45,200	35,500	49,300	26,400
1909–1929	91,800	77,500	87,400	64,900	58,000	55,000	78,100	51,800	44,600	58,400	32,000
1917–1929	92,900	91,100	91,100	81,600	76,000	72,300	89,700	70,100	60,600	72,600	38,900
1922–1929	89,800	85,800	89,900	79,000	72,000	68,600	87,700	65,400	57,600	66,100	45,800
Total reservoir capacity, including additional storage for increasing in-season water, in acre-feet	175,000	270,000	175,000	270,000	370,000	470,000	175,000	270,000	370,000	175,000	270,000

The period, 1917–1929, shows the largest amounts of additional "in-season" water as related to the additional storage. In a season of minimum run-off such as 1923–1924, the studies show that the increased amount of "in-season" water obtainable would be practically equal to the additional storage capacity provided up to 100,000 acre-feet or more. It should be noted that the provision of additional storage capacity for the purpose of obtaining an increased amount of "in-season" water would not appreciably increase the total seasonal reservoir yield.

The data on the permissible economic increase in storage capacity (above the economic storage capacity shown by Curve "A-A" on Plate XLVI), for providing additional "in-season" water to furnish a surface irrigation supply in place of "out-of-season" supplies requiring ground water storage and pumping are presented in Table 90. Starting with the economic reservoir and canal capacities as shown by curve "A-A" on Plate XLVI, trial studies were made using different amounts of additional reservoir capacity for obtaining increased amounts of "in-season" water and comparative estimates made of cost of additional storage and savings that would be effected in pumping costs. The economic additional storage capacities shown in Table 90 are those for which a balance was reached between cost of additional storage and the saving in pumping cost effected by the substitution for a pumped supply of the "in-season" surface irrigation supply obtained from the additional storage.

TABLE 90

ECONOMIC INCREASE OF STORAGE CAPACITY IN FRIANT RESERVOIR FOR PROVIDING ADDITIONAL "IN-SEASON" SURFACE IRRIGATION SUPPLIES IN PLACE OF "OUT-OF-SEASON" SUPPLIES REQUIRING GROUND WATER STORAGE AND PUMPING

San Joaquin River-Kern County Canal capacity, in second-feet	Economic net reservoir capacity exclusive of additional storage, in acre-feet	Economic additional storage capacity, in acre-feet	Total net storage capacity, in acre-feet	Average seasonal increase of in-season water for 40-year period 1889-1929, in per cent of additional storage capacity
2,000	80,000	120,000	200,000	47
2,500	170,000	75,000	245,000	55
3,000	210,000	60,000	270,000	60
3,500	230,000	60,000	290,000	64

To illustrate the method of determining the economic additional storage capacities shown in Table 90, the following example is presented:

With a canal capacity of 3000 second-feet and an economic net reservoir capacity of 210,000 acre-feet as shown by Curve "A-A" on Plate XLVI, an additional storage capacity of 60,000 acre-feet reserved for providing additional "in-season" water would have resulted in an average increase of 36,000 acre-feet of "in-season" water during the 40-year period, 1889–1929. The additional average yield of "in-season" water is 60 per cent of the additional storage capacity provided for this purpose. In a season of minimum run-off such as 1923–1924, the additional amount of "in-season" water obtained would have been 60,000 acre-feet or 100 per cent of the additional storage provided. As shown on Plate XLVI, the average annual cost per acre-foot of the additional 60,000 acre-feet of storage capactiy is $2.31.

The saving which would be effected in pumping cost is estimated as follows: Interest and fixed charges would be based upon the maximum required pumping installation to furnish a water supply equivalent in amount to that provided by the additional storage capacity in a season of minimum run-off such as 1923–1924. On this basis the cost per acre-foot for interest and fixed charges on pumping, with an estimated maximum lift of 75 feet and a volume of pumping equal to 100 per cent of the additional storage capacity provided, would be \$1.50 (\$0.02×75×100%). Operation and energy charges would be based upon an average estimated pumping lift of 45 feet and an average volume of water pumped during the 40-year period of 60 per cent of the additional storage capacity provided. On this basis operation and energy charges would amount to \$0.81 (\$0.03×45×60%). The total annual cost per acre-foot which would be saved in pumping costs would, therefore, be $2.31, or an amount equal to the cost per acre-foot of additional storage capacity to provide the substitute "in-season" surface irrigation supply. A further additional storage of 30,000 acre-feet would increase the average amount of "in-season" water by 50 per cent of such additional storage. The average annual cost of an additional 30,000 acre-feet of storage, as shown by Plate XLVI, would be about $2.44 per acre-foot. The saving in pumping cost by the substitution of the surface irrigation supply obtained thereby would be but $2.18 per acre-foot. Hence, any further additional storage capacity in excess of 60,000 acre-feet to provide additional "in-season" water would result in a greater annual cost for storage than the saving in pumping cost that could be effected. The additional economic storage capacities for other combinations of canal and reservoir capacity have been estimated similarly.

Based upon the data presented in Table 90, the dotted curve, designated as "B-B," has been plotted on Plate XLVI. The points on this curve show the approximate economic capacity of Friant Reservoir for different capacities of the San Joaquin River-Kern County Canal, based upon obtaining the most economical combination of all elements of cost, including storage, conveyance and water supply utilization. Since the total seasonal yield is not materially increased by the additional storage provided for increasing the amount of "in-season" water, the seasonal yields, for the combination of reservoir and canal capacities indicated by curve "B-B," are shown for particular canal capacities by the points of intersection of curve "A-A" with the yield curves. Based on the required yield of Friant Reservoir to furnish the ultimate requirements for an imported water supply to the area on the east side of the upper San Joaquin Valley south of the San Joaquin River, it is finally concluded that the most desirable and economic capacities for Friant Reservoir and the San Joaquin River-Kern County Canal would be 270,000 acre-feet and 3000 second-feet respectively. This required reservoir capacity would be above the required diversion level of the San Joaquin River-Kern County Canal below which there would be a dead storage of 130,000 acre-feet. The required gross storage capacity of Friant Reservoir would, therefore be 400,000 acre-feet, with a net utilizable storage of 270,000 acre-feet

Based upon the adopted canal capacities of 3000 second-feet for the San Joaquin River-Kern County Canal and 1500 second-feet for the Madera Canal, the cost of storage and seasonal yield for various reservoir capacities is shown on Plate XLVII, "Cost of Reservoir Capacity and Unit Yield of Water for Irrigation from Friant Reservoir."

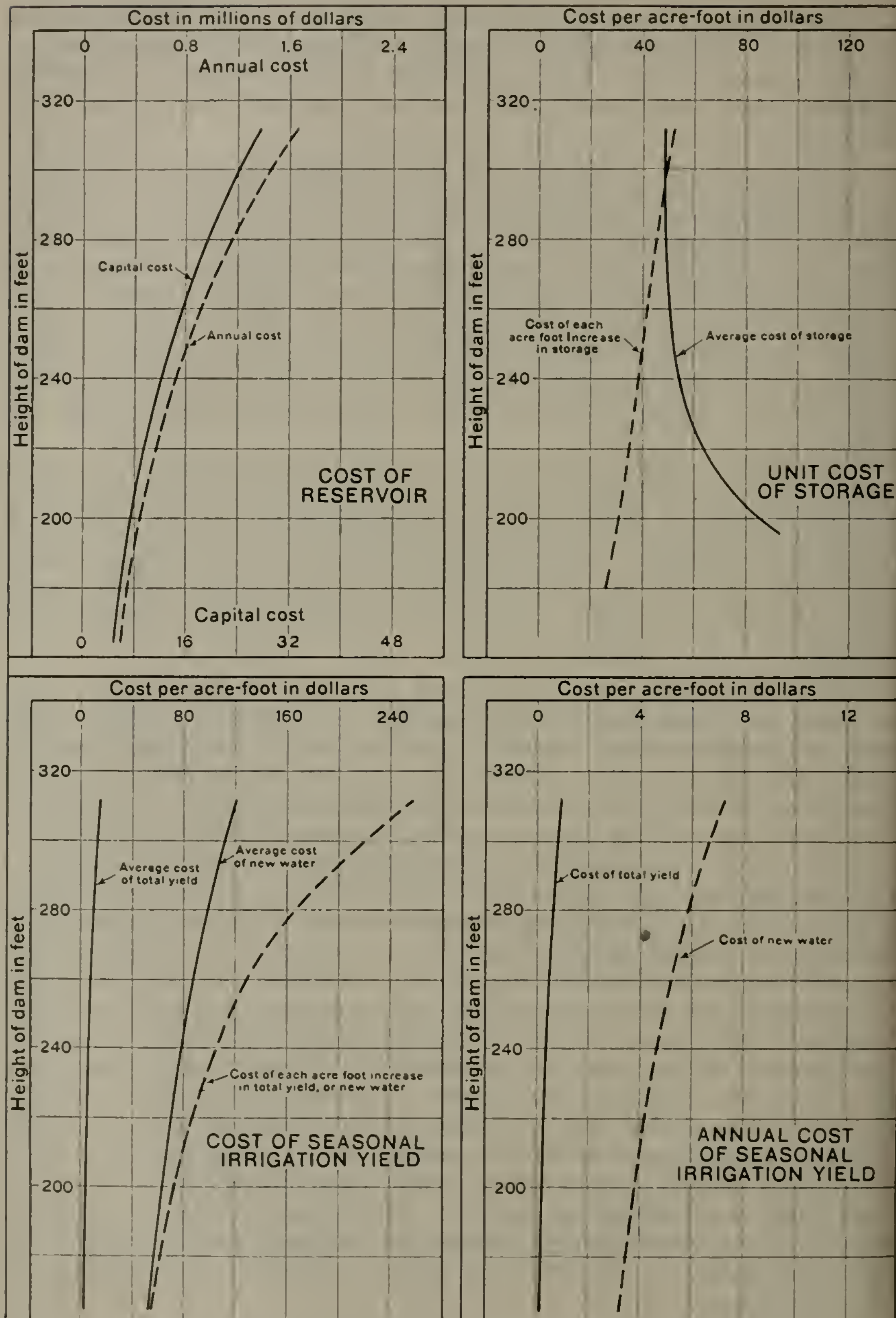
Reservoir Site and Yield—The Friant Reservoir site is situated in the low mountain or foothill area just above the point where the San Joaquin River has cut its channel into the eastern rim of the valley floor. The bottom of the reservoir basin around the site of the former town of Millerton is open. The side slopes further upstream are covered with brush and a few pine trees. The area is used for cattle range. At the flow line elevation of 555 feet for a gross storage capacity of 400,000 acre-feet, the reservoir would flood an area of 4200 acres having a length of six miles and a maximum width of about two miles.

In making yield studies at this site, a net seasonal reservoir evaporation loss of 4.0 feet in depth on the reservoir surface was used. For the 40-year period, 1889–1929, the operation of this reservoir in conjunction with ground water storage in the upper San Joaquin Valley would have resulted in an average irrigation yield of 1,726,000 acre-feet. Details of reservoir yields and utilization are presented in Chapter VII.

Dam Site—The dam site, located about one mile upstream from the town of Friant, has a rather shallow "U" shaped profile so that with the height of dam proposed, 252 feet above the stream bed, the total crest length would be 3800 feet. A geological examination was made of river channel and slopes from Friant upstream to Temperance Flat dam site and the general geology together with the results of detailed examinations of Friant, Fort Millerton and Temperance Flat sites are presented in Appendix C. The Friant site occupies an area of complex metamorphic rocks which have been given the general name, mica schist. Sound rock is found at the surface in the streambed and at moderate depths below the side slope surface. The Madera Irrigation District has explored the site with test pits and diamond drill holes and examination of test pits and analyses of cores reveal the character of the bed rock to be entirely satisfactory as a foundation for a concrete structure as proposed. It is estimated that the sound rock should be found at a depth of about 25 feet measured at right angles to the slope on the left abutment. An average depth of stripping of 40 feet may be required on the right abutment, as a portion of it contains an old stream terrace. The estimated stripping requirements in the stream bed vary from eight to fifteen feet in depth. The estimated depths of stripping are shown graphically in Appendix C of this report.

Dam and Appurtenances—The topography of the site and the general layout of the proposed dam and appurtenances are shown on Plate XLVIII, "Friant Reservoir on San Joaquin River." The dam is a concrete gravity type structure, straight in plan across the stream

PLATE XLVII



COST OF RESERVOIR CAPACITY AND UNIT YIELD OF WATER FOR IRRIGATION FROM FRIANT RESERVOIR

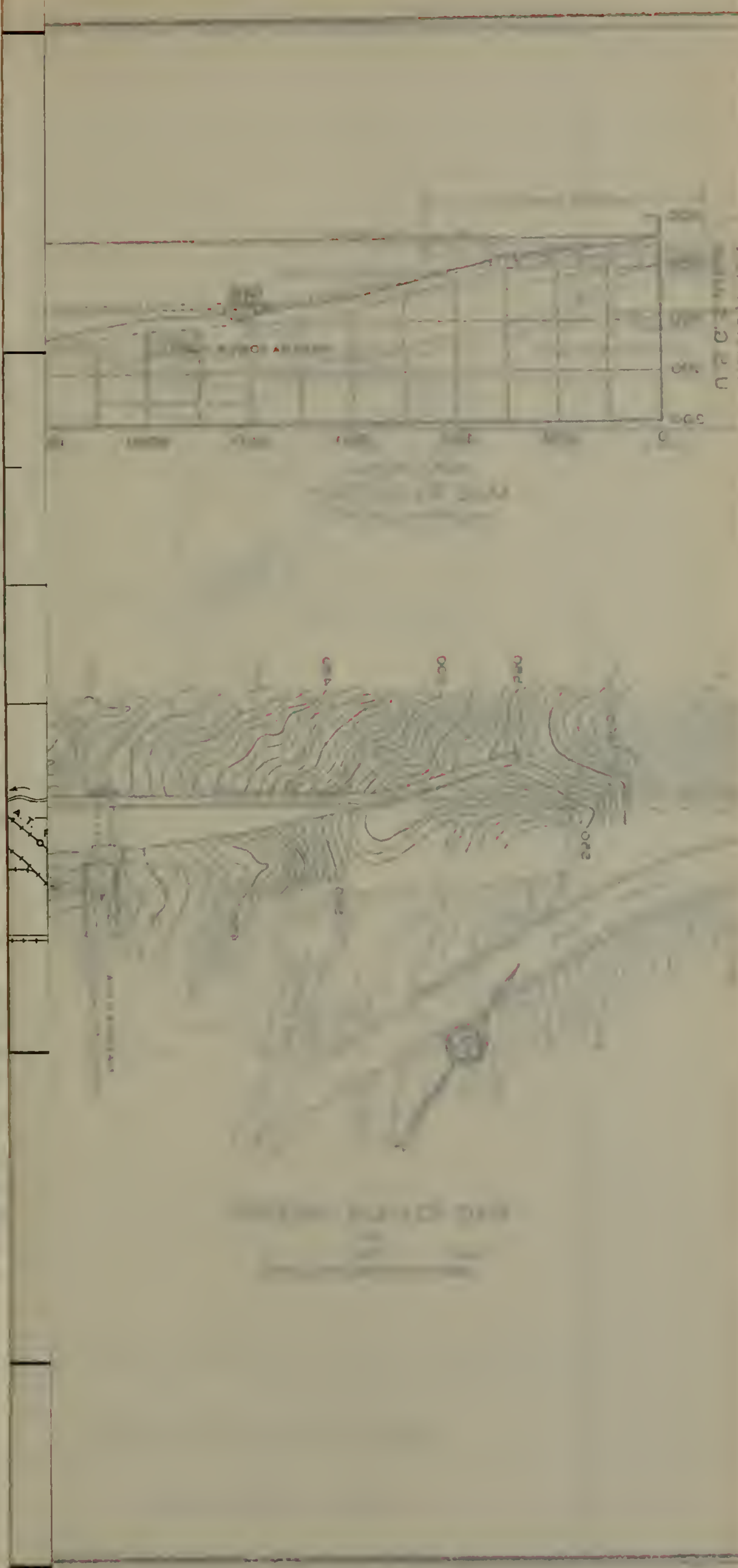
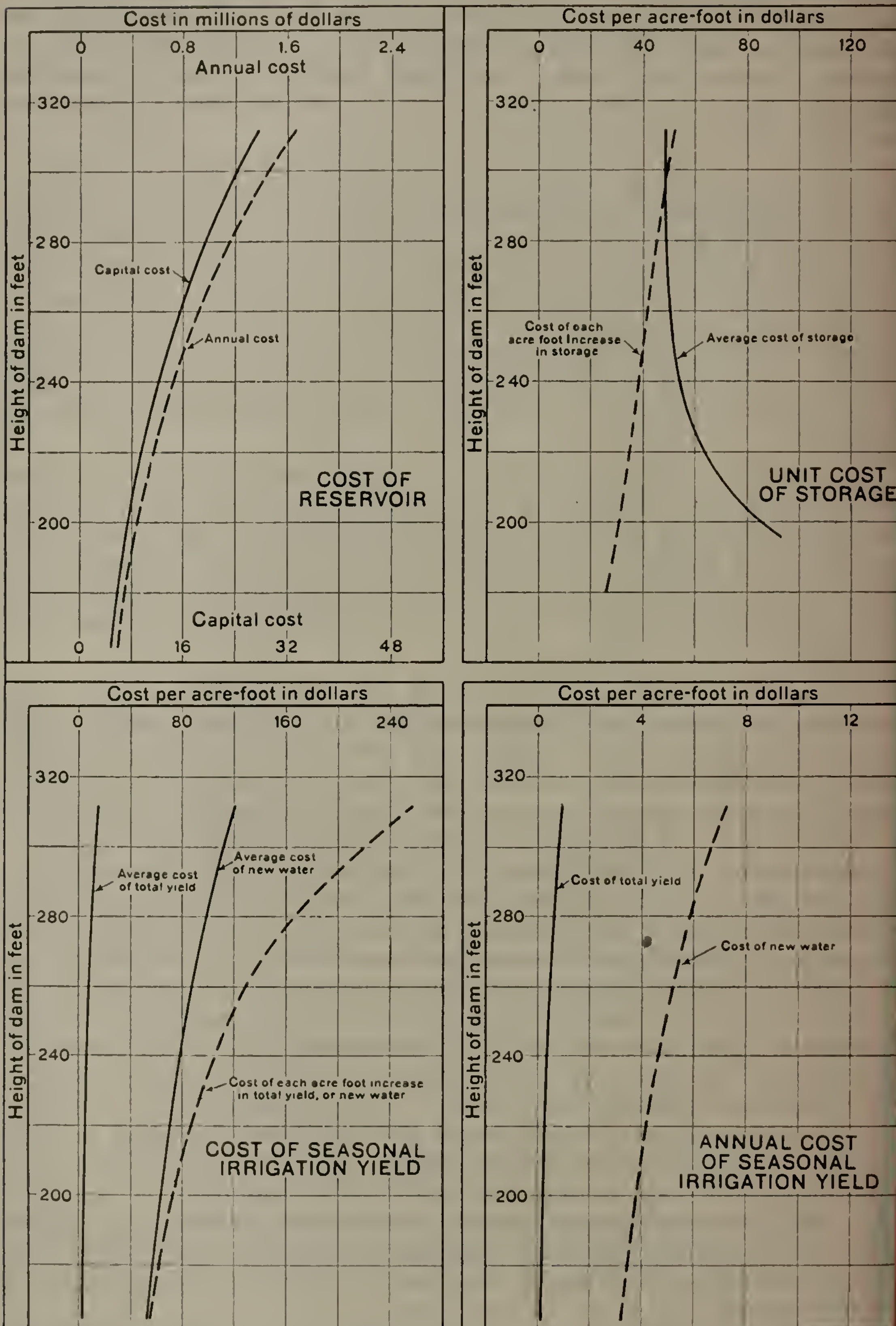
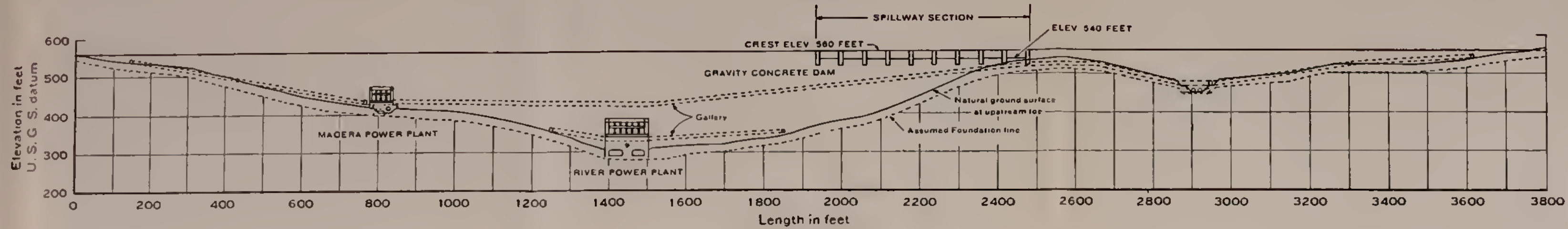


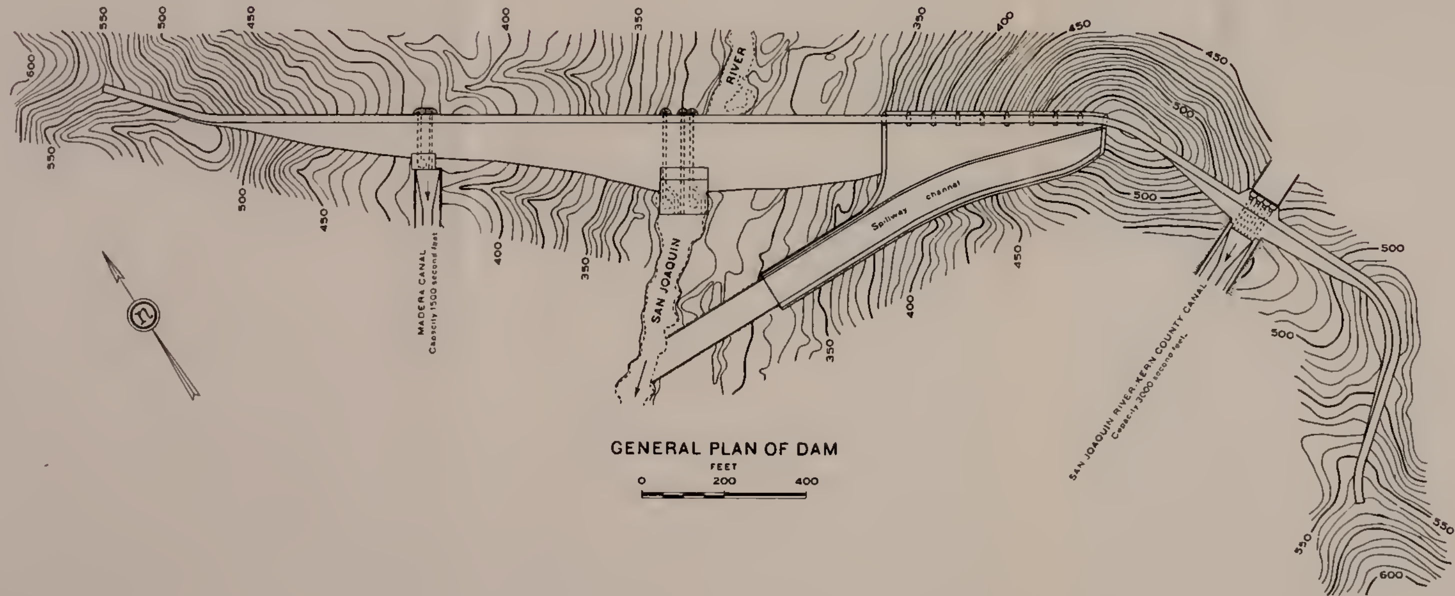
PLATE XLVII



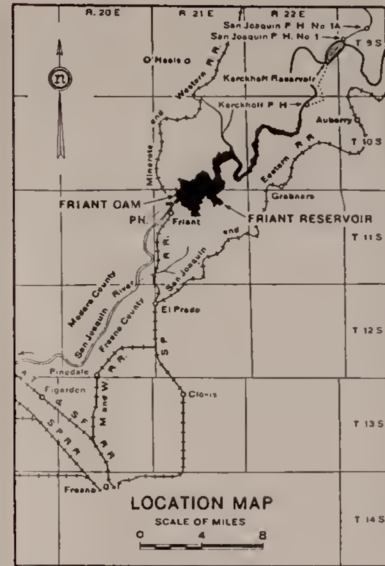
COST OF RESERVOIR CAPACITY AND UNIT YIELD OF WATER FOR IRRIGATION FROM FRIANT RESERVOIR



PROFILE OF DAM
LOOKING UPSTREAM



GENERAL PLAN OF DAM



LOCATION MAP

FRIANT RESERVOIR
ON
SAN JOAQUIN RIVER

channel, with a maximum height above the stream bed of 252 feet and a crest length of 3800 feet. An overflow spillway is provided at the left abutment. The spillway controls consist of nine drum gates, 15 feet high by 50 feet long, having an estimated combined discharging capacity of 92,000 second-feet, or 2.8 times the once-in-25-year flood. A concrete lined spillway channel 900 feet long and an unlined cut 300 feet long would convey the discharge to the river about 400 feet below the downstream toe of the dam. Two sets of irrigation outlets are located on either side of the river. The outlets for the Madera Canal are on the north side at elevation 418 feet and have a discharging capacity of 1500 second-feet, with a maximum water surface elevation of 415 feet in the canal. The San Joaquin River-Kern County Canal outlets are located in a saddle on the south side at elevation 455 feet and have a discharging capacity of 3000 second-feet, with a maximum water surface elevation of 467 feet in the canal. Outlets also are provided near the stream bed to be utilized for the release of lower San Joaquin River "Crop Land" waters under conditions of immediate initial development.

For flood regulation, a reserve storage space of 75,000 acre-feet and a maximum draw-down of 20 feet would be required. The required regulatory flood control outlet capacity of 15,000 second-feet is provided by the utilization of power plant by-passes and irrigation water outlets, with a reservoir water surface at elevation 535 feet.

Power Plants—A power plant of 30,000 kilovolt amperes capacity is located at the lower toe of the dam for utilizing the lower San Joaquin River "Crop Land" waters (see Chapter VIII) which would be released under the immediate initial development for the lower San Joaquin Valley. This plant is to be abandoned upon completion of the San Joaquin River Pumping System, or at such time when all the San Joaquin River water would be diverted at high elevations for exportation to the upper San Joaquin Valley. Based on a 10-year amortization period, the economic capacity of this plant has been determined as 30,000 kilovolt amperes. A second power plant of 10,000 kilovolt amperes capacity is proposed under conditions of ultimate development for utilization of water released at elevation 415 feet for the Madera Canal.

Cost of Friant Reservoir—The capital and annual costs of Friant Reservoir, estimated in accord with bases previously presented in this chapter, are shown in Table 91. The estimated revenue from sale of electric energy and the net annual cost not covered by power revenue also are given in the table for both the immediate initial and ultimate developments.

TABLE 91

COST OF FRIANT RESERVOIR

Height of dam, 252 feet. Gross capacity of reservoir, 400,000 acre-feet.
Net effective capacity of reservoir, 270,000 acre-feet.
Capacity of spillway, 92,000 second-feet.
Capacity of irrigation outlets, 7,500 second-feet.
Flood control outlet capacity, 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		50,000
Lands and improvements flooded and clearing		250,000
Excavation for dam, 350,000 cubic yards at $1.00 to $5.00	$1,000,000	
Mass concrete, 1,293,000 cubic yards at $6.30	8,146,000	
Reinforced concrete, 3,600 cubic yards at $17.00 to $30.00	68,000	
Spillway gates	170,000	
Spillway channel	360,000	
Irrigation outlet and sluiceways	164,000	
(Power outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	126,000	
		10,034,000
Miscellaneous		128,000
Subtotal		$10,472,000
Administration and engineering at 10 per cent		1,047,000
Contingencies at 15 per cent		1,571,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		910,000
Total capital cost of dam and reservoir		$14,000,000

Cost of Power Plants and Appurtenances for Friant Reservoir

Immediate Initial Development.—Power plant located at lower toe of dam for utilizing lower San Joaquin "crop land" waters, to be abandoned at such time as all San Joaquin River water shall be diverted for exportation at higher elevations. Selection of economic capacity based on a 10-year amortization period.

Capacity, 30,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant including outlets, penstocks and controls	$1,500,000

Ultimate Development.—Power plant located at elevation 415 for utilizing water diverted through Madera Canal.

Capacity, 10,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant	$500,00

Annual Cost of Friant Reservoir and Power Plants

Immediate Initial Development—	
Gross annual cost of dam and reservoir	$840,000
Gross annual cost of power plant	222,000
Total gross annual cost	$1,062,000
Average annual revenue from sale of electric energy, 105,000,000 kilowatt-hours at $0.0035	$367,000
Average net annual cost not covered by revenue from sale of electric energy	$695,000
Ultimate Development—	
Gross annual cost of dam and reservoir	$840,000
Gross annual cost of power plant	45,000
Total gross annual cost	$885,000
Average annual revenue from sale of electric energy, 23,000,000 kilowatt-hours at $0.0035	$80,000
Average net annual cost not covered by revenue from sale of electric energy	$805,000

Pine Flat Reservoir on Kings River.

In order to provide for the fullest practicable development and utilization of the run-off of Kings River for ultimate development, surface storage is desirable. It would increase the amount of water available for utilization, would improve the characteristics of supply and would provide a more flexible plan of development and operation than one without surface storage regulation. Accordingly, a surface storage unit is proposed on Kings River for ultimate development.

The dam site for the Pine Flat Reservoir on the Kings River is located in Section 2, Township 13 South, Range 24 East, M. D. B. and M., in Fresno County, about 26 miles easterly from the city of Fresno.

The Pine Flat site is the only one on Kings River strategically located and of adequate potential capacity to properly regulate the waters of the stream to meet the ultimate needs of the Kings River service area. There are several other sites on the South and Middle forks above Pine Flat which have been investigated by public and private agencies in connection with water supply and hydroelectric power projects. Some of these if developed would be useful in supplementing Pine Flat storage.

The drainage areas on the Kings River watershed, above the Pine Flat dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	386 square miles
Area between elevations 5000 and 10,000 feet	824 square miles
Area between elevations 2500 and 5000 feet	201 square miles
Area below elevation 2500 feet	133 square miles
Total area above Pine Flat dam site	1544 square miles

Present Developments on Kings River—The only existing development above the Pine Flat site is the Balch Power Plant of the San Joaquin Light and Power Corporation with an installed capacity of 33,000 kilovolt amperes. The present plant operates entirely on natural stream flow. Additional installation, dependent on storage development, is contemplated. Below Piedra are the diversions of an elaborate system of canals for the distribution of water to a gross area of some 900,000 acres of land on or below the Kings River Delta. A discussion of these diversions and water rights has been presented in Chapter IV. The total area irrigated in 1929 was approximately 600,000 acres.

Water Supply—The water supply available for regulation is the flow of Kings River, for which the estimated mean seasonal run-off for the 40-year period, 1889–1929, is 1,889,000 acre feet. Details of run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 1200 feet, was prepared from surveys made by the Kings River Water Conservation District in 1922. A map of the dam site, scale one inch equals 100 feet, was prepared from these surveys and supplemental surveys made by the State in 1925. Table 92 sets forth areas and capacities for various heights of dam.

The difference in total annual cost of water delivered on the land in the Kings River area, whether regulation of Kings River run-off be effected entirely by the utilization of ground water storage and pumping, or whether it be obtained by a combination of surface storage regulation and ground water storage and pumping, was shown by analysis to be very slight. However, after making trial studies of yield and cost for various capacity reservoirs, and after consideration of the limitations and possible accomplishments of a proposed plan of development and operation, including the value of existing rights and the operations thereunder, the methods of irrigation practiced in various parts of the Kings River area, the value of incidental power development, the value of storage space for flood control, and the desirability and necessity of surface storage regulation for ground water recharge and for furnishing an adequate surface supply for the nonabsorptive areas in Tulare Lake vicinity, it was concluded that

TABLE 92

AREAS AND CAPACITIES OF PINE FLAT RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
48	600	125	2,000
68	620	325	6,000
88	640	550	15,000
108	660	850	28,000
128	680	1,225	49,000
148	700	1,525	77,000
168	720	1,875	110,000
188	740	2,200	152,000
208	760	2,475	198,000
228	780	2,850	251,000
248	800	3,225	312,000
268	820	3,575	380,000
274	826	3,680	400,000
288	840	3,925	455,000
308	860	4,375	537,000
328	880	4,745	630,000
348	900	5,450	732,000

Pine Flat Reservoir should be included as a unit for ultimate development of the State Water Plan for the San Joaquin River Basin and that its economic and practicable capacity for this purpose would be 400,000 acre-feet.

The reservoir site is situated in the lower mountain area, about six miles above the edge of the valley floor, below all intereference with present or future power development and at a point where practically the entire Kings River run-off can be regulated. With the capacity selected, the reservoir would have a flow line elevation of 826 feet, a length of 14 miles, a maximum width of one and one-half miles and a surface area of 3680 acres. Most of the flooded area is steep, rocky, mountain land, covered with brush and small timber. In Pine Flat about 80 acres are planted to orchard and vineyard. Other improvements consist of a few scattered ranch houses. The main Kings River Canyon road would be submerged and would require about twelve miles of relocation together with a telephone line of light construction.

In making yield studies, a net seasonal reservoir evaporation loss of four feet depth on the reservoir surface was used. The mean seasonal irrigation yield from this reservoir, operated in conjunction with ground water storage in the Kings River Delta, for the 40-year period, 1889–1929, would have been 1,764,000 acre feet. Details of reservoir yields and utilization are given in Chapter VII.

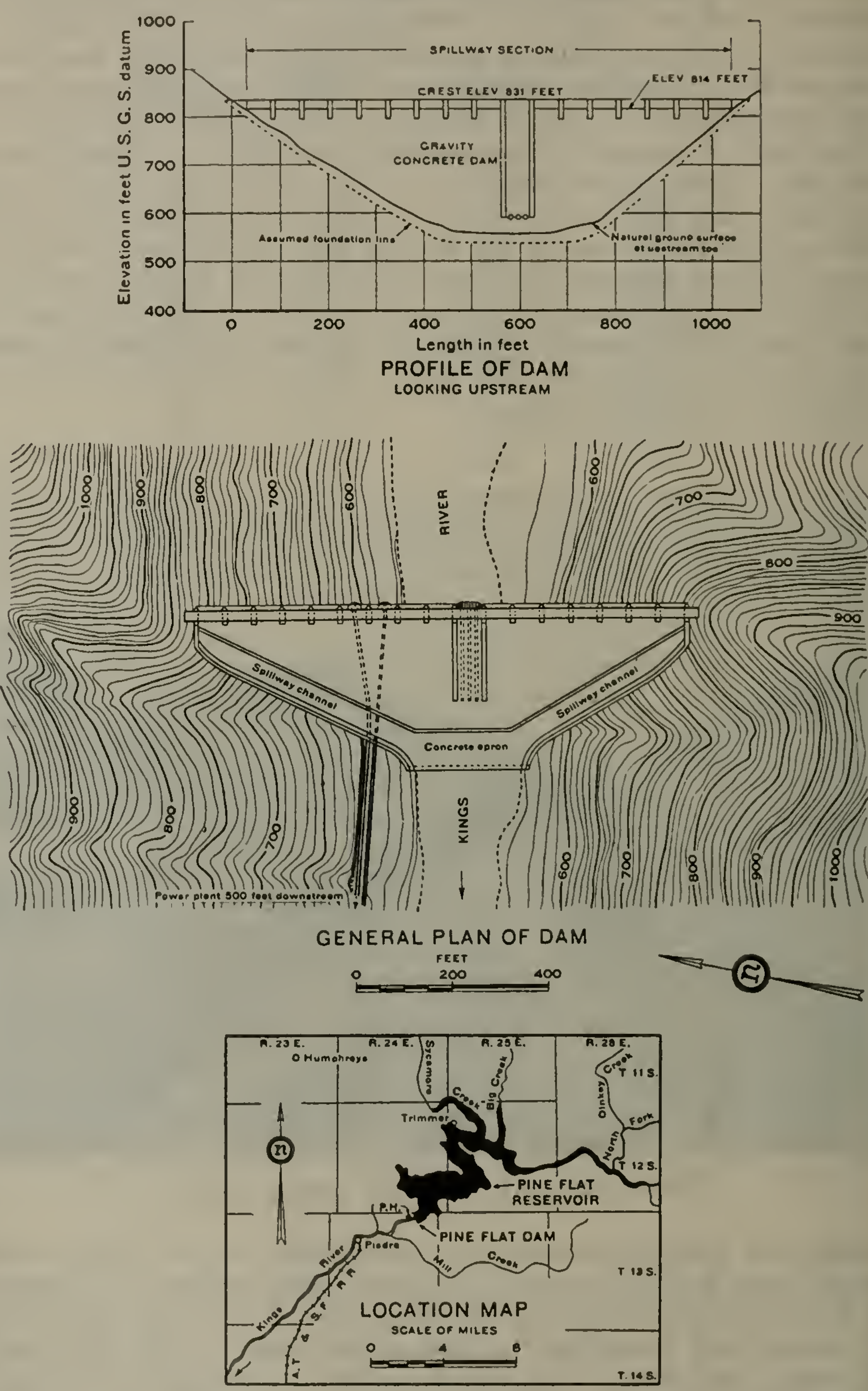
Dam Site—Several dam sites have been investigated by different interests in the section of the canyon between Pine Flat and Piedra. Surveys, exploration and examination of the adopted site were made by the Kings River Water Conservation District. After making a geological examination (see Appendix C) and additional topographic surveys, this same site was chosen. The geological examination shows that the character of the rock and the topographic development at this site are well suited to the construction of a concrete dam. The rock mass is a ''greenstone,'' the chief rock making member of which is horneblende. Several systems of joints break the rock mass into relatively small blocks, but without displacement of the joint blocks or parting of the joint walls. Although being a universal structural defect of the rock mass, this system of joints is not to be considered as greatly reducing the strength of the whole rock mass or the safety of a structure founded upon it. Examination of the cores shows the joints to be closed and tight at a shallow depth below the rock line in the stream bed to the extent that they would probably refuse grout. On the abutments, the rock is covered with a shallow overburden of clay soil and is partially disintegrated to depths of from three to fifteen feet. Spotted over the site are some joints below these depths where water has circulated. It is estimated that, on the average, stripping of 20 to 30 feet in the stream bed and 10 to 12 feet on the abutments would remove all loose material and reveal sound rock. Some portions would require but five to eight feet of stripping, while limited areas would require as much as 30 feet. The general geology and the location of diamond drill holes at this site are shown on plates in Appendix C of this report.

PLATE XLIX

PINE FLAT DAM SITE ON KINGS RIVER

Dam and Appurtenances—The topography of the dam site and general layout of the proposed dam and appurtenances are shown on Plate L, "Pine Flat Reservoir on Kings River." The height of dam above stream bed, including five feet of freeboard, is 274 feet and the crest length, 1080 feet. The dam is a concrete gravity-type structure, straight in plan, with an overflow spillway occupying all of the crest except 70 feet in the center and 30 feet at each abutment. The spillway is controlled by 16 drum gates 12 feet high by 50 feet long and has an estimated discharging capacity of 120,000 second-feet or 3.5 times the once-in-25-year flood. A bucket section and concrete lined spillway channels along the downstream toe of the dam are provided to convey the discharge to a concrete apron in the river channel.

PLATE I



PINE FLAT RESERVOIR

ON

KINGS RIVER

Reserve space of 80,000 acre-feet with a maximum drawdown of 25 feet would be required for the regulation of winter floods to a maximum flow of 15,000 second-feet, exceeded once in 100 years on the average. The required outlet capacity of 15,000 second-feet is provided through the irrigation outlets and power plant by-passes.

Three 78-inch diameter pipes through the dam, at elevation 590 feet, are provided for the release of irrigation water. These have a combined discharging capacity of 3000 second-feet under a minimum head of 30 feet and are controlled by needle valves and emergency slide gates. Additional irrigation water would be released through the power plant turbines and by-passes.

Power Plant—Considering the average value of power at $0.002 per kilowatt hour with no power reserve storage and assuming releases in accordance with irrigation use only, the economic capacity of the power installation for Pine Flat Reservoir is estimated to be 40,000 kilovolt amperes. The power plant would be located on the right side of the river about 1000 feet below the downstream toe of the dam, the turbines being supplied through steel penstocks. The cost of the complete power development is estimated at $50 per kilovolt ampere.

Cost of Pine Flat Reservoir—The capital and annual costs of Pine Flat Reservoir estimated in accord with bases previously presented in this chapter, are set forth in Table 93. The estimated revenue from the sale of electric energy and the net annual cost not covered by power revenue also are given in the table.

TABLE 93

COST OF PINE FLAT RESERVOIR

Height of dam, 274 feet. Capacity of reservoir, 400,000 acre-feet.
Capacity of spillway, 120,000 second-feet.
Capacity of irrigation outlets, 3,000 second-feet.
Flood control outlet capacity of 15,000 second-feet available through combined irrigation outlets and power plant by-passes.

Exploration		$10,000
Diversion of river during construction		75,000
Lands and improvements flooded and clearing		500,000
Excavation for dam, 168,000 cubic yards at $3.50 to $5.00	$702,000	
Mass concrete, 727,000 cubic yards at $6.50	4,726,000	
Reinforced concrete, 5,500 cubic yards at $18.00 to $30.00	106,000	
Spillway gates	234,000	
Spillway channel	400,000	
Irrigation outlets and sluiceways	167,000	
(Power plant outlets and controls included in cost of power plant)		
Drilling, grouting, drains and contraction seals	64,000	
		6,399,000
Miscellaneous		196,000
Subtotal		$7,180,000
Administration and engineering at 10 per cent		718,000
Contingencies at 15 per cent		1,077,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		625,000
Total capital cost of dam and reservoir		$9,600,000

Cost of Power Plant for Pine Flat Reservoir

Capacity, 40,000 kilovolt amperes.
Power factor=0.80. Load factor=1.00.

Total capital cost of power plant, including outlets, penstocks and controls	$2,000,000

Annual Cost of Pine Flat Reservoir and Power Plant

Gross annual cost of dam and reservoir	$574,000
Gross annual cost of power plant	168,000
Total gross annual cost	$742,000
Average annual revenue from sale of electric energy, 100,500,000 kilowatt hours at $0.002	$201,000
Average net annual cost not covered by revenue from sale of electric energy	$541,000

Ward Reservoir Site on Kaweah River.

The dam site for the Ward Reservoir site on the Kaweah River is located in Section 33, Township 17 South, Range 28 East, M. D. B. and M., in Tulare County about 20 miles east of the city of Visalia. This is the only reservoir site on the main stream offering possibilities of full regulation of the Kaweah River. No sites of sufficient size to be important have been found on the main branches of the stream.

The drainage areas on the Kaweah River watershed, above the Ward dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	37 square miles
Area between elevations 5000 and 10,000 feet	275 square miles
Area between elevations 2500 and 5000 feet	141 square miles
Area below elevation 2500 feet	61 square miles
Total area above Ward dam site	514 square miles

Present Developments on Kaweah River—The only existing developments above the Ward site consist of three power plants of the Southern California Edison Company, Kaweah No. 1, No. 2 and No. 3, having installed capacities of 2500, 3500 and 3500 kilovolt amperes, respectively. The supply for Kaweah No. 1 is diverted from East Fork. Kaweah No. 3 diverts near the junction of the Marble Fork and Middle Fork. Diversion for Kaweah No. 2 is made from the Middle Fork immediately below Kaweah No. 3 tailrace. The diversion systems, water rights and irrigated areas on the Kaweah Delta have been discussed in Chapter IV.

Water Supply—The water supply available at this site is the full natural run-off of the Kaweah River of which the seasonal mean for the 40-year period, 1889–1929, is estimated as 443,000 acre-feet. The mean seasonal yield for this period, utilizable without surface storage, is estimated as 435,000 acre-feet. Details of run-off and utilization by ground water storage have been presented in Chapters II and IV, respectively.

Reservoir Site and Capacity—A contour map of the reservoir site, scale one inch equals 400 feet, was prepared by George B. Sturgeon from a survey made in 1917. The State made a survey and prepared a contour map of the dam site, scale one inch equals 100 feet, in 1930. Table 94 sets forth areas and capacities for various heights of dam.

TABLE 94

AREAS AND CAPACITIES OF WARD RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
45	660	101	1,800
65	680	173	4,500
85	700	253	8,800
105	720	384	15,200
125	740	518	24,000
145	760	691	36,300
165	780	901	51,900
185	800	1,111	72,000
205	820	1,291	96,000
225	840	1,527	124,000
245	860	1,778	156,800
265	880	2,031	195,500
285	900	2,296	238,600
305	920	2,582	287,400
325	940	2,725	341,800

Economics of Surface Storage on Kaweah River—The construction f the Ward Reservoir is not included in the State Plan. The wide 'U'' shaped channel at this dam site makes the unit cost of surface torage relatively expensive. The present high degree of conservation f stream flow in the Kaweah Delta area is secured by the utilization f ground water storage and pumping in a large absorptive area. The et irrigable area of about 35,000 acres, some of which is nonabsorptive, ituated above the proposed location of the San Joaquin River-Kern County Canal in the Kaweah Basin, could be furnished an ample urface supply every season by direct diversion from the Kaweah River without surface storage development. Cost estimates and yield tudies were made of a reservoir at the Ward site for various storage

PLATE LI

WARD DAM SITE ON KAWEAH RIVER

apacities. Analyses of the economics of stream flow utilization with eservoirs of various capacities at this site, operated in conjunction ith ground water storage and pumping, showed that no increase in tilizable yield could be obtained thereby and that the unit cost of ater delivered to the land would considerably exceed that obtainable rom a supply developed without surface storage.

Dam Site—The dam site is located about three miles below the own of Three Rivers and lies wholly within an area composed of ranitic rock. The stream has cut a wide "U" shaped channel through his formation. A geological examination (see Appendix C) shows hat the granite mass has developed a complex series of irregular joint lanes. The effect of weathering along joint planes makes it uncertain ithout subsurface exploration as to the extent of stripping and ressure grouting necessary. For the purposes of preliminary estimating it was considered that the stripping would be uneven, and an verage allowance was made for 25 feet of excavation perpendicular the slope, over the entire site.

Pleasant Valley Reservoir on Tule River.

The dam site for the Pleasant Valley Reservoir on the Tule River is located in Sections 17 and 18, Township 21 South, Range 29 East, M. D. B. and M., in Tulare County, about nine miles east of the city of Porterville. The South Fork joins the main river about three miles below the Pleasant Valley dam site. A reservoir site was investigated on that fork, just below the Tule River Indian Reservation, but sufficient capacity could not be obtained to control the run-off. On the Middle Fork there is a small reservoir site below the mouth of Bear Creek. The Pleasant Valley site on the main stream is the only one capable of being developed to the capacity required for a high degree of utilization of the run-off of most of the watershed.

The drainage areas on the Tule River watershed, above the Pleasant Valley dam site, are segregated by zones of elevation as follows:

Area above elevation 5000 feet	98 square miles
Area between elevations 2500 and 5000 feet	73 square miles
Area below elevation 2500 feet	93 square miles
Total area above Pleasant Valley dam site	264 square miles

The South Fork has a drainage area of 74 square miles above the gaging station on the Tule River Indian Reservation.

Present Developments on Tule River—The only existing developments above the Pleasant Valley site are two power plants on Middle Fork. The upper plant, owned by the San Joaquin Light and Power Corporation, has an installed capacity of 6000 kilovolt amperes. It is located at the junction of the north and south forks of Middle Fork and diverts its water supply from the former. The lower plant, owned by Southern California Edison Company, has an installed capacity of 2500 kilovolt amperes. It is located on Middle Fork above its junction with North Fork and diverts its supply immediately below the tailrace of the upper plant. Existing conditions of irrigation development on the Tule River Delta have been discussed in Chapter IV.

Water Supply—The estimated mean seasonal run-off above the Pleasant Valley dam site for the 40-year period, 1889–1929, is 99,700 acre-feet. The South Fork, with a mean seasonal run-off for the 40-year period of 30,300 acre-feet, could not be regulated by storage, but the run-off therefrom would be pooled with reservoir releases on the main river, so regulated as to result in a high degree of utilization of the entire Tule River run-off. Details in regard to run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir and dam site, scale one inch equals 500 feet, was prepared from a survey made by the State in 1921. Table 95 sets forth areas and capacities for various heights of dam.

A study of the economics of utilization of the run-off of Tule River, including South Fork, with surface storage regulation on the main Tule River operated in conjunction with ground water storage, shows that a surface reservoir capacity of 39,000 acre-feet would be required and justified. At this capacity the flow line elevation of Pleasant Valley Reservoir would be 775 feet and the submerged area

TABLE 95

AREAS AND CAPACITIES OF PLEASANT VALLEY RESERVOIR

Height of dam, in feet (10-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
50	700	96	1,500
60	710	168	2,800
70	720	239	4,900
80	730	319	7,700
90	740	415	11,300
100	750	612	16,500
110	760	845	23,700
120	770	1,093	33,400
125	775	1,270	39,000
130	780	1,451	46,200
140	790	1,849	62,700
150	800	2,198	82,900

1270 acres. This reservoir area is chiefly uncultivated grazing land. Several citrus groves fringe the valley but are situated above the flow line. About three miles of the Porterville-Springville Highway would require relocation and about 3.5 miles of the Springville branch of the Southern Pacific Railroad would be submerged, involving relocation or compensation for abandonment.

In making the irrigation yield studies on the Tule River, a net seasonal reservoir evaporation loss of four feet in depth on the reservoir surface was used. With the regulated flow allocated to high rim lands in the form of a gravity supply and unregulated flows used for the irrigation of lower lands and the replenishment of ground water storage, the mean seasonal utilizable yield for the 40-year period, 1889–1929, including that from the South Fork, would have been 128,000 acre-feet. Details of reservoir yields and utilization are given in Chapter VII.

PLATE LII

PLEASANT VALLEY DAM SITE ON TULE RIVER

Dam Site—A geological examination (see Appendix C) of the Pleasant Valley dam site shows the bedrock to be of granitic formation varying in texture and mineral constituents within comparatively small areas. Weathering has attacked the rock, producing gentle slopes at the dam site abutments. The rock outcrops are principally dislodged joint blocks with but little rock found in place. The topographic and geological characteristics of the site dictate the adoption of an earth-fill dam as most suitable and designs and estimates have been based on this type of dam. No subsurface exploration has been made. As the deep weathering of the bedrock has produced gentle slopes and no outcrops show near the stream bed, it is estimated that excavation to a depth of 50 feet would be required for the cutoff wall at the upstream toe of the main dam, and from 50 to 60 feet for the auxiliary dam required in a saddle northwest of the main dam site.

Dam and Appurtenances—The topography of the dam site and the general layout of the proposed dam and appurtenances are shown on Plate LIII, "Pleasant Valley Reservoir on Tule River." The maximum height of the main dam is 125 feet, and that of the auxiliary dam 45 feet, including 10 feet of freeboard. The main dam has a crest length of 1660 feet, an upstream slope of 3 to 1 and a downstream slope of $2\frac{1}{2}$ to 1. The auxiliary dam has the same slopes as the main dam and a crest length of 1150 feet.

The spillway, of the overflow wing type, is located at the left abutment of the auxiliary dam. It discharges into a lined channel extending about 500 feet downstream from the crest of the dam. It has an estimated capacity of 20,000 second-feet or 3.2 times the once-in-25-year flood.

The irrigation outlet consists of a reinforced concrete gate tower equipped with three, five feet by five feet inlet gates of the caterpillar type, connecting with a 70-inch diameter reinforced concrete conduit 670 feet long extending under the dam. The discharging capacity with a minimum head of eight feet is estimated at 260 second-feet. No hydroelectric power development is proposed at this site.

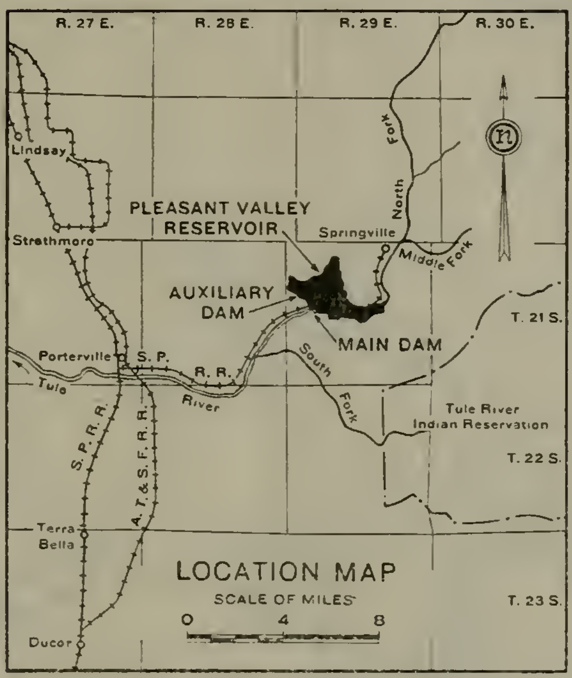
Cost of Pleasant Valley Reservoir—The capital and annual costs of Pleasant Valley Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 96.

TABLE 96

COST OF PLEASANT VALLEY RESERVOIR

Height of dam, 125 feet. Capacity of reservoir, 39,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlet, 260 second-feet.

Exploration		$12[illegible]
Diversion of river during construction		60[illegible]
Lands and improvements flooded and clearing		325[illegible]
Excavation for dam, 75,000 cubic yards at $0.75 to $3.00	$90,000	
Earth fill in dam, 1,290,000 cubic yards at $0.75	968,000	
Reinforced concrete face, 9,200 cubic yards at $15.00	138,000	
Miscellaneous reinforced concrete and cut-off walls, 12,000 cubic yards at $15.00 to $18.00	195,000	
Spillway overflow weir	90,000	
Spillway channel	160,000	
Irrigation outlet tower, conduit and gates	55,000	
		1,69[illegible]
Miscellaneous		7[illegible]
Subtotal, dam and reservoir		$2,16[illegible]
Administration and engineering at 10 per cent		21[illegible]
Contingencies at 15 per cent		32[illegible]
Interest during construction, based on an interest rate of 4.5 per cent per annum		18[illegible]
Total capital cost of dam and reservoir		$2,90[illegible]
Total annual cost of dam and reservoir		$17[illegible]



PLEASANT VALLEY RESERVOIR

ON

TULE RIVER

joint blocks with but little rock found in place. The topographic and geological characteristics of the site dictate the adoption of an earth-fill dam as most suitable and designs and estimates have been based on this type of dam. No subsurface exploration has been made. As the deep weathering of the bedrock has produced gentle slopes and no outcrops show near the stream bed, it is estimated that excavation to a depth of 50 feet would be required for the cutoff wall at the upstream toe of the main dam, and from 50 to 60 feet for the auxiliary dam required in a saddle northwest of the main dam site.

Dam and Appurtenances—The topography of the dam site and the general layout of the proposed dam and appurtenances are shown on Plate LIII, "Pleasant Valley Reservoir on Tule River." The maximum height of the main dam is 125 feet, and that of the auxiliary dam, 45 feet, including 10 feet of freeboard. The main dam has a crest length of 1660 feet, an upstream slope of 3 to 1 and a downstream slope of 2½ to 1. The auxiliary dam has the same slopes as the main dam and a crest length of 1150 feet.

The spillway, of the overflow wing type, is located at the left abutment of the auxiliary dam. It discharges into a lined channel extending about 500 feet downstream from the crest of the dam. It has an estimated capacity of 20,000 second-feet or 3.2 times the once-in-25-year flood.

The irrigation outlet consists of a reinforced concrete gate tower, equipped with three, five feet by five feet inlet gates of the caterpillar type, connecting with a 70-inch diameter reinforced concrete conduit 670 feet long extending under the dam. The discharging capacity with a minimum head of eight feet is estimated at 260 second-feet. No hydroelectric power development is proposed at this site.

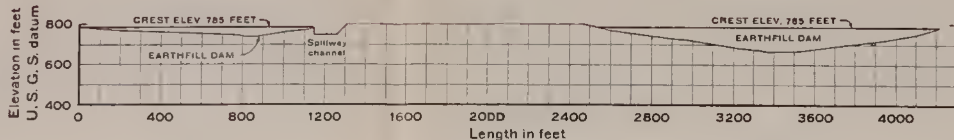
Cost of Pleasant Valley Reservoir—The capital and annual costs of Pleasant Valley Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 96.

TABLE 96

COST OF PLEASANT VALLEY RESERVOIR

Height of dam, 125 feet. Capacity of reservoir, 39,000 acre-feet.
Capacity of spillway, 20,000 second-feet.
Capacity of irrigation outlet, 260 second-feet.

Exploration		$12,000
Diversion of river during construction		60,000
Lands and improvements flooded and clearing		325,000
Excavation for dam, 75,000 cubic yards at $0.75 to $3.00	$90,000	
Earth fill in dam, 1,290,000 cubic yards at $0.75	968,000	
Reinforced concrete face, 9,200 cubic yards at $15.00	138,000	
Miscellaneous reinforced concrete and cut-off walls, 12,000 cubic yards at $15.00 to $18.00	195,000	
Spillway overflow weir	90,000	
Spillway channel	160,000	
Irrigation outlet tower, conduit and gates	55,000	
		1,696,000
Miscellaneous		76,000
Subtotal, dam and reservoir		$2,169,000
Administration and engineering at 10 per cent		217,000
Contingencies at 15 per cent		325,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		189,000
Total capital cost of dam and reservoir		$2,900,000
Total annual cost of dam and reservoir		$171,000



PROFILE OF DAMS
LOOKING UPSTREAM

GENERAL PLAN OF DAMS
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LOCATION MAP
SCALE OF MILES
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PLEASANT VALLEY RESERVOIR
ON
TULE RIVER

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Isabella Reservoir on Kern River.

The main dam site for the Isabella Reservoir on the Kern River is located about three miles below the confluence of North and South forks in Section 36, Township 26 South, Range 32 East, M. D. B. and M., in Kern County, about 35 miles northeasterly from the city of Bakersfield. An auxiliary dam also would be required at the crest of Hot Springs Valley 1.5 miles south of the town of Isabella in Sections 29 and 30, Township 26 South, Range 33 East.

There are two favorable reservoir sites located on the South Fork—one at Monache Meadows and the other at Rock House Meadows. Due to the relatively smaller run-off of the South Fork, the utilization of these sites would regulate only a small part of Kern River run-off. The North Fork offers no opportunity for adequate storage above the junction with the South Fork. Two other sites have been investigated below Isabella on the main Kern River. These comprise Bakersfield and Borel sites.

The dam site for the Borel Reservoir is located in Section 32, Township 27 South, Range 31 East, and Section 5, Township 28 South, Range 31 East, M. D. B. and M., above the intake of the existing Kern No. 1 Power Plant. The reservoir would extend 13 miles upstream to the tailrace of the existing Borel Power Plant. Although unoccupied at the present time, the Southern California Edison Company has considered the development of this section of the river for power. A reservoir constructed to the maximum capacity that would not interfere with the operation of the Borel Power Plant would require a dam 415 feet high, flood an area of 1830 acres and impound 238,000 acre feet of water. This capacity is considered inadequate for proper irrigation regulation of Kern River run-off.

The dam site for the Bakersfield Reservoir is located in Section 35, Township 28 South, Range 28 East, M. D. B. and M., about six miles northeast of Bakersfield. A dam 226 feet in height, the highest one investigated at this site, would back water up to the tailrace of the Kern Canyon Power Plant of the San Joaquin Light and Power Corporation, the elevation of which is 685 feet. A reservoir constructed to this elevation would flood an area of 5560 acres and impound 569,000 acre-feet of water. A geological examination in the region of this site (see Appendix C) showed that suitable foundations for a concrete dam could not be obtained. However, it is thought that an earth-fill dam of proper dimensions could be built that would be stable and safe. As the elevation of this reservoir is below the diversion elevation of the Kern River Canal required in the Ultimate State Water Plan for the delivery of Kern River water to the rim lands south of Kern River, it is not suitable for inclusion in the proposed plan of development.

The Isabella site is the only one having a potential capacity adequate for proper regulation of Kern River run-off and located at a sufficiently high elevation to permit the regulated supply to be diverted by gravity to the valley floor rim lands south of Kern River.

The drainage areas on the Kern River watershed, above the Isabella dam site, are segregated by zones of elevation as follows:

Area above elevation 10,000 feet	266 square miles
Area between elevations 5000 and 10,000 feet	1392 square miles
Area between elevations 2500 and 5000 feet	421 square miles
Area below elevation 2500 feet	1 square mile
Total area above Isabella dam site	2080 square miles

PLATE LIV

Site of Main Isabella Dam

Site of Auxiliary Dam Across Hot Spring Valley

ISABELLA DAM SITE ON KERN RIVER

PLATE LV

BOREL DAM SITE ON KERN RIVER

Present Developments on Kern River—The present developments of importance on Kern River above the valley floor are the power plants of the Southern California Edison Company and the San Joaquin Light and Power Corporation. The former company has three plants which develop most of the head from elevation 3600 feet down to elevation 950 feet. Kern No. 3, with an installed capacity of 35,000 kilovolt amperes, located above Kernville, is the newest and largest of the system. The Borel Plant with an installed capacity of 10,000 kilovolt amperes, located at the upper end of the canyon below Kernville, is the oldest and smallest of the system. Kern No. 1 with an installed capacity of 20,000 kilovolt amperes utilizes most of the steep drop at the lower end of the canyon. Immediately below Kern No. 1 is the Kern Canyon Plant of the San Joaquin Light and Power Corporation which utilizes the remaining head above the mouth of the canyon. It has an installed capacity of 10,600 kilovolt amperes. All of the foregoing plants, except Kern No. 1, utilize up to about 600 second-feet of flow. The conveyance capacity of Kern No. 1 development is limited to about 390 second-feet. Irrigation development and diversions on the valley floor have been discussed in Chapter IV.

Water Supply—The water supply available for regulation in Isabella Reservoir is the impaired run-off of Kern River as measured at the gaging station (First Point of Measurement) about five miles northeast of Bakersfield. The run-off originating between that station and the Isabella dam site is relatively small. The mean seasonal ultimate net run-off for the 40-year period, 1889–1929, is estimated as 714,000 acre-feet. Details of ultimate net run-off have been presented in Chapter II.

Reservoir Site, Capacity and Yield—A contour map of the reservoir site, scale one inch equals 2000 feet, was made under the supervision of Ralph Bennett in 1916 to the 2700-foot contour. In 1920 a topographic survey of the reservoir site below elevation 2600 feet, scale one inch equals 400 feet, was made by the State. The Kern River Water Storage District made a survey and prepared a contour map of the dam site, scale one inch equals 50 feet, in 1925. Table 97 sets forth areas and capacities for various heights of dam.

TABLE 97

AREAS AND CAPACITIES OF ISABELLA RESERVOIR

Height of dam, in feet (5-foot freeboard)	Water surface elevation of reservoir, in feet	Area of water surface, in acres	Capacity of reservoir, in acre-feet
70	2,460	80	2,000
90	2,480	225	5,000
110	2,500	700	13,000
130	2,520	1,800	37,000
150	2,540	3,750	93,000
170	2,560	6,250	188,000
190	2,580	8,575	338,000
210	2,600	11,050	533,000
230	2,620	14,340	792,000
250	2,640	16,300	1,098,000

A study of the utilization of the Kern River run-off under conditions of ultimate development, through the combined means of surface and undergound storage, shows that a storage capacity of 338,000 acre-feet in Isabella Reservoir would provide most economically for the required surface storage regulation. For this capacity with a flow line at elevation 2580 feet, the reservoir would flood an area of 8575 acres, extending four miles up the North Fork and six miles up the South Fork from the dam site. The reservoir site is clear of timber and brush with the exception of willows and cottonwood trees along the stream channels, and the wooded growth in the three miles of river canyon between the dam site and the junction of the two forks. The lands in the North Fork Valley are not farmed as they were purchased years ago by the Kern River Development Company for the acquisition of diversion rights on that stream. Some 3750 acres of land in South Fork Valley, under the proposed flow line, are irrigated and cropped to corn and alfalfa or used for winter pasture. The improvements which would be submerged include the small settlements of Isabella and Kernville. The relocation and reconstruction of about ten miles of the Kern Canyon-Walker Pass State Highway along the south side of South Fork Valley and about ten miles of county road from Erskine Creek to a point one mile above Kernville with a river crossing at each end would be required. About ten miles of power transmission line and ten miles of telephone line also would require relocation.

Chief of the improvements to be submerged are the intake works and upper four miles of the Borel Canal. This canal, with a diversion right of 600 second-feet from the North Fork only, serves the Borel Power Plant of the Southern California Edison Company. It diverts at Kernville into an unlined channel leading to a settling basin formerly about one-half mile in length but now considerably restricted due to silt accumulation. The water surface elevation in this basin at the inlet to the canal proper is 2556 feet, U. S. G. S. datum. Four miles below this point the canal crosses the saddle of Hot Springs Valley with a flow line at elevation 2549. At this point an earth dam 55 feet in height would be required as an auxiliary to the concrete dam on Kern River, to develop the proposed storage. The treatment proposed for the interference with this established right on the stream is to provide an outlet to the Borel Canal at the site of the earth dam and, at all times when the reservoir surface would be above elevation 2549, to deliver the full capacity of 600 second-feet to that conduit. At times when the reservoir surface would be below elevation 2549, the Borel Plant would be out of service. The average seasonal loss in power output due to this method of operation has been calculated and its value at $0.004 per kilowatt hour capitalized at 10 per cent to estimate the cost of this interference. No additional hydroelectric power installation is proposed in the development of the Isabella site.

The net seasonal reservoir evaporation loss used in making yield studies at the Isabella site was three feet in depth on the reservoir surface. The mean seasonal yield for the 40-year period, 1889–1929, which could have been obtained for irrigation utilization from the operation of this reservoir in conjunction with ground water storage, is 670,000 acre-feet or 94 per cent of the mean seasonal impaired run-off for that period.

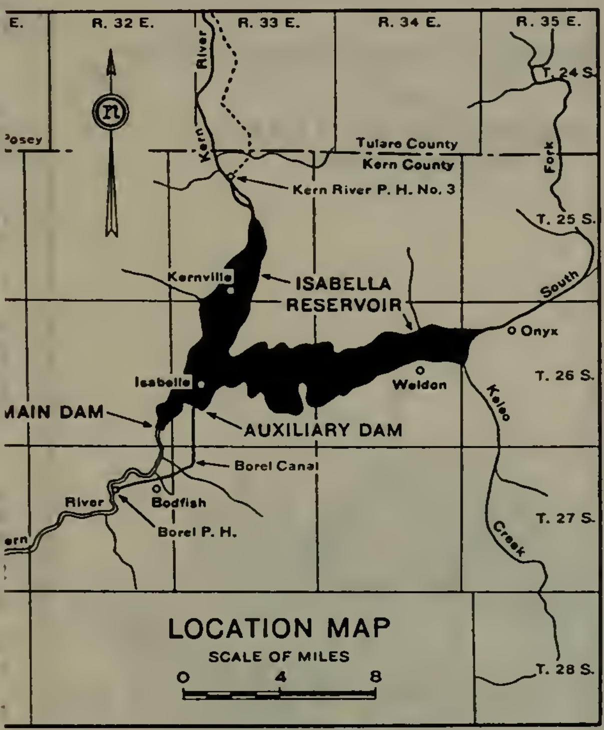
Dam Sites—A geological examination of the main dam site (see Appendix C) shows the bedrock to be a close textured granodiorite, with some large joint blocks displaced from the mass, but with joint walls of clean, unweathered sound rock. It is probable that few, if any, joints that might cause leakage or uplift under the dam would be found open upon uncovering streambed rock. Displaced joint blocks on the abutments would necessarily be removed in stripping the site. Some joints may be found open without appreciable displacement of the joint blocks, but the mass could be rendered sound by grouting. The upper abutments carry some disintegrated joint blocks and a light soil cover. On the average 20 feet of stripping should provide sound rock foundation. The site is well suited to a concrete structure.

The storage requirement necessitates an auxiliary dam in Hot Springs Valley. The log of a water well drilled on property a few hundred feet from the proposed auxiliary dam site at the saddle crest of this valley shows water-bearing sand to 110 feet and blue clay to 255 feet. The geologic history of the valley filling would lead to the conclusion that bedrock would not be found within reach of a cut-off wall, except possibly near the town of Isabella which lies at the easterly mouth of this valley at an elevation 25 feet below the valley crest. At Isabella, the rock would lie within the shear zone of a rift passing through Hot Springs Valley from Kernville to Bodfish and would probably contain open fractures which would pass water more freely than alluvium. Considering that the maximum height of an earth dam at the valley crest would be only 55 feet and that some leakage loss would be allowable, the proposed auxiliary dam site was concluded to be more desirable than the site considered near Isabella.

Dams and Appurtenances—The topography of the sites and the general layouts of the proposed dams and appurtenances are shown on Plate LVI, "Isabella Reservoir on Kern River." The main dam has a crest length of 780 feet and a maximum height of 190 feet above stream bed, including five feet of freeboard. It is a concrete gravity type structure, somewhat curved in plan to fit the topography. It has an overflow spillway at the right abutment, having an estimated discharging capacity of 57,000 second-feet or 3.4 times the once-in-25-year flood. The spillway discharge would be controlled by four drum gates 20 feet high by 45 feet long. A lined spillway channel is provided to convey the water to the river channel below the dam.

Reserve space of 67,000 acre-feet, involving a maximum drawdown of nine feet, would be provided for regulation of winter floods to a maximum flow of 7500 second-feet, exceeded once in 100 years on the average. The required capacity for flood regulation is provided by the irrigation outlets. These outlets consist of two 98-inch pipes through the dam, with a combined discharging capacity of 3500 second-feet under a minimum head of 25 feet and 8500 second-feet under a head of 170 feet. The outlets are controlled by needle valves and emergency slide gates. The inlets are at elevation 2400 feet.

The auxiliary dam in Hot Springs Valley is an earth embankment with a six-inch reinforced concrete apron on the upstream slope connecting with a cut-off wall at the toe. It has an upstream slope of 3 to 1 and a downstream slope of 4 to 1. The maximum height is 55 feet and the crest length 2100 feet. An outlet is located in the left abutment with a discharging capacity of 600 second-feet for release of water to the Borel Power Plant Canal. It consists of two reinforced concrete conduits 10 feet in diameter, extending through the dam and controlled by 10 feet by 10 feet caterpillar type gates located in a gate tower at the upstream end.



ISABELLA RESERVOIR

ON

KERN RIVER

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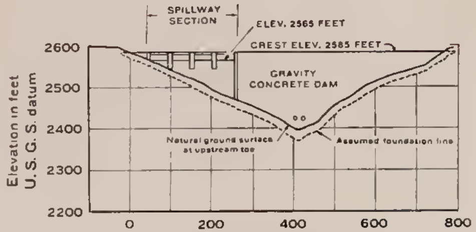
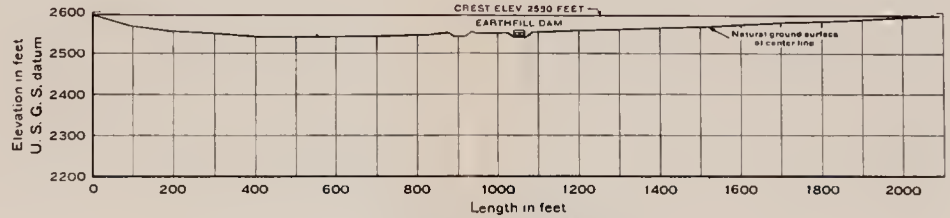
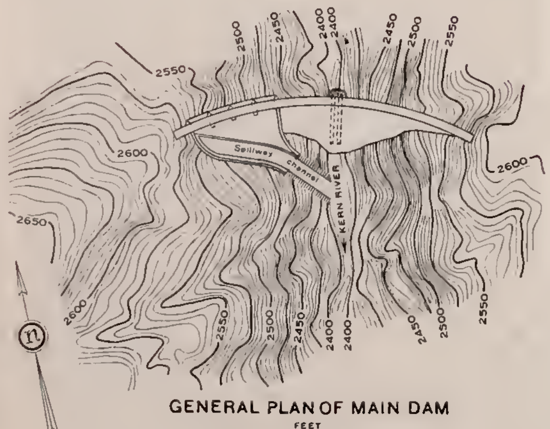


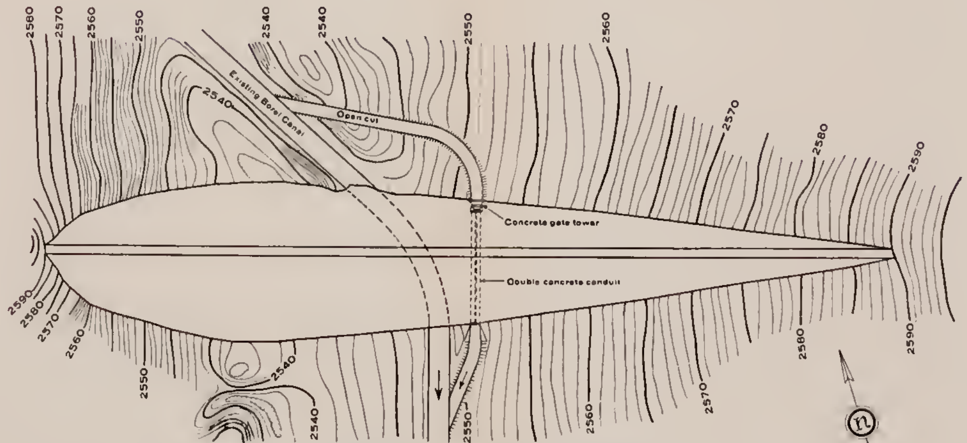
PROFILE OF MAIN DAM
LOOKING UPSTREAM



PROFILE OF AUXILIARY DAM
LOOKING UPSTREAM



GENERAL PLAN OF MAIN DAM
FEET
0 200 400



GENERAL PLAN OF AUXILIARY DAM
HOT SPRINGS VALLEY
FEET
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ISABELLA RESERVOIR
ON
KERN RIVER

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Cost of Isabella Reservoir—The capital and annual costs of Isabella Reservoir, estimated in accord with bases previously presented in this chapter, are set forth in Table 98.

TABLE 98

COST OF ISABELLA RESERVOIR

Height of main concrete dam, 190 feet. Capacity of reservoir, 338,000 acre-feet.
Height of auxiliary earthfill dam, 55 feet.
Capacity of spillway, 57,000 second-feet.
Capacity of irrigation outlets, 3,500 second-feet.
Capacity of outlets, through auxiliary dam, to release water for existing Borel Power Canal, 600 second-feet.

Exploration		$15,000
Diversion of river during construction		20,000
Lands and improvements flooded and clearing (including capitalized values of loss of power output of Borel Power Plant)		1,363,000
Main concrete dam—		
Excavation, 52,000 cubic yards at $3.00 to $5.00	$184,000	
Mass concrete, 190,000 cubic yards at $9.00	1,710,000	
Reinforced concrete, 1,200 cubic yards at $19.00 to $30.00	26,000	
Spillway gates	130,000	
Spillway channel	106,000	
Irrigation outlets and sluiceways	113,000	
Drilling, grouting, drains and contraction seals	20,000	
		2,289,000
Auxiliary earthfill dam—		
Excavation, 50,000 cubic yards at $0.50	$25,000	
Earthfill in dam, 370,000 cubic yards at $0.75	277,000	
Reinforced concrete face, 4,000 cubic yards at $16.00	64,000	
Miscellaneous reinforced concrete and cut-off walls, 1,700 cubic yards at $25.00 to $30.00	47,000	
Borel Canal outlet tower, conduit and gates	31,000	
		444,000
Miscellaneous		132,000
Subtotal dams and reservoir		$4,263.000
Administration and engineering at 10 per cent		426,000
Contingencies at 15 per cent		640,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		371,000
Total capital cost of dams and reservoir		$5,700,000
Total annual cost of dams and reservoir		$340,000

Summary of Surface Storage Reservoirs.

A summary of the cost estimates and principal physical features of all of the major surface storage reservoirs of the ultimate State Water Plan for the San Joaquin River Basin is set forth in Table 99. The heights of dams, capacities and capital and gross annual costs of reservoirs and power plants, average annual electric energy outputs and estimated revenues therefrom, net annual costs not covered by revenues from sale of electric energy and average seasonal irrigation yields are included in the tabulation.

UNDERGROUND RESERVOIRS

Utilization of underground storage is growing increasingly important throughout the State. In the upper San Joaquin Valley, the south coastal basin of southern California, Ventura County, the Santa Clara Valley and most of the Central Pacific Coast valleys, underground storage now is being utilized to a large extent. It has been practiced for many years in the upper San Joaquin Valley. The extent and feasibility of this practice has been demonstrated in Chapter IV, where it is shown that, in 1929, the aggregate capacity of wells and pumping plants for the whole area was 20,600 second-feet or 1,236,000 acre-feet per month, if operated continuously. Where suitable underground storage is available and a proper control of draft and replacement is exercised, it is a most flexible, efficient and economical means of conserving and utilizing water over a period of years.

Locations and Capacities of Underground Reservoirs in San Joaquin Valley.

Due to the importance of underground storage, a geologic study was made of the San Joaquin Valley to locate underground storage areas, to estimate their capacity and to determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development. This study reveals that the absorptive areas and available underground storage capacities are large and extensive, particularly in the upper San Joaquin Valley, but limited in their effective utilization due to the lack of readily available surplus water for their charge and recharge. These underground storage reservoir areas are confined to the eastern slope, principally to the alluvial cones and flood plains of the major streams. The surface soil and the geologic formation on the western slope and within the trough of the valley are of such character that no utilizable underground capacity exists. The surface areas of the ground water storage reservoirs and the depths of pervious formations were estimated through field examination of the physical characteristics of surface soils and the application of geologic reasoning, checked and aided as to subsurface characteristics by the penetration records of several hundred wells. The maximum usable storage capacity was limited by economic pumping lift and the availability of ground water storage to the irrigable areas. The locations of the ground water storage reservoirs are shown in Appendix B, "Geology and Underground Water Storage Capacity of San Joaquin Valley."

Results of experimental work furnish a measure for estimating the free water content of various types of alluvial material and soils. The materials logged in the well penetration records available were evaluated and estimates made of the average effective capacity of the soil column per foot of water table lowering. These results were checked with indicated drainage factors obtained by analyses presented in Chapter IV for present developed areas, in which quantities of depletion and water table lowering could be determined. The estimated total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the valley are shown in Table 100. The usable capacities are shown, first, between a depth of 10 feet below ground surface and the underground water level of 1929, and second, between depths of 10 and 50 feet below ground surface. Within some of these areas a greater depth of water table lowering than 50 feet, on the average, would be desirable and probably economically warranted at the end of a long dry period. For this reason, there also is included in the table the estimated underground capacity between the depths of 10 feet below ground surface and the assumed economic limit of pumping lift.

In proportioning the physical works for the ultimate development of the State Water Plan for the lower San Joaquin Valley, the only account taken of the availability of potential underground storage

TER PLAN IN SAN JOAQUIN RIVER BASIN

Total cost		Average annual electric energy output, in kilowatt hours (reservoir operated primarily for irrigation)	Value of electric energy per kilowatt hour, in mills	Average annual revenue from sale of electric energy	Average net annual cost, not covered by revenue from sale of electric energy	Average seasonal irrigation yield, in acre-feet
Capital	Annual					
$7,400,000	$441,000				$441,000	(1)163,000
8,600,000	517,000				517,000	(1), (2)150,000
						(1), (3)294,000
7,600,000	452,000				452,000	(1)98,000
26,200,000	1,657,000	240,000,000	3.00	$720,000	937,000	(5)887,000
32,500,000	2,074,000	365,000,000	3.00	1,095,000	979,000	(5)1,303,000
						(5), (6)728,000
2,600,000	155,000				155,000	(5)53,000
3,300,000	200,000				200,000	(5)45,000
14,500,000	885,000	23,000,000	3.50	80,000	805,000	(5), (6)1,726,000
(8)15,500,000	(6)1,062,000	(9)105,000,000	3.50	(9)367,000	(9)695,000	(9), (6)602,000
11,600,000	742,000	100,500,000	2.00	201,000	541,000	(5), (6)1,764,000
						(5), (6)435,000
2,900,000	171,000				171,000	(5), (6), (10)128,000
5,700,000	340,000				340,000	(5), (6)670,000

per month, if operated continuously. Where suitable underground storage is available and a proper control of draft and replacement is exercised, it is a most flexible, efficient and economical means of conserving and utilizing water over a period of years.

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Due to the importance of underground storage, a geologic study was made of the San Joaquin Valley to locate underground storage areas, to estimate their capacity and to determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development. This study reveals that the absorptive areas and available underground storage capacities are large and extensive, particularly in the upper San Joaquin Valley, but limited in their effective utilization due to the lack of readily available surplus water for their charge and recharge. These underground storage reservoir areas are confined to the eastern slope, principally to the alluvial cones and flood plains of the major streams. The surface soil and the geologic formation on the western slope and within the trough of the valley are of such character that no utilizable underground capacity exists. The surface areas of the ground water storage reservoirs and the depths of pervious formations were estimated through field examination of the physical characteristics of surface soils and the application of geologic reasoning, checked and aided as to subsurface characteristics by the penetration records of several hundred wells. The maximum usable storage capacity was limited by economic pumping lift and the availability of ground water storage to the irrigable areas. The locations of the ground water storage reservoirs are shown in Appendix B, "Geology and Underground Water Storage Capacity of San Joaquin Valley."

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In proportioning the physical works for the ultimate development of the State Water Plan for the lower San Joaquin Valley, the only account taken of the availability of potential underground storage

TABLE 99

SUMMARY OF COSTS AND PRINCIPAL PHYSICAL FEATURES OF SURFACE STORAGE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Name of reservoir or site	Stream	Height of dam, in feet	Capacity of reservoir, in acre-feet	Power plant			Cost of reservoir		Cost of power plant		Total cost		Average annual electric energy output, in kilowatt hours (reservoir operated primarily for irrigation)	Value of electric energy per kilowatt hour, in mills	Average annual revenue from sale of electric energy	Average net annual cost, not covered by revenue from sale of electric energy	Average seasonal irrigation yield, in acre-feet
				Installed capacity, in kilovolt amperes	Power factor	Load factor	Capital	Annual	Capital	Annual	Capital	Annual					
Nashville	Cosumnes River	270	281,000	0	----	----	$7,400,000	$441,000	----	----	$7,400,000	$441,000	----	----	----	$441,000	(1)163,000
Ione	Dry Creek	120	610,000	0	----	----	8,600,000	517,000	----	----	8,600,000	517,000	----	----	----	517,000	(1), (2)150,000
Pardee (constructed)	Mokelumne River	343	222,000	18,750	0 80	1.00	----	----	----	----	----	----	----	----	----	----	(1), (3)294,000
Valley Springs	Calaveras River	200	(4)325,000	0	----	----	7,600,000	452,000	----	----	7,600,000	452,000	----	----	----	452,000	(1)98,000
Melones	Stanislaus River	460	1,090,000	68,000	0 80	1 00	22,200,000	1,334,000	$4,000,000	$323,000	26,200,000	1,657,000	240,000,000	3 00	$720,000	937,000	(5)887,000
Don Pedro	Tuolumne River	455	1,000,000	120,000	.80	1.00	26,500,000	1,590,000	6,000,000	484,000	32,500,000	2,074,000	365,000,000	3.00	1,095,000	979,000	(5)1,303,000
Exchequer (constructed)	Merced River	307	279,000	31,250	.80	1.00	----	----	----	----	----	----	----	----	----	----	(5), (6)728,000
Buchanan	Chowchilla River	147	84,000	0	----	----	2,600,000	155,000	----	----	2,600,000	155,000	----	----	----	155,000	(5)53,000
Windy Gap	Fresno River	206	62,000	0	----	----	3,300,000	200,000	----	----	3,300,000	200,000	----	----	----	200,000	(5)45,000
Friant	San Joaquin River	252	(7)400,000	10,000	.80	1.00	14,000,000	840,000	500,000	45,000	14,500,000	885,000	23,000,000	3 50	80,000	805,000	(5), (6)1,726,000
				(8)30,000	.80	1.00			(8)1,500,000	(8)222,000	(8)15,500,000	(8)1,062,000	(8)105,000,000	3.50	(8)367,000	(9)695,000	(9), (6)602,000
Pine Flat	Kings River	274	400,000	40,000	.80	1.00	9,600,000	574,000	2,000,000	168,000	11,600,000	742,000	100,500,000	2 00	201,000	541,000	(5), (6)1,764,000
Ward	Kaweah River	No reservoir at this site included in State plan.															(5), (6)435,000
Pleasant Valley	Tule River	125	39,000	0	----	----	2,900,000	171,000	----	----	2,900,000	171,000	----	----	----	171,000	(5), (6), (10)128,000
Isabella	Kern River	190	338,000	0	----	----	5,700,000	340,000	----	----	5,700,000	340,000	----	----	----	340,000	(5), (6)670,000

(1) Average for 11-year period, 1918-1929.
(2) Includes spill from Pardee Reservoir on Mokelumne River.
(3) Excludes 200,000,000 gallons per day for East Bay Municipal Utility District.
(4) Includes 165,000 acre-feet of storage space, reserved solely for flood control.
(5) Average for 40-year period, 1889-1929.
(6) Includes yield available for and utilizable by ground-water storage.
(7) Net utilizable capacity, 270,000 acre-feet.
(8) Immediate initial development. Life of power plant and period of amortization assumed as 10 years.
(9) Average for 12-year period, 1917-1929.
(10) Includes run-off from South Fork.

TABLE 100

UTILIZABLE UNDERGROUND STORAGE CAPACITY IN SAN JOAQUIN VALLEY BY HYDROGRAPHIC DIVISIONS

Hydrographic division	Gross absorptive area, in acres	Usable underground capacity, in acre-feet		
		Between a depth of 10 feet below ground surface and ground water levels of 1929	Between depths of 10 and 50 feet below ground surface	Between a depth of 10 feet below ground surface and assumed economic limit of pumping lift
1	525,000	3,707,000	3,000,000	3,750,000
2	322,000	2,224,000	1,900,000	3,650,000
3	308,000	1,212,000	1,800,000	2,300,000
4	996,000	1,097,000	6,000,000	8,000,000
5				
6	281,000	760,000	2,000,000	2,300,000
7				
8	146,000	0	850,000	850,000
9	215,000	0	1,260,000	1,260,000
10				
11	83,000	0	470,000	470,000
12	104,000	160,000	420,000	520,000
13	10,000	Not utilizable		

capacity was in the absorptive area to be ultimately served in Hydrographic Division 8 with Merced River water.* However, if underground reservoirs in other areas were operated in conjunction with surface storage, a greater use could be made of the run-off of the tributary streams. In the upper San Joaquin Valley, except in Hydrographic Division 6 (Madera Unit), full account was taken of the available underground capacity in the design of the works to serve this region. Both local and imported supplies must be husbanded if the fullest practicable utilization for beneficial purposes and maximum economy are to be attained. To accomplish the desired results would require the operation of the underground reservoirs in a specific manner similar to that of surface reservoirs. A large portion of the gross draft upon the ground water would be through the medium of privately owned pumping plants, and, in order to maintain a balance in supply and draft over long periods throughout the area, it would be necessary that works for the distribution of surplus waters and pumping equipment in strategic locations be under the control of recognized local public agencies.

It is demonstrated in Chapter VII that the utilization of this underground capacity affords the cyclic storage necessary in the plan for the full practical ultimate development of the eastern slope of the upper San Joaquin Valley. Furthermore, when operated in conjunction with surface regulation and distribution, it is shown to result in the cheapest, most flexible and dependable plan of any that has been suggested or investigated to furnish the required water supply for this region.

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–31 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to provide the required water supplies with the available run-off from 1929 to 1931, including the dry season 1930–31, the studies presented in Appendix D show that it would be necessary to utilize the available underground storage in several additional areas in the lower San Joaquin Valley and also in Hydrographic Division No. 6 of the upper San Joaquin Valley.

Cost of Utilization of Underground Reservoirs.

Contributions to ground water reservoirs are made by absorption of surface run-off in natural stream channels and spreading areas, from artificial conveyance channels and through irrigation applications in excess of net use, which may or may not involve expenditure of funds. The extraction of ground water by means of wells and pumping plants constitutes the principal item of expense in the utilization of ground water. The determination of pumping costs for a particular area is the principal element in a study of the economics of ground water utilization and is, in many cases, one of the important factors governing the economic capacity of surface storage regulation on streams supplying that area. The costs of ground water pumping, in the San Joaquin Valley, have been estimated by analyses of the costs and performance of modern pumping plants under actual operating conditions.

Cost of Pumping from Wells.

Capital Cost—The installation cost of pumping plants and wells varies with the capacity and lift. The capacity varies with the extent of the area to be served. A well established criterion is that the plant should have sufficient capacity to deliver at least six inches in depth per month to the area served. This criterion establishes about the minimum cost of installation for a given area. This capacity requires five months of continuous operation to obtain a gross delivery of 2.5 acre-feet per acre. Table 101 sets forth in column (6) an estimate of the capital costs of pumping plants varying in capacity from 225 to 1125 gallons per minute and for total lifts varying from 25 to 250 feet. The costs of wells have been based on the use of 12-gage hard red steel casing for 10 and 12-inch diameter wells and on 10-gage casing for larger sizes. The depth of each well was assumed to be 100 feet more than the total lift. This assumption is applicable in delta areas. In areas away from streams, much greater depths are required. Estimates of the costs of pumping equipment are based on the direct-connected, electrically-driven well turbine type pump installations. The usual diameter of the well casing and the installed horsepower of the motor are set forth in columns (3) and (4), respectively, of the tabulation for each of the various capacities and heights of lift considered.

Items of Annual Cost—The annual cost of ground water pumping varies with the period of operation, efficiency of the pumping plant, capacity and lift. The items making up the annual cost are plant depreciation, interest on the investment, taxes and insurance, operation, maintenance and power. In this analysis all charges except power are considered as fixed although depreciation and operation and maintenance vary from year to year depending on the period of operation.

Plant Depreciation—The normal useful life of a well and pumphouse is estimated at from 25 to 30 years. The life of a motor is estimated as 20 years and the useful life of a pump as 15 years. Many motors have been in nearly continuous service for 25 years. Pumps used under conditions where corrosive chemicals or sand are carried in the water may have a life of only five years. On the other hand, where clean pure water is pumped, a life of from 25 to 30 years is not

Total height of lift, in feet	year		8 months per year			9 months per year		
		Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total
(1)		(33)	(34)	(35)	(36)	(37)	(38)	(39)
25	7	5.8	1.9	3.7	5.6	1.7	3.6	5.3
	8	5.3	1.3	3.7	5.0	1.1	3.7	4.8
	3	4.5	1.0	3.3	4.3	0.9	3.3	4.2
	4	4.3	0.8	3.4	4.2	0.7	3.3	4.0
	1	4.0	0.7	3.1	3.8	0.7	3.0	3.7
50	8	5.4	1.4	3.7	5.1	1.2	3.7	4.9
	4	4.5	0.9	3.4	4.3	0.8	3.3	4.1
	1	3.9	0.7	3.0	3.7	0.6	3.0	3.6
	7	3.3	0.6	2.6	3.2	0.5	2.6	3.1
	6	3.2	0.5	2.6	3.1	0.5	2.6	3.1
75	3	4.7	1.2	3.3	4.5	1.1	3.3	4.4
	1	4.0	0.8	3.0	3.8	0.7	3.0	3.7
	6	3.2	0.6	2.5	3.1	0.5	2.5	3.0
	4	2.9	0.5	2.4	2.9	0.4	2.4	2.8
	4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
100	4	4.7	1.1	3.4	4.5	1.0	3.3	4.3
	7	3.5	0.7	2.6	3.3	0.6	2.6	3.2
	4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
	2	2.6	0.4	2.2	2.6	0.3	2.1	2.4
150	1	4.2	1.0	3.0	4.0	0.9	3.0	3.9
	4	3.1	0.6	2.4	3.0	0.5	2.4	2.9
	3	2.8	0.4	2.2	2.6	0.4	2.2	2.6
	2	2.6	0.4	2.1	2.5	0.3	2.1	2.4
	1	2.5	0.3	2.1	2.4	0.3	2.1	2.4
200	7	3.8	0.9	2.6	3.5	0.8	2.6	3.4
	4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	2	2.7	0.4	2.1	2.5	0.4	2.1	2.5
	1	2.5	0.3	2.1	2.4	0.3	2.0	2.3
	9	2.2	0.3	1.9	2.2	0.3	1.8	2.1
250	6	3.6	0.9	2.6	3.5	0.8	2.6	3.4
	2	2.8	0.5	2.2	2.7	0.5	2.1	2.6
	1	2.5	0.4	2.1	2.5	0.3	2.1	2.4
	9	2.3	0.3	1.9	2.2	0.3	1.8	2.1
	8	2.1	0.3	1.8	2.1	0.2	1.8	2.0

Cost of Utilization of Underground Reservoirs.

Contributions to ground water reservoirs are made by absorption of surface run-off in natural stream channels and spreading areas, from artificial conveyance channels and through irrigation applications in excess of net use, which may or may not involve expenditure of funds. The extraction of ground water by means of wells and pumping plants constitutes the principal item of expense in the utilization of ground water. The determination of pumping costs for a particular area is the principal element in a study of the economics of ground water utilization and is, in many cases, one of the important factors governing the economic capacity of surface storage regulation on streams supplying that area. The costs of ground water pumping, in the San Joaquin Valley, have been estimated by analyses of the costs and performance of modern pumping plants under actual operating conditions.

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Plant Depreciation—The normal useful life of a well and pumphouse is estimated at from 25 to 30 years. The life of a motor is estimated as 20 years and the useful life of a pump as 15 years. Many motors have been in nearly continuous service for 25 years. Pumps used under conditions where corrosive chemicals or sand are carried in the water may have a life of only five years. On the other hand, where clean pure water is pumped, a life of from 25 to 30 years is not

TABLE 101

COST OF GROUND WATER PUMPING

Total height of lift, in feet	Capacity of plant, in gallons per minute	Usual diameter of well casing, in inches	Usual installed size of motor, in horsepower	Average overall plant efficiency, in per cent	Capital cost of installation. Well, motor, pump, building, etc.	Average annual fixed charges at 14 per cent of capital cost	Acre-feet per month of thirty 24-hour days	Acre-feet feet per month	Kilowatt-hours per month	Annual power demand charge	Energy charge for one month	Annual cost per foot acre-foot, in cents																										
										S-P-2 Schedule		1 month per year			2 months per year			3 months per year			4 months per year			5 months per year			6 months per year			7 months per year			8 months per year			9 months per year		
												Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total	Fixed charges	Power charges	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
25	225	10	3.0	40	$800	$112	30	750	1,020	$15.00	$25.23	14.9	5.4	20.3	7.5	4.4	11.9	5.0	4.0	9.0	3.7	3.9	7.6	3.0	3.8	6.8	2.5	3.7	6.2	2.1	3.7	5.8	1.9	3.7	5.6	1.7	3.6	5.3
	450	12	7½	43	1,100	154	60	1,500	3,570	37.50	51.25	10.3	5.9	16.2	5.1	4.7	9.8	3.4	4.2	7.6	2.6	4.0	6.6	2.1	3.9	6.0	1.7	3.8	5.5	1.5	3.8	5.3	1.3	3.7	5.0	1.1	3.7	4.8
	675	12-14	10	44	1,300	182	90	2,250	5,240	50.00	68.16	8.1	5.2	13.3	4.0	4.1	8.1	2.7	3.7	6.4	2.0	3.6	5.6	1.6	3.5	5.1	1.3	3.4	4.7	1.2	3.3	4.5	1.0	3.3	4.3	0.9	3.3	4.2
	900	14	15	45	1,400	196	120	3,000	6,830	67.50	92.97	6.5	5.4	11.9	3.3	4.2	7.5	2.2	3.9	6.1	1.6	3.7	5.3	1.3	3.5	4.8	1.1	3.5	4.6	0.9	3.4	4.3	0.8	3.4	4.2	0.7	3.3	4.0
	1,125	16	15	46	1,600	224	150	3,750	8,350	67.50	106.65	6.0	4.6	10.6	3.0	3.7	6.7	2.0	3.4	5.4	1.5	3.3	4.8	1.2	3.2	4.4	1.0	3.1	4.1	0.9	3.1	4.0	0.7	3.1	3.8	0.7	3.0	3.7
50	225	10	7½	43	1,200	168	30	1,500	3,570	37.50	51.25	11.2	5.9	17.1	5.6	4.7	10.3	3.7	4.2	7.9	2.8	4.0	6.8	2.2	3.9	6.1	1.0	3.8	5.7	1.6	3.8	5.4	1.4	3.7	5.1	1.2	3.7	4.9
	450	12	15	45	1,600	224	60	3,000	6,830	67.50	92.97	7.5	5.4	12.9	3.7	4.2	7.9	2.5	3.9	6.4	1.9	3.7	5.6	1.5	3.5	5.0	1.2	3.5	4.7	1.1	3.4	4.5	0.9	3.4	4.3	0.8	3.3	4.1
	675	12-14	20	49	1,800	252	90	4,500	9,410	85.00	126.69	5.6	4.7	10.3	2.8	3.8	6.6	1.9	3.4	5.3	1.4	3.3	4.7	1.1	3.2	4.3	0.9	3.1	4.0	0.8	3.1	3.9	0.7	3.0	3.7	0.6	3.0	3.6
	900	14	25	50	1,900	266	120	6,000	12,290	102.50	145.82	4.4	4.1	8.5	2.2	3.3	5.5	1.5	3.0	4.5	1.1	2.9	4.0	0.9	2.8	3.7	0.7	2.7	3.4	0.6	2.7	3.3	0.6	2.6	3.2	0.5	2.6	3.1
	1,125	16	30	51	2,200	308	150	7,500	15,070	120.00	177.56	4.1	4.0	8.1	2.0	3.2	5.2	1.4	2.9	4.3	1.0	2.8	3.8	0.8	2.7	3.5	0.7	2.6	3.3	0.6	2.6	3.2	0.5	2.6	3.1	0.5	2.6	3.1
75	225	10	10	44	1,600	224	30	2,250	5,240	50.00	68.16	10.0	5.2	15.2	5.0	4.1	9.1	3.3	3.7	7.0	2.5	3.6	6.1	2.0	3.5	5.5	1.7	3.4	5.1	1.4	3.1	4.7	1.2	3.3	4.5	1.1	3.3	4.4
	450	12	20	49	2,000	280	60	4,500	9,410	85.00	126.69	6.2	4.7	10.9	3.1	3.8	6.9	2.1	3.4	5.5	1.6	3.3	4.9	1.2	3.2	4.4	1.0	3.1	4.1	0.9	3.0	4.0	0.8	3.0	3.8	0.7	3.0	3.7
	675	12-14	25	50	2,200	308	90	6,750	13,830	102.50	158.14	4.6	3.9	8.5	2.3	3.1	5.4	1.5	2.8	4.3	1.2	2.7	3.9	0.9	2.6	3.5	0.8	2.6	3.4	0.6	2.6	3.2	0.6	2.5	3.1	0.5	2.5	3.0
	900	14	30	51	2,400	336	120	9,000	18,080	120.00	201.64	3.7	3.6	7.3	1.9	2.9	4.8	1.2	2.7	3.9	0.9	2.6	3.5	0.7	2.5	3.2	0.6	2.5	3.1	0.5	2.4	2.9	0.5	2.4	2.9	0.4	2.4	2.8
	1,125	16	40	52	2,700	378	150	11,250	22,160	155.00	253.28	3.4	3.6	7.0	1.7	2.9	4.6	1.1	2.7	3.8	0.8	2.6	3.4	0.7	2.5	3.2	0.6	2.5	3.1	0.5	2.4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
100	225	10	15	45	1,900	266	30	3,000	6,830	67.50	92.97	8.9	5.4	14.3	4.4	4.2	8.6	3.0	3.9	6.9	2.2	3.7	5.9	1.8	3.5	5.3	1.5	3.5	5.0	1.3	3.4	4.7	1.1	3.4	4.5	1.0	3.3	4.3
	450	12	25	50	2,400	336	60	6,000	12,290	102.50	145.82	5.6	4.1	9.7	2.8	3.3	6.1	1.9	3.0	4.9	1.4	2.9	4.3	1.1	2.8	3.9	0.9	2.7	3.6	0.8	2.7	3.5	0.7	2.6	3.3	0.6	2.6	3.2
	675	12-14	30	51	2,700	378	90	9,000	18,080	120.00	201.64	4.2	3.6	7.8	2.1	2.9	5.0	1.4	2.7	4.1	1.0	2.6	3.6	0.8	2.5	3.3	0.7	2.5	3.2	0.6	2.4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	900	14	40	52	2,800	392	120	12,000	23,640	155.00	265.12	3.3	3.5	6.8	1.6	2.9	4.5	1.1	2.6	3.7	0.8	2.5	3.3	0.7	2.5	3.2	0.5	2.4	2.9	0.5	2.4	2.9	0.4	2.4	2.8	0.4	2.4	2.8
	1,125	16	50	54	3,100	434	150	15,000	28,400	190.00	299.70	2.9	3.3	6.2	1.4	2.6	4.0	1.0	2.4	3.4	0.7	2.3	3.0	0.6	2.3	2.9	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.2	2.6	0.3	2.1	2.4
150	225	10	20	49	2,500	350	30	4,500	9,410	85.00	126.69	7.8	4.7	12.5	3.9	3.8	7.7	2.6	3.4	6.0	1.9	3.3	5.2	1.6	3.2	4.8	1.3	3.1	4.4	1.1	3.1	4.2	1.0	3.0	4.0	0.9	3.0	3.9
	450	12	30	51	3,100	434	60	9,000	18,080	120.00	201.64	4.8	3.6	8.4	2.4	2.9	5.3	1.6	2.7	4.3	1.2	2.6	3.8	1.0	2.5	3.5	0.8	2.5	3.3	0.7	2.4	3.1	0.6	2.4	3.0	0.5	2.4	2.9
	675	12-14	50	54	3,400	476	90	13,500	25,610	190.00	278.33	3.5	3.5	7.0	1.8	2.8	4.6	1.2	2.5	3.7	0.9	2.4	3.3	0.7	2.3	3.0	0.6	2.3	2.9	0.5	2.3	2.8	0.4	2.2	2.6	0.4	2.2	2.6
	900	14	60	55	3,600	504	120	18,000	33,530	225.00	354.97	2.8	3.2	6.0	1.4	2.6	4.0	0.9	2.4	3.3	0.7	2.3	3.0	0.6	2.2	2.8	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.1	2.5	0.3	2.1	2.4
	1,125	16	75	56	4,000	560	150	22,500	41,160	277.50	438.08	2.5	3.2	5.7	1.2	2.6	3.8	0.8	2.4	3.2	0.6	2.3	2.9	0.5	2.2	2.7	0.4	2.2	2.6	0.4	2.1	2.5	0.3	2.1	2.4	0.3	2.1	2.4
200	225	10	25	50	3,200	448	30	6,000	12,290	102.50	145.82	7.5	4.1	11.6	3.7	3.3	7.0	2.5	3.0	5.5	1.9	2.9	4.8	1.5	2.8	4.3	1.2	2.7	3.9	1.1	2.7	3.8	0.9	2.6	3.5	0.8	2.6	3.4
	450	12	40	52	3,700	518	60	12,000	23,640	155.00	265.12	4.3	3.5	7.8	2.2	2.9	5.1	1.4	2.6	4.0	1.1	2.5	3.6	0.9	2.5	3.4	0.7	2.4	3.1	0.6	2.4	3.0	0.5	2.4	2.9	0.5	2.4	2.9
	675	12-14	60	55	4,100	574	90	18,000	33,530	225.00	354.97	3.2	3.2	6.4	1.6	2.6	4.2	1.1	2.4	3.5	0.8	2.3	3.1	0.6	2.2	2.8	0.5	2.2	2.7	0.5	2.2	2.7	0.4	2.1	2.5	0.4	2.1	2.5
	900	14	75	56	4,500	630	120	24,000	43,910	277.50	458.70	2.6	3.1	5.7	1.3	2.5	3.8	0.9	2.3	3.2	0.7	2.2	2.9	0.5	2.1	2.6	0.4	2.1	2.5	0.4	2.1	2.5	0.3	2.1	2.4	0.3	2.0	2.3
	1,125	16	100	58	5,000	700	150	30,000	53,000	365.00	516.00	2.3	2.9	5.2	1.2	2.3	3.5	0.8	2.1	2.9	0.6	2.0	2.6	0.5	2.0	2.5	0.4	1.9	2.3	0.3	1.9	2.2	0.3	1.9	2.2	0.3	1.8	2.1
250	225	10	30	51	3,800	532	30	7,500	15,070	120.00	177.56	7.1	4.0	11.1	3.5	3.2	6.7	2.4	2.9	5.3	1.8	2.8	4.6	1.4	2.7	4.1	1.2	2.6	3.8	1.0	2.6	3.6	0.9	2.6	3.5	0.9	2.5	3.4
	450	12	50	54	4,400	616	60	15,000	28,450	190.00	299.70	4.1	3.3	7.4	2.1	2.6	4.7	1.4	2.4	3.8	1.0	2.3	3.3	0.8	2.3	3.1	0.7	2.2	2.9	0.6	2.2	2.8	0.5	2.2	2.7	0.5	2.1	2.6
	675	12-14	75	50	4,900	686	90	22,500	41,160	277.50	438.08	3.0	3.2	6.2	1.5	2.6	4.1	1.0	2.4	3.4	0.8	2.3	3.1	0.6	2.2	2.8	0.5	2.2	2.7	0.4	2.1	2.5	0.4	2.1	2.5	0.3	2.1	2.4
	900	14	100	55	5,400	756	120	30,000	53,000	365.00	516.00	2.5	2.9	5.4	1.3	2.3	3.6	0.8	2.1	2.9	0.8	2.0	2.6	0.5	2.0	2.5	0.4	1.9	2.3	0.4	1.9	2.3	0.3	1.9	2.2	0.3	1.8	2.1
	1,125	16	125	60	6,000	840	150	37,500	64,030	452.50	629.46	2.2	2.9	5.1	1.1	2.3	3.4	0.7	2.1	2.8	0.6	2.0	2.6	0.4	1.9	2.3	0.4	1.9	2.3	0.3	1.8	2.1	0.3	1.8	2.1	0.2	1.8	2.0

unusual. The average life of the entire plant is estimated herein at 18 years. With this estimated average life, the annual depreciation on a 4 per cent sinking fund basis amounts to 3.9 per cent of the capital cost.

Interest—With depreciation allowed for on a sinking fund basis, interest on the full amount of the initial investment is a proper fixed annual charge. In making an estimate of annual costs on the basis of private financing, an interest rate of 6 per cent has been used.

Taxes and Insurance—It is not possible to arrive at an exact value for taxes because of lack of information on the methods used by various county assessors in determining assessed valuations of wells and pumping plants. An annual amount equal to 1.1 per cent of the capital cost, however, is believed to be a fair average allowance for taxes and insurance.

Operation and Maintenance—This item includes repairs, lubrication and attendance. The average annual repair charges on electrically-driven pumping plants may vary from $0.50 to $5.00 per motor horsepower, depending on the period of operation and speed of the unit and to some degree on the size of the motor. The cost of lubricants varies from $0.005 to $0.01 per hour of operation. Attendance consumes a very small fraction of the irrigator's time. The total annual cost of operation and maintenance varies from 1 to 3 per cent of the capital cost of the plant. The latter value has been used herein, in order to insure an ample allowance for repairs and replacements.

Total Annual Fixed Charges—These include all of the foregoing items which are summarized in per cent of capital cost as follows:

Depreciation	3.9 per cent
Interest	6.0 per cent
Taxes and insurance	1.1 per cent
Operation and maintenance	3.0 per cent
Total	14.0 per cent

Based on 14 per cent of capital cost, the fixed annual charges for all of the various plants considered have been set forth in column (7) of Table 101.

Plant Efficiencies—Efficiencies vary with both the capacity of the plant and the total lift. Better efficiencies are obtained with large plants and high lifts. The repair charges used in the estimated costs for operation and maintenance include a sufficient amount to replace or rebuild worn pump runners and bearings. Minor ground water fluctuations sometimes result in the pump operating at speeds which do not give maximum efficiencies. Large fluctuations covering long periods can be compensated for by changes in the number or size of runners and in the size of motor. Column (5) of Table 101 sets forth an estimate of the long time overall average operating efficiency for a plant with each of the various capacities and heights of lift considered.

Power Costs—For each of the various installations shown in Table 101, there are set forth in columns (8), (9) and (10), respectively, the acre-feet pumped per month, the acre-feet feet per month and the kilowatt hours consumed per month based on the plant efficiencies given in column (5).

In a decision of the Railroad Commission of California, No. 24809, May 24, 1932, power schedule S-P-2, applicable to irrigation pumping by individual users in the territory served by San Joaquin Light and Power Corporation, was adopted. This schedule was used in estimating power costs herein. It provides for intermittent or seasonal use of energy. The total power charge consists of an annual demand charge of $5.00 per horsepower per year up to 10 horsepower of connected load and $3.50 per horsepower of connected load for all over 10 horsepower, and a graduated energy charge varying in price per kilowatt-hour with the connected load and period of operation. The schedule for energy charges is as follows:

H.p. of connected load	*Rate per k.w.h. for monthly consumption of*			
	First 50 k.w.h. per h.p.	*Next 50 k.w.h. per h.p.*	*Next 150 k.w.h. per h.p.*	*All over 250 k.w.h. per h.p.*
2–4	4.0 cents	2.2 cents	1.2 cents	0.9 cents
5–9	3.9	2.1	1.2	0.9
10–24	3.4	2.0	1.1	0.9
25–49	2.9	1.9	1.0	0.8
50–99	2.5	1.7	1.0	0.75
100–249	2.2	1.5	0.9	0.7
250–499	2.0	1.3	0.8	0.65
500–999	1.9	1.2	0.8	0.6
1000–2499	1.8	1.1	0.8	0.6
2500 and over	1.7	1.0	0.8	0.6

Columns (11) and (12) in Table 101 set forth, for each installation, the annual demand charge and the energy charge for one month's continuous operation. Actual operation may or may not be continuous. If not continuous, the average cost per kilowatt-hour for the month would be greater.

Total Annual Costs Per Foot Acre-foot—Based on all of the foregoing values, the total annual costs per foot acre-foot, including both fixed and power charges for each installation considered for periods of operation varying from one to nine months per year, have been computed and set forth in columns (13) to (39), inclusive, of Table 101. A study of the table reveals how variable the costs per foot acre-foot may be and demonstrates the relative effect of the different factors. Based upon the furnishing of a full supply of 2.5 acre-feet per acre per season and a total pumping lift of 50 feet, a pumping plant with a required capacity of 450 gallons per minute to serve an area of 120 acres would require five months' pumping. The pumping cost per foot acre-foot would be 1.5 cents for fixed charges and 3.5 cents for power charges or a total of 5.0 cents. If the lift were 75 feet, fixed charges would be 1.2 cents, power charges 3.2 cents and the total cost 4.4 cents; if 100 feet, 1.1 cents, 2.8 cents and 3.9 cents, respectively, per foot acre-foot. If only a 60 per cent supply were pumped from ground water, the charges for a 50-foot lift would be 2.5 cents, 3.9 cents and 6.4 cents, respectively; for 75 feet, 2.1 cents, 3.4 cents and 5.5 cents; and, for 100 feet, 1.9 cents, 3.0 cents and 4.9 cents. Plants of twice this capacity for twice the area, have charges about 25 per cent lower. Plants of twice the lift also have charges about 25 per cent lower and so on. For estimating pumping costs in the upper San Joaquin Valley, general average values of 2.0 cents per foot acre-foot for fixed charges and 3.0 cents per foot acre-foot for power charges or a total of 5.0 cents per foot acre-foot have been used.

CONVEYANCE UNITS

The proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin are designed primarily to bring necessary water supplies from the Sacramento River Basin to the San Joaquin Valley to supplement the available local water supplies in and furnish the ultimate water requirements of the San Joaquin River Basin. In the formulation of a plan for conveyance of Sacramento River water to the San Joaquin Valley, many alternate plans were investigated. These alternate plans were based upon an imported supply of 3000 second-feet to supply lands on the eastern slope of the upper San Joaquin Valley in accord with the plan for complete initial development. The ultimate plan provides for the importation of 8000 second-feet which, together with the development of local sources of supply, would make available a water supply for practically all of the net irrigable area in the San Joaquin Valley. However, the results of the economic studies for the initial capacity are conclusive also with respect to ultimate capacity.

Among the plans investigated was one with a gravity canal extending from the Feather River to Kern River. A second plan investigated, which would involve the exchange of water supplies on the upper San Joaquin River, was a conduit extending from the Folsom Reservoir on the American River to Mendota on the San Joaquin River where canals, which now serve large irrigated areas in the lower San Joaquin Valley, head. A third plan considered involved an exchange of supplies from one stream to another, on the eastern side of the valley from the Feather River to Kern River. All of these plans would divert water above riparian owners and appropriative diversions in the Sacramento Valley. A fourth plan studied was a direct pumping system from the delta channels of the Sacramento and San Joaquin rivers to the upper San Joaquin Valley, without exchange of supplies. A fifth plan studied and adopted for this report provides for the diversion of the supplemental water supply by pumping from the Sacramento-San Joaquin Delta and an exchange of supplies on the San Joaquin River. A summarized comparison of these plans, together with estimates of capital and annual costs for a conveyance capacity of 3000 second-feet, are presented in Chapter VIII in the discussion of the plan for complete initial development.

The adopted plan of conveyance includes a pumping system on the San Joaquin River to transport water from Sacramento-San Joaquin Delta to Mendota. It provides for the exchange of a portion of the pumped water for San Joaquin River water which would be diverted at the Friant Reservoir, 61 miles farther upstream and 308 feet higher in elevation than the point of delivery of imported water at Mendota. It provides conduits leading north and south from Friant Reservoir to convey San Joaquin River water to the lands on the eastern slope of the upper San Joaquin Valley. An extension of the pumping system southerly from Mendota is provided to serve the lands on the western slope of the upper San Joaquin Valley. The advantages of the plan are many. Both capital and annual costs would be much less than for conveyance by any other method. By means of the proposed exchange at Mendota, a pumping lift of about 300 feet would be saved over a direct pumping plan. Diversion in the Sacramento-San Joaquin Delta would be effected below all the riparian lands in the Sacramento River Basin. The source of the water supply in the Sacramento-San Joaquin Delta is the temporary catch-basin of the run-off and return water from 42,900 square miles of drainage area, which comprises 74 per cent of the entire area of the Sacramento and San Joaquin River basins and contributes 91 per cent of the run-off of the two basins. Water developed in any part of the two basins north of the upper San Joaquin River would naturally find its way to this catch-basin. The flexibility of the plan would be of great advantage. It would lend itself more readily to progressive development with minimum expenditures and it would interfere least with present rights and interests. By this plan, full recharge of ground water storage would be made by gravity diversion from Friant, whereas any other plan not providing for exchange of water at Mendota would require a greatly increased pumping lift for such purpose. These great advantages would not be attained by any scheme that does not utilize the delta as a source of supply, and only in part, if not combined with exchange with San Joaquin River water.

The conveyance units, natural and constructed, which would be required for the exportation and delivery of water from the Sacramento River Basin to the lands of the San Joaquin River Basin would extend from the Sacramento River at the head of Snodgrass Slough to the southern extremity of the San Joaquin Valley. These major conveyance units and their principal physical features are set forth in Table 102. Their locations are indicated in outline on Plate XXVI.

TABLE 102

MAJOR CONVEYANCE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Maximum capacity, in second-feet	Length, in miles	Number of pumping plants	Elevation of diversion, in feet*	Elevation of terminus, in feet*	Pumping lift, in feet	
						Maximum	Average weighted
Sacramento-San Joaquin Delta Cross Channel	10,000	24	0	3±	1±	0	0
San Joaquin River Pumping System	8,000	167	10	0	159	202	185
San Joaquin River-Kern County Canal	3,000	165	0	467	358	0	0
Madera Canal	1,500	18	0	415	391	0	0
Kern River Canal	1,500	75	0	680	591	0	0
Mendota West Side Pumping System	4,500	100	6	159	250	150	117
Totals		549	16				

* U. S. Geological Survey datum.

In making studies of the conveyance units of the adopted plan and also of the various alternates, full use was made of all available maps and surveys. Preliminary locations of all conveyance channels were made first on U. S. Geological Survey topographic maps. It was desirable and necessary, however, to make additional surveys in many instances. This was done particularly for the units which are of more immediate importance.

In studying the locations of the Sacramento-San Joaquin Delta Cross Channel and the San Joaquin River Pumping System, topographic surveys were made of channels from Hood to New Hope in the delta. Existing U. S. Engineer Department maps of the delta and San Joaquin River channels and levees, all on a scale of one inch equals 400 feet, were revised to date by a plane table survey from New Hope to Mendota, a distance of about 200 miles. Additional maps also were made of Fresno Slough for 10 miles south of Mendota. These surveys cover an area of about 130,000 acres.

Two locations were investigated for the San Joaquin River-Kern County Canal. The first location involved an exchange of supplies at Kings River. It would have diverted from Friant Dam at an elevation of 420 feet and discharged into the Kings River about two miles south of Sanger at elevation 325. The second location studied and adopted has a diversion elevation at Friant Dam of 467 feet and crosses the Kings River without exchange of supplies at elevation 445 feet. From Kings River south the same location was used for both plans. In studying these plans, two field locations with profiles and supplemental topographic surveys were made between Friant dam site and Kings River, each traversing a distance of about 35 miles. A field location was made and a profile secured from Kings River south to Kern Island Canal a distance of 132 miles. Special topographic surveys were made of river, canal, road and railroad crossings and of all parts of the location in irregular topography and other points where more detailed information was desired, and mapped on a large scale for location studies.

The Madera Canal was located on U. S. Geological Survey topographic maps and the location compared with a location plotted on topographic surveys, scale one inch equals 200 feet, made by the Madera Irrigation District for a canal traversing practically the same route.

A preliminary field location was made of the Kern River Canal from the point of diversion southward and around the head of the valley for a distance of about 40 miles. The total length of this canal location is 75 miles. The last 35 miles on flat smooth topography were located partly on U. S. Geological Survey topographic maps and partly on topographic maps made by private agencies. A special topographic survey for preparing a large scale map was made of the first seven miles where more detailed information was required for determining the most economical combination of canal and tunnel location along the south side of Kern River and under the mesa about eight miles east of Bakersfield.

The location of the Mendota-West Side Pumping System was made entirely on U. S. Geological Survey topographic maps aided by field examinations. These maps have a scale of two inches equals one mile and a five-foot contour interval. The topography traversed by the location is relatively flat and smooth.

Estimates of cost for the conveyance units are presented under the following discussions of each unit. The unit prices of construction set forth herein are for the items in place and are exclusive of amounts for administration, engineering, contingencies and interest during construction. To each cost estimate there has been added 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction at 4.5 per cent, computed on a basis of financing at the beginning of each six months and compounded to the end of the construction period.

Annual costs, including interest and amortization on bonds, depreciation, and operation and maintenance, were estimated for each unit. Annual electric energy costs were estimated for conveyance units having pumping plants. The bases for estimating the annual costs are as follows:

Item	*Annual cost, in per cent of capital cost*
Interest	4.5
Amortization of capital investment (40-year sinking fund basis at 4 per cent)	1.05
Depreciation:	
Canals	0.65
Minor concrete structures	0.35
Tunnels	0.35
Pumping plants—	
Concrete buildings and structures	0.35
Electrical and mechanical equipment	2.40
Steel leaf dams	1.05
Operating expenses and maintenance:	
Canals	2.30
Minor concrete structures	1.60
Tunnels	1.60
Canal right of ways	0.45
Pumping Plants—	
Concrete buildings and structures	1.60
Electrical and mechanical equipment	5.55
Steel leaf dams	3.90

Electric energy charges for pumping are in accord with the power schedules of the public utilities distributing power in the regions in which the pumping plants are located.

A description, types of conveyance channels and appurtenances, considerations governing location, other pertinent physical data and estimates of capital and annual costs are set forth for each major conveyance unit in the following presentation.

Sacramento-San Joaquin Delta Cross Channel.

The most northerly unit of the conveyance system, the Sacramento-San Joaquin Delta Cross Channel, is designed to carry from the Sacramento River to the San Joaquin River Delta the water required to meet the four-fold demand of salinity control, delta consumptive use, agricultural and industrial uses in Contra Costa County and exportation to the San Joaquin Valley. The present channel capacity provided by the two interconnecting channels of Georgiana and Three Mile sloughs is hardly sufficient to take care of the consumptive demands in the San Joaquin Delta, if all or most of the water supply required were to come from the Sacramento River. Approximately two-thirds of the irrigable area of the Sacramento-San Joaquin Delta is in the San Joaquin portion thereof. The net stream flow past Antioch required for the prevention of saline invasion into the delta, under the proposed plan of salinity control*, must be distributed in both the Sacramento and San Joaquin river channels, in proportion to the magnitude of tidal diffusion therein. Therefore, it is necessary to provide additional channel capacity from the Sacramento River to the San Joaquin Delta, of such magnitude that complete flexibility in

*Bulletin No. 27, "Variation and Control of Salinity in Sacramento–San Joaquin Delta and Upper San Francisco Bay, Division of Water Resources, 1931."

the distribution of the inflow would be available to allow the water to flow automatically to the portions of the basin where needed to satisfy the consumptive demands and demands of salinity control in the delta and transfer surplus water from the Sacramento River through the San Joaquin Delta channels to the lower end of the San Joaquin River pumping system.

Under present conditions, most of the flow of the Sacramento River into the San Joaquin Delta goes through Georgiana Slough. This slough diverts from the Sacramento River just below Walnut Grove and connects with the Mokelumne River about 3½ miles above its junction with the San Joaquin River. It is a tidal channel and the flow is nonuniform and fluctuates with the rise and fall of the tide. However, except for conditions of relatively low flow in the Sacramento River when there is an occasional reversal of flow of short duration from the San Joaquin River into the Sacramento River, the flow although varying in rate is predominantly from the Sacramento River to the San Joaquin River. Based upon the measurements in 1929, the flow through Georgiana Slough in per cent of the flow in the Sacramento River passing Sacramento is as follows:

Flow in Sacramento River passing Sacramento in second-feet	*Flow through Georgiana Slough in per cent of flow passing Sacramento*
3,000	43½
5,000	36
10,000	24
20,000	17½
40,000 to 60,000	15

Continuous records of tidal stage at each end of Georgiana Slough show that the mean tidal elevation at the Walnut Grove end is higher than the mean tidal elevation at the lower Mokelumne River end.

The flow through Three Mile Slough, as shown by detailed measurements in 1929, is extremely variable. There is a complete reversal of flow through the channel between the Sacramento and San Joaquin rivers with each successive flood and ebb tide, regardless of the flow in the Sacramento River up to flows of 100,000 second-feet passing Sacramento. Over a considerable period of time, the measurements show that there is a net transfer of water from the Sacramento to the San Joaquin River. However, it is small in amount and hence Three Mile Slough is of small importance as a means of transferring water from the Sacramento River to the San Joaquin Delta.

With the regulated flows which would be required in the Sacramento River for ultimate development, the flow through Georgiana Slough into the San Joaquin Delta would provide only a part of the water required to meet the fourfold demand previously stated. The flow through Georgiana Slough would be only 2000 to 3000 second-feet whereas the flow required into the San Joaquin Delta to meet the fourfold demand previously stated would amount in the maximum month of demand to about 12,000 second-feet for ultimate development. The additional channel capacity required for ultimate development would, therefore, amount to about 9000 to 10,000 second-feet. Studies have been made to determine the most practicable plan of obtaining the required additional connecting channel capacity. A consideration of possible locations for a new connecting channel showed that the most practicable route would be through Snodgrass Slough and the Mokelumne River Channels. Snodgrass Slough heads below Hood near the east bank of the Sacramento River about ten miles above Walnut Grove and joins the Mokelumne River at Dead Horse Island near New Hope Landing. At New Hope Landing, the Mokelumne River divides into two channels, the North and South forks, which subsequently join near the junction of the Mokelumne River and Georgiana Slough, about two miles upstream from the junction of the Mokelumne and San Joaquin rivers at Central Landing. Other sloughs, the principal of which are Potato and Little Connection, connect the South Fork of the Mokelumne River directly with the San Joaquin River.

Plans for Development Investigated—Two plans of development were considered. The first plan provides for the utilization of Georgiana Slough with an additional channel cut from the head of this slough to Snodgrass Slough at the westerly end of Dead Horse Island; and, in addition, a new connecting channel cut through from the Sacramento River to the head of Snodgrass Slough which would be enlarged to its junction with the Mokelumne River. No diversion dam would be provided in the Sacramento River and the channels would be designed to obtain the required capacity under conditions of tidal fluctuation. The second plan of development considered provides for a similar new connecting channel along the route of Snodgrass Slough with the diversions into and through this new channel controlled by a dam across the Sacramento River and gates at the head of the new cut leading into Snodgrass Slough.

Under the first plan considered, a channel with a bottom width of about 325 feet from the upper end of Snodgrass Slough to Dead Horse Island would be required. In addition extensive enlargement would be necessary in the upper end of the South Fork of the Mokelumne River. A headgate at the intake of Snodgrass Slough having practically the same area of opening as the cross-sectional area of the Sacramento River opposite its head would be required. Draw or bascule highway bridges would be required at New Hope Landing on the South Fork and near the junction with Snodgrass Slough on the North Fork of the Mokelumne River. A new draw or bascule bridge also would be required for the Southern Pacific railroad crossing over Snodgrass Slough. The new channel cut from the head of Georgiana Slough to Snodgrass Slough would require a gate structure at its head, and, in addition, an embankment about 2000 feet in length and a bridge crossing for the Southern Pacific Railroad.

The second plan, although requiring a dam across the Sacramento River which would be equipped with locks to accommodate navigation, would require a channel along Snodgrass Slough of only about 125 feet in bottom width. Channel excavation and enlargement would be but a small percentage of that required in the first plan. No new bascule or draw bridges for either highway or railroad crossings would be required. The headgate structure at the head of the new channel would require a much smaller opening and involve a smaller cost than under the first plan. This plan would not include a new channel cut from the head of Georgiana Slough to Snodgrass Slough as provided in the first plan.

The second plan would appear to have advantages over the first plan. In the first place, the estimated cost of the second plan is less than that for the first. Secondly, the second plan would be more positive in operation and accomplishment. Thirdly, although the necessity for lockage would be of some disadvantage by delays to navigation, it would have the advantage of affording slack water navigation above the dam to Sacramento. Therefore, it is believed that the second plan involving a controlled channel would be the more advantageous plan of development for adoption.

Cost of Sacramento-San Joaquin Delta Cross Channel—In the light of the investigations and studies which have been made thus far, the plan of controlled channel development for the Sacramento-San Joaquin Delta Cross Channel has been adopted tentatively as a basis for estimating the cost of this unit. Table 103 sets forth the estimate of cost, including the capital costs of the channel and all appurtenant works, right of ways and spoil areas, and the total annual cost. The cost of the control works on the Sacramento River is based on the cost of a dam and lock as estimated by the U. S. Army Engineers and set forth on pages 74 and 75 in House of Representatives Document No. 123, Sixty-ninth Congress, first session.

TABLE 103

COST OF SACRAMENTO-SAN JOAQUIN DELTA CROSS CHANNEL

Control works on Sacramento River	$2,300,000
Headgate structure at head of Snodgrass Slough for channel 125 feet wide	150,000
2 secondary road bridges over Snodgrass Slough	126,000
Minor structures and protective works	100,000
Excavation, enlarging Snodgrass Slough and upper end of North and South Forks of Mokelumne River, 2,000,000 cubic yards at $0.10	200,000
Right of way and spoil areas	150,000
Subtotal	$3,026,000
Administration and engineering, at 10 per cent	303,000
Contingencies, at 15 per cent	454,000
Interest during construction, based on an interest rate of 4½ per cent per annum	217,000
Total capital cost	$4,000,000
Total annual cost	$300,000

San Joaquin River Pumping System.

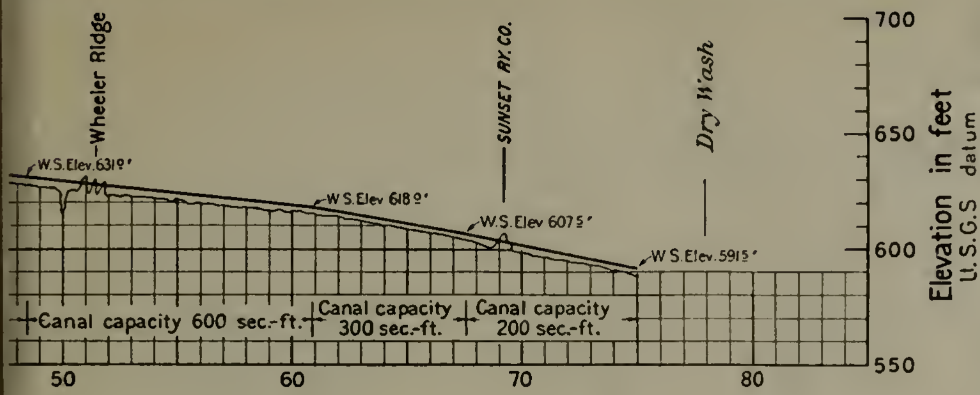
From Central Landing at the lower end of the Sacramento-San Joaquin Delta Cross Channel to the first unit of the San Joaquin River Pumping System below Mossdale Bridge, the conveyance system would comprise chiefly three existing channels, each about 30 miles in length. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity is adequate to meet the requirements for exportation to the San Joaquin River Basin and also for delta irrigation use.

Many different plans were considered for a pumping system to convey water from the delta to Mendota. These varied in range from that of a plan to attain the total elevation required by a series of pumping lifts located on the shortest line possible from a point near Paradise Dam westerly toward the foothills and thence continuing southerly through a constructed gravity canal along the west slope of the valley to Mendota, to a plan with a series of dams and pumping lifts utilizing the channel of the San Joaquin River throughout its entire length from the delta to Mendota. Several of the more feasible of the alternate plans investigated are presented in Chapter VIII for a 3000 second-feet capacity plan for complete initial development. The plan adopted for this unit of the proposed conveyance system for ultimate development is the one which, in the light of the studies and investigations made thus far, seems to present the greatest advantages from all viewpoints.

The first unit of the proposed San Joaquin River Pumping System is located just above the point of bifurcation of the San Joaquin River and Old River. From this point to the mouth of the Merced River, the channel of the San Joaquin River would be utilized for a distance of 72 miles. By means of a series of five successive dams and pumping plants, water would be conveyed from the delta and raised to an elevation of 62 feet, U. S. Geological Survey datum. The dams used for this portion of the pumping system are of the collapsible type providing an unobstructed channel to permit free discharge in case of large flows. The maximum capacity of the pumping system would be 8000 second-feet.

From the pond above Plant No. 5, it is proposed to depart westerly from the river with a constructed canal extending southerly along the most favorable topography. By means of three pumping lifts in a distance of seven miles, the water would be raised to an elevation of 137 feet at the discharge of Plant No. 8 and would continue a distance of sixteen miles to Plants No. 9 and No. 10, about five miles west of Los Banos. A portion of the pumped water would be diverted into existing canal systems serving lands lying below Plant No. 9. From the discharge of Plant No. 10, at an elevation of 180 feet, the canal would extend southerly about 38 miles to the Mendota Weir, delivering water at an elevation of 159 feet. The pond above the Mendota Weir would be the source of supply for lands now served by diversions at and near this point. Local pumping projects would be required for serving west side rim lands above present developed areas. The total distance from Pumping Plant No. 1 to Mendota Weir would be 135 miles. The location and profile of the San Joaquin River Pumping System are shown respectively on Plate XXVI and on Plate LVII, "Profile of Major Conveyance Units of State Plan for Ultimate Development in San Joaquin Valley, Sacramento-San Joaquin Delta to Kern County." Plans of typical pumping plants and a collapsible steel leaf dam are shown on Plate LVIII, "Typical Designs, Dam and Pumping Plants for San Joaquin River Pumping System."

The height of each pumping lift and the capacity of each pumping plant are set forth in Table 104. The average seasonal amount of water that would have been pumped through each lift and the estimated average seasonal energy consumption for the 12-year period 1917–1929 also are given in the tabulation. In arriving at these values, credit was allowed for return flows from the Merced, Tuolumne and Stanislaus rivers for conditions of ultimate irrigation and municipal development. The probable return flows above each dam were estimated very conservatively to insure an energy consumption estimate that would provide for repumping possible seepage losses between lifts.



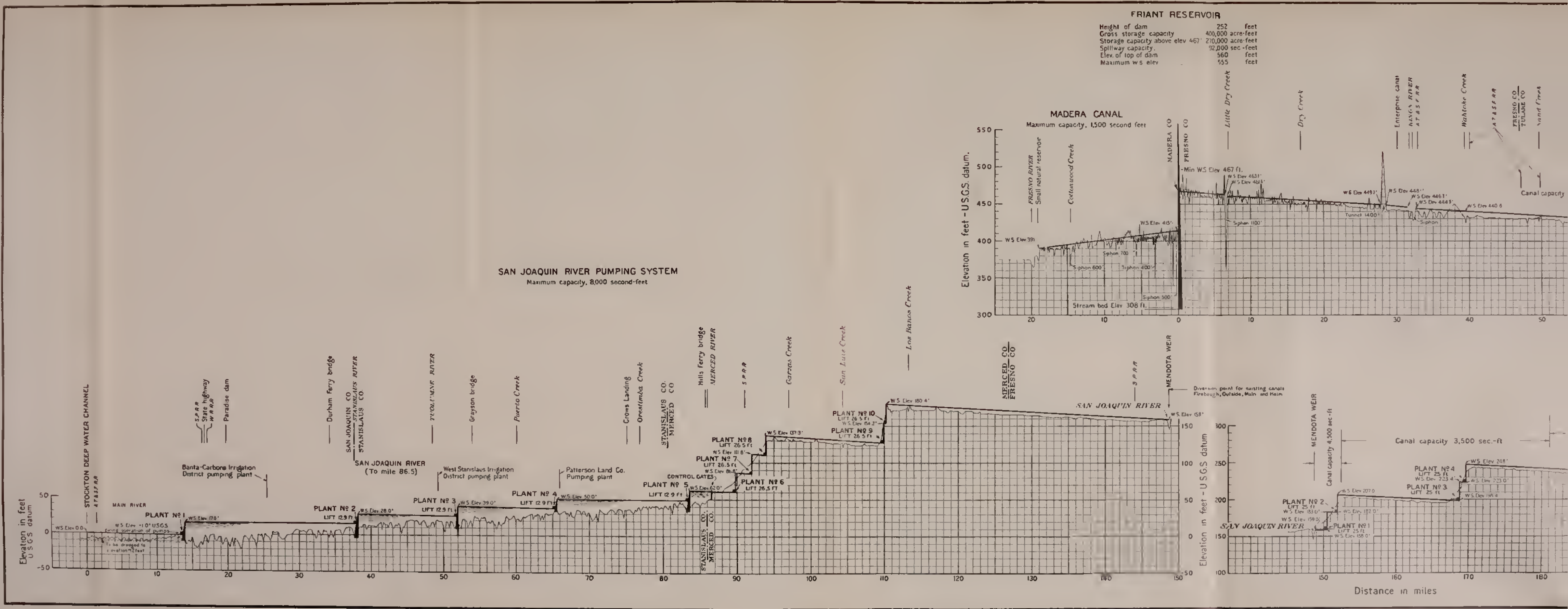
PROFILE OF

ANCE UNITS OF STATE PLAN

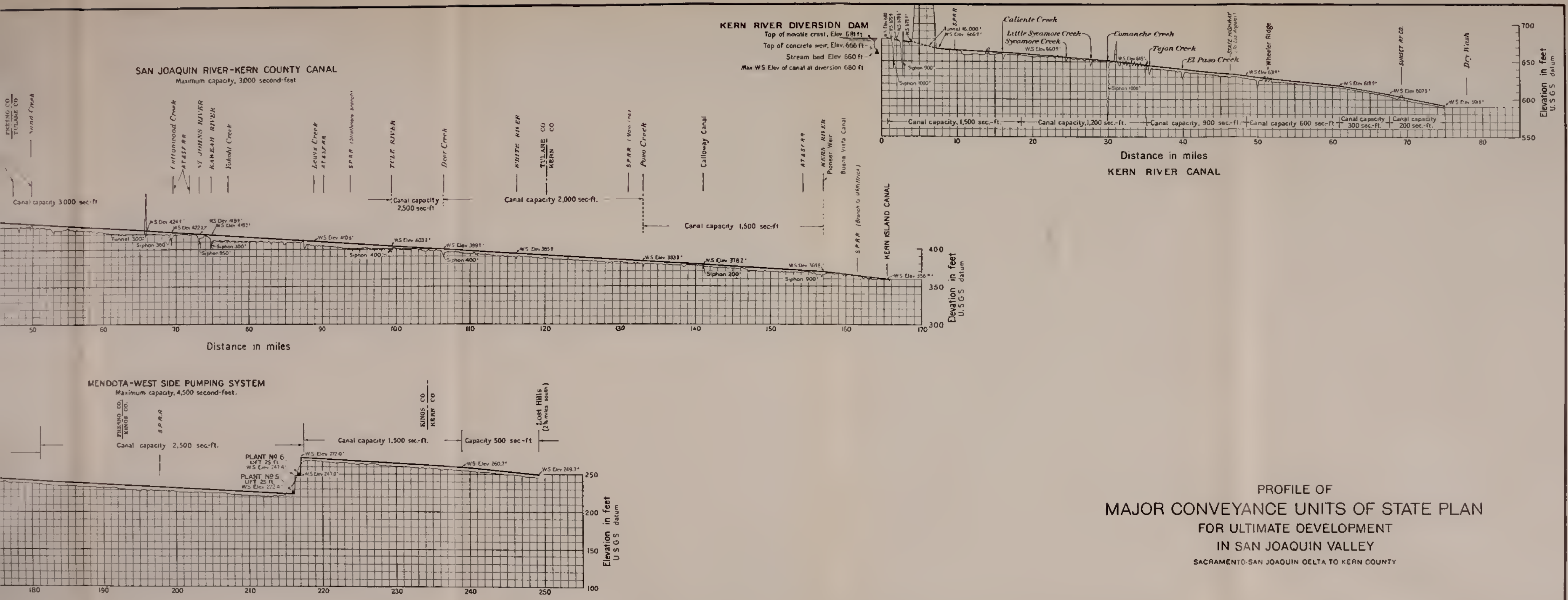
TIMATE DEVELOPMENT

AN JOAQUIN VALLEY

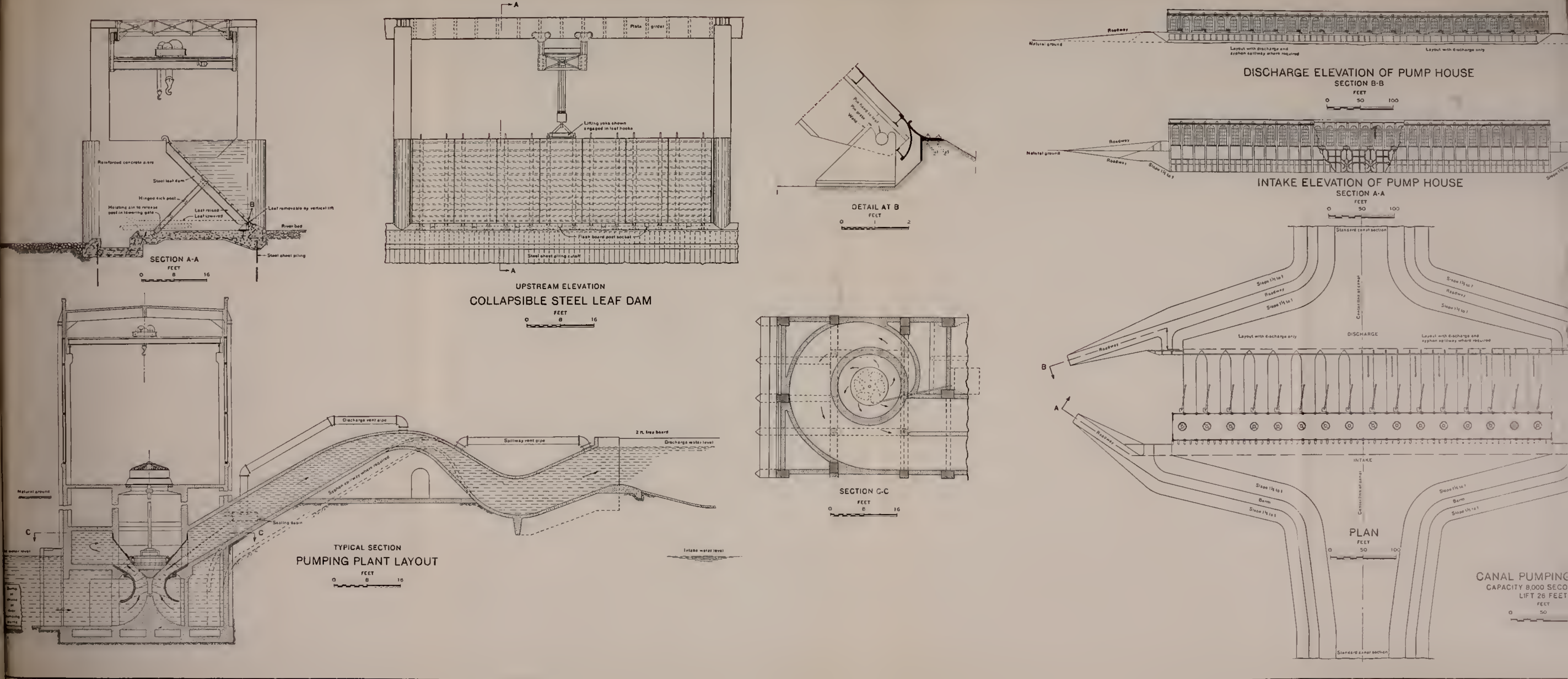
-SAN JOAQUIN DELTA TO KERN COUNTY

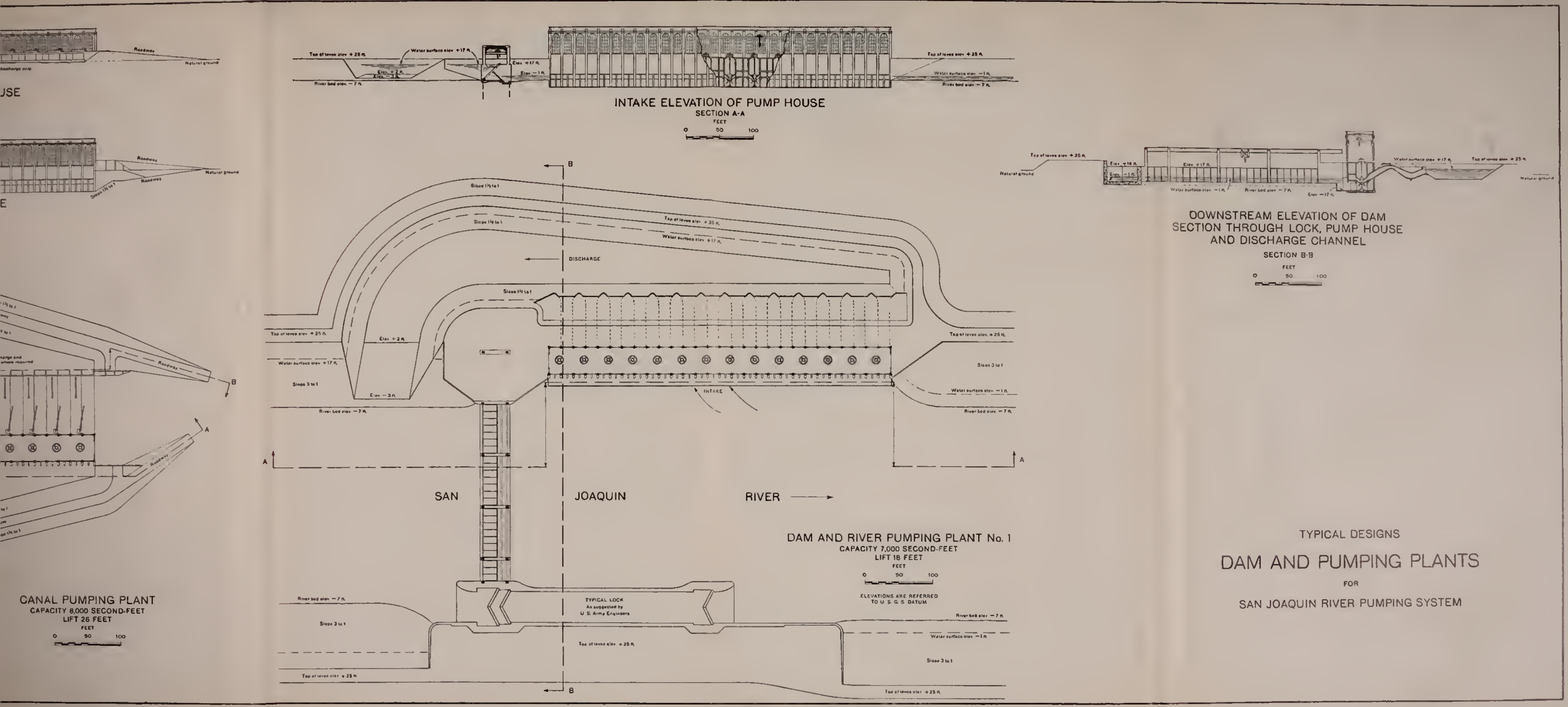

FRIANT RESERVOIR
Height of dam 252 feet
Gross storage capacity 400,000 acre-feet
Storage capacity above elev 467' 270,000 acre-feet
Spillway capacity 92,000 sec.-feet
Elev. of top of dam 560 feet
Maximum W.S. elev 555 feet
MADERA CANAL
Maximum capacity, 1,500 second feet
SAN JOAQUIN RIVER PUMPING SYSTEM
Maximum capacity, 8,000 second-feet
Elevation in feet - U.S.G.S. datum
Elevation in feet U.S.G.S. datum
Distance in miles
STOCKTON DEEP WATER CHANNEL
PLANT Nº 1
PLANT Nº 2
PLANT Nº 3
PLANT Nº 4
PLANT Nº 5
PLANT Nº 6
PLANT Nº 7
PLANT Nº 8
PLANT Nº 9
PLANT Nº 10
SAN JOAQUIN RIVER
(To mile 86.5)
Banta-Carbona Irrigation District pumping plant
West Stanislaus Irrigation District pumping plant
Patterson Land Co. Pumping plant
CONTROL GATES
MENDOTA WEIR
Diversion point for existing canals Firebaugh, Outside, Main and Helm
Canal capacity 3,500 sec.-ft
Canal capacity 4,500 sec.-ft

80997



PROFILE OF
MAJOR CONVEYANCE UNITS OF STATE PLAN
FOR ULTIMATE DEVELOPMENT
IN SAN JOAQUIN VALLEY
SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY


SECTION A-A
FEET
0 8 16
UPSTREAM ELEVATION
COLLAPSIBLE STEEL LEAF DAM
FEET
0 8 16
DETAIL AT B
FEET
0 1 2
SECTION C-C
FEET
0 8 16
TYPICAL SECTION
PUMPING PLANT LAYOUT
FEET
0 8 16
DISCHARGE ELEVATION OF PUMP HOUSE
SECTION B-B
FEET
0 50 100
INTAKE ELEVATION OF PUMP HOUSE
SECTION A-A
FEET
0 50 100
PLAN
FEET
0 50 100
DISCHARGE
INTAKE
CANAL PUMPING
CAPACITY 8,000 SECO
LIFT 26 FEET
FEET
0 50



USE
E
CANAL PUMPING PLANT
CAPACITY 8,000 SECOND-FEET
LIFT 26 FEET
FEET
0 50 100
INTAKE ELEVATION OF PUMP HOUSE
SECTION A-A
FEET
0 50 100
DOWNSTREAM ELEVATION OF DAM
SECTION THROUGH LOCK, PUMP HOUSE
AND DISCHARGE CHANNEL
SECTION B-B
FEET
0 50 100
DISCHARGE
INTAKE
SAN
JOAQUIN
RIVER
TYPICAL LOCK
As suggested by
U. S. Army Engineers
DAM AND RIVER PUMPING PLANT No. 1
CAPACITY 7,000 SECOND-FEET
LIFT 18 FEET
FEET
0 50 100
ELEVATIONS ARE REFERRED
TO U. S. G. S. DATUM
TYPICAL DESIGNS
DAM AND PUMPING PLANTS
FOR
SAN JOAQUIN RIVER PUMPING SYSTEM

TABLE 104

PUMPING LIFTS AND CAPACITIES, SEASONAL QUANTITY OF WATER PUMPED AND SEASONAL ENERGY CONSUMPTION FOR SAN JOAQUIN RIVER PUMPING SYSTEM

Location and number of pumping plant	Height of lift, in feet	Capacity of plant, in second-feet	Seasonal quantity of water pumped, in acre-feet[1]	Seasonal energy consumption, in kilowatt hours[1]
At Dams on San Joaquin River—				
1	18.0	7,000	1,828,000	56,184,000
2	12.9	7,000	1,845,000	40,639,000
3	12.9	7,500	2,158,000	47,534,000
4	12.9	7,500	2,158,000	47,534,000
5	12.9	7,500	2,124,000	46,785,000
First Group of Canal Lifts near Newman—				
6	26.5	8,000	2,438,000	110,316,000
7	26.5	8,000	2,438,000	110,316,000
8	26.5	8,000	2,438,000	110,316,000
Second Group of Canal Lifts near Los Banos				
9	26.5	6,500	2,225,000	100,679,000
10	26.5	6,500	2,225,000	100,679,000
Totals	202.1			770,982,000
Average weighted lift	185.0			

[1] Average for 12-year period 1917-1929.

PLATE LIX

MENDOTA WEIR ON SAN JOAQUIN RIVER

Cost of San Joaquin River Pumping System—An estimate of cost based on unit prices set forth in Table 105 is presented in Table 106. The estimate sets forth the capital cost of the complete pumping system including conveyance channels, pumping plants, steel leaf dams, minor structures, right of ways and spoil areas. The total annual cost, including the average annual charge for electric energy, also is given in the tabulation.

TABLE 105

UNIT PRICES USED IN COST ESTIMATE OF SAN JOAQUIN RIVER PUMPING SYSTEM

Excavation and embankment—	
River channel excavation	$0.10 per cu. yd.
Levee embankment	.15 per cu. yd.
Canal excavation in earth:	
First 13 feet in depth	.18 per cu. yd.
13 to 18 feet in depth	.22 per cu. yd.
18 to 23 feet in depth	.25 per cu. yd.
23 to 28 feet in depth	.28 per cu. yd.
28 to 33 feet in depth	.32 per cu. yd.
Canal excavation in hardpan	.60 per cu. yd.
Canal embankment in earth (10 per cent shrinkage allowance):	
First 8 feet of fill	.18 per cu. yd.
8 to 13 feet of fill	.20 per cu. yd.
Concrete—	
Reinforced concrete canal lining, 3¼ inches thick, based on concrete at $10.00 per cubic yard and steel at $0.06 per pound in place	$0.15 per sq. ft.
Concrete in dams and pumping plants, exclusive of reinforcing	17.00 per cu. yd.
Reinforcing steel	.06 per lb.
Concrete in bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.
Steel leaf dams—	
Excavation—20 cu. yds. at $0.30 and 7 cu. yds. at $6.00	$48.00 per lin. ft. of dam
Steel sheet piling—3,100 lbs. at $0.06	186.00 per lin. ft. of dam
Concrete, exclusive of reinforcing—	
7 cu. yds. at $17.00	119.00 per lin. ft. of dam
Reinforcing steel—500 lbs. at $0.06	30.00 per lin. ft. of dam
Gate steel—leaf and struts—1,250 lbs. at $0.10	125.00 per lin. ft. of dam
Superstructure steel—bridge and bracing—650 lbs. at $0.10	65.00 per lin. ft. of dam
Traveling crane, total cost $10,000. Average	40.00 per lin. ft. of dam
Total	$613.00 per lin. ft. of dam
Pumping Plants—	
For a lift of 13 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	31,500 per 500 sec. ft. unit
Pump and metal liner in pump shell	5,100 per 500 sec. ft. unit
Synchronous motor	6,200 per 500 sec. ft. unit
Transformer	4,750 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	1,600 per 500 sec. ft. unit
Total	$53,150 per 500 sec. ft. unit
For a lift of 18 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	34,000 per 500 sec. ft. unit
Pump and metal liner in pump shell	6,000 per 500 sec. ft. unit
Synchronous motor	7,250 per 500 sec. ft. unit
Transformer	5,600 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	1,900 per 500 sec. ft. unit
Total	$58,750 per 500 sec. ft. unit
For a lift of 26.5 feet:	
Excavation	$4,000 per 500 sec. ft. unit
Concrete sump, building, pump shell, discharge and spillway	38,000 per 500 sec. ft. unit
Pump and metal liner in pump shell	7,500 per 500 sec. ft. unit
Synchronous motor	9,000 per 500 sec. ft. unit
Transformer	7,000 per 500 sec. ft. unit
Exciters, switches and other electrical equipment	2,500 per 500 sec. ft. unit
Total	$68,000 per 500 sec. ft. unit

TABLE 106

COST OF SAN JOAQUIN RIVER PUMPING SYSTEM

Central Landing to Hills Ferry—		
Length, 102 miles. Capacity, varies from 7,000 to 7,500 second-feet.		
Excavation and embankment:		
Enlargement of delta channels below Dam No. 1, 8,000,000 cubic yards at $0.10	$800,000	
Channel changes and enlargement between dams, 4,000,000 cubic yards at $0.10	400,000	
Levee embankments above dams, 600,000 cubic yards at $0.15	90,000	
Pumping plants:		
Lift No. 1, capacity 7,000 second-feet	823,000	
Lift No. 2, capacity 7,000 second-feet	744,000	
Lift No. 3, capacity 7,500 second-feet	796,000	
Lift No. 4, capacity 7,500 second-feet	797,000	
Lift No. 5, capacity 7,500 second-feet	796,000	
Steel leaf dams:		
Dam No. 1	172,000	
Dam No. 2	172,000	
Dam No. 3	123,000	
Dam No. 4	208,000	
Dam No. 5	147,000	
Minor structures:		
Drainage culverts through levees	20,000	
Control works at Paradise Dam	25,000	
Maintaining existing bridges during construction	50,000	
Right of ways:		
Delta channel enlargement and spoil areas	150,000	
River levees and spoil areas	120,000	
		$6,433,000
Hills Ferry to Mendota—		
Length, 63 miles. Capacity, varies from 8,000 to 6,500 second-feet.		
Excavation:		
Canals in deep cut and fill sections near pumping plants, 3,200,000 cubic yards at $0.20 to $0.23	$713,000	
Canals with regular concrete lined section:		
Earth, 7,388,000 cubic yards at $0.18	1,330,000	
Hardpan, 213,000 cubic yards at $0.60	128,000	
Spillway channel near Los Banos:		
Earth, 278,000 cubic yards at $0.18	50,000	
Reinforced concrete canal lining:		
37,895,000 square feet at $0.15	5,684,000	
Pumping plants:		
Lift No. 6, capacity 8,000 second-feet	1,088,000	
Lift No. 7, capacity 8,000 second-feet	1,088,000	
Lift No. 8, capacity 8,000 second-feet	1,088,000	
Lift No. 9, capacity 6,500 second-feet	884,000	
Lift No. 10, capacity 6,500 second-feet	884,000	
Minor structures on portion of canal having a capacity of 8,000 second-feet:		
Intake gates in cut near Hills Ferry	60,000	
Siphons, 3 at $30,000	90,000	
Railroad crossing	50,000	
Road bridges, 20 at $12,000	240,000	
Spillway channel control	30,000	
Bridges on spillway channel, 3 at $8,000	24,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 3 at $4,000	12,000	
Minor structures on portion of canal having a capacity of 6,500 second-feet:		
Road bridges, 18 at $10,000	180,000	
Siphon	25,000	
Railroad crossing	40,000	
Outlets, 2 at $5,000	10,000	
Underdrains, 5 at $3,000	15,000	
Right of ways and fencing	444,000	
		14,167,000
Subtotal		$20,600,000
Administration and engineering, at 10 per cent		2,060,000
Contingencies, at 15 per cent		3,090,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		2,750,000
Total capital cost		$28,500,000
Annual cost, exclusive of energy		$2,539,000
Average annual energy charge, 770,982,000 kilowatt hours at $0.0055		4,240,000
Total annual cost		$6,779,000

San Joaquin River-Kern County Canal.

The San Joaquin River-Kern County Canal is proposed for the conveyance of San Joaquin River water for use on the eastern slope of the upper San Joaquin Valley south of San Joaquin River. It extends from Friant Reservoir southward along the eastern rim of the valley a distance of 165 miles to a point about five miles south of

Bakersfield. The location of this canal is shown on Plate XXVI and its profile on Plate LVII.

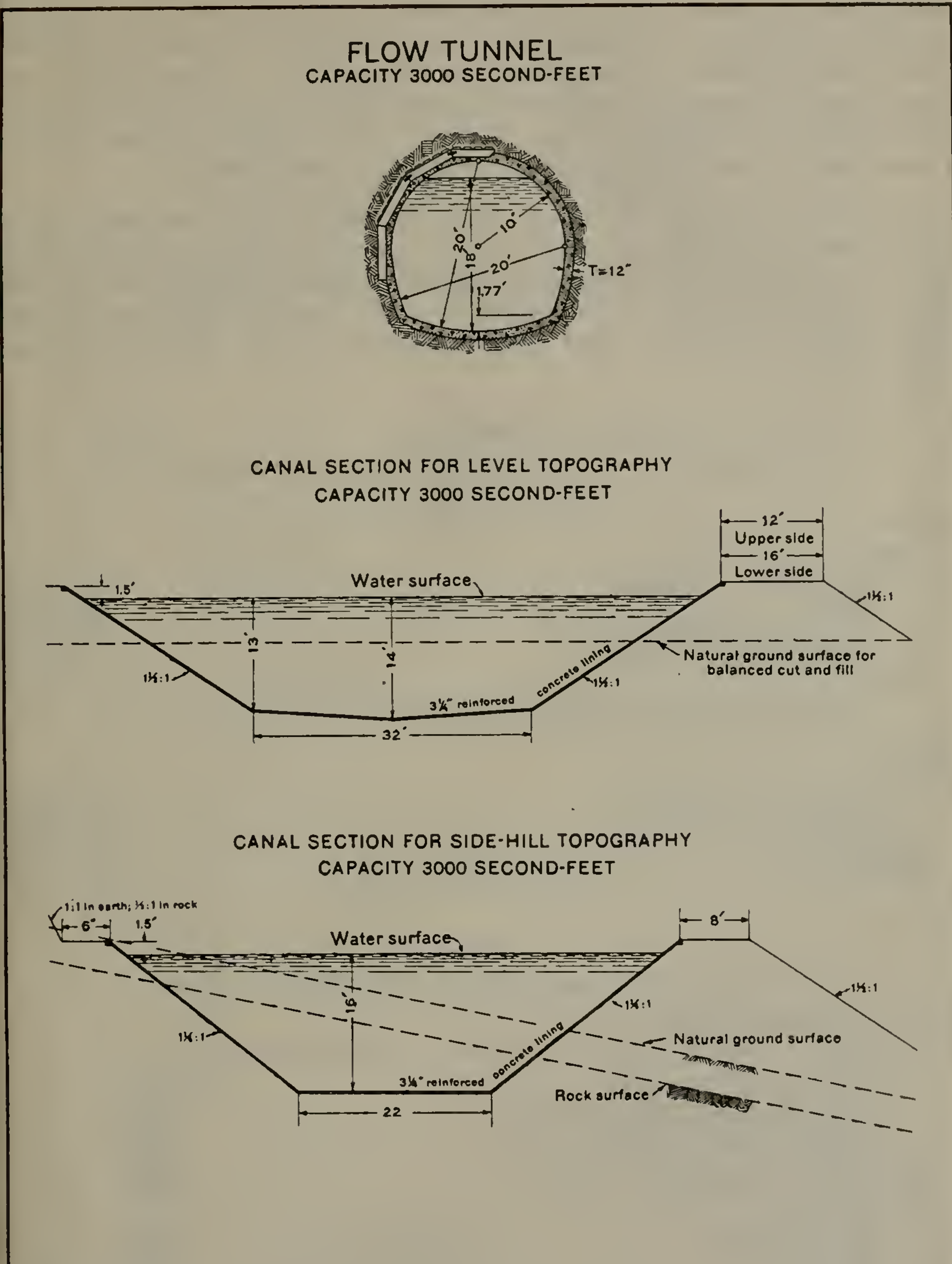
From the outlet at Friant Dam, at elevation 467 feet, the canal extends in a general southeasterly direction over the rough foothill topography lying between the San Joaquin and Kings River, a distance of 32 miles. Along this section the channels of Little Dry Creek and Dry Creek would be crossed by means of inverted siphons. An inverted siphon is provided for the crossing of Kings River, with a water surface elevation of 446 feet at the intake. Leaving the outlet of the Kings River siphon crossing with a water surface elevation of 445 feet, the canal extends in a direction somewhat more southerly and follows the toe of the mountain slopes for 55 miles to the town of Lindsay. Along this stretch the St. Johns and Kaweah rivers are crossed in reinforced concrete inverted siphons. At Lindsay, the canal turns due south and gradually swings with the trend of the topography of the valley floor to a direction somewhat west of south, continuing this general course for a distance of 50 miles to a point about four miles north of Shafter in Kern County. Between Lindsay and Shafter, the canal crosses the channels of Tule River, Deer Creek, White River and Poso Creek with inverted siphons. North of Shafter the alignment swings in a direction generally southeast and the canal extends an additional 19 miles to the siphon crossing of Kern River at elevation 369 feet, just upstream from the existing Pioneer Weir in Section 6, T. 30 S., R. 27 E., M. D. B. and M. Leaving the Kern River crossing, the canal continues an additional nine miles in a southeasterly direction gradually swinging to due east, intersecting the Buena Vista, Stine and Farmers canals en route and terminating at the Kern Island Canal, with a water surface elevation of 358 feet, in the northwest quarter of Section 30, T. 30 S., R. 28 E., five miles south of Bakersfield. The lengths, water surface elevations, grades, velocities and capacities of various sections of the San Joaquin River-Kern County Canal are set forth in Table 107. All portions of the canal in open conduit are concrete lined.

TABLE 107

PHYSICAL FEATURES AND HYDRAULIC ELEMENTS OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Point on canal location	Mile	Water surface elevation, in feet	Length of section, in miles	Grade in feet, per foot of length	Velocity of flow at full capacity, in feet per second	Capacity, in second-feet
Friant Dam	0	467				
			32.6	0.0001	4.6	3,000
Kings River	32.6	445				
			65.6	0.0001	4.4	3,000
Tule River	98.2	403				
			7.1	0.0001	4.2	2,500
Deer Creek	105.3	399				
			26.7	0.0001	4.0	2,000
Poso Creek	132.0	383				
			23.8	0.0001	3.7	1,500
Kern River	155.8	369				
			2.9	0.00015	3.9	1,000
Buena Vista Canal	158.7	367				
			5.8	0.00025	4.0	500
Kern Island Canal	164.5	358				

PLATE LX



TYPICAL CONDUIT SECTIONS
OF
SAN JOAQUIN VALLEY CONVEYANCE SYSTEMS

Plate LX, "Typical Conduit Sections of San Joaquin Valley Conveyance Systems," shows hydraulic properties and detail cross sections of the main types of conveyance channels used for a capacity of 3000 second-feet. Designs of typical structures for a canal of 3000 second-feet capacity are presented on Plate LXI, "River Syphon and Appurtenant Canal Structures"; Plate LXII, "Railroad Syphon"; Plate LXIII, "Highway Skew Bridge"; Plate LXIV, "Box Culvert Underdrain"; and Plate LXV, "County Road Bridge."

Cost of San Joaquin River-Kern County Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 109. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, tunnels, siphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 108

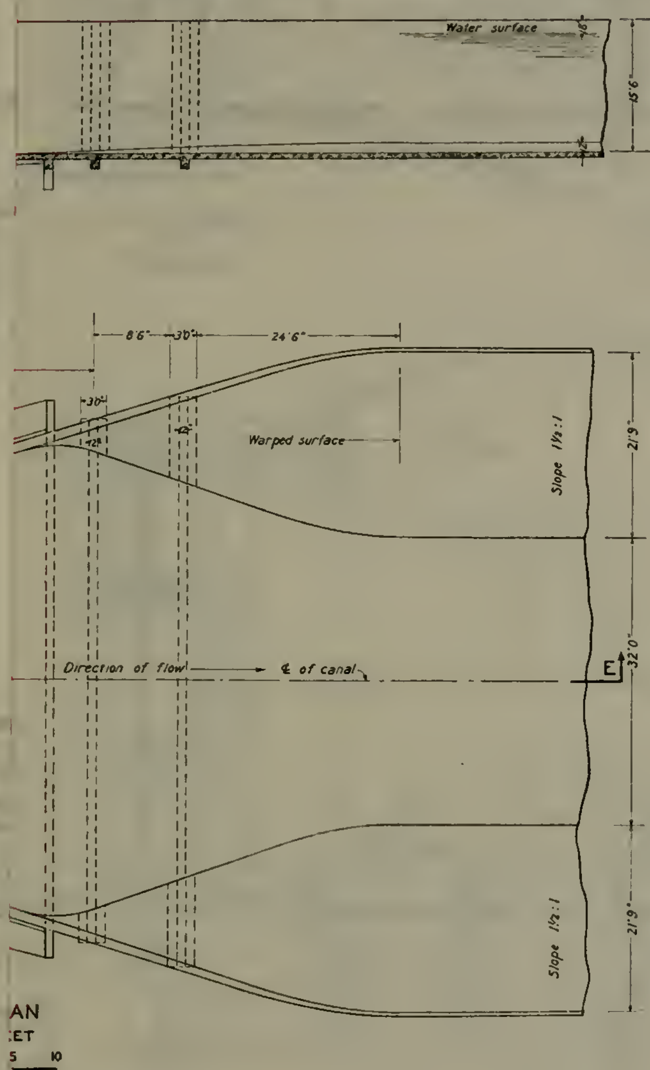
UNIT PRICES USED IN COST ESTIMATES OF SAN JOAQUIN VALLEY CONVEYANCE UNITS

Excavation—	
Canals:	
Rock, exclusive of trimming	$1.00 per cu. yd.
Trimming rock for concrete lining	.10 per sq. ft.
Hardpan	.60 per cu. yd.
Earth and cobble conglomerate	.60 per cu. yd.
Earth overlying rock excavation	.25 per cu. yd.
Earth, typical valley floor classification	.18 per cu. yd.
Tunnels:	
Section sufficiently large for mucking machines. Based on assumptions of ten per cent overbreak and a timbering requirement for 50 per cent of length	$9.00 per cu. yd.
Concrete—	
Reinforced canal lining, 3¼ inches thick:	
For canals with 1½:1 side slopes	$0.15 per sq. ft.
For canals with 1¼:1 side slopes	.16 per sq. ft.
Tunnel lining	19.00 per cu. yd.
Siphons, bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.

TABLE 109

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Friant Dam to South Side of Kings River—		
Mile 0 to mile 32.6. Length, 32.6 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 1,820,000 cubic yards at $1.00	$1,820,000	
Earth overlying rock, 1,015,000 cubic yards at $0.25	254,000	
Earth and cobbles, 279,000 cubic yards at $0.60	167,000	
Earth, 286,000 cubic yards at $0.18	52,000	
Rock trimming, 7,187,000 square feet at $0.10	719,000	
Concrete lining, 13,205,000 square feet at $0.16	2,113,000	
Tunnel, 1,400 linear feet at $220	308,000	
Structures:		
Little Dry Creek siphon	176,000	
Dry Creek siphon	19,000	
Kings River siphon	507,000	
Minor siphon	7,000	
Bridges	90,000	
Culverts	59,000	
Main check and wasteway	18,000	
Operation of existing Enterprise Canal during construction	15,000	
Right of ways and fencing	50,000	
		$6,374,000



TYPICAL DESIGN

RIVER SIPHON

AND

TENANT CANAL STRUCTURES

FOR

3000 SECOND-FOOT CANAL

Plate LX, "Typical Conduit Sections of San Joaquin Valley Conveyance Systems," shows hydraulic properties and detail cross sections of the main types of conveyance channels used for a capacity of 3000 second-feet. Designs of typical structures for a canal of 3000 second-feet capacity are presented on Plate LXI, "River Syphon and Appurtenant Canal Structures"; Plate LXII, "Railroad Syphon"; Plate LXIII, "Highway Skew Bridge"; Plate LXIV, "Box Culvert Underdrain"; and Plate LXV, "County Road Bridge."

Cost of San Joaquin River-Kern County Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 109. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, tunnels, siphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 108

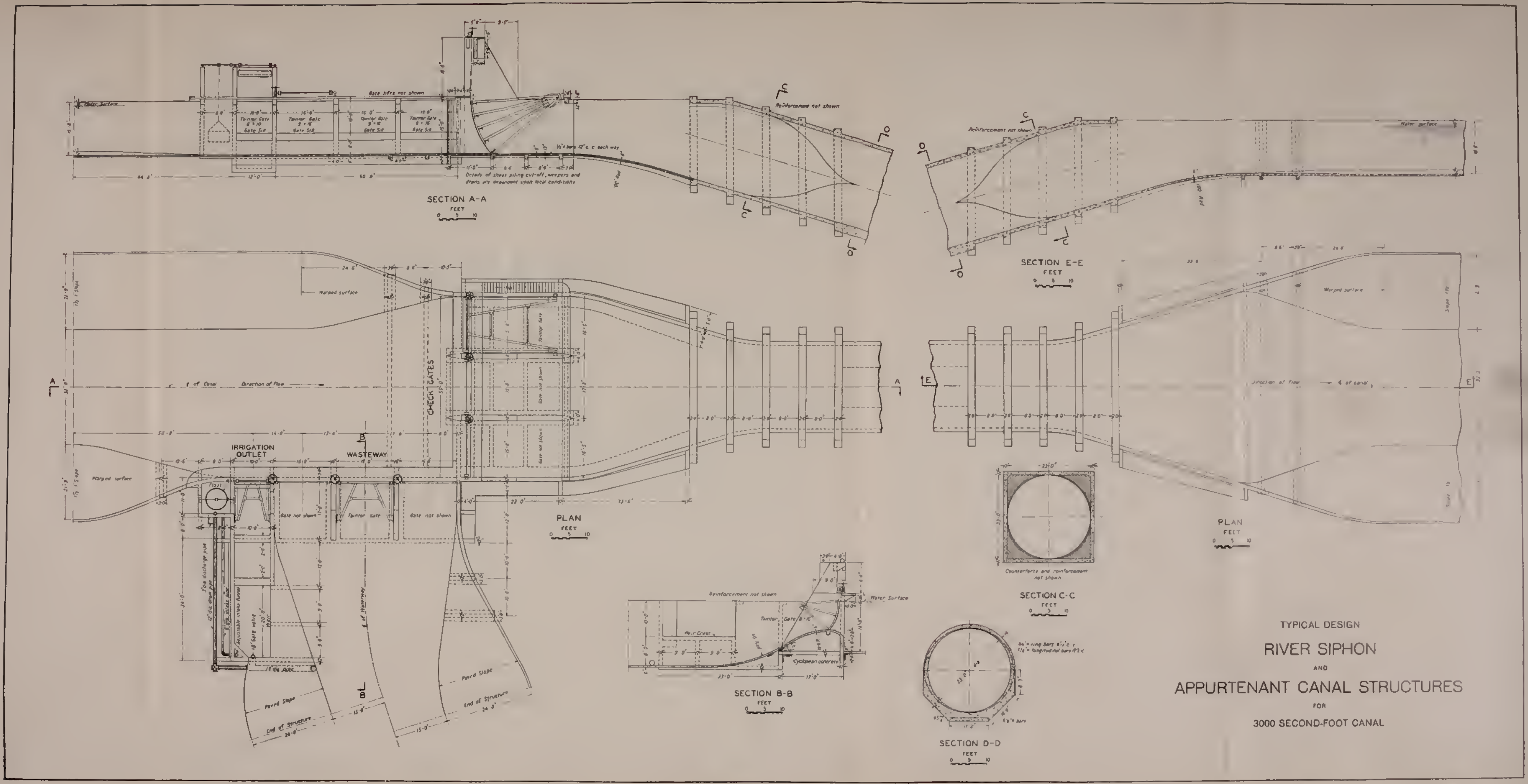
UNIT PRICES USED IN COST ESTIMATES OF SAN JOAQUIN VALLEY CONVEYANCE UNITS

Excavation—	
Canals:	
Rock, exclusive of trimming	$1.00 per cu. yd.
Trimming rock for concrete lining	.10 per sq. ft.
Hardpan	.60 per cu. yd.
Earth and cobble conglomerate	.60 per cu. yd.
Earth overlying rock excavation	.25 per cu. yd.
Earth, typical valley floor classification	.18 per cu. yd.
Tunnels:	
Section sufficiently large for mucking machines. Based on assumptions of ten per cent overbreak and a timbering requirement for 50 per cent of length	$9.00 per cu. yd.
Concrete—	
Reinforced canal lining, 3¼ inches thick:	
For canals with 1½:1 side slopes	$0.15 per sq. ft.
For canals with 1¼:1 side slopes	.16 per sq. ft.
Tunnel lining	19.00 per cu. yd.
Siphons, bridges and minor structures, exclusive of reinforcing	15.00 per cu. yd.
Reinforcing steel	.06 per lb.

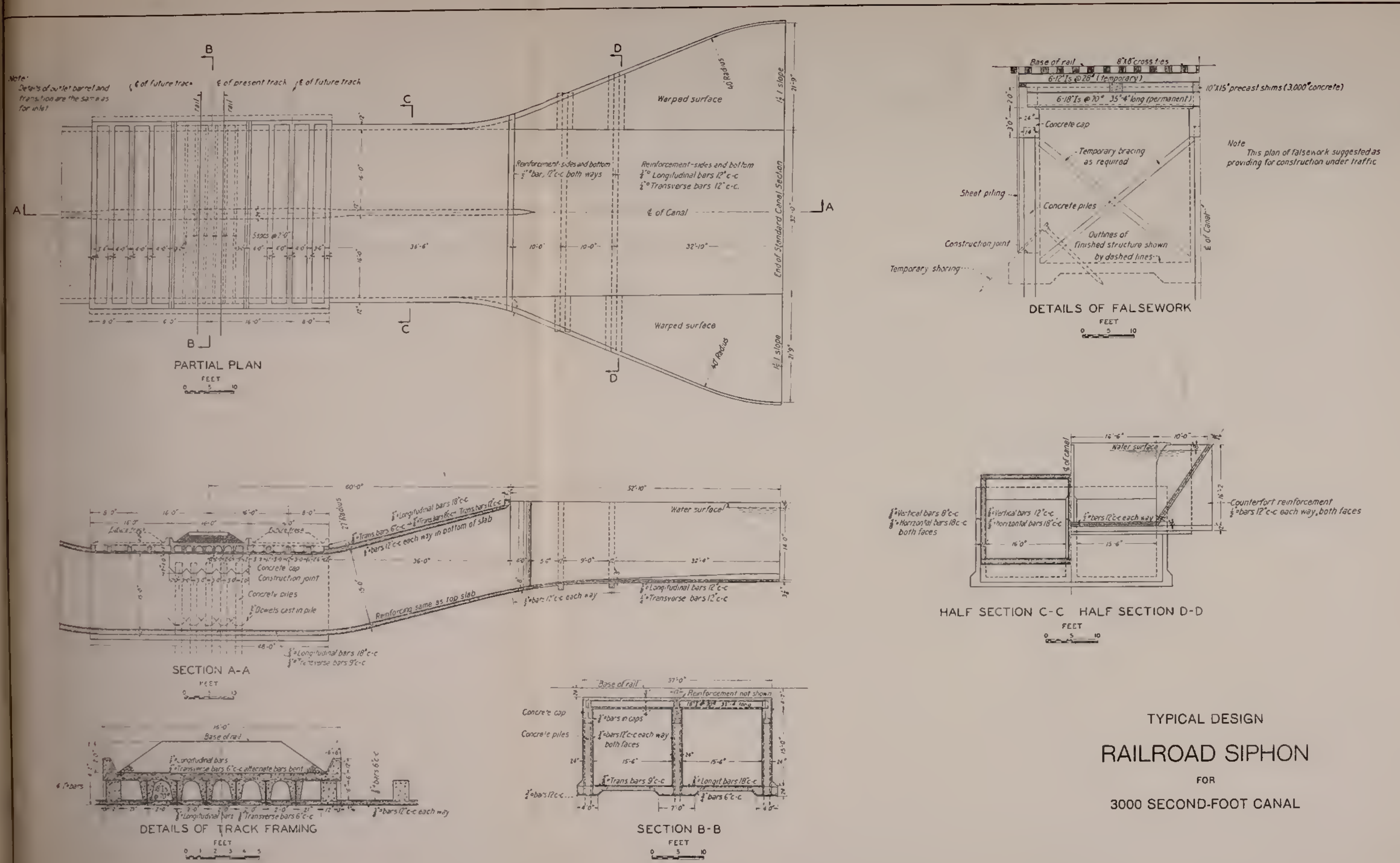
TABLE 109

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Friant Dam to South Side of Kings River—		
Mile 0 to mile 32.6. Length, 32.6 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 1,820,000 cubic yards at $1.00	$1,820,000	
Earth overlying rock, 1,015,000 cubic yards at $0.25	254,000	
Earth and cobbles, 279,000 cubic yards at $0.60	167,000	
Earth, 286,000 cubic yards at $0.18	52,000	
Rock trimming, 7,187,000 square feet at $0.10	719,000	
Concrete lining, 13,205,000 square feet at $0.16	2,113,000	
Tunnel, 1,400 linear feet at $220	308,000	
Structures:		
Little Dry Creek siphon	176,000	
Dry Creek siphon	19,000	
Kings River siphon	507,000	
Minor siphon	7,000	
Bridges	90,000	
Culverts	59,000	
Main check and wasteway	18,000	
Operation of existing Enterprise Canal during construction	15,000	
Right of ways and fencing	50,000	
		$6,374,000


SECTION A-A
SECTION E-E
PLAN
CHECK GATES
IRRIGATION OUTLET
WASTEWAY
SECTION C-C
SECTION B-B
SECTION D-D
Reinforcement not shown
Water Surface
Cyclopean concrete
End of Structure
Paved Slope
Warped surface
Direction of flow
Gate not shown
Tainter Gate
Counterforts and reinforcement not shown
TYPICAL DESIGN
RIVER SIPHON
AND
APPURTENANT CANAL STRUCTURES
FOR
3000 SECOND-FOOT CANAL

80997

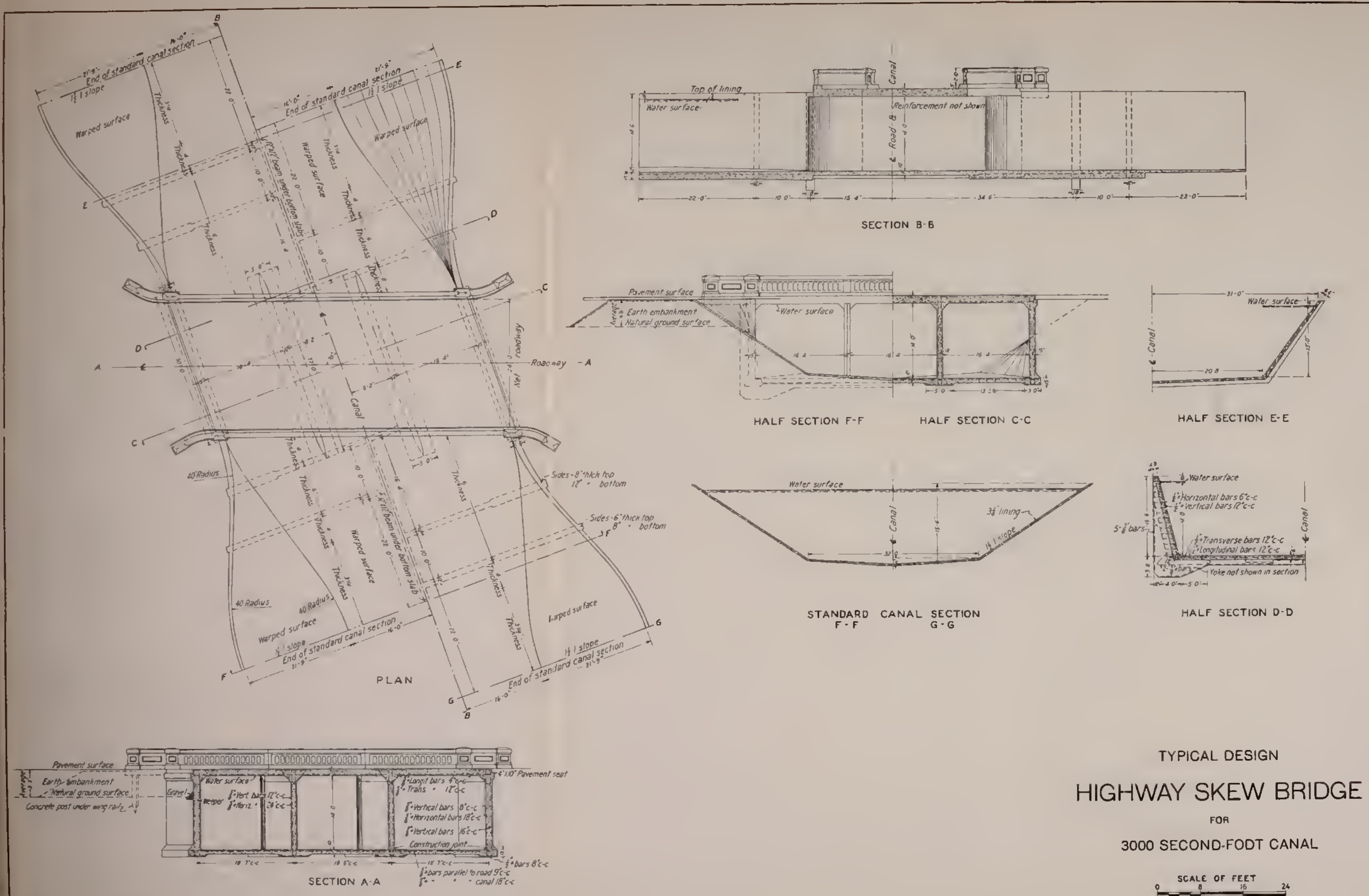


TYPICAL DESIGN

RAILROAD SIPHON

FOR

3000 SECOND-FOOT CANAL

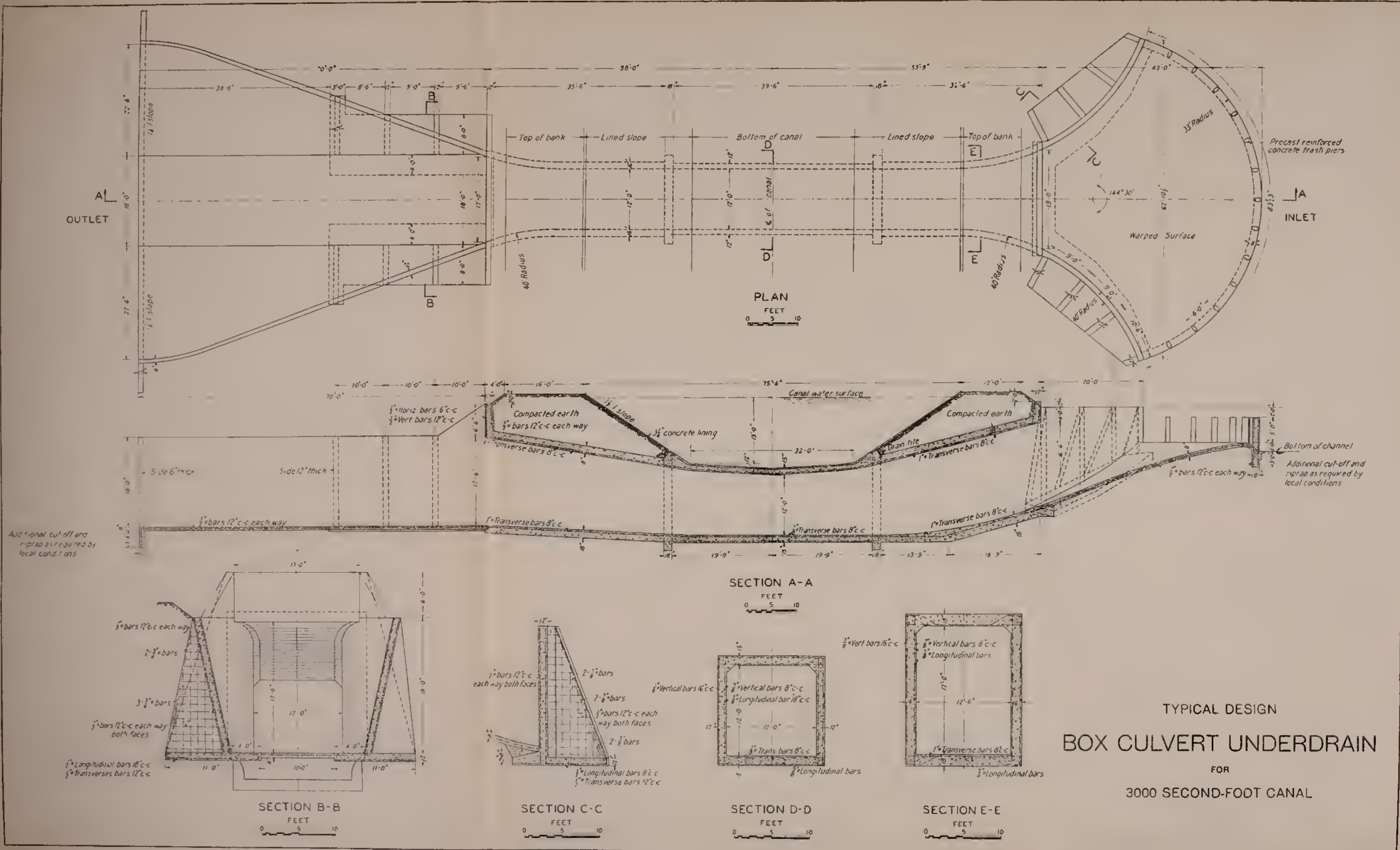


TYPICAL DESIGN

HIGHWAY SKEW BRIDGE

FOR

3000 SECOND-FOOT CANAL

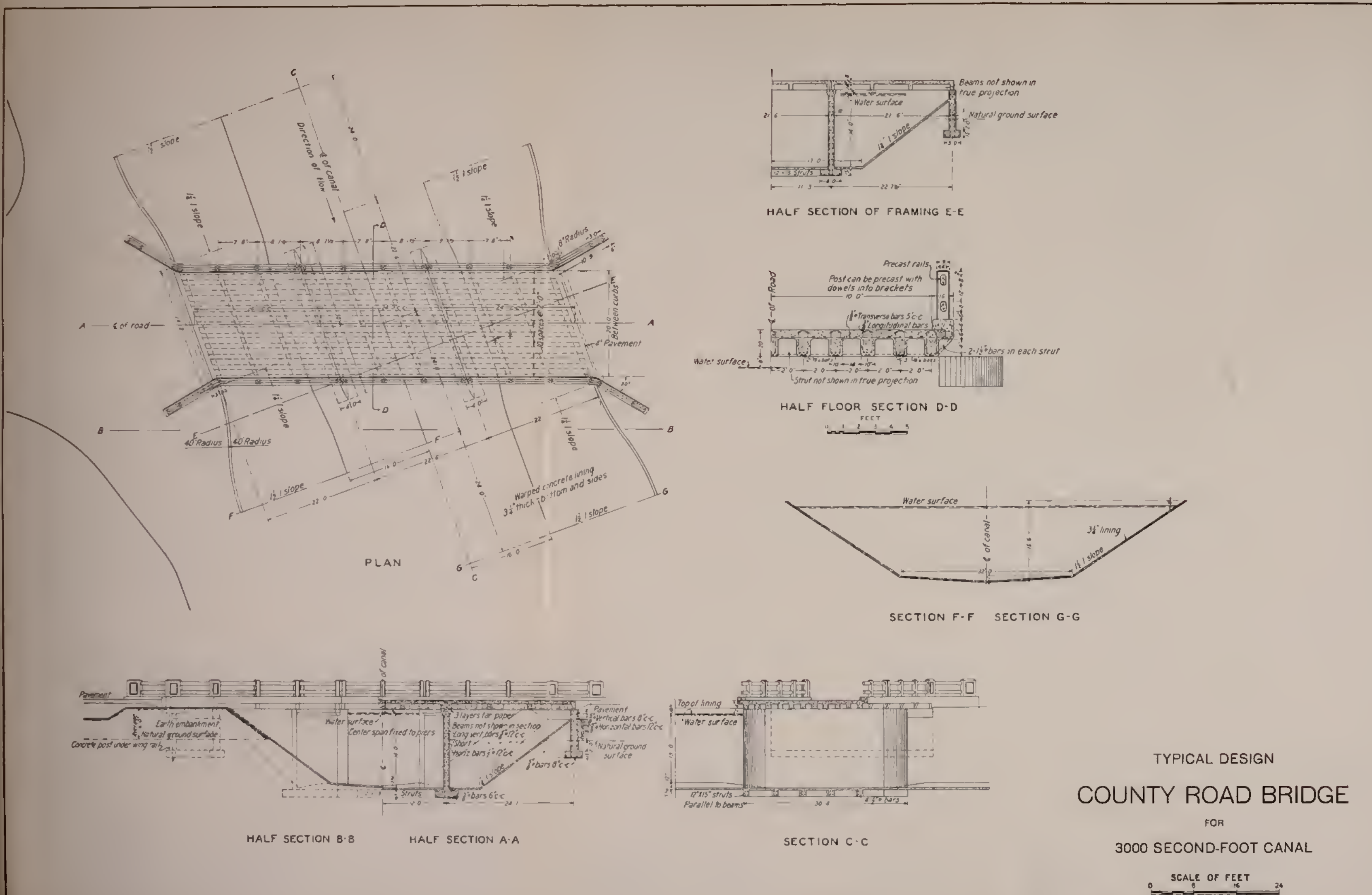


TYPICAL DESIGN

BOX CULVERT UNDERDRAIN

FOR

3000 SECOND-FOOT CANAL



TYPICAL DESIGN

COUNTY ROAD BRIDGE

FOR

3000 SECOND-FOOT CANAL

TABLE 109—Continued

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Kings River to Cottonwood Creek—		
Mile 32.6 to mile 68.7. Length, 36.1 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 293,000 cubic yards at $1.00	$293,000	
Earth overlying rock, 140,000 cubic yards at $0.25	35,000	
Hardpan, 15,000 cubic yards at $0.60	9,000	
Earth, 2,476,000 cubic yards at $0.18	446,000	
Rock trimming, 2,239,000 square feet at $0.10	224,000	
Concrete lining, 16,271,000 square feet at $0.15	2,441,000	
Tunnel, 300 linear feet at $280	84,000	
Structures:		
Cottonwood Creek siphon	85,000	
Minor siphons	143,000	
Bridges	249,000	
Culverts	129,000	
Main checks and wasteways	22,000	
Right of ways and fencing	370,000	
		$4,530,000
Cottonwood Creek to Tule River—		
Mile 68.7 to mile 98.2. Length, 29.5 miles. Capacity, 3,000 second-feet.		
Excavation:		
Rock, 5,000 cubic yards at $1.00	$5,000	
Hardpan, 69,000 cubic yards at $0.60	41,000	
Earth, 2,197,000 cubic yards at $0.18	396,000	
Rock trimming, 72,000 square feet at $0.10	7,000	
Concrete lining, 13,226,000 square feet at $0.15	1,984,000	
Structures:		
St. Johns River siphon	150,000	
Kaweah River siphon	53,000	
Tule River siphon	74,000	
Minor siphons	144,000	
Bridges	250,000	
Culverts	113,000	
Main checks and wasteways	46,000	
Right of ways and fencing	702,000	
		3,965,000
Tule River to Deer Creek—		
Mile 98.2 to mile 105.3. Length, 7.1 miles. Capacity, 2,500 second-feet.		
Earth excavation, 505,000 cubic yards at $0.18	$91,000	
Concrete lining, 2,983,000 square feet at $0.15	448,000	
Structures:		
Deer Creek siphon	70,000	
Minor siphon	11,000	
Bridges	43,000	
Culverts	8,000	
Main check and wasteway	12,000	
Right of ways and fencing	33,000	
		716,000
Deer Creek to Poso Creek—		
Mile 105.3 to mile 132.0. Length, 26.7 miles. Capacity, 2,000 second-feet.		
Earth excavation, 1,450,000 cubic yards at $0.18	$261,000	
Concrete lining, 10,874,000 square feet at $0.15	1,631,000	
Structures:		
White River siphon	25,000	
Rag Gulch siphon	25,000	
Poso Creek siphon	25,000	
Minor siphons	41,000	
Bridges	169,000	
Culverts	108,000	
Main check and wasteway	11,000	
Right of ways and fencing	147,000	
		2,443,000
Poso Creek to North Side of Kern River—		
Mile 132.0 to mile 155.8. Length, 23.8 miles. Capacity, 1,500 second-feet.		
Earth excavation, 1,061,000 cubic yards at $0.18	$191,000	
Concrete lining, 8,358,000 square feet at $0.15	1,254,000	
Structures:		
Minor siphons	25,000	
Bridges	68,000	
Culverts	59,000	
Main check and wasteway	8,000	
Right of ways and fencing	99,000	
		1,704,000

TABLE 109—Continued

COST OF SAN JOAQUIN RIVER-KERN COUNTY CANAL

Kern River to Buena Vista Canal—		
Mile 155.8 to mile 158.7. Length, 2.9 miles. Capacity, 1,000 second-feet.		
Earth excavation, 80,000 cubic yards at $0.18	$14,000	
Concrete lining, 783,000 square feet at $0.15	117,000	
Structures:		
Kern River siphon	59,000	
Bridges	15,000	
Culverts	12,000	
Main check and outlet	9,000	
Right of ways and fencing	8,000	
		$234,000
Buena Vista Canal to Kern Island Canal—		
Mile 158.7 to mile 164.5. Length, 5.8 miles. Capacity, 500 second-feet.		
Earth excavation, 136,000 cubic yards at $0.18	$25,000	
Concrete lining, 1,173,000 square feet at $0.15	176,000	
Structures:		
Minor siphons	13,000	
Bridges	16,000	
Culverts	10,000	
Outlet	5,000	
Right of ways and fencing	27,000	
		272,000
Subtotal		$20,238,000
Administration and engineering, at 10 per cent		2,024,000
Contingencies, at 15 per cent		3,036,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		2,702,000
Total capital cost		$28,000,000
Total annual cost		$2,281,000

Madera Canal.

The Madera Canal is proposed for the conveyance of San Joaquin River water for use on the eastern slope of that part of the upper San Joaquin Valley north of San Joaquin River. With a capacity of 1500 second-feet and a total length of 18 miles, it extends along the eastern rim of the valley between Friant Dam and Fresno River. The location of this canal is shown on Plate XXVI and its profile on Plate LVII.

From the outlet at Friant Dam, at elevation 415 feet, the canal extends in a general southwesterly direction over rough rocky foothill topography for a distance of four miles. The location then turns westerly for a distance of three miles passing through a gap in the main ridge on the south side of Little Table Mountain. It then traverses rolling foothill topography, above and east of the irrigable areas, in a general northeasterly direction for a distance of 11 miles to its terminous at a natural reservoir located in Section 16, Township 10 South, Range 19 East, M. D. B. and M., at elevation 391 feet on the south side of Fresno River. From this point, water would be released for local distribution. The proposed canal is concrete lined for its entire length. It has a water depth of 11.0 feet, a bottom width of 14.0 feet and side slopes of $1\frac{1}{4}$:1. The grade is .0002 feet per foot of length and the velocity would be 5.0 feet per second when conveying the full capacity of 1500 second-feet.

Cost of Madera Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 110. The estimate sets forth the capital cost of the entire conduit and appurtenant structures, including canals, syphons, bridges, other minor structures and right of ways. The total annual cost also is given.

TABLE 110

COST OF MADERA CANAL

Friant Dam to Fresno River

Length, 18 miles. Capacity, 1,500 second-feet.

Excavation:		
Rock, 458,000 cubic yards at $1.00	$458,000	
Earth overlying rock, 560,000 cubic yards at $0.25	140,000	
Rock trimming, 2,540,000 square feet at $0.10	254,000	
Concrete lining, 5,300,000 square feet at $0.16	848,000	
Structures:		
Siphons	70,000	
Bridges and culverts	96,000	
Right of ways and fencing	25,000	
Subtotal		$1,891,000
Administration and engineering, at 10 per cent		189,000
Contingencies, at 15 per cent		284,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		136,000
Total capital cost		$2,500,000
Total annual cost		$213,000

NOTE:—If the Madera Canal were extended a distance of 17 miles from the Fresno to the Chowchilla River, with a capacity of 1000 second-feet to Dalton Creek and a capacity of 500 second-feet from Dalton Creek to Chowchilla River the capital and annual costs would be increased by $800,000 and $65,000 respectively.

Kern River Canal.

A portion of the San Joaquin River water conveyed to the Kern River by the San Joaquin River-Kern County Canal would be utilized on lands now irrigated from Kern River, thus making available Kern River water for use on higher lands which are at present unirrigated and without a water supply. By means of this exchange of supplies the higher lands could be served by gravity diversion from Kern River with a considerable saving in cost as compared to service with imported supplies requiring a high pumping lift. The Kern River Canal is designed to serve these higher lands and would divert a large part of the waters of Kern River to the rim lands around the extreme southern limit of the San Joaquin Valley. The point of diversion for this canal is at elevation 680 feet, about four feet lower than the minimum tail water of the Kern Canyon plant of the San Joaquin Light and Power Corporation. Thus this canal would divert at an elevation of about 311 feet higher than the San Joaquin River-Kern County Canal where it crosses the Kern River. The site of the diversion dam is about 1800 feet downstream from the power house in Section 6, Township 29 South, Range 30 East, M. D. B. and M.

From the diversion site, the canal location extends southwest along the south side of the stream, crosses Cottonwood Creek and, at a point three miles below its head, enters a tunnel 16,000 feet long under the mesa about eight miles east of Bakersfield. The outlet of the tunnel is about two miles north of Edison Station on the Southern Pacific Railway. From this point, the canal extends in a southeasterly direction, crosses the Southern Pacific Railroad about two miles east of Edison and reaches the mile wide channel of Caliente Creek, 15 miles from the point of diversion, at about elevation 660 feet.

The conduit is designed to carry 1500 second-feet for the first 17 miles so that waters in excess of the irrigation draft could be carried during periods of large run-off and used for replenishing the underground reservoir on Caliente Creek Cone.

Based upon the possibilities indicated by preliminary surveys, it is proposed to extend the canal an additional distance of 58 miles, encircling the south end of the valley at the base of the mountain slopes to a point just west of Buena Vista Lake at about elevation 591 feet. Such a location would afford gravity service to lands below an average elevation of 630 feet and with pumping could serve an area of rim lands above the canal. The lengths, water surface elevations, grades, velocities and capacities of various sections of the Kern River Canal are set forth in Table 111. The location of the canal is shown on Plate XXVI and its profile on Plate LVII.

Cost of Kern River Canal—An estimate of cost, based on unit prices set forth in Table 108, is presented in Table 112. The estimate sets forth the capital cost of the entire conduit and appurtenant structures including canals, tunnels, siphons, minor structures and right of ways. The total annual cost also is given.

TABLE 111

PHYSICAL FEATURES AND HYDRAULIC ELEMENTS OF KERN RIVER CANAL

Section	Type of conduit	Water surface elevation, in feet	Length of section, in miles	Grade, in feet per foot of length	Velocity of flow at full capacity, in second-feet	Capacity, in second-feet
Mile 0		680.0				
	Concrete lined canal in earth, rock and boulders.		0.4	.00015	4.3	1,500
Mile 0.4		679.4				
	Concrete siphon, 17 feet diameter		0.2	.0006	6.6	1,500
Mile 0.6		678.6				
	Concrete lined canal in earth, rock and boulders.		1.2	.00015	4.3	1,500
Mile 1.8		677.6				
	Concrete siphon, 17 feet diameter		0.2	.0006	6.6	1,500
Mile 2.0		677.1				
	Concrete lined canal in earth, rock and boulders.		1.3	.00015	4.3	1,500
Mile 3.3		676.0				
	Concrete lined tunnel, 16 feet diameter		3.0	.0006	7.2	1,500
Mile 6.3		666.0				
	Concrete lined canal, in earth		11.4	.0001	3.7	1,500
Mile 17.7		660.0				
	Concrete lined canal, on side hill, in earth and rock.		13.0	.00015	4.1	1,200
Mile 30.7		649.2				
	Concrete siphon, 14 feet diameter		0.2	.001	7.8	1,200
Mile 30.9		648.0				
	Concrete lined canal, on side hill, in earth and rock.		3.7	.00015	4.1	1,200
Mile 34.6		645.0				
	Concrete lined canal, in earth		13.3	.0002	4.2	900
Mile 47.9		631.0				
	Concrete lined canal, in earth		12.3	.0002	3.9	600
Mile 60.2		618.0				
	Concrete lined canal, in earth		6.6	.0003	3.8	300
Mile 66.8		607.5				
	Concrete lined canal, in earth		7.6	.0004	3.5	200
Mile 74.4		591.5				

TABLE 112

COST OF KERN RIVER CANAL

Diversion dam		$150,000
Mile 0 to mile 17.7. Length, 17.7 miles. Capacity, 1,500 second-feet.		
Canal excavation:		
Rock, 35,000 cubic yards at $1.00	$35,000	
Earth overlying rock, 114,000 cubic yards at $0.25	28,000	
Earth, 566,000 cubic yards at $0.18	102,000	
Rock trimming, 397,000 square feet at $0.10	40,000	
Concrete lining, reinforced:		
855,000 square feet at $0.16	137,000	
4,020,000 square feet at $0.15	603,000	
Tunnel, concrete lined, 16,000 linear feet at $170.00	2,720,000	
Structures:		
2 major siphons, total length, 2,000 feet	160,000	
1 railroad and highway crossing	20,000	
2 underdrains at Caliente Creek	8,000	
4 secondary road crossings	16,000	
Right of ways and fencing	12,000	
		$3,881,000
Mile 17.7 to mile 34.6. Length, 16.9 miles. Capacity, 1,200 second-feet.		
Canal excavation:		
Rock, 231,000 cubic yards at $1.00	$231,000	
Earth overlying rock, 510,000 cubic yards at $0.25	128,000	
Rock trimming, 2,288,000 square feet at $0.10	229,000	
Concrete lining, reinforced, 4,576,000 square feet at $0.16	732,000	
Structures:		
1 major siphon, total length 1,000 feet	60,000	
4 secondary road crossings	12,000	
5 underdrains	8,000	
Right of ways and fencing	12,000	
		$1,412,000
Mile 34.6 to mile 47.9. Length, 13.3 miles. Capacity, 900 second-feet.		
Canal excavation, earth, 408,000 cubic yards at $0.18	$73,000	
Concrete lining, reinforced, 3,360,000 square feet at $0.15	504,000	
Structures:		
4 secondary road crossings	10,000	
4 underdrains	6,000	
Right of ways and fencing	9,000	
		$602,000
Mile 47.9 to mile 60.2. Length, 12.3 miles. Capacity, 600 second-feet.		
Canal excavation, earth, 307,000 cubic yards at $0.18	$55,000	
Concrete lining, reinforced, 2,665,000 square feet at $0.15	400,000	
Structures:		
2 secondary road crossings	4,000	
2 underdrains	2,000	
Right of ways and fencing	8,000	
		$469,000
Mile 60.2 to mile 66.8. Length, 6.6 miles. Capacity, 300 second-feet.		
Canal excavation, earth, 97,000 cubic yards at $0.18	$17,000	
Concrete lining, reinforced, 1,050,000 square feet at $0.15	158,000	
Structures:		
2 secondary road crossings	3,000	
2 underdrains	2,000	
Right of ways and fencing	4,000	
		$184,000
Mile 66.8 to mile 74.4. Length, 7.6 miles. Capacity, 200 second-feet.		
Canal excavation, earth, 56,000 cubic yards at $0.18	$10,000	
Concrete lining, reinforced 1,000,000 square feet at $0.15	150,000	
Structures:		
2 secondary road crossings	3,000	
1 single track railroad crossing	3,000	
2 underdrains	1,000	
Right of ways and fencing	5,000	
		$172,000
Subtotal		$6,870,000
Administration and engineering, at 10 per cent		687,000
Contingencies, at 15 per cent		1,031,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		412,000
Total capital cost		$9,000,000
Total annual cost		$721,000

Mendota-West Side Pumping System.

To make water available for the good land lying on the western slope of the upper San Joaquin Valley would require a pumping system extending from Mendota Pool to Elk Hills. Water for this area would be conveyed to Mendota through the San Joaquin River Pumping System. The conveyance channel required for full development would be 100 miles long and would have a capacity varying from 4500 to 500 second-feet.

The proposed Mendota-West Side Pumping System departs from the Mendota Pool at elevation 159 feet, with a constructed canal extending southerly along the most favorable topography. By means of two pumping lifts in a distance of three miles the water is raised to an elevation of 207.0 feet at the discharge of Plant No. 2. The capacity is reduced at this point to 3500 second-feet and the canal continues to Plant No. 3 located at Mile 20. By means of Plants No. 3 and No. 4 the water is raised to an elevation of 248.0 feet at Mile 21 and the canal continues to Mile 32 where the capacity is reduced to 2500 second-feet. Plants No. 5 and No. 6 raise the water to an elevation of 272 feet at Mile 68, where the canal capacity is reduced to 1500 second-feet. This capacity continues to Mile 90 where it is reduced to 500 second-feet and the canal continues at this latter capacity to its terminus at Mile 100 at elevation 250.0 feet. At each point of reduction in capacity local distribution systems, consisting of pumping plants and conveyance channels, would be required. At Mile 19, Mile 32, Mile 66, Mile 90 and Mile 100, spillway channels extending to the valley trough are provided, with capacities of 3500, 1000, 2500, 1000, and 500 second-feet respectively, and with lengths varying from three to eight miles.

Minor structures comprise one set of intake gates at Mendota Pool, two railroad siphons, five highway bridges, 61 county road bridges, three canal control structures and five spillway structures. Pumping plants are of the same type as shown for the San Joaquin River Pumping System on Plate LVIII. The height of each lift and the capacity of each pumping plant are set forth in Table 113. The seasonal amount of water to be pumped through each lift and the estimated seasonal energy consumption also are given in the tabulation.

TABLE 113

PUMPING LIFTS AND CAPACITIES, SEASONAL QUANTITY OF WATER PUMPED AND SEASONAL ENERGY CONSUMPTION FOR MENDOTA-WEST SIDE PUMPING SYSTEM

Pumping plant number	Location of plant	Height of lift, in feet	Capacity of plant, in second-feet	Seasonal quantity of water pumped, in acre-feet	Seasonal energy consumption, in kilowatt hours
1	Mile 2	25	4,500	1,544,000	65,910,000
2	Mile 3	25	4,500	1,544,000	65,910,000
3	Mile 20	25	3,500	1,201,000	51,268,000
4	Mile 21	25	3,500	1,201,000	51,268,000
5	Mile 67	25	2,500	858,000	36,626,000
6	Mile 68	25	2,500	858,000	36,626,000
	Totals	150			307,608,000
	Average weighted lift	117			

Cost of Mendota-West Side Pumping System—An estimate of cost, based on unit prices set forth in Table 105 for San Joaquin River Pumping System, is presented in Table 114. The estimate sets forth the capital cost of the complete pumping system including canals, pumping plants, spillway channels, minor structures and right of ways. The total annual cost, including the average annual charge for electric energy, also is given in the tabulation.

TABLE 114

COST OF MENDOTA-WEST SIDE PUMPING SYSTEM

Length, 100 miles. Capacity varies from 4,500 to 500 second-feet.

Excavation:		
Canals in deep cut and fill sections near pumping plants, 1,890,000 cubic yards at $0.20 to $0.23	$400,000	
Canals with regular concrete lined section, 6,514,000 cubic yards at $0.18	1,172,000	
Spillway channels, 2,644,000 cubic yards at $0.18	476,000	
		$2,048,000
Reinforced concrete canal lining:		
39,309,000 square feet at $0.15		5,897,000
Pumping plants:		
Lift No. 1, capacity 4,500 second-feet	612,000	
Lift No. 2, capacity 4,500 second-feet	612,000	
Lift No. 3, capacity 3,500 second-feet	476,000	
Lift No. 4, capacity 3,500 second-feet	476,000	
Lift No. 5, capacity 2,500 second-feet	340,000	
Lift No. 6, capacity 2,500 second-feet	340,000	
		2,856,000
Structures:		
On portion of canal having a capacity of 4,500 second-feet:		
Control works in cut from Mendota Pool	40,000	
Highway and railroad crossing	55,000	
County road bridge	10,000	
On portion of canal having a capacity of 3,500 second-feet:		
Control structure	15,000	
Highway bridges, 2 at $11,000	22,000	
County road bridges, 13 at $8,000	104,000	
Spillway structure, capacity 3,500 second-feet	12,000	
Spillway structure, capacity 1,000 second-feet	5,000	
On portion of canal having a capacity of 2,500 second-feet:		
Control structure	10,000	
Highway bridges, 2 at $9,000	18,000	
County road bridges, 15 at $6,000	90,000	
Railroad crossing	20,000	
Spillway structure	8,000	
On portion of canal having a capacity of 1,500 second-feet:		
County road bridges, 10 at $5,000	50,000	
Spillway structure	4,000	
On portion of canal having a capacity of 500 second-feet:		
County road bridges, 4 at $3,000	12,000	
Control structure	3,000	
Spillway structure	3,000	
On spillway channels:		
County road bridges on spillway channel having a capacity of 3,500 second-feet, 4 at $4,000	16,000	
County road bridges on spillway channel having a capacity of 2,500 second-feet, 3 at $3,000	9,000	
County road bridges on spillway channels having a capacity of 1,000 second-feet, 7 at $2,000	14,000	
County road bridges on spillway channel having a capacity of 500 second-feet, 4 at $1,500	6,000	
		526,000
Right of ways and fencing		240,000
Subtotal		$11,567,000
Administration and engineering, at 10 per cent		1,156,000
Contingencies, at 15 per cent		1,735,000
Interest during construction, based on an interest rate of 4.5 per cent per annum		1,542,000
Total capital cost		$16,000,000
Annual cost exclusive of energy		$1,396,000
Average annual energy charge, 307,608,000 kilowatt-hours at $0.0055		1,692,000
Total annual cost		$3,088,000

Summary of Conveyance Units.

A summary of the cost estimates and principal physical features of all the major conveyance units of the Ultimate State Plan in the San Joaquin River Basin has been compiled from the foregoing estimates and data and is set forth in Table 115. The length, capacity, number of pumping plants, elevations of diversion and terminus, maximum and average weighted pumping lifts, capital costs of various features and annual costs, exclusive and inclusive of energy charges, are set forth in the tabulation for each unit.

SUMMARY OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the foregoing pages of this chapter there has been presented a discussion, description and estimates of capital and annual costs of each major storage and conveyance unit of the Ultimate State Water Plan in the San Joaquin River Basin. Table 99 sets forth a somewhat detailed summary of the main physical features and principal items of capital and annual costs of surface storage reservoirs and power plants. Corresponding data for conveyance units have been summarized in Table 115.

In Table 100, the total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the San Joaquin Valley are set forth, first, between a depth of 10 feet below ground surface and the underground water level of 1929, second, between depths of 10 and 50 feet below ground surface and third, between depths of 10 feet below ground surface and the assumed economic limit of pumping. The available and utilizable underground storage capacity in the upper San Joaquin Valley would be operated to obtain the fullest practicable beneficial use of the local and imported supplies. The results of analyses of the cost of ground water pumping for various sizes of installation, heights of lift and periods of operation have been set forth in Table 101. The general average values, for estimating the cost of ground water pumping in the upper San Joaquin Valley, have been determined as two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot.

Table 116 sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Plans for four of the reservoirs include power plants. The net annual cost is obtained by deducting from the gross annual cost of the reservoir and power plant the anticipated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The net annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

\TER PLAN IN SAN JOAQUIN RIVER BASIN

				Annual cost		
	ıinistra- ı, engi- :ing and ingencies	Interest during construction	Total	Exclusive of electric energy for pumping	Electric energy for pumping	Total
Sacramen Hood t	757,000	$217,000	$4,000,000	$300,000	0	$300,000
San Joaq	150,000	2,750,000	28,500,000	2,539,000	$4,240,000	6,779,000
San Joaq	060,000	2,702,000	28,000,000	2,281,000	0	2,281,000
Madera (	473,000	136,000	2,500,000	213,000	0	213,000
Kern Riv	718,000	412,000	9,000,000	721,000	0	721,000
Mendota	891,000	1,542,000	16,000,000	1,396,000	1,692,000	3,088,000
Tota	049,000	$7,759,000	$88,000,000	$7,450,000	$5,932,000	$13,382,000

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Summary of Conveyance Units.

A summary of the cost estimates and principal physical features of all the major conveyance units of the Ultimate State Plan in the San Joaquin River Basin has been compiled from the foregoing estimates and data and is set forth in Table 115. The length, capacity, number of pumping plants, elevations of diversion and terminus, maximum and average weighted pumping lifts, capital costs of various features and annual costs, exclusive and inclusive of energy charges, are set forth in the tabulation for each unit.

SUMMARY OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

In the foregoing pages of this chapter there has been presented a discussion, description and estimates of capital and annual costs of each major storage and conveyance unit of the Ultimate State Water Plan in the San Joaquin River Basin. Table 99 sets forth a somewhat detailed summary of the main physical features and principal items of capital and annual costs of surface storage reservoirs and power plants. Corresponding data for conveyance units have been summarized in Table 115.

In Table 100, the total usable capacities of the ground water reservoirs in each of the various hydrographic divisions of the San Joaquin Valley are set forth, first, between a depth of 10 feet below ground surface and the underground water level of 1929, second, between depths of 10 and 50 feet below ground surface and third, between depths of 10 feet below ground surface and the assumed economic limit of pumping. The available and utilizable underground storage capacity in the upper San Joaquin Valley would be operated to obtain the fullest practicable beneficial use of the local and imported supplies. The results of analyses of the cost of ground water pumping for various sizes of installation, heights of lift and periods of operation have been set forth in Table 101. The general average values, for estimating the cost of ground water pumping in the upper San Joaquin Valley, have been determined as two cents per foot acre-foot for fixed charges and three cents per foot acre-foot for power charges or a total of five cents per foot acre-foot.

Table 116 sets forth the capital and net annual costs of all major surface storage and conveyance units in the San Joaquin River Basin. Plans for four of the reservoirs include power plants. The net annual cost is obtained by deducting from the gross annual cost of the reservoir and power plant the anticipated average annual revenue from the sale of electric energy. Two of the conveyance units include pumping systems. The net annual cost of each of these units includes the estimated average annual cost of electric energy required for pumping.

TABLE 115

SUMMARY OF MAIN PHYSICAL FEATURES AND PRINCIPAL ITEMS OF COST OF MAJOR CONVEYANCE UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Length, in miles	Maximum capacity, in second-feet	Elevation in feet, U. S. G. S. datum		Pumping plants			Capital cost							Annual cost		
			Point of diversion	Terminus	Number	Maximum lift, in feet	Average weighted lift, in feet	Pumping plants	Diversion, control and other structures	Main conveyance channels	Right of ways	Administration, engineering and contingencies	Interest during construction	Total	Exclusive of electric energy for pumping	Electric energy for pumping	Total
Sacramento-San Joaquin Delta Cross Channel, Hood to Central Landing	24	10,000							$2,676,000	$200,000	$150,000	$757,000	$217,000	$4,000,000	$300,000	0	$300,000
San Joaquin River Pumping System	165	8,000	0	159	10	202	185	$8,988,000	1,703,000	9,195,000	714,000	5,150,000	2,750,000	28,500,000	2,539,000	$4,240,000	6,779,000
San Joaquin River-Kern County Canal	165	3,000	467	358					3,196,000	15,606,000	1,436,000	5,060,000	2,702,000	28,000,000	2,281,000	0	2,281,000
Madera Canal	18	1,500	415	391					166,000	1,700,000	25,000	473,000	136,000	2,500,000	213,000	0	213,000
Kern River Canal	75	1,500	680	591					468,000	6,352,000	50,000	1,718,000	412,000	9,000,000	721,000	0	721,000
Mendota-West Side Pumping System	100	4,500	159	250	6	150	117	2,856,000	526,000	7,945,000	240,000	2,891,000	1,542,000	16,000,000	1,396,000	1,602,000	3,088,000
Totals	547				16			$11,844,000	$8,735,000	$40,998,000	$2,615,000	$16,049,000	$7,759,000	$88,000,000	$7,450,000	$5,932,000	$13,382,000

TABLE 116

SUMMARY OF COSTS OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

Unit	Location	Capital cost	Net annual cost
Surface Storage Units			
Nashville Reservoir	Cosumnes River	$7,400,000	$441,000
Ione Reservoir	Dry Creek	8,600,000	517,000
Pardee Reservoir	Mokelumne River	Constructed	Constructed
Valley Springs Reservoir	Calaveras River	7,600,000	452,000
Melones Reservoir[1]	Stanislaus River	26,200,000	937,000
Don Pedro Reservoir[1]	Tuolumne River	32,500,000	979,000
Exchequer Reservoir	Merced River	Constructed	Constructed
Buchanan Reservoir	Chowchilla River	2,600,000	155,000
Windy Gap Reservoir	Fresno River	3,300,000	200,000
Friant Reservoir[2]	San Joaquin River	14,500,000	805,000
Pine Flat Reservoir[1]	Kings River	11,600,000	541,000
Pleasant Valley Reservoir	Tule River	2,900,000	171,000
Isabella Reservoir	Kern River	5,700,000	340,000
Subtotals		$122,900,000	$5,538,000
Conveyance Units			
Sacramento-San Joaquin Delta Cross Channel	Sacramento-San Joaquin Delta	$4,000,000	$300,000
San Joaquin River Pumping System	West side lower San Joaquin Valley	28,500,000	[3]6,779,000
Mendota-West Side Pumping System	West side upper San Joaquin Valley	16,000,000	[4]3,088,000
Madera Canal	East side upper San Joaquin Valley, north of San Joaquin River	2,500,000	213,000
San Joaquin River-Kern County Canal	East side upper San Joaquin Valley, south of San Joaquin River	28,000,000	2,281,000
Kern River Canal	East side and south end of upper San Joaquin Valley, south of Kern River	9,000,000	721,000
Subtotals		$88,000,000	$13,382,000
Totals, all units		$210,900,000	$18,920,000

[1] Includes power plant.
[2] Includes power plant for ultimate development, only.
[3] Includes energy cost of $4,240,000.
[4] Includes energy cost of $1,692,000.

CHAPTER VII

OPERATION AND ACCOMPLISHMENTS OF ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

The operation and accomplishments of the ultimate State Water Plan in the San Joaquin River Basin are closely related to and interdependent with those in the plan for the Sacramento River Basin because of the dependence of the San Joaquin River Basin upon the Sacramento River Basin for a portion of the supply required to meet its ultimate water requirements. The ultimate water requirements of the San Joaquin River Basin are materially in excess of the water supplies which could be made available from local tributary sources by full practicable development and utilization. The logical source of supplemental water supply is the Sacramento River Basin where a surplus over and above the full ultimate water requirements in that basin, including the Sacramento-San Joaquin Delta, would be made available by the major units proposed for ultimate development therein. The ultimate State Water Plan proposes to import surplus water from the Sacramento River Basin to meet the deficiency between availabl local supply and ultimate demand in the San Joaquin River Basin Accordingly, consideration of the operation and accomplishments o the plan in the San Joaquin River Basin must be combined with thos in the Sacramento River Basin. The proposed major units for ulti mate development in the two basins constitute a unified project for th entire Great Central Valley. It is proposed to operate these majo units coordinately to provide the ultimate water requirements and t accomplish the objectives sought for the fullest practicable develop ment, regulation, distribution and utilization of the water resources

Objectives of Ultimate State Water Plan in Great Central Valley.

The primary objective of the ultimate State Water Plan in th Great Central Valley is to provide a water supply sufficient in amoun and with suitable rates of delivery to meet the ultimate water requir ments for all purposes, including domestic and municipal suppl industrial supply, irrigation, salinity control, navigation, hydroelectri power development and other desirable and necessary uses. In additio to supplying water for these purposes in the Great Central Valley, is proposed to furnish the supplemental water supply required in th adjacent San Francisco Bay Basin from supplies developed withi the Great Central Valley Basin. It is also proposed to provide add tional flood protection required for the lands in the Sacramento an San Joaquin valleys. Navigation would be improved on both th Sacramento and San Joaquin rivers. Hydroelectric power develo ment would be made in connection with major surface storage rese voirs where economically feasible and giving promise of yieldin revenues from sale of electric energy which would assist in defrayin the cost of the project. The plan for ultimate development provid for the conservation, regulation, distribution and utilization of the available water resources to accomplish these desirable and necessary objectives.

Major Units of Ultimate State Water Plan in Great Central Valley.

The ultimate State Water Plan in the Great Central Valley provides for surface and underground storage to regulate the run-off of the major streams to supply the water requirements for irrigation and other necessary purposes. In addition to the surface storage units on the major streams in the Great Central Valley Basin, a storage reservoir on the Trinity River with works for diversion of the regulated supplies therefrom into the Sacramento River Basin are provided to augment the available water supply in the Great Central Valley. Conduits are provided to convey surplus water from the Sacramento River Basin to the areas of deficient supply in the San Joaquin Valley. Other conveyance conduits from the San Joaquin and Kern rivers are provided in the plan for the purpose of effecting an exchange between imported and local supplies in accord with the most economical plan of development.

The major units of the ultimate State Water Plan in the Great Central Valley are summarized in Table 117 and are shown on Plate XXVI. Those in the Sacramento River Basin are described in another report.* The major storage and conveyance units in the San Joaquin River Basin have been descried in detail in Chapter VI.

TABLE 117

MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY

Storage Units

Reservoir	Stream on which reservoir is located	Height of main dam, in feet	Capacity of reservoir, in acre-feet	Installed capacity of power plants, in kilovolt amperes
Sacramento River Basin				
Kennett	Sacramento River	520	5,967,000	450,000
Oroville	Feather River	580	1,705,000	314,000
Narrows	Yuba River	580	853,000	160,000
Camp Far West	Bear River	180	151,000	
Auburn	American River	440	831,000	110,000
Coloma	American River	345	766,000	60,000
Folsom	American River	190	355,000	125,000
Fairview (Trinity River diversion)	Trinity River	365	1,436,000	193,000
Millsite	Stony Creek	135	115,000	
Capay	Cache Creek	170	378,000	
Monticello	Putah Creek	150	130,000	
San Joaquin River Basin				
Nashville	Cosumnes River	270	281,000	
Ione	Dry Creek	120	610,000	
Pardee	Mokelumne River	343	222,000	18,750
Valley Springs	Calaveras River	200	325,000	
Melones	Stanislaus River	460	1,090,000	[1]68,000
Don Pedro	Tuolumne River	455	1,000,000	[2]120,000
Exchequer	Merced River	307	279,000	31,250
Buchanan	Chowchilla River	147	84,000	
Windy Gap	Fresno River	206	62,000	
Friant	San Joaquin River	252	[3]400,000	[4]10,000
Pine Flat	Kings River	274	400,000	40,000
Pleasant Valley	Tule River	125	39,000	
Isabella	Kern River	190	338,000	
Totals			17,817,000	1,700,000

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

TABLE 117—Continued

Conveyance Units

Unit	Maximum capacity, in second-feet	Length, in miles
San Joaquin River Basin		
Sacramento-San Joaquin Delta cross channel		24
San Joaquin River pumping system	8,000	167
Madera canal	1,500	18
San Joaquin River-Kern County canal	3,000	165
Kern River canal	1,500	75
Mendota-West Side pumping system	4,500	100
Total		549

[1] Present installed capacity 27,000 kilovolt amperes.
[2] Present installed capacity 33,740 kilovolt amperes.
[3] Effective capacity 270,000 acre-feet.
[4] A 30,000 kilovolt ampere power plant would be constructed on the river and the cost thereof amortized in ten years. A 10,000 kilovolt ampere plant would then be constructed on the Madera canal to utilize the power drop at the dam into that canal after water is no longer available for the larger river plant.

In addition to the major surface storage and conveyance units in the San Joaquin River Basin, the underground storage reservoirs, particularly in the upper San Joaquin Valley, are an essential feature of the proposed plan of development. The utilization of these underground reservoirs for storage and subsequent extraction of water supplies by pumping is of fundamental importance. The area, location and utilizable capacity of these underground reservoirs have been presented in detail in Chapter VI, together with data on the cost of utilization by pumping.

Operation and Accomplishments of Ultimate State Water Plan in Great Central Valley.

In order to accomplish the objectives sought and desired under the ultimate State Water Plan for the Great Central Valley, the major units for storage, both surface and underground, and for conveyance would be operated coordinately under a unified plan of development. The proposed major units in the Sacramento River Basin would be operated not only to take care of the requirements for all purposes within that basin itself, including the Sacramento-San Joaquin Delta, but also would be operated coordinately with the major units in the San Joaquin River Basin to provide the supplemental supplies required therein.

The ultimate water requirements are governed chiefly by the requirements for irrigation which now use more than 90 per cent of the water developed and utilized in this area and which probably will continue to predominate in like proportion. The required ultimate water supply, with the exception of that for special uses such as navigation improvement and salinity control, is based upon the requirements for irrigation. The supply provided on this basis would be ample for domestic, municipal and industrial uses in areas in which water is required for these purposes.

Within the Sacramento River Basin where ample water supplies are available, it is proposed to furnish, under the ultimate plan of development, a full surface irrigation supply without deficiency for the ultimate needs of the entire basin, including valley floor, foothill and mountain valley agricultural lands. In addition, it is proposed to furnish from surplus waters of the Sacramento River Basin and from such waters as reach the delta from the San Joaquin River Basin a full supply without deficiency for the Sacramento-San Joaquin Delta to meet the consumptive demands therein and to keep the water in the delta channels fresh by preventing saline invasion from the bay into the delta channels; a supplemental supply for the San Francisco Bay Basin, with some deficiency in an exceptionally dry year in the portion of the supply provided for irrigation; and finally a supplemental supply for the areas deficient in local supply in the San Joaquin Valley. It is proposed to improve navigation on the Sacramento River by providing adequate and dependable navigation depths from Sacramento to Red Bluff. This improvement would be effected by the provision of a regulated flow in the river sufficient in amount, if coupled with open channel improvements, to maintain required depths for commercial navigation. It is also proposed to provide additional flood protection which is desirable and necessary for the lands in the Sacramento Valley, by the reservation and utilization of storage space in the major reservoirs for flood regulation during the flood season.

Within the San Joaquin River Basin, the ultimate plan of development proposes to furnish irrigation supplies to meet the ultimate requirements in varying degree in different portions of the basin. In general, for the irrigable areas to be served under the ultimate State Water Plan as set forth in Chapter VI, it is proposed to furnish a surface irrigation supply with a maximum deficiency of 35 per cent in an exceptionally dry year for the lands in the lower San Joaquin Valley and on the west side of the upper San Joaquin Valley. On the eastern side of the upper San Joaquin Valley, through the combined means of surface storage and underground storage and pumping, it is proposed to furnish practically a full supply without deficiency for the irrigable lands to be served under the ultimate State Water Plan. The ultimate water requirements for the areas to be served under the ultimate State Water Plan in the San Joaquin River Basin have been presented in Chapter V and will be referred to subsequently in this chapter in the detailed presentation of the operation and accomplishments of the plan.

Additional flood protection which is desirable and necessary for the lands in the San Joaquin Valley is proposed to be effected through the reservation and utilization of storage space in several major surface reservoirs for the regulation of floods during the flood season. In addition, it is proposed to improve navigation on the San Joaquin River above Stockton by means of canalization by dams equipped with locks. The San Joaquin River Pumping System, as designed most economically for irrigation service primarily, includes a series of dams which would canalize the river to Hills Ferry and provide adequate navigation depths. The dams would be equipped with locks for this purpose. The San Joaquin River Pumping System could be extended from Hills Ferry to Mendota with dams and pumping lifts in the river channel as in the section below Hills Ferry and thus canalize the river and provide for navigation to Mendota if the dams were equipped with locks. Although this would entail greater expense than the canal plan provided in the proposed San Joaquin River Pumping System between Hills Ferry and Mendota, it might prove desirable and feasible if the additional cost could be provided for in the interest of navigation. A more detailed consideration of navigation improvement on the upper San Joaquin River is presented in Chapter X.

Three methods of operation of the major units of the ultimate plan have been considered and are presented in detail in other reports.* Under the method designated "II" in the reports cited, which may be considered to be best adapted to the accomplishments sought, the proposed plan of operation and the accomplishments are summarized briefly as follows:

1. The amount of water utilized for storage and regulation in the major reservoir units and underground storage basins was obtained by deducting from the full natural run-off of the streams entering the Great Central Valley, the net use of 2,283,000 acre-feet per season for an adequate and dependable irrigation supply for 1,439,000 acres of land, being the net irrigable mountain valley and foothill lands lying at elevations too high to be irrigated by gravity from the major reservoir units, thus providing for the ultimate needs of these areas; and also deducting 448,000 acre-feet per year from the Tuolumne River for the water supply of the city of San Francisco. An additional amount of 224,000 acre-feet per year also was deducted for the San Francisco Bay Basin from water regulated in Pardee Reservoir on the Mokelumne River.

2. Reserve storage space would have been held in the reservoirs listed in Table 118 for controlling floods. The amount of this space and the regulated flow to which floods on each stream would have been controlled also are shown in the same table.

3. Stored water would have been drawn from the major surface reservoir units, and underground basins in the upper San Joaquin Valley, in such amounts and at such times as to supplement unregulated flows and return waters, to make water available for:

   a. A supply of 9,033,000 acre-feet per season, gross allowance, without deficiency, available in the principal streams, for the irrigation of all of the net area of 2,640,000 acres of irrigable lands of all classes on the Sacramento Valley floor.
   b. A supply of 1,200,000 acre-feet per season, without deficiency, for the irrigation of all the net area of 392,000 acres of irrigable lands, and for unavoidable losses, in the Sacramento-San Joaquin Delta.
   c. Improvement of navigation on Sacramento River to Red Bluff.
   d. A fresh water flow of not less than 3300 second-feet past Antioch into Suisun Bay, which would have controlled salinity to the lower end of the Sacramento-San Joaquin Delta.

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* Bulletin No. 25, "Report to Legislature of 1931 on State Water Plan," Division of Water Resources, 1930, and
Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

e. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent, for the irrigation of all the net area of 1,810,000 acres of irrigable land of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley below the major reservoirs.
f. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of class 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley. This would have been accomplished by the utilization of underground storage capacity in conjunction with the major reservoir and conveyance units proposed.
g. A supply of 1,570,000 acre-feet per season, with a maximum deficiency of 35 per cent, for the irrigation of all the net irrigable area of 785,000 acres of class 1 and 2 lands lying chiefly on the western slope of the upper San Joaquin Valley.
h. A water supply and channel depth in the San Joaquin River sufficient to provide a navigable depth of six feet as far upstream as Salt Slough, nine miles above the Merced River.
i. A supply of 403,000 acre-feet per season in the Sacramento-San Joaquin Delta, for use in the San Francisco Bay Basin. There would have been a deficiency of 35 per cent in 1924 in the 323,000 acre-foot portion of this supply allotted to use for irrigation. This amount of 403,000 acre-feet per season, together with full practicable development of local resources and annual importations of 224,000 acre-feet from the Mokelumne River and 448,000 acre-feet from the Tuolumne River, and an importation from the Eel River, would have given an adequate and dependable supply for the ultimate development of this basin.
j. The generation of more than five billion kilowatt hours of electric energy, on the average, annually.

Table 118 sets forth the streams on which flood control by reservoirs is proposed, the maximum reservoir space required to regulate winter floods to certain controlled flows, the amount of the controlled flows, and the frequency with which the controlled flows would be exceeded. The operation of all these reservoirs specifically for flood control, employing the reservoir space assigned to each reservoir for the purpose of controlling floods to the specified flows, would result in a substantial reduction in flood flows and in an increased degree of protection to the areas subject to overflow in the Sacramento and San Joaquin valleys, and therefore would decrease the potential annual flood damages in those areas.

TABLE 118

RESERVOIR SPACE REQUIRED FOR CONTROLLING WINTER FLOODS TO CERTAIN SPECIFIED FLOWS

Reservoir	Stream	Point of control	Maximum reservoir space employed, in acre-feet	Controlled flow, in second-feet	Number of times controlled flow would be exceeded on the average
Kennett	Sacramento River	Red Bluff	512,000	[2]125,000	Once in 14 years
Oroville	Feather River	Oroville	521,000	100,000	Once in 100 years
Narrows	Yuba River	Smartsville	272,000	70,000	Once in 100 years
Camp Far West	Bear River	Wheatland	50,000	20,000	Once in 100 years
Folsom, Auburn and Coloma	American River	Fairoaks	300,000	[3]80,000	One day in 250 yrs.
Nashville	Cosumnes River	Michigan Bar	56,000	15,000	Once in 100 years
Ione	Dry Creek	Galt	[1]121,000	5,000	Once in 100 years
Pardee	Mokelumne River	Clements	[1]0	10,000	Once in 100 years
Valley Springs	Calaveras River	Jenny Lind	165,000	25,000	Once in 100 years
Melones	Stanislaus River	Knights Ferry	204,000	[4]15,000	Once in 100 years
Don Pedro	Tuolumne River	La Grange	214,000	[4]15,000	Once in 100 years
Exchequer	Merced River	Exchequer	59,000	[4]25,000	Once in 100 years
Friant	San Joaquin River	Friant	75,000	[4]15,000	Once in 100 years
Pine Flat	Kings River	Piedra	80,000	[4]15,000	Once in 100 years
Isabella	Kern River	Bakersfield	67,000	[4]7,500	Once in 100 years

[1] Floods which would cause flows in excess of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reservoir to Dry Creek by the Jackson Creek Spillway and the water stored in Ione Reservoir.

[2] Mean daily flow on day of flood crest. Floods would be controlled to 125,000 second-feet maximum flow exceeded once in 100 years, except when this amount is exceeded by uncontrolled run-off between Kennett Reservoir and Red Bluff. Flows greater than 125,000 second-feet would continue for only a short time.

[3] Folsom reservoir alone would control the flow at Fairoaks to a maximum of 100,000 second-feet exceeded one day in 100 years on an average, by employing 175,000 acre-feet of space in the reservoir for flood control.

[4] Amounts shown are controlled flows during winter floods. During summer floods, the flows would be controlled to amounts not exceeding those shown by combining some reservoir regulation with diversions from the streams for irrigation and underground storage. The control points would not be at those shown with winter floods but would be at points down stream where control is desired to protect lands subject to inundation.

Table 119 sets forth, for various points on the main stream channels, the winter flood flows exceeded once in 100 years on the average, except as noted, without and with reservoir control. The flows in the Sacramento Valley are those that would obtain with the completed Sacramento Flood Control Project, including the protection of Butte Basin. In the San Joaquin Valley, the flows without reservoir control are those that would obtain with levees constructed along the San Joaquin River from a point below Herndon to the delta to form a channel of sufficient width to care for these flows and protect the remaining land now subject to overflow. The flows with reservoir control are those that would obtain with the same channel, but with the flood flows from the larger streams controlled by means of regulation in the major reservoir units of the State Water Plan in this basin to those at the foothill gaging stations shown in Table 118. If protection of the valley lands by means of levees were not effected until after the reservoirs with flood control features were completed, a narrower flood channel along the river could be constructed because of the smaller regulated flows. Under this condition, however, the flows might be slightly larger than those shown in the third column of Table 119, since the reduction of quantities by storage in the narrower channel might be less and the rate of concentration somewhat greater. Flows during summer floods in the San Joaquin River Basin would not exceed those shown in Table 119. Additional details as to flood control in the San Joaquin River Basin are presented in Chapter IX.

Most of the water to be imported from the Sacramento River Basin to the San Joaquin River Basin would be obtained from surplus

TABLE 119

WINTER FLOOD FLOWS IN GREAT CENTRAL VALLEY WITHOUT AND WITH RESERVOIR CONTROL

Stream	Maximum mean daily flow, in second-feet		Number of times flow would be exceeded, on the average
	Without reservoir control	With reservoir control	
Sacramento River at Red Bluff	303,000	[1]187,000	Once in 100 years
Sacramento River at Red Bluff	218,000	[1]125,000	Once in 14 years
Sacramento River and Sutter-Butte By-pass opposite Colusa	370,000	250,000	Once in 100 years
Sacramento River and Sutter-Butte By-pass opposite Colusa	254,000	170,000	Once in 14 years
Sacramento River at Sacramento and Yolo By-pass at Lisbon	670,000	535,000	Once in 100 years
Feather River below confluence with Yuba River	400,000	201,000	Once in 100 years
Feather River below confluence with Bear River	430,000	226,000	Once in 100 years
American River at Fairoaks	185,000	80,000	Once in 250 years
San Joaquin River below confluence with Merced River	70,000	50,000	Once in 100 years
San Joaquin River below confluence with Tuolumne River	103,000	64,000	Once in 100 years
San Joaquin River below confluence with Stanislaus River	133,000	82,000	Once in 100 years
Sacramento and San Joaquin rivers at confluence	780,000	596,000	Once in 100 years

[1] Floods would be controlled to 125,000 second-feet maximum flow exceeded once in 100 years, except when this amount is exceeded by uncontrolled run-off between Kennett Reservoir and Red Bluff. Flows greater than 125,000 second-feet would continue for only a short time.

supplies made available in the Sacramento-San Joaquin Delta channels and would be conveyed to the San Joaquin Valley through the San Joaquin River Pumping System. However, a portion of the imported water supply from the Sacramento River Basin would be furnished by diversion from Folsom Reservoir on the American River to provide a supplemental supply for the area in the San Joaquin River Basin lying east of the delta from the Cosumnes to the Calaveras River (hydrographic divisions Nos. 12 and 13). As a part of the coordinated operation of the American and Cosumnes rivers, it is proposed to furnish by diversion from the Cosumnes River above the Nashville Reservoir a portion of the water requirements for foothill lands in the American River area of the Sacramento River Basin, which can be more economically and practically served in this manner. Sacramento River water from the delta channels, together with return flow and unregulated surplus water from the lower San Joaquin Valley, conveyed through the San Joaquin River Pumping System, would be utilized in part to furnish the water requirements of lands now served by San Joaquin River water and other irrigable lands at present undeveloped in the lower San Joaquin Valley; and in part for the irrigation of the undeveloped irrigable lands to be served on the western slope of the upper San Joaquin Valley with water conveyed thereto through the Mendota-West Side Pumping System.

With the irrigable areas in the lower San Joaquin Valley which would be naturally served by the San Joaquin River furnished a supply by imported Sacramento River water, practically the entire run-off of the San Joaquin River would be regulated at Friant Reservoir and conveyed through the Madera Canal northerly and through the San Joaquin River-Kern County Canal southerly to provide the supplemental supply required for the lands lying on the east side of the upper San Joaquin Valley. The water supplies developed by the major units on the streams tributary to the area on the east side of the upper San Joaquin Valley would be regulated in coordination with supplies from Friant Reservoir, with regulation obtained through the combined use of surface and underground storage. A portion of the water conveyed from the San Joaquin River through the San Joaquin River-Kern County Canal would supply areas now served with Kern River water and make possible the diversion of Kern River water through the Kern River Canal to serve higher lying rim lands along the southern edge of the upper San Joaquin Valley.

The lands on the east side of the lower San Joaquin Valley from the Stanislaus to the Merced rivers, with the exception of a small acreage in the Merced area lying immediately adjacent to the San Joaquin River, would be served by regulated supplies from the main east side tributaries of the San Joaquin River.

Surplus Water in Great Central Valley—Under the proposed plan of operation of the major units of the State Water Plan in the Great Central Valley as just described, there would have been substantial amounts of water, over and above the requirements for the purposes provided for, which would have wasted each year during the eleven-year period 1918–1929 into San Francisco Bay. Most of this waste would have occurred in years of large run-off and in the winter months of other years. Part of the waste water would have spilled from the reservoirs. During the summer months there would have been just sufficient water released from the reservoirs to care for all needs. Part of the waste waters could have been conserved by reservoirs other than the major units of the State Water Plan or by larger major units. Studies showed, however, that these additional regulated waters would not have been necessary during the eleven-year period 1918–1929, for the accomplishments set forth in the foregoing paragraphs.

Although the imported water from the Trinity River would add somewhat to the surplus in years of large run-off in the Sacramento River Basin, more than half of it would be required for the irrigation of lands which could be served by gravity from no other source and a considerable portion of the remainder would be required in the winter months of the drier years for salinity control and navigation. This unit and all of the other selected major units of the State Water Plan would have been required to furnish regulated supplies distributed in accordance with the demand, especially in years of low run-off.

Table 120 shows the net flows into the Sacramento-San Joaquin Delta, the amounts required from this water for all uses in the delta and adjacent uplands, the amounts required for supplemental supplies for irrigation in the San Joaquin Valley and for irrigation and other uses in the San Francisco Bay Basin, the amounts of water which would have flowed past Antioch into Suisun Bay for salinity control, the surplus water which would have reached the delta in addition to that for all requirements, and the total amounts of water which would have flowed into Suisun Bay after all requirements had been satisfied. The amounts shown for net flow into the delta from the San Joaquin Valley include such portions of the unregulated surplus and return waters intercepted by the San Joaquin River Pumping System before reaching the delta, as could have been used in supplying "crop land" rights or new lands in this valley south of the Merced River, obviating the pumping of that portion of this supply from the delta; but do not

TABLE 120

ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1918-1929

Year	Net flow into delta, in acre-feet[1]			Requirements from net flow into delta, in acre-feet					Surplus water above all requirements, in acre-feet	Total flow into Suisun Bay, in acre-feet
	From Sacramento Valley, including area east of delta[2]	From San Joaquin Valley, excluding area east of delta[2]	From both valleys	Total gross allowance for delta and adjacent uplands	Salinity control to lower end of delta	Full irrigation supply for "crop lands" in San Joaquin Valley having rights to water to be diverted at Friant[3]	Irrigation supply for additional new lands in San Joaquin Valley[4]	Supplemental supply for San Francisco Bay Basin		
1918	9,726,000	968,000	10,694,000	1,551,000	2,389,000	896,000	1,570,000	403,000	3,885,000	6,274,000
1919	9,953,000	968,000	10,921,000	1,551,000	2,389,000	896,000	1,570,000	403,000	4,112,000	6,501,000
1920	8,146,000	957,000	9,103,000	1,551,000	2,395,000	896,000	1,570,000	403,000	2,288,000	4,683,000
1921	13,915,000	965,000	14,880,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,071,000	10,460,000
1922	13,651,000	1,592,000	15,243,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,434,000	10,823,000
1923	8,693,000	1,050,000	9,743,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,934,000	5,323,000
1924	6,081,000	760,000	6,841,000	1,551,000	2,395,000	583,000	1,020,000	290,000	1,002,000	3,397,000
1925	8,727,000	942,000	9,669,000	1,551,000	2,389,000	896,000	1,570 000	403,000	2,860,000	5,249,000
1926	8,957,000	777,000	9,734,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,925,000	5,314,000
1927	15,361,000	917,000	16,278,000	1,551,000	2,389,000	896,000	1,570,000	403,000	9,469,000	11,858,000
1928	13,339,000	968,000	14,307,000	1,551,000	2,395,000	896,000	1,570,000	403,000	7,498,000	9,893,000
Averages	10,595,000	988,000	11,583,000	1,551,000	2,390,000	868,000	1,520,000	392,000	4,862,000	7,252,000

[1] Includes regulated and unregulated water from reservoirs and return waters. The amounts shown from the San Joaquin Valley include such portions of the unregulated surplus and return flow waters intercepted by the San Joaquin River Pumping System before reaching the delta as could be used in supplying "crop land" rights or additional new lands in this valley south of Merced River, obviating the pumping of that portion of this supply from the delta; but do not include the portion of such waters intercepted and used in the west side area north of Merced River in Hydrographic Division 7 and in the west side rim lands in Hydrographic Division 7 (a).

[2] Area east of delta includes the watersheds of the Cosumnes, Mokelumne and Calaveras rivers.

[3] "Crop lands" are those areas suitable for growing crops which are now served or probably will be served in the near future by diversions from the San Joaquin River above the mouth of the Merced River under existing rights.

[4] Does not include water requirements of west side area north of Merced River in Hydrographic Division 7, and in west side rim lands in Hydrographic Division 7 (a), amounting to 410,000 acre-feet annually.

include the portion of such waters intercepted and used in the west side area north of Merced River in Hydrographic Division 7 and in the west side rim lands in Hydrographic Division 7(a). Table 136 shows the amounts of such return flow and surplus waters which would be intercepted by the San Joaquin River Pumping System and the areas in which such supplies would be utilized. It also shows the residual flow into the delta after being reduced by the amounts intercepted. However, the return flow and surplus water would have reached the delta under natural conditions and the amounts of such waters intercepted would have to be replaced in the delta by Sacramento River water for irrigation and salinity control uses. Therefore, the water supply to be made available in the delta for exportation to the San Joaquin Valley would be based upon the full amount of the requirements to be met in the areas to be served by the San Joaquin River and Mendota-West Side pumping systems. The amounts shown in the seventh and eighth columns of Table 120 for the San Joaquin Valley are for the full requirements, except those for the west side area north of Merced River in Hydrographic Division 7 and on the west side rim lands in Hydrographic Division 7(a), which were previously deducted from the inflow. "Crop lands" are those lands suitable for growing crops which are now or probably will be served in the near future by diversions, under existing rights, from the San Joaquin River above the mouth of the Merced River.

Table 121 shows the amounts of surplus water in the delta and the total flows into Suisun Bay, by months, for the years of maximum and minimum run-off, and the average for the period 1918–1929. It may be noted that under this method of operation there would have been no surplus in July, August and September of any year. The flow into Suisun Bay shown for these months is that required for salinity control.

TABLE 121

MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY UNDER OPERATION OF MAJOR UNITS OF ULTIMATE STATE WATER PLAN IN GREAT CENTRAL VALLEY, 1918-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1918-1929	
	Surplus water above all requirements in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet	Surplus water above all requirements, in acre-feet	Flow into Suisun Bay, in acre-feet
January	1,054,000	1,257,000	204,000	407,000	722,000	925,00
February	4,043,000	4,227,000	249,000	439,000	1,320,000	1,505,00
March	1,719,000	1,922,000	0	203,000	1,486,000	1,689,00
April	1,029,000	1,225,000	0	196,000	167,000	363,00
May	357,000	560,000	0	203,000	219,000	422,00
June	0	196,000	0	196,000	113,000	309,00
July	0	203,000	0	203,000	0	203,00
August	0	203,000	0	203,000	0	203,00
September	0	196,000	0	196,000	0	196,00
October	32,000	235,000	55,000	258,000	33,000	236,00
November	588,000	784,000	248,000	444,000	328,000	524,00
December	647,000	850,000	246,000	449,000	474,000	677,00
Totals	9,469,000	11,858,000	1,002,000	3,397,000	4,862,000	7,252,00

The data compiled in the foregoing Tables 120 and 121, covering the generally subnormal period of run-off 1918–1929, show that the amounts of water which the plan proposes to export from the Sacramento River Basin to the San Joaquin Valley could have been furnished in each year of this period with an allowable maximum deficiency in supply in the driest year of record of 1924; and that, after providing the amounts proposed for exportation, there still would have been surplus water in each year during the period over and above all the requirements provided for in the proposed ultimate plan of operation and accomplishments of the State Water Plan in the Great Central Valley.

The following portion of Chapter VII is devoted to a presentation of detailed data and information on the operation and accomplishments of the ultimate State Water Plan in the San Joaquin River Basin, with the major units therein operating coordinately with those in the Sacramento River Basin. There are presented: first, the utilizable water supply made available from the major streams as regulated by proposed surface storage reservoirs, underground reservoirs and combinations thereof; second, the utilization of underground reservoirs for storage and pumping of water derived from local tributary run-off and imported supplies brought in by the conveyance units, particularly in the upper San Joaquin Valley; third, the operation and accomplishments of the conveyance units; and, lastly the water supply furnished to meet the water requirements in each hydrographic division of the San Joaquin River Basin, demonstrating the sufficiency of the proposed ultimate plan of development and operation.

Utilizable Water Supply from Major Streams in San Joaquin River Basin.

The utilizable water supply from the major streams, under the ultimate plan of development in the San Joaquin River Basin, varies for different streams and groups of streams and depends upon the water requirements of the area to be served from a particular stream or group of streams, the practicability and economic feasibility of surface storage regulation, the availability of and practicability of utilizing underground storage reservoirs, the necessity in some areas for coordination of local supplies with required importations of supplemental water, and the possible or proposed combinations of underground storage and pumping with surface storage regulation.

Certain surface storage reservoirs on major streams would be of sufficient capacity to regulate the available run-off and provide a surface irrigation supply fully sufficient for the area to be served therefrom. Others would provide only a portion of the regulated supply required and it would be necessary to obtain the remainder of the supply required by underground storage and pumping. On certain streams, full practicable utilization of the run-off could be effected more economically by direct diversions and underground storage regulation and pumping than by surface storage. On some streams, the utilizable supply made available from the fullest practicable regulation by either surface or underground storage or by a combination of both would not be sufficient to meet the water requirements and imported supplies would be required. In such cases, both surface and underground regulation of local supplies would be coordinated with the supplies made available by importation and the regulatory operations and yields of local streams would be governed to some extent by such imported supplies.

In the lower San Joaquin Valley, the proposed storage reservoirs on the Cosumnes, Calaveras and Mokelumne rivers and Dry Creek would be operated coordinately with storage units on the American River in the Sacramento River Basin so that the combined amount of water obtained from these local sources and from the supplies imported from the American River would meet the ultimate water requirements of the irrigable area to be served in hydrographic divisions 12 and 13. The proposed major surface reservoirs on the Stanislaus and Tuolumne rivers would be operated to provide an adequate surface irrigation supply for all irrigable lands to be served in their respective service areas. The requirements of the irrigable lands to be served in the Merced River area are in excess of the surface irrigation supply obtainable from the storage reservoir on Merced River and it is proposed to utilize surplus and waste waters of Merced River through ground water storage and pumping to serve a portion of the area. In addition, the western portion of the Merced area adjacent to the San Joaquin River would be served from the surplus and return flow waters of the lower San Joaquin River and imported Sacramento River water by means of the San Joaquin River Pumping System.

For the area on the east side of the upper San Joaquin Valley from the Chowchilla River to the southern end of the valley, the proposed major reservoirs would be operated in combination with ground water storage and pumping to provide a full supply in all years to the irrigable area to be served under the ultimate plan of development. The utilization of the underground storage in this area is essential to the obtaining of a sufficient water supply to fully meet the ultimate needs. The local sources of water supply utilizable through the proposed major surface storage units and underground storage would be inadequate to meet the demands. The cost of importing water from distant sources would be large. The studies show that, in order to effect the most practicable and economical plan of development, full utilization must be made of the available underground reservoir capacity by means of controlled operations of replenishments and extractions by pumping. Within this entire section on the east side of the upper San Joaquin Valley, the water supplies from the San Joaquin River obtained by regulation through Friant Reservoir would be distributed and used to supplement the available local supplies. Each major reservoir on other streams in this area, in combination with ground water storage and pumping, would be operated coordinately with the imported water supplies from Friant Reservoir to furnish its individual service area a full supply for ultimate needs.

The utilizable yields obtainable from the major streams in the San Joaquin River Basin by surface or underground storage regulation or combinations thereof, with regulatory operations coordinated with imported supplies for areas served by certain streams, are shown in Table 122. The table shows, for each stream, the surface irrigation supply, the additional supply utilizable by ground water storage (for certain streams particularly in the upper San Joaquin Valley), and, finally, the total utilizable supply, which would have been made available each season during the 40-year period 1889–1929. The utilizable yields for the Cosumnes, Mokelumne and Calaveras rivers and Dry Creek are shown each year for the 11-year period 1918–1929 only. The table also shows the name of the surface storage reservoir and its capacity for each of the streams where surface storage is proposed and sets forth the area in which the supply would be utilized.

The seasonal amounts of utilizable water supply shown are those resulting from a month by month study throughout the periods considered. For any one season, they represent the net contribution from the run-off of that season to the utilizable water supply, but do not include supplemental pumping drafts from utilizable supplies previously stored in underground reservoirs.

TABLE 122

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KERN RIVER

Regulated at Isabella Reservoir, Capacity 338,000 acre-feet. Supply utilized in Hydrographic Division 1

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	606,000	37,800	643,800
1890–91	606,000	0	606,000
1891–92	606,000	38,500	644,500
1892–93	606,000	1,000	607,000
1893–94	606,000	0	606,000
1894–95	606,000	285,300	891,300
1895–96	606,000	14,000	620,000
1896–97	606,000	276,400	882,400
1897–98	493,400	0	493,400
1898–99	330,700	0	330,700
1899–00	319,200	0	319,200
1900–01	585,500	0	585,500
1901–02	606,000	27,300	633,300
1902–03	606,000	0	606,000
1903–04	576,000	0	576,000
1904–05	543,500	0	543,500
1905–06	582,100	669,800	1,251,900
1906–07	606,000	486,000	1,092,000
1907–08	606,000	0	606,000
1908–09	606,000	773,500	1,379,500
1909–10	606,000	232,700	838,700
1910–11	606,000	287,100	893,100
1911–12	606,000	0	606,000
1912–13	420,500	0	420,500
1913–14	584,600	211,600	796,200
1914–15	606,000	84,400	690,400
1915–16	606,000	1,029,600	1,635,600
1916–17	606,000	282,600	888,600
1917–18	606,000	0	606,000
1918–19	606,000	0	606,000
1919–20	606,000	0	606,000
1920–21	531,300	0	531,300
1921–22	583,700	0	583,700
1922–23	606,000	0	606,000
1923–24	323,600	0	323,600
1924–25	463,600	0	463,600
1925–26	340,100	0	340,100
1926–27	584,100	0	584,100
1927–28	521,400	0	521,400
1928–29	328,500	0	328,500
Averages for 40-year period 1889–1929	551,000	119,000	670,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

TULE RIVER

Run-off from main stream regulated at Pleasant Valley Reservoir, Capacity 39,000 acre-feet. Includes yield from run-off of South Fork, without surface storage regulation.
Supply utilized in Hydrographic Division 2

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	103,700	46,200	149,900
1890–91	93,900	0	93,900
1891–92	101,300	20,000	121,300
1892–93	97,400	6,000	103,400
1893–94	93,800	30,100	123,900
1894–95	104,400	102,200	206,600
1895–96	100,800	12,800	113,600
1896–97	99,400	69,200	168,600
1897–98	50,000	0	50,000
1898–99	47,200	0	47,200
1899–00	41,600	0	41,600
1900–01	100,600	46,300	146,900
1901–02	100,500	43,000	143,500
1902–03	100,800	39,700	140,500
1903–04	90,800	0	90,800
1904–05	88,100	0	88,100
1905–06	105,100	333,200	438,300
1906–07	112,000	99,100	211,100
1907–08	97,200	12,300	109,500
1908–09	105,100	257,500	362,600
1909–10	99,100	66,600	165,700
1910–11	100,200	38,000	138,200
1911–12	67,100	0	67,100
1912–13	37,500	0	37,500
1913–14	97,800	60,200	158,000
1914–15	100,900	30,000	130,900
1915–16	105,900	220,700	326,600
1916–17	108,900	68,900	177,800
1917–18	54,500	0	54,500
1918–19	74,300	0	74,300
1919–20	94,200	13,900	108,100
1920–21	88,600	0	88,600
1921–22	100,600	34,100	134,700
1922–23	94,500	5,800	100,300
1923–24	25,000	0	25,000
1924–25	87,300	0	87,300
1925–26	47,700	0	47,700
1926–27	92,500	35,400	127,900
1927–28	47,200	0	47,200
1928–29	53,400	0	53,400
Averages for 40-year period 1889–1929	86,000	42,000	128,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KAWEAH RIVER

No surface storage regulation. Supply utilized in Hydrographic Division 3

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889-90	318,800	659,800	978,600
1890-91	275,800	233,200	509,000
1891-92	292,900	355,100	648,000
1892-93	287,900	319,100	607,000
1893-94	261,600	137,400	399,000
1894-95	302,300	430,700	733,000
1895-96	255,300	146,200	401,500
1896-97	246,500	224,700	471,200
1897-98	182,600	41,800	224,400
1898-99	228,100	63,400	291,500
1899-00	231,600	79,900	311,500
1900-01	297,000	434,700	731,700
1901-02	239,300	115,800	355,100
1902-03	249,300	154,600	403,900
1903-04	232,200	113,500	345,700
1904-05	251,700	86,000	337,700
1905-06	321,300	623,100	944,400
1906-07	297,600	295,900	593,500
1907-08	220,100	32,500	252,600
1908-09	292,500	468,500	761,000
1909-10	216,200	193,000	409,200
1910-11	281,300	264,700	546,000
1911-12	183,200	24,200	207,400
1912-13	208,600	12,100	220,700
1913-14	265,600	220,400	486,000
1914-15	245,600	123,900	369,500
1915-16	290,700	471,500	762,200
1916-17	273,800	197,700	471,500
1917-18	203,800	25,900	229,700
1918-19	208,000	81,200	289,200
1919-20	232,900	139,200	372,100
1920-21	247,800	113,000	360,800
1921-22	255,400	205,700	461,100
1922-23	247,800	115,700	363,500
1923-24	101,700	0	101,700
1924-25	243,300	82,200	325,500
1925-26	172,500	46,300	218,800
1926-27	251,200	232,000	483,200
1927-28	182,800	20,200	203,000
1928-29	192,100	30,700	222,800
Averages for 40-year period 1889-1929	245,000	190,000	435,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

KINGS RIVER

Regulated at Pine Flat Reservoir, Capacity 400,000 acre-feet. Supply utilized in Hydrographic Division 4

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889-90	1,639,500	1,120,300	2,759,800
1890-91	1,660,000	664,500	2,324,500
1891-92	1,660,000	766,400	2,426,400
1892-93	1,660,000	749,600	2,409,600
1893-94	1,660,000	209,700	1,869,700
1894-95	1,627,700	862,100	2,489,800
1895-96	1,660,000	283,200	1,943,200
1896-97	1,565,400	438,800	2,004,200
1897-98	879,900	0	879,900
1898-99	1,219,800	0	1,219,800
1899-00	1,279,700	0	1,279,700
1900-01	1,596,000	986,200	2,582,200
1901-02	1,548,100	164,400	1,712,500
1902-03	1,491,400	188,000	1,679,400
1903-04	1,502,200	232,500	1,734,700
1904-05	1,421,600	0	1,421,600
1905-06	1,581,000	998,700	2,579,700
1906-07	1,660,000	1,109,400	2,769,400
1907-08	1,181,200	0	1,181,200
1908-09	1,601,900	771,900	2,373,800
1909-10	1,499,200	383,900	1,883,100
1910-11	1,597,500	916,500	2,514,000
1911-12	1,099,200	0	1,099,200
1912-13	940,900	0	940,900
1913-14	1,591,400	776,800	2,368,200
1914-15	1,660,000	264,200	1,924,200
1915-16	1,616,800	973,700	2,590,500
1916-17	1,660,000	345,100	2,005,100
1917-18	1,361,900	0	1,361,900
1918-19	1,199,700	0	1,199,700
1919-20	1,398,100	0	1,398,100
1920-21	1,507,900	15,900	1,523,800
1921-22	1,586,500	423,500	2,010,000
1922-23	1,599,800	0	1,599,800
1923-24	392,000	0	392,000
1924-25	1,285,900	0	1,285,900
1925-26	1,032,900	0	1,032,900
1926-27	1,574,900	398,600	1,973,500
1927-28	969,500	0	969,500
1928-29	847,600	0	847,600
Averages for 40-year period 1889-1929	1,413,000	351,000	1,764,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

SAN JOAQUIN RIVER

Regulated at Friant Reservoir; Utilizable Capacity, 270,000 acre-feet.
Supply utilized in Hydrographic Divisions 1, 2, 3 and 6

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	1,590,900	721,800	2,312,700
1890–91	1,590,900	665,400	2,256,300
1891–92	1,590,900	679,500	2,270,400
1892–93	1,590,900	676,800	2,267,700
1893–94	1,514,900	413,300	1,928,200
1894–95	1,590,900	618,200	2,209,100
1895–96	1,509,000	502,600	2,011,600
1896–97	1,590,900	424,400	2,015,300
1897–98	794,100	218,600	1,012,700
1898–99	1,137,000	119,400	1,256,400
1899–00	1,116,000	218,800	1,334,800
1900–01	1,578,400	593,600	2,172,000
1901–02	1,427,500	334,900	1,762,400
1902–03	1,516,600	217,900	1,734,500
1903–04	1,560,400	162,600	1,723,000
1904–05	1,276,600	319,600	1,596,200
1905–06	1,580,000	549,000	2,129,000
1906–07	1,590,900	772,000	2,362,900
1907–08	978,400	354,100	1,332,500
1908–09	1,576,600	532,300	2,108,900
1909–10	1,516,500	603,800	2,120,300
1910–11	1,590,900	660,900	2,251,800
1911–12	990,600	236,900	1,227,500
1912–13	817,100	62,400	879,500
1913–14	1,565,100	550,200	2,115,300
1914–15	1,590,900	445,900	2,036,800
1915–16	1,590,900	642,400	2,233,300
1916–17	1,582,600	408,700	1,991,300
1917–18	1,377,200	158,900	1,536,100
1918–19	1,120,600	223,400	1,344,000
1919–20	1,253,800	47,100	1,300,900
1920–21	1,328,300	222,300	1,550,600
1921–22	1,561,800	301,000	1,862,800
1922–23	1,403,700	304,100	1,707,800
1923–24	515,600	120,800	636,400
1924–25	1,212,400	59,900	1,272,300
1925–26	1,088,700	137,500	1,226,200
1926–27	1,560,300	313,000	1,873,300
1927–28	996,900	214,200	1,211,100
1928–29	811,700	58,400	870,100
Averages for 40-year period 1889–1929	1,355,000	371,000	1,726,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Season	FRESNO RIVER Regulated at Windy Gap Reservoir. Capacity, 62,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 6.	CHOWCHILLA RIVER Regulated at Buchanan Reservoir. Capacity, 84,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 6
1889-90	45,700	54,000
1890-91	45,700	54,000
1891-92	45,700	54,000
1892-93	45,700	54,000
1893-94	45,700	54,000
1894-95	45,700	54,000
1895-96	45,700	54,000
1896-97	45,700	54,000
1897-98	45,700	54,000
1898-99	45,700	54,000
1899-00	45,700	54,000
1900-01	45,700	54,000
1901-02	45,700	54,000
1902-03	45,700	54,000
1903-04	45,700	54,000
1904-05	45,700	54,000
1905-06	45,700	54,000
1906-07	45,700	54,000
1907-08	45,700	54,000
1908-09	45,700	54,000
1909-10	45,700	54,000
1910-11	45,700	54,000
1911-12	45,700	54,000
1912-13	45,700	39,700
1913-14	45,700	54,000
1914-15	45,700	54,000
1915-16	45,700	54,000
1916-17	45,700	54,000
1917-18	45,700	54,000
1918-19	45,700	54,000
1919-20	45,700	35,300
1920-21	45,700	54,000
1921-22	45,700	54,000
1922-23	45,700	54,000
1923-24	45,700	54,000
1924-25	45,700	54,000
1925-26	32,800	54,000
1926-27	43,900	54,000
1927-28	45,700	54,000
1928-29	31,700	50,800
Averages for 40-year period 1889-1929	45,000	53,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

MERCED RIVER

Regulated at Exchequer Reservoir, Capacity 279,000 acre-feet.
Supply utilized in Hydrographic Division 8

Season	Surface irrigation supply	Supply utilizable by ground water storage and pumping	Total utilizable supply
1889–90	440,000	539,200	979,200
1890–91	440,000	320,900	760,900
1891–92	440,000	352,300	792,300
1892–93	440,000	428,200	868,200
1893–94	440,000	421,500	861,500
1894–95	440,000	491,000	931,000
1895–96	440,000	219,600	659,600
1896–97	440,000	332,500	772,500
1897–98	440,000	48,200	488,200
1898–99	440,000	65,800	505,800
1899–00	440,000	262,400	702,400
1900–01	440,000	457,900	897,900
1901–02	440,000	306,900	746,900
1902–03	440,000	319,500	759,500
1903–04	440,000	333,200	773,200
1904–05	440,000	336,000	776,000
1905–06	440,000	531,600	971,600
1906–07	440,000	533,400	973,400
1907–08	440,000	73,500	513,500
1908–09	440,000	401,600	841,600
1909–10	440,000	281,200	721,200
1910–11	440,000	507,400	947,400
1911–12	440,000	0	440,000
1912–13	384,300	0	384,300
1913–14	422,400	437,100	859,500
1914–15	440,000	385,100	825,100
1915–16	440,000	384,200	824,200
1916–17	440,000	390,000	830,000
1917–18	440,000	296,300	736,300
1918–19	440,000	159,700	599,700
1919–20	440,000	79,600	519,600
1920–21	440,000	373,000	813,000
1921–22	440,000	379,800	819,800
1922–23	440,000	327,100	767,100
1923–24	303,900	0	303,900
1924–25	422,400	232,400	654,800
1925–26	440,000	147,500	587,500
1926–27	440,000	350,200	790,200
1927–28	440,000	257,100	697,100
1928–29	432,600	0	432,600
Averages for 40-year period 1889–1929	434,000	294,000	728,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Season	TUOLUMNE RIVER Regulated at Don Pedro Reservoir. Capacity 1,000,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 9.	STANISLAUS RIVER Regulated at Melones Reservoir. Capacity 1,090,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 11.
1889-90	1,330,000	905,000
1890-91	1,330,000	905,000
1891-92	1,330,000	905,000
1892-93	1,330,000	905,000
1893-94	1,330,000	905,000
1894-95	1,330,000	905,000
1895-96	1,330,000	905,000
1896-97	1,330,000	905,000
1897-98	1,330,000	905,000
1898-99	1,193,100	760,500
1899-00	1,307,900	825,600
1900-01	1,330,000	900,800
1901-02	1,330,000	905,000
1902-03	1,330,000	905,000
1903-04	1,330,000	905,000
1904-05	1,330,000	905,000
1905-06	1,330,000	905,000
1906-07	1,330,000	905,000
1907-08	1,330,000	905,000
1908-09	1,330,000	905,000
1909-10	1,330,000	905,000
1901-11	1,330,000	905,000
1911-12	1,330,000	905,000
1912-13	1,294,200	905,000
1913-14	1,279,300	905,000
1914-15	1,330,000	905,000
1915-16	1,330,000	905,000
1916-17	1,330,000	905,000
1917-18	1,330,000	905,000
1918-19	1,330,000	905,000
1919-20	1,317,600	905,000
1920-21	1,317,000	889,700
1921-22	1,330,000	905,000
1922-23	1,330,000	905,000
1923-24	1,071,500	905,000
1924-25	1,291,800	873,500
1925-26	1,091,200	721,200
1926-27	1,279,900	872,500
1927-28	1,330,000	905,000
1928-29	1,102,500	667,200
Averages for 40-year period 1889-1929	1,303,000	887,000

TABLE 122—Continued

UTILIZABLE YIELD FROM MAJOR STREAMS FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN, IN ACRE-FEET

Year	CALAVERAS RIVER Regulated at Valley Springs Reservoir. Capacity 325,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A.	MOKELUMNE RIVER Regulated at Pardee Reservoir. Capacity 222,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A[1].
1918	122,900	338,800
1919	103,500	338,800
1920	55,800	216,100
1921	117,500	338,800
1922	122,900	338,800
1923	126,400	338,800
1924	83,100	75,600
1925	95,700	338,800
1926	48,500	231,400
1927	114,100	338,800
1928	89,100	338,800
Averages for 11-year period 1918–1929	98,000	294,000

Year	DRY CREEK Regulated at Ione Reservoir. Capacity 610,000 acre-feet. Surface irrigation supply utilized in Hydrographic Divisions 12 and 12A[2].	COSUMNES RIVER Regulated at Nashville Reservoir. Capacity 281,000 acre-feet. Surface irrigation supply utilized in Hydrographic Division 13[3].
1918	184,900	151,800
1919	66,100	151,800
1920	28,700	131,200
1921	234,300	151,800
1922	234,300	199,200
1923	234,300	230,500
1924	88,600	151,800
1925	158,200	151,800
1926	30,000	151,700
1927	220,700	151,800
1928	174,000	169,300
Averages for 11-year period 1918–1929	150,000	163,000

[1] Exclusive of allowance for a draft of 200 million gallons per day by the East Bay Municipal Utility District and spill regulated in Ione Reservoir.

[2] Includes yield from regulation of spill from Pardee Reservoir.

[3] These yields are exclusive of an average annual exportation of 64,000 acre-feet diverted from the Cosumnes River above Nashville Reservoir to the American River Basin.

Operation and Accomplishments of Friant Reservoir—Inasmuch as Friant Reservoir is a key unit for the entire east side of the upper San Joaquin Valley in the ultimate plan of development, it is of importance to present detailed data with respect to its operation and accomplishments. It would be operated primarily to furnish necessary supplies of water to supplement the amounts made available from local sources of supply through the combined utilization of surface and underground storage reservoirs. Tho basis of operation and the amounts of water provided from this reservoir are set forth in the following discussion.

The impaired run-off of the San Joaquin River would be regulated by Friant Reservoir with the proposed utilizable net storage capacity of 270,000 acre-feet. The entire regulated supply obtained therefrom would be conveyed through the Madera and San Joaquin River-Kern County canals to the areas of deficient local supply on the east side of the upper San Joaquin Valley. The total utilizable water supply delivered from the reservoir would be pooled with local water supplies made available from the operation of surface and underground storage units to meet the requirements in the areas served therefrom, both as to total seasonal amounts and rates of delivery.

The amount of water which would be provided for the Madera area is based upon the assumed right of the Madera Irrigation District to acquire San Joaquin River water. It is proposed to furnish seasonally a safe surface irrigation supply of 329,200 acre-feet and additional supplies for ground water storage, with a maximum rate of delivery of 1500 second-feet. Water for ground water storage released for the Madera area would be furnished up to the maximum capacity of the canal from any surplus or waste water from the Friant Reservoir. The desirable monthly distribution of the surface irrigation supply for the Madera area under conditions of ultimate development, in per cent of the total seasonal supply, is as follows:

TABLE 123

DESIRABLE MONTHLY DISTRIBUTION OF SURFACE IRRIGATION SUPPLY FOR SERVICE AREA OF MADERA CANAL UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

In per cent of total seasonal supply

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
1.4	0	0	0	1.1	7.0	17.0	23.5	21.6	13.4	7.8	7.2

For the area to be served by the San Joaquin River-Kern County Canal south of the San Joaquin River, it is not proposed to furnish the full amount of required supplemental water as a surface irrigation supply. As presented in Chapter VI, the most desirable and economical development must be based upon the fullest practicable utilization of ground water storage in the areas of deficient water supply. With the available run-off regulated by the proposed Friant Reservoir, the supply obtainable would not be sufficient to meet the demands of a surface irrigation supply in certain months and seasons of the period of run-off considered.

The desirable monthly distribution of a surface irrigation supply for the service area of the San Joaquin River-Kern County Canal under conditions of ultimate development would be as follows:

TABLE 124

DESIRABLE MONTHLY DISTRIBUTION OF SURFACE IRRIGATION SUPPLY FOR SERVICE AREA OF SAN JOAQUIN RIVER-KERN COUNTY CANAL UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

In per cent of total seasonal supply

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
5.0	1.0	1.0	2.0	3.0	7.0	11.0	14.0	16.0	16.0	14.0	10.0

If the entire supplemental water supply adequate in amount to meet the requirements in the areas served from the San Joaquin River-Kern County Canal were to be furnished during the irrigation season as a surface irrigation supply, the capacity of the canal, as designed most economically, would not be sufficient to deliver the monthly requirements in accord with the above percentages in the months of May, June, July and August. Therefore, under the proposed plan of operation, water would be delivered through the San Joaquin River-Kern County Canal up to its maximum capacity of 3,000 second feet during the months of heavy irrigation demand, March to October, inclusive, whenever that rate of flow would be obtainable. During the remaining four months, November to February, inclusive, the maximum rate of release to the San Joaquin River-Kern County Canal would be 2300 second-feet, which is estimated to be the maximum rate at which water could be absorbed for underground storage in addition to taking care of net use requirements during these months.

Under this proposed plan of operation for Friant Reservoir, the seasonal utilization of the impaired run-off of San Joaquin River under conditions of ultimate development which would have been effected during the 40-year period, 1889–1929, is shown in Table 125. This is a seasonal summary of studies made on a month by month basis. There are shown in this table, for each season during this period, the diversions to the upper San Joaquin Valley through both the Madera and San Joaquin River-Kern County canals for surface irrigation supplies and ground water recharge. There also are shown the evaporation losses in the reservoir and waste past the reservoir and the net accretions or depletions in reservoir storage at the end of each season.

Table 126 shows the diversions to the upper San Joaquin Valley through Madera and San Joaquin River-Kern County canals by months for each season during the 40-year period, 1889–1929. The diversions through the latter canal are graphically shown on Plate LXVI, "Yield from Friant Reservoir for San Joaquin River-Kern County Canal Under Plan of Ultimate Development." The monthly diversions shown on this plate are graphically compared to the desirable monthly surface irrigation demands, predicated upon a supplemental water supply being furnished during the irrigation season.

TABLE 125

SEASONAL UTILIZATION OF THE IMPAIRED RUN-OFF OF THE SAN JOAQUIN RIVER AT FRIANT RESERVOIR UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

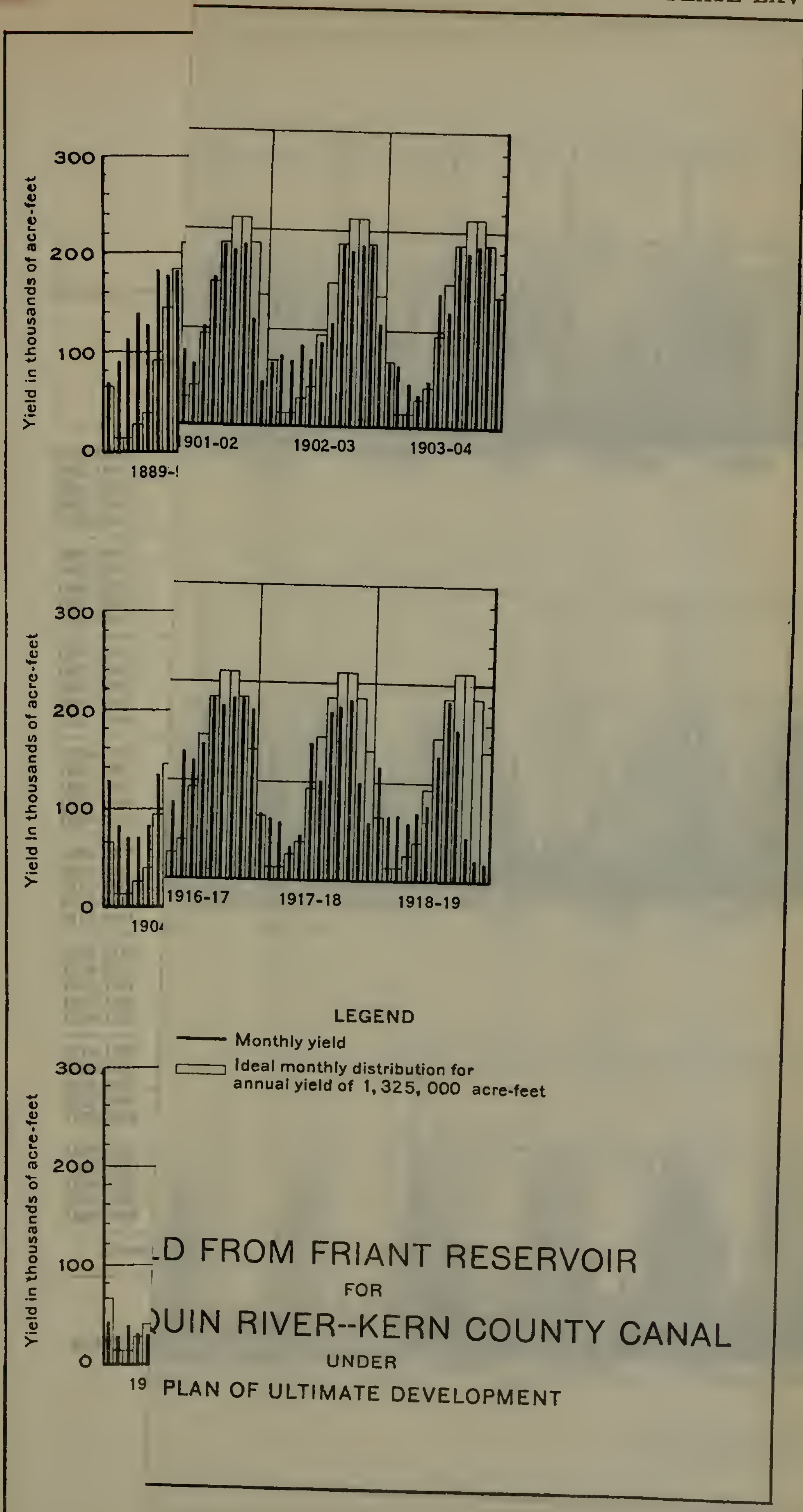
Season	Diversions for upper San Joaquin Valley, in acre-feet							Reservoir evaporation loss, in acre-feet	Waste past reservoir, in acre-feet	Net contribution to reservoir storage, in acre-feet	Total impaired run-off,[1] in acre-feet
	Madera Canal			San Joaquin River-Kern County Canal			Totals				
	Surface supply	Ground water storage	Totals	Surface supply	Ground water storage	Totals					
1889-90	329,200	165,800	495,000	1,261,700	556,000	1,817,700	2,312,700	15,300	2,001,700	+100,900	4,430,600
1890-91	329,200	22,200	351,400	1,261,700	643,200	1,904,900	2,256,300	14,100	186,300	—58,500	2,398,200
1891-92	329,200	81,200	410,400	1,261,700	598,300	1,860,000	2,270,400	14,700	621,700	+11,500	2,918,300
1892-93	329,200	76,800	406,000	1,261,700	600,000	1,861,700	2,267,700	14,600	493,100	—3,500	2,771,900
1893-94	329,200	0	329,200	1,185,700	413,300	1,599,000	1,928,200	10,600	0	—50,400	1,888,400
1894-95	329,200	81,200	410,400	1,261,700	537,000	1,798,700	2,209,100	14,000	459,700	+66,900	2,749,700
1895-96	329,200	18,300	347,500	1,179,800	484,300	1,664,100	2,011,600	12,500	27,600	—38,600	2,013,100
1896-97	329,200	33,200	362,400	1,261,700	391,200	1,652,900	2,015,300	13,400	237,800	—28,300	2,238,200
1897-98	329,200	0	329,200	464,900	218,600	683,500	1,012,700	8,600	0	0	1,021,300
1898-99	329,200	0	329,200	807,800	119,400	927,200	1,256,400	8,600	0	0	1,265,000
1899-00	329,200	0	329,200	786,800	218,800	1,005,600	1,334,800	8,600	0	0	1,343,400
1900-01	329,200	44,700	373,900	1,249,200	548,900	1,798,100	2,172,000	15,300	603,900	+80,800	2,872,000
1901-02	329,200	0	329,200	1,098,300	334,900	1,433,200	1,762,400	10,300	0	—80,800	1,691,900
1902-03	329,200	18,300	347,500	1,187,400	199,600	1,387,000	1,734,500	12,400	16,500	0	1,763,400
1903-04	329,200	18,300	347,500	1,231,200	144,300	1,375,500	1,723,000	12,400	53,700	0	1,789,100
1904-05	329,200	0	329,200	947,400	319,600	1,267,000	1,596,200	8,900	0	0	1,605,100
1905-06	329,200	147,600	476,800	1,250,800	401,400	1,652,200	2,129,000	14,900	1,574,800	+174,500	3,893,200
1906-07	329,200	81,200	410,400	1,261,700	690,800	1,952,500	2,362,900	15,400	643,700	—97,300	2,924,700
1907-08	329,200	0	329,200	649,200	354,100	1,003,300	1,332,500	8,900	0	—77,200	1,264,200
1908-09	329,200	81,200	410,400	1,247,400	451,100	1,698,500	2,108,900	14,400	649,700	+48,400	2,821,400
1909-10	329,200	14,900	344,100	1,187,300	588,900	1,776,200	2,120,300	13,000	3,000	—48,400	2,087,900
1910-11	329,200	153,100	482,300	1,261,700	507,800	1,769,500	2,251,800	15,300	1,196,000	+72,700	3,535,800
1911-12	329,200	0	329,200	661,400	236,900	898,300	1,227,500	9,100	0	—72,700	1,163,900
1912-13	329,200	0	329,200	487,900	62,400	550,300	879,500	8,600	0	0	888,100
1913-14	329,200	104,100	433,300	1,235,900	446,100	1,682,000	2,115,300	15,100	558,800	+80,800	2,770,000

1914–15	329,200	26,700	355,900	1,261,700	419,200	1,680,900	2,036,800	12,700	0	—42,700	2,006,800
1915–16	329,200	114,500	443,700	1,261,700	527,900	1,789,600	2,233,300	15,200	505,100	+6,000	2,759,600
1916–17	329,200	0	329,200	1,253,400	408,700	1,662,100	1,991,300	12,100	0	—44,100	1,959,300
1917–18	329,200	0	329,200	1,048,000	158,900	1,206,900	1,536,100	9,800	0	0	1,545,900
1918–19	329,200	0	329,200	791,400	223,400	1,014,800	1,344,000	9,100	0	0	1,353,100
1919–20	329,200	0	329,200	924,600	47,100	971,700	1,300,900	9,700	0	0	1,310,600
1920–21	329,200	0	329,200	999,100	222,300	1,221,400	1,550,600	9,300	0	0	1,559,900
1921–22	329,200	59,000	388,200	1,232,600	242,000	1,474,600	1,862,800	13,400	368,900	+34,400	2,279,500
1922–23	329,200	0	329,200	1,074,500	304,100	1,378,600	1,707,800	10,100	0	—34,400	1,683,500
1923–24	280,200	0	280,200	235,400	120,800	356,200	636,400	8,600	0	0	645,000
1924–25	329,200	0	329,200	883,200	59,900	943,100	1,272,300	9,000	0	0	1,281,300
1925–26	329,200	0	329,200	759,500	137,500	897,000	1,226,200	9,000	0	0	1,235,200
1926–27	329,200	0	329,200	1,231,100	313,000	1,544,100	1,873,300	12,400	0	0	1,885,700
1927–28	329,200	0	329,200	667,700	214,200	881,900	1,211,100	8,600	0	0	1,219,700
1928–29	329,200	0	329,200	482,500	58,400	540,900	870,100	8,600	0	0	878,700
Average, 1889–1929	328,000	33,500	361,500	1,026,500	338,100	1,364,600	1,726,100	11,700	255,000	0	1,992,800

[1] Existing upstream power storage assumed to be operated to obtain the maximum power output.

Under the proposed plan of operation, the Madera area would have received a full surface irrigation supply of 329,200 acre-feet in all seasons during the 40-year period, except 1923–1924, when the supply would have been 280,200 acre-feet. In addition there would have been supplied through the Madera Canal a seasonal average of 33,500 acre-feet during the 40-year period for ground water storage and subsequent utilization by pumping. The ultimate seasonal water requirements of the Madera area (Hydrographic Division No. 6 excluding the Columbia Canal area) aggregate 368,000 acre-feet for a net irrigable area to be served of 184,000 acres. The total requirements for this area are based on a net use of two acre-feet per acre on the assumption that the water would be obtained partly from surface supplies and partly by pumping from the underground reservoir. The primary sources of water supply for this area comprise the San Joaquin, Fresno and Chowchilla rivers. The total safe surface irrigation supply made available from these combined sources aggregates 429,000 acre-feet per season or an amount materially exceeding the estimated water requirements. Therefore, it would appear that the amount of water proposed to be furnished to this area from the San Joaquin River through Friant Reservoir, based upon the assumed right of the Madera Irrigation District to acquire San Joaquin River water, is considerably greater than would be required from this source in addition to the amounts which would be made available from the Fresno and Chowchilla rivers. Moreover, it would appear that the safe surface irrigation supply furnished from the three sources combined would be sufficient to meet the water requirements as estimated without underground storage and pumping. However, extensive pumping from underground is now practiced in this area and it would be necessary to continue utilizing underground storage and pumping under ultimate development in order to fully meet the water demands with a resulting seasonal net use of two acre-feet per acre with the contemplated methods of irrigation distribution and application. In addition, water from underground would be necessary to meet the requirements of a full supply in dry years such as 1924. The total seasonal water supply which would be furnished from the three sources combined, based upon the 40-year period of run-off 1889–1929, would be greater than that required to meet the net use requirements under ultimate development if a practicable and economical utilization were made of the underground reservoir for storage and pumping.*

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to meet the water requirements of the areas on the east side of the upper San Joaquin Valley, during the period of run-off to and including the dry season, 1930–1931, it was found necessary to allocate more of the water supply made available from Friant Reservoir to the areas south of the San Joaquin River and less to the Madera area than that proposed in the plan of operation based on the study of the 40-year period 1889–1929. Under the revised plan of operation presented in Appendix D, the Madera area would be furnished from Friant Reservoir only sufficient water to supplement the amounts available from the Fresno and Chowchilla rivers for meeting the full ultimate net use rquirements under the combined utilization of surface irrigation supplies and underground storage and pumping. This revised plan would require a full practicable utilization of the underground storage reservoir in the Madera area with cyclic underground storage and pumping operations extending throughout the dry period of 1917 to 1931.


Yield in thousands of acre-feet
300
200
100
0
1889-!
901-02
1902-03
1903-04
Yield in thousands of acre-feet
300
200
100
0
190
1916-17
1917-18
1918-19
LEGEND
Monthly yield
Ideal monthly distribution for annual yield of 1,325,000 acre-feet
Yield in thousands of acre-feet
300
200
100
0
19
.D FROM FRIANT RESERVOIR
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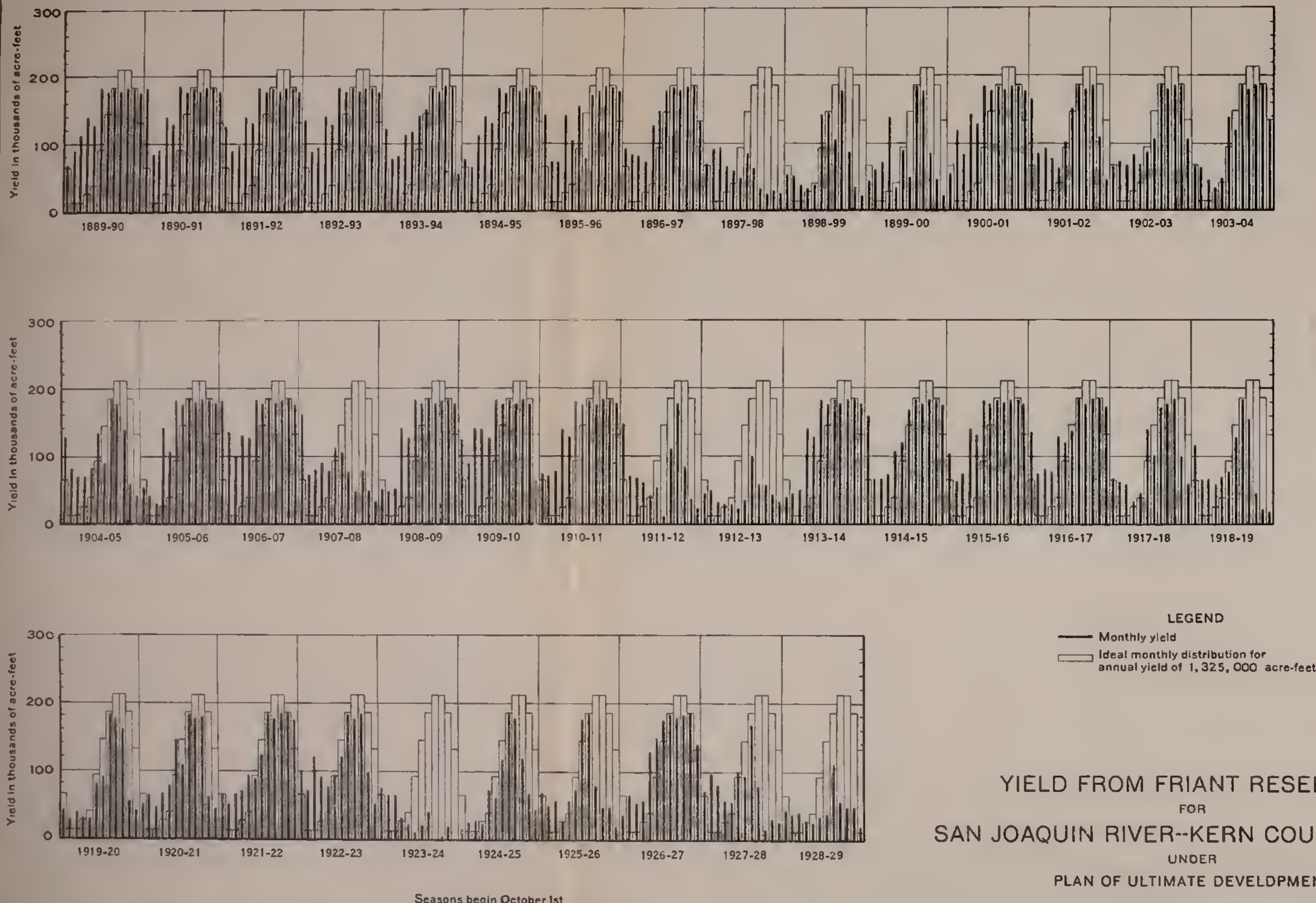
UNDER
PLAN OF ULTIMATE DEVELOPMENT



YIELD FROM FRIANT RESERVOIR

FOR

SAN JOAQUIN RIVER--KERN COUNTY CANAL

UNDER

PLAN OF ULTIMATE DEVELDPMENT

TABLE 126

MONTHLY DIVERSIONS FROM SAN JOAQUIN RIVER AT FRIANT RESERVOIR TO UPPER SAN JOAQUIN VALLEY UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

Quantities in acre-feet

Season	October		November		December		January		February		March		April		May		June		July		August		September		The season		Total yield
	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	Madera Canal	San Joaquin River-Kern County Canal	
1889-1890	4,600	70,700	0	90,700	0	114,100	0	141,400	3,600	127,700	74,400	184,400	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	495,000	1,817,700	2,312,700
1890-1891	4,600	184,400	0	85,500	0	92,800	0	141,400	3,600	127,700	23,100	184,400	55,900	178,500	77,300	184,400	89,200	178,500	48,100	184,400	25,800	184,400	23,800	178,500	351,400	1,904,900	2,256,300
1891-1892	4,600	125,200	0	89,800	0	98,200	0	141,400	3,600	132,300	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,860,000	2,270,400
1892-1893	4,600	135,700	0	87,900	0	95,900	0	141,400	3,600	127,700	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	87,800	184,400	25,800	184,400	23,800	178,500	406,000	1,861,700	2,267,700
1893-1894	4,600	125,100	0	78,100	0	84,300	0	114,200	3,600	117,800	23,100	141,600	55,900	150,700	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	56,500	329,200	1,599,000	1,928,200
1894-1895	4,600	78,000	0	66,700	0	111,800	0	141,400	3,600	127,700	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,798,700	2,209,100
1895-1896	4,600	142,300	0	73,800	0	70,800	0	141,400	3,600	104,600	23,100	157,100	55,900	77,500	77,300	170,800	80,200	178,500	44,200	184,400	25,800	184,400	23,800	178,500	347,500	1,664,100	2,011,600
1896-1897	4,600	94,700	0	83,900	0	81,900	0	71,700	3,600	127,700	23,100	149,000	55,900	178,500	92,200	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	133,800	362,400	1,652,900	2,015,300
1897-1898	4,600	68,900	0	90,700	0	93,000	0	64,700	3,600	60,200	23,100	48,100	55,900	85,000	77,300	60,800	70,900	31,200	44,200	24,800	25,800	29,700	23,800	26,400	329,200	683,500	1,012,700
1898-1899	4,600	55,800	0	50,700	0	39,400	0	33,600	3,600	37,700	23,100	140,600	55,900	146,600	77,300	104,000	70,900	178,500	44,200	85,300	25,800	34,200	23,800	20,200	329,200	927,200	1,256,400
1899-1900	4,600	44,700	0	62,000	0	71,000	0	138,700	3,600	35,600	23,100	88,400	55,900	50,000	77,300	182,800	70,900	178,500	44,200	85,200	25,800	46,900	23,800	21,800	329,200	1,005,600	1,334,800
1900-1901	4,600	53,700	0	118,800	0	83,400	0	141,400	3,600	127,700	23,100	184,400	67,400	178,500	92,200	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	178,500	373,900	1,798,100	2,172,000
1901-1902	4,600	103,900	0	84,900	0	90,800	0	77,200	3,600	64,900	23,100	101,000	55,900	149,700	77,300	184,400	70,900	178,500	44,200	184,400	25,800	107,300	23,800	46,200	329,200	1,433,200	1,762,400
1902-1903	4,600	66,500	0	73,400	0	67,500	0	82,600	3,600	68,500	23,100	86,500	55,900	106,200	77,300	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	104,100	347,500	1,387,000	1,734,500
1903-1904	4,600	64,900	0	62,800	0	46,200	0	34,700	3,600	47,200	23,100	138,600	55,900	116,600	77,300	184,400	89,200	178,500	44,200	184,400	25,800	184,400	23,800	132,800	347,500	1,375,500	1,723,000
1904-1905	4,600	127,800	0	82,300	0	70,100	0	72,200	3,600	85,500	23,100	133,400	55,900	91,700	77,300	184,400	70,900	178,500	44,200	137,800	25,800	60,000	23,800	43,300	329,200	1,267,000	1,596,200
1905-1906	4,600	55,300	0	41,600	0	33,300	0	141,400	3,600	107,500	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	92,200	184,400	23,800	178,500	476,800	1,652,200	2,129,000
1906-1907	4,600	184,400	0	136,800	0	99,200	0	131,300	3,600	127,700	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,952,500	2,362,900
1907-1908	4,600	163,400	0	74,200	0	82,000	0	92,100	3,600	79,500	23,100	114,600	55,900	104,200	77,300	76,900	70,900	50,600	44,200	80,500	25,800	50,200	23,800	35,100	329,200	1,003,300	1,332,500
1908-1909	4,600	51,900	0	50,600	0	53,800	0	141,400	3,600	127,700	23,100	184,400	55,900	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	410,400	1,698,500	2,108,900
1909-1910	4,600	123,700	0	89,300	0	141,400	0	141,400	3,600	127,700	23,100	184,400	55,900	178,500	92,200	184,400	70,900	178,500	44,200	184,400	25,800	177,700	23,800	64,800	344,100	1,776,200	2,120,300
1910-1911	4,600	75,500	0	72,500	0	79,300	0	141,400	3,600	127,700	61,700	184,400	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	482,300	1,769,500	2,251,800
1911-1912	4,600	148,800	0	70,600	0	69,000	0	62,800	3,600	44,600	23,100	55,200	55,900	12,500	77,300	110,000	70,900	178,500	44,200	84,700	25,600	37,500	23,800	24,100	329,200	898,300	1,227,500
1912-1913	4,600	44,800	0	50,000	0	33,800	0	31,500	3,600	31,500	23,100	24,500	55,900	36,100	77,300	101,300	70,900	59,400	44,200	59,100	25,800	44,300	23,800	34,000	329,200	550,300	879,500
1913-1914	4,600	40,400	0	46,900	0	52,500	0	141,400	3,600	127,700	23,100	184,400	78,800	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	433,300	1,682,000	2,115,300
1914-1915	4,600	160,300	0	68,600	0	60,700	0	75,400	3,600	107,700	23,100	121,300	55,900	167,700	77,300	184,400	70,900	178,500	70,900	184,400	25,800	184,400	23,800	178,500	355,900	1,680,900	2,036,800
1915-1916	4,600	104,200	0	63,000	0	75,600	0	141,400	3,600	132,300	23,100	184,400	89,200	178,500	92,200	184,400	89,200	178,500	92,200	184,400	25,800	184,400	23,800	178,500	443,700	1,789,600	2,233,300
1916-1917	4,600	136,000	0	75,200	0	81,600	0	78,500	3,600	127,700	23,100	121,400	55,900	137,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	172,500	329,200	1,662,100	1,991,300
1917-1918	4,600	66,900	0	63,200	0	60,200	0	34,600	3,600	47,200	23,100	138,500	55,900	101,100	77,300	172,100	70,900	178,500	44,200	184,400	25,800	100,200	23,800	60,000	329,200	1,206,900	1,536,100
1918-1919	4,600	117,200	0	66,000	0	69,400	0	60,000	3,600	69,700	23,100	77,400	55,900	120,000	77,300	184,400	70,900	154,100	44,200	45,200	25,800	22,600	23,800	19,800	329,200	1,014,800	1,344,000
1919-1920	4,600	43,200	0	28,000	0	39,500	0	32,500	3,600	30,500	23,100	82,300	55,900	90,900	77,300	184,400	70,900	178,500	44,200	162,100	25,800	58,800	23,800	41,000	329,200	971,700	1,300,900
1920-1921	4,600	51,800	0	64,900	0	48,600	0	68,500	3,600	79,700	23,100	146,100	55,900	110,100	77,300	184,400	70,900	178,500	44,200	181,000	25,800	61,700	23,800	46,100	329,200	1,221,400	1,550,600
1921-1922	4,600	64,900	0	53,100	0	68,200	0	71,200	3,600	96,200	23,100	87,900	55,900	122,900	82,300	184,400	89,200	178,500	79,900	184,400	25,800	184,400	23,800	178,500	388,200	1,474,600	1,862,800
1922-1923	4,600	99,100	0	73,000	0	121,000	0	93,300	3,600	76,500	23,100	92,900	55,900	123,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	98,500	23,800	53,500	329,200	1,378,600	1,707,800
1923-1924	4,600	76,800	0	65,600	0	65,500	0	32,000	3,600	24,200	23,100	10,200	55,900	21,400	77,300	40,600	27,500	0	44,200	500	25,800	19,400	18,200	0	280,200	356,200	636,400
1924-1925	4,600	15,900	0	26,000	0	28,100	0	24,600	3,600	72,000	23,100	61,500	55,900	118,900	77,300	184,400	70,900	178,500	44,200	117,600	25,800	69,200	23,800	46,400	329,200	943,100	1,272,300
1925-1926	4,600	70,400	0	51,900	0	56,600	0	28,200	3,600	56,600	23,100	74,800	55,900	178,500	77,300	184,400	70,900	79,500	44,200	48,200	25,800	48,100	23,800	19,800	329,200	897,000	1,226,200
1926-1927	4,600	35,600	0	64,800	0	55,100	0	59,200	3,600	127,700	23,100	150,100	55,900	178,500	77,300	184,400	70,900	178,500	44,200	184,400	25,800	184,400	23,800	141,400	329,200	1,544,100	1,873,3[illegible]
1927-1928	4,600	70,700	0	98,000	0	80,600	0	59,600	3,600	56,000	23,100	101,000	55,900	93,900	77,300	168,000	70,900	80,000	44,200	15,700	25,800	31,100	23,800	27,300	329,200	881,900	1,211,100
1928-1929	4,600	45,200	0	30,900	0	41,100	0	30,306	3,600	24,700	23,100	34,400	55,900	40,000	77,300	112,200	70,900	55,900	44,200	49,500	25,800	50,000	23,800	17,700	329,200	540,900	870,1[illegible]
Average, 1889-1929	4,600	91,200	0	70,400	0	72,900	0	89,800	3,600	88,800	25,300	126,900	59,200	131,000	82,300	166,200	77,600	155,600	57,700	144,700	27,500	125,500	23,700	101,600	361,500	1,364,600	1,726,100

The areas served under the San Joaquin River-Kern County Canal would have received a surface irrigation supply in accord with the demand averaging 1,026,500 acre-feet per season, but varying in amount considerably for different seasons of the 40-year period. In addition, an average seasonal supply of 338,100 acre-feet for ground water storage and subsequent utilization by pumping would have been made available during the 40-year period. The total supply furnished during the 40-year period would have averaged 361,500 acre-feet for the areas served by the Madera Canal and 1,364,600 acre-feet for the areas served by the San Joaquin River-Kern County Canal, or a total average seasonal supply of 1,726,100 acre-feet.

The allocation of the total supply delivered through the San Joaquin River-Kern County Canal to the individual areas served therefrom is dependent upon the deficiencies between water requirements and local supplies and is further related to the capacity and practicable degree of utilization of the underground reservoirs in each area. The actual allocation was based upon a detailed study of the combined operation of local surface storage and underground storage reservoirs in the individual local areas. After making preliminary trial studies leading up to the final study of the operation of the underground reservoirs as presented hereafter, the allocation of the supplemental water supply furnished from Friant Reservoir, in per cent of the total monthly and seasonal deliveries, to the several hydrographic divisions was made as follows:

Division 1	31 per cent
Division 2	64 per cent
Division 3	5 per cent
Division 4	0 per cent

With this allocation of supplemental water from the San Joaquin River added to the supplies made available from local sources in the individual hydrographic units, the detailed studies presented hereafter show that the water requirements for the areas to be served under the ultimate plan would have been fully met; and that, in addition, water in excess of the net use requirements would have accumulated in underground storage reservoirs over the forty-year period 1889–1929.

Utilization of Underground Reservoirs in San Joaquin River Basin.

The utilization of underground reservoirs for the storage of water and subsequent extraction by pumping is a basic feature of the proposed ultimate plan of development in the San Joaquin River Basin. Such utilization is essential, particularly in the upper San Joaquin Valley, where the ultimate water requirements are materially in excess of the local supplies which can be developed, and for which supplemental water supplies must be imported from areas of surplus supply. Therefore, under the ultimate State Water Plan, it is proposed to utilize the available underground storage capacity in those sections of the basin where practicable, necessary and desirable.

The locations, extent and capacities of underground storage reservoirs in the San Joaquin Valley have been discussed in Chapter VI. The results of a geologic study made to locate these storage reservoirs, to estimate their capacities and determine the practicability of their utilization for the storage and regulation of water supplies in irrigation development are presented in Appendix B of this report, "Geology and Underground Water Storage Capacity of San Joaquin Valley." It has been demonstrated in Chapter IV that, under existing conditions of development in the upper San Joaquin Valley, gross absorptive areas totaling more than 1,600,000 acres are now utilized for the storage and regulation of water supplies serving an aggregate net area of more than 800,000 acres. In the upper San Joaquin Valley the gross absorptive areas total 2,432,000 acres and have aggregate estimated utilizable storage capacities of some 20,000,000 acre-feet. The gross absorptive areas in the lower San Joaquin Valley total 558,000 acres with estimated utilizable aggregate storage capacities of more than 3,000,000 acre-feet. All of these absorptive areas are confined to the eastern slope of the valley, principally to the alluvial cones and flood plains of the major streams. The surface soil and geologic formation on the western slope and in the trough of the valley are of such character that no utilizable underground capacity exists. The total usable capacities of the ground water reservoirs have been set forth for each hydrographic division in Table 100, Chapter VI.

Operation of Underground Reservoirs in Upper San Joaquin Valley.

Within Hydrographic Division 6, considerable underground storage space is now utilized. The capacity available between a depth of 10 feet and the ground water levels of 1929 is estimated as 760,000 acre-feet, and between depths of 10 and 55 feet, as 2,300,000 acre-feet. The underground storage capacity would be utilized to some extent under ultimate development. However, with the water supplies furnished from the San Joaquin, Fresno and Chowchilla rivers providing a safe surface irrigation supply of 429,000 acre-feet per season to the Madera area and with a safe surface irrigation supply of 26,000 acre-feet per season furnished from the San Joaquin River Pumping System for the Columbia Canal area, based upon the regulation of available run-off up to 1929, adequate service to this area would be provided with a very moderate degree of utilization of the underground storage capacity.*

For the remaining portion of the east side of the upper San Joaquin Valley south of the San Joaquin River, the underground reservoirs would be utilized to the fullest practicable extent. The practicable degree of utilization and the results of a practical plan of operation, with the local and imported water supplies which would have been available and with the water requirements fully met each season,

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield have been extended to include the period 1929–1931 and are presented in Appendix D. In order to meet the water requirements of the areas on the east side of the upper San Joaquin Valley during the period of run-off to and including the dry season 1930–1931, it was found necessary to allocate more of the water supply made available from Friant Reservoir to the areas south of the San Joaquin River and less to the Madera area than that proposed in the plan of operation based on the study of the 40-year period 1889–1929. Under the revised plan of operation presented in Appendix D, the Madera area would be furnished from Friant Reservoir only sufficient water to supplement the amounts available from the Fresno and Chowchilla rivers for meeting the full ultimate net use requirements under the combined utilization of surface irrigation supplies and underground storage and pumping. This revised plan would require a full practicable utilization of the underground storage reservoir in the Madera area with cyclic underground storage and pumping operations extending throughout the dry period of 1917 to 1931.

have been determined by a detailed study for the forty-year period 1889–1929. The study resolved itself into two parts:

1. The determination of monthly "net use" requirements and the maximum capacity of water supply utilization.

2. The determination of amounts of accumulative ground water storage resulting from the utilization of local and imported supplies through the combined means of surface application, ground water draft and replenishment.

Net Use and Maximum Capacity of Water Supply Utilization—The "capacity of water supply utilization" in a particular area is defined as that amount of the total supply made available thereto from local and imported sources which would be utilized in the area for net use requirements and ground water storage. For any particular period, it is the sum of total net use and net contributions to ground water through seepage from artificial conveyance channels, absorption in natural stream channels and spreading areas, and through irrigation applications in excess of net use. As used in this report, the "maximum capacity of water supply utilization" in any specified period for a particular area is the sum of the total net use and the maximum amount of water that could be absorbed for storage in the underground reservoir based upon rates of absorption well within those established by measurements on streams and conveyance channels and upon application losses resulting from usual irrigation practice in fully developed irrigated areas.

Based upon the data presented in Chapters IV and V, the average seasonal net use has been established as 2.0 acre-feet per net irrigable acre for all of the upper San Joaquin Valley. The ideal monthly net use was varied for each division in proportion to its present irrigation demand as influenced by local conditions of climate and existing development. These values expressed in acre-feet per acre are shown in Table 127.

TABLE 127

MONTHLY DISTRIBUTION OF SEASONAL NET USE

In acre-feet per acre

Month	Hydrographic Division			
	1	2	3	4
October	0 10	0.10	0.10	0.10
November	0.06	0.06	0.04	0.02
December	0.06	0.06	0.04	0.02
January	0.08	0.08	0.06	0.04
February	0.08	0.08	0.06	0.06
March	0.16	0.16	0.16	0.14
April	0.22	0.22	0.22	0.22
May	0.24	0.24	0.26	0.28
June	0.28	0.28	0.30	0.32
July	0.28	0.28	0.30	0.32
August	0.24	0.24	0.26	0.28
September	0.20	0.20	0.20	0.20
Totals	2.00	2.00	2.00	2.00

The total amount of water that would be absorbed for storage in underground reservoirs in the several hydrographic divisions of the upper San Joaquin Valley would be made up of, first, the water absorbed by deep percolation from application of irrigation supplies in excess of net use; second, the water absorbed through seepage losses from artificial conveyance channels; and third, the water absorbed from losses in natural stream channels and spreading areas.

The average maximum net application on irrigated lands in absorptive areas in months when excess water would be available has been estimated as exceeding the net use by about 50 per cent from October to March, inclusive, and about 100 per cent from April to September, inclusive, with slight modifications for differing local conditions. These values expressed in acre-feet per acre are shown in Table 128. The amounts of water actually applied in excess of net use would percolate downward and be stored in the underground reservoirs. In addition to these amounts of water applied for irrigation in excess of net use which are based upon usual irrigation practice, deep percolation losses caused by poor land leveling and wasteful application methods have been estimated at an average of 0.25 acre-foot per net acre per season.

TABLE 128

MONTHLY DISTRIBUTION OF MAXIMUM NET IRRIGATION APPLICATIONS ON ABSORPTIVE AREAS

In acre-feet per acre

Month	Hydrographic Division			
	1	2	3	4
October	0.14	0.14	0.15	0.15
November	0.10	0.10	0.06	0.03
December	0.10	0.10	0.06	0.03
January	0.12	0.12	0.09	0.06
February	0.12	0.12	0.09	0.09
March	0.24	0.24	0.24	0.21
April	0.47	0.47	0.47	0.34
May	0.51	0.51	0.52	0.69
June	0.51	0.51	0.54	0.69
July	0.51	0.51	0.54	0.64
August	0.46	0.46	0.50	0.42
September	0.37	0.37	0.39	0.30

In estimating the amounts of water absorbed through seepage losses from unlined canals, it has been assumed that the main canal and branch canals would be lined; that the branch canals would deliver water to each section of land; and that distribution in each section would be made to each forty-acre tract by means of unlined laterals. Seepage losses have been calculated at the rate of 1.3 cubic feet per square foot of wetted perimeter in 24 hours, as determined by actual measurements on canals and ditches on the Kaweah Delta. Maximum monthly and total seasonal seepage losses from the unlined laterals, computed on the bases assumed, would amount respectively to 0.06 acre-foot and 0.50 acre-foot per net acre of irrigable land in absorptive areas. These estimated maximum monthly and total seasonal seepage losses for unlined laterals only, as related to irrigable area, are but 25 per cent of corresponding quantities for an entirely unlined canal system, which would amount to 0.24 acre-foot per net acre in a maximum month, and 2.0 acre-feet per season, based on the same seepage loss rate of 1.3 cubic feet per square foot in 24 hours.

The foregoing estimated total seasonal maximum capacities of water supply utilization involved in the conveyance and application of irrigation supplies, comprising normal maximum irrigation applications, excess irrigation applications due to rough land and seepage losses from lateral ditches, aggregate 4.40 acre-feet per acre of net irrigable area in each hydrographic division, of which 2 acre-feet per acre would be for net use requirements. The maximum amount of water delivered in any season would be much less than 4.40 acre-feet per acre, because no season of record would yield sufficient water for more than a few months to satisfy the maximum capacities of water supply utilization involved in this total.

The areas of irrigation application in each hydrographic division were divided into absorptive and nonabsorptive lands above and below the location of the San Joaquin River-Kern County Canal, deductions being made for areas supplied by yields of minor streams. The nonabsorptive areas are considered capable of utilizing a net use delivery only, and the absorptive areas a maximum net application delivery. In addition, the percolation losses from unlined laterals and excess application losses due to rough land and wasteful application methods are considered to apply only to absorptive areas. The net areas of these subdivisions follow:

Division	*Acres*
Hydrographic Division 1, exclusive of west side rim lands.	
Net absorptive area, above location of San Joaquin River-Kern County Canal and south of Kern River	247,000
Net absorptive area, below location of canal	128,000
Net nonabsorptive area, below location of canal	154,000
Total net area to be served by water from San Joaquin and Kern rivers	529,000
Hydrographic Division 2, exclusive of west side rim lands.	
Net nonabsorptive area, above location of San Joaquin River-Kern County Canal, to be supplied jointly by Tule River and pumping from canal	111,000
Net nonabsorptive area, below location of canal	196,000
Net absorptive area, below location of canal	178,000
Total net area to be served by water from San Joaquin and Tule rivers	485,000
Hydrographic Division 3	
Net absorptive area	207,000
Net nonabsorptive area	42,000
Total net area to be served by water from San Joaquin and Kaweah rivers	249,000
Hydrographic Division 4	
Net absorptive area	622,000
Net nonabsorptive area adjacent to foothills	104,000
Net nonabsorptive area in Tulare Lake vicinity	104,000
Total net area to be served by Kings River	830,000

In addition to maximum net applications and losses from unlined canals, estimates have been made of the maximum absorptive capacities of the natural stream channels and other existing channels that could be used for absorption of water into the underground reservoirs in each hydrographic division. These maximum absorptive capacities for natural stream channels, sloughs and existing artificial canals were determined by a study of available stream and channel seepage measurements aided by field examinations on certain streams and sloughs and by direct field seepage measurements on others.

In Hydrographic Division 1, the Kern River has an estimated absorptive capacity of 170 second-feet above and 150 second-feet below the location of the San Joaquin River-Kern County Canal; and contributing chiefly to the area below the canal location, the Calloway and Lerdo canals, 250 second-feet, and the East Side Canal, Rim Ditch and upper reach of Kern Island Canal, 100 second-feet. The total absorptive capacity of these channels amounts to about 40,000 acre-feet per month.

In Hydrographic Division 2, the Tule River has an estimated absorptive capacity of 200 second-feet above and 300 second-feet below the location of the San Joaquin River-Kern County Canal. Deer Creek, Old Deer Creek and White River have an estimated total absorptive capacity of 100 second-feet above the canal location. Below the canal location small channels near Strathmore, Old Slough, Dead Horse Slough, Porter Slough, Poplar Ditch, Old Deer Creek, Deer Creek and White River have an estimated total absorptive capacity of 350 second-feet. The total absorptive capacity of these channels amounts to about 57,000 acre-feet per month.

In Hydrographic Division 3, the Kaweah River has an estimated absorptive capacity of 300 second-feet, and the many spreading channels, now in use, have a capacity of 530 second-feet. The total absorptive capacity of these channels amounts to about 50,000 acre-feet per month.

In Hydrographic Division 4, the Kings River channels have an estimated absorptive capacity of 500 second-feet which amounts to about 30,000 acre-feet per month.

Based upon the foregoing estimated maximum capacities of utilization involved in conveyance and application of irrigation supplies and in absorption from stream channels, the maximum monthly capacities of water supply utilization and all factors appertaining thereto are shown for each of the hydrographic divisions 1, 2, 3 and 4 in Tables 129, 130, 131 and 132, respectively. In Tables 129 and 130, "upper area" and "lower area" designate the areas respectively above and below the location of the San Joaquin River-Kern County Canal.

TABLE 129

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 1, EXCLUSIVE OF WEST SIDE RIM LANDS

In acre-feet

Month	Assumed delivery per acre of irrigable land				Upper area	Lower area		Both areas
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net irrigable absorptive area, 247,000 acres	Net irrigable absorptive area, 128,000 acres	Net irrigable nonabsorptive area, 154,000 acres	Total net irrigable area, 529,000 acres
		On absorptive areas			Maximum monthly capacity, including 10,000 acre-feet in river channels	Maximum monthly capacity, including 30,000 acre-feet in river and other spreading channels	Net use delivery	Total maximum monthly capacity
October	0.10	0.14	0.05	0.19	56,900	54,300	15,400	126,600
November	0.06	0.10	0.03	0.13	42,100	46,600	9,200	97,900
December	0.06	0.10	0.03	0.13	42,100	46,700	9,300	98,100
January	0.08	0.12	0.03	0.15	47,100	49,200	12,300	108,600
February	0.08	0.12	0.03	0.15	47,100	49,200	12,300	108,600
March	0.16	0.24	0.06	0.30	84,100	68,400	24,600	177,100
April	0.22	0.47	0.08	0.55	145,800	100,400	33,900	280,100
May	0.24	0.51	0.09	0.60	158,200	106,800	37,000	302,000
June	0.28	0.51	0.09	0.60	158,200	106,800	43,100	308,100
July	0.28	0.51	0.09	0.60	158,200	106,800	43,100	308,100
August	0.24	0.46	0.09	0.55	145,900	100,400	37,000	283,300
September	0.20	0.37	0.08	0.45	121,100	87,600	30,800	239,500

TABLE 130

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 2, EXCLUSIVE OF WEST SIDE RIM LANDS

In acre-feet

Month	Assumed delivery per acre of irrigable land				Upper area	Lower area		Both areas
					Net irrigable nonabsorptive area, 111,000 acres	Net irrigable nonabsorptive area, 196,000 acres	Net irrigable absorptive area, 178,000 acres	Total net irrigable area, 485,000 acres
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net use delivery plus 36,000 acre-feet in stream and other spreading channels	Net use delivery	Maximum monthly capacity, including 21,000 acre-feet in stream and other spreading channels	Total maximum monthly capacity
		On absorptive areas						
October	0.10	0.14	0.05	0.19	47,100	19,600	54,800	121,500
November	0.06	0.10	0.03	0.13	42,700	11,800	44,100	98,600
December	0.06	0.10	0.03	0.13	42,700	11,800	44,200	98,700
January	0.08	0.12	0.03	0.15	44,900	15,700	47,700	108,300
February	0.08	0.12	0.03	0.15	44,900	15,700	47,700	108,300
March	0.16	0.24	0.06	0.30	53,700	31,300	74,400	159,400
April	0.22	0.47	0.08	0.55	60,400	43,100	118,900	222,400
May	0.24	0.51	0.09	0.60	62,600	47,000	127,800	237,400
June	0.28	0.51	0.09	0.60	67,100	54,900	127,800	249,800
July	0.28	0.51	0.09	0.60	67,100	54,900	127,800	249,800
August	0.24	0.46	0.09	0.55	62,600	47,000	118,900	228,500
September	0.20	0.37	0.08	0.45	58,200	39,200	101,100	198,500

TABLE 131

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 3

In acre-feet

Month	Assumed delivery per acre of irrigable land				Net irrigable nonabsorptive area, 42,000 acres	Net irrigable absorptive area, 207,000 acres	Total net irrigable area, 249,000 acres
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net use delivery	Maximum monthly capacity including 50,000 acre-feet in river and other spreading channels	Total maximum monthly capacity
		On absorptive areas					
October	0.10	0.15	0.05	0.20	4,200	91,400	95,600
November	0.04	0.06	0.03	0.09	1,700	68,600	70,300
December	0.04	0.06	0.03	0.09	1,700	68,600	70,300
January	0.06	0.09	0.03	0.12	2,500	74,800	77,300
February	0.06	0.09	0.03	0.12	2,500	74,900	77,400
March	0.16	0.24	0.06	0.30	6,700	112,100	118,800
April	0.22	0.47	0.08	0.55	9,300	163,900	173,200
May	0.26	0.52	0.09	0.61	10,900	176,300	187,200
June	0.30	0.54	0.09	0.63	12,600	180,400	193,000
July	0.30	0.54	0.09	0.63	12,600	180,400	193,000
August	0.26	0.50	0.09	0.59	10,900	172,100	183,000
September	0.20	0.39	0.08	0.47	8,400	147,300	155,700

TABLE 132

MAXIMUM MONTHLY CAPACITY OF WATER SUPPLY UTILIZATION UNDER CONDITIONS OF ULTIMATE DEVELOPMENT IN HYDROGRAPHIC DIVISION 4

In acre-feet

Month	Assumed delivery per acre of irrigable land				Net irrigable nonabsorptive area, 208,000 acres	Net irrigable absorptive area, 622,000 acres	Total net irrigable area, 830,000 acres
	Net use	Maximum normal net application	Canal seepage and excess application losses	Maximum delivery including canal and application losses	Net use delivery	Maximum monthly capacity including 30,000 acre-feet in river channels	Total maximum monthly capacity
		On absorptive areas					
October	0.10	0.15	0.05	0.20	21,000	154,000	175,000
November	0.02	0.03	0.03	0.06	4,000	68,000	72,000
December	0.02	0.03	0.03	0.06	4,000	68,000	72,000
January	0.04	0.06	0.03	0.09	8,000	86,000	94,000
February	0.06	0.09	0.03	0.12	13,000	104,000	117,000
March	0.14	0.21	0.06	0.27	29,000	198,000	227,000
April	0.22	0.34	0.08	0.42	46,000	291,000	337,000
May	0.28	0.69	0.09	0.78	58,000	515,000	573,000
June	0.32	0.69	0.09	0.78	67,000	515,000	582,000
July	0.32	0.64	0.09	0.73	66,000	485,000	551,000
August	0.28	0.42	0.09	0.51	58,000	347,000	405,000
September	0.20	0.30	0.08	0.38	42,000	266,000	308,000

Results of Underground Reservoir Operation—Based upon the amounts of utilizable water supply of the major streams and the maximum capacities of water supply utilization as previously presented, a detailed study month by month during the forty-year period 1889–1929 was made of the operation of the underground reservoirs in each hydrographic division of the upper San Joaquin Valley south of the San Joaquin River. The monthly utilizable water supplies for each hydrographic division comprise the combined amounts made available from local major streams and the supplemental water supplies furnished from the San Joaquin River. The amounts of available run-off in any month which were in excess of the maximum capacity of water supply utilization were considered as waste water and not a part of the utilizable water supply of particular hydrographic divisions. The monthly amounts of utilizable water supply were compared with the net use requirements in each hydrographic division. The amount required for net use was deducted from the utilizable supply delivered and the water in excess of net use, if any, was considered as a contribution to ground water storage. If the water supply delivered in any month was less than net use, the deficiency between supply and net use was considered to be the required draft from ground water storage. In this manner, the net accretions to and extractions from the underground reservoirs in each hydrographic division were determined month by month for the forty-year period 1889–1929. The areas assumed to be furnished by water supplies from minor streams in certain of the hydrographic divisions were excluded from this analysis, both as to water supply and water requirements.

The results of this detailed month by month study of the operation of underground reservoirs are set forth in Table 133, and graphically depicted on Plate LXVII, "Operation of Underground Reservoirs in Upper San Joaquin Valley, Under Plan of Ultimate Development, South of San Joaquin River." Table 133 shows the net seasonal accumulative amounts of water remaining in storage in underground reservoirs at the conclusion of each season's operations of ground water recharge and extraction, in each hydrographic division during the forty-year period 1889–1929. The difference between the amounts shown for any two successive seasons represents the net contribution to or draft from the underground reservoir. The table also shows the amounts of water for each season which would have been available from the run-off in excess of the maximum capacities of water supply utilization and considered as waste water not utilizable in particular hydrographic divisions. It may be noted that the total amount of non-utilizable excess water supplies in all four divisions of the upper San Joaquin Valley included in this study is somewhat greater than the net accumulative amount of water remaining in storage in the underground reservoirs at the end of the forty-year period considered. Plate LXVII is based upon the data tabulated in Table 133.

The study of accumulated ground water storage shows that the utilizable water supplies made available for hydrographic divisions 1 to 4, inclusive, in the upper San Joaquin Valley would have been sufficient to fully meet the water requirements of the areas to be served under the ultimate development and in addition to provide considerable

TABLE 133

WATER SUPPLY REMAINING IN STORAGE AT END OF EACH SEASON IN UNDERGROUND RESERVOIRS OF UPPER SAN JOAQUIN VALLEY SOUTH OF SAN JOAQUIN RIVER UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1889-1929

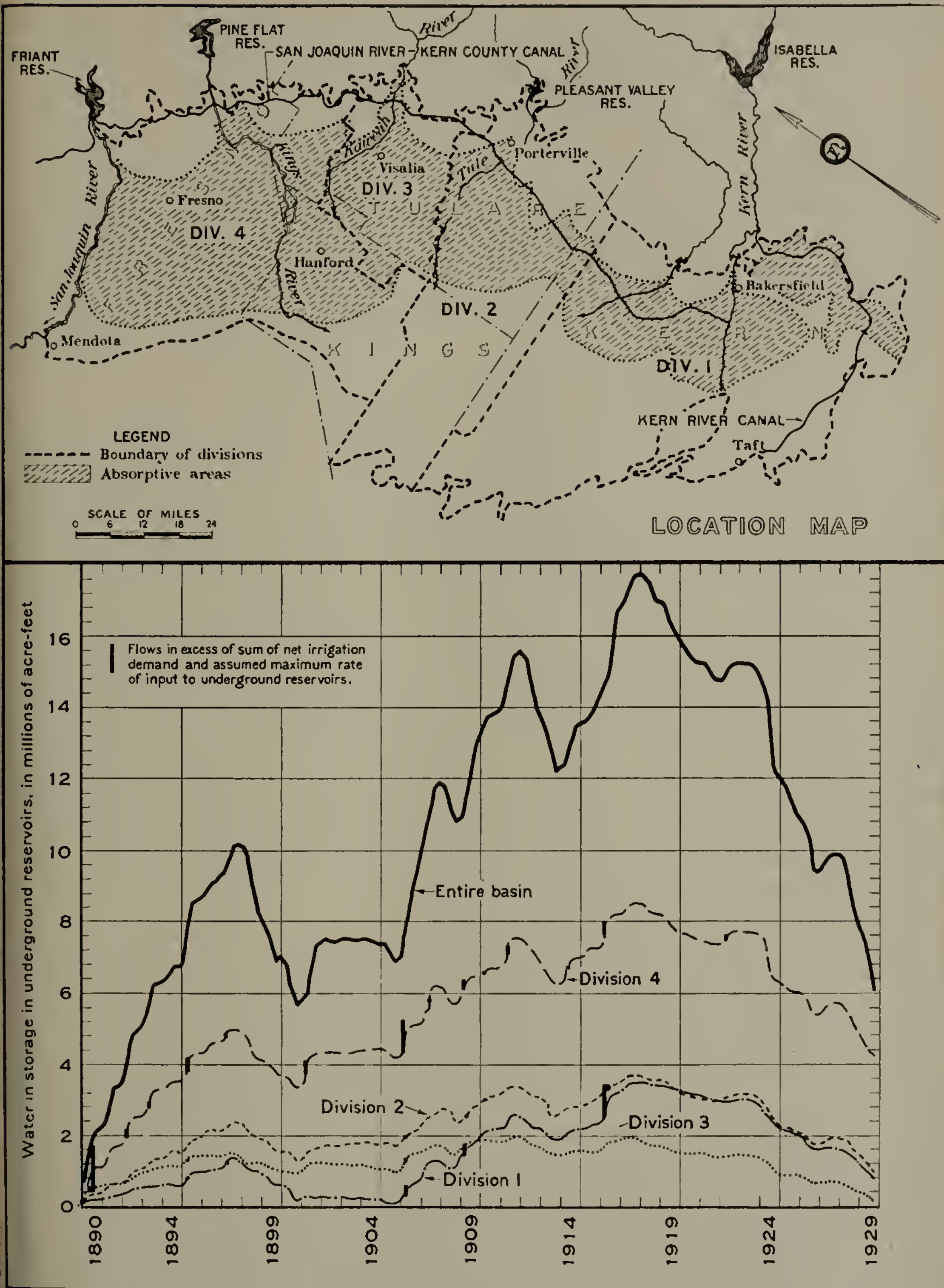
In acre-feet

Season	Hydrographic Division				Total
	1	2	3	4	
1889-90	149,300	343,100	540,900	1,100,900	2,134,200
1890-91	287,800	686,000	647,100	1,766,500	3,387,400
1891-92	448,100	1,027,700	890,100	2,534,000	4,899,900
1892-93	574,200	1,352,600	1,092,100	3,284,700	6,303,600
1893-94	617,900	1,529,900	1,073,000	3,495,500	6,716,300
1894-95	988,300	1,917,600	1,393,400	4,326,400	8,625,700
1895-96	1,066,100	2,126,200	1,380,100	4,610,700	9,183,100
1896-97	1,365,300	2,382,600	1,435,900	4,956,000	10,139,800
1897-98	1,011,600	1,900,000	1,196,500	4,177,000	8,285,100
1898-99	571,600	1,570,600	1,036,300	3,737,900	6,916,400
1899-00	144,500	1,285,800	900,100	3,358,700	5,689,100
1900-01	229,400	1,613,400	1,223,700	4,282,000	7,348,500
1901-02	248,900	1,704,100	1,152,500	4,335,600	7,441,100
1902-03	226,900	1,762,300	1,127,700	4,356,100	7,473,000
1903-04	171,300	1,763,300	1,044,200	4,431,900	7,410,700
1904-05	49,500	1,692,300	947,300	4,194,600	6,883,700
1905-06	643,100	2,140,100	1,480,200	5,115,400	9,378,800
1906-07	1,282,400	2,630,700	1,673,300	6,225,900	11,812,300
1907-08	1,141,400	2,412,300	1,478,100	5,748,200	10,780,000
1908-09	1,856,100	2,819,700	1,832,000	6,463,100	12,970,900
1909-10	2,187,400	3,127,500	1,832,000	6,687,300	13,834,200
1910-11	2,571,100	3,428,100	1,968,500	7,542,400	15,510,100
1911-12	2,212,100	3,100,100	1,722,800	6,982,700	14,017,700
1912-13	1,909,300	2,519,800	1,473,000	6,264,700	12,166,800
1913-14	2,168,900	2,784,200	1,545,100	6,974,000	13,472,200
1914-15	2,322,400	3,020,800	1,500,600	7,239,300	14,083,100
1915-16	3,188,800	3,439,400	1,854,300	8,170,900	16,653,400
1916-17	3,534,700	3,710,900	1,910,900	8,517,100	17,673,600
1917-18	3,456,800	3,567,800	1,702,900	8,220,100	16,947,600
1918-19	3,319,400	3,321,600	1,544,800	7,760,900	15,946,700
1919-20	3,168,600	3,081,600	1,467,500	7,500,100	15,217,800
1920-21	3,020,500	2,981,900	1,391,400	7,365,000	14,758,800
1921-22	3,003,300	3,089,300	1,428,200	7,716,100	15,236,900
1922-23	2,978,600	3,102,900	1,362,600	7,657,000	15,101,100
1923-24	2,354,600	2,385,900	984,100	6,390,100	12,114,700
1924-25	2,052 600	2,106,800	858,700	6,017,100	11,035,200
1925-26	1,612,800	1,758,600	624,300	5,391,100	9,386,800
1926-27	1,617,600	1,904,700	686,700	5,705,700	9,914,700
1927-28	1,354,400	1,546,300	435,800	5,016,300	8,352,800
1928-29	792,600	975,900	187,700	4,205,000	6,161,200

Water in Excess of the Maximum Monthly Utilizable Yields. Not Considered as Part of the Available Supply for Net Use or Ground Water Storage

Season	Hydrographic Division				Total
	1	2	3	4	
1889-90			152,000	1,284,500	1,436,50
1890-91				1,400	1,40
1891-92				252,600	252,60
1892-93				176,900	176,90
1894-95	20,500		4,500	408,200	433,20
1896-97	37,600			110,000	147,60
1900-01				377,800	377,80
1905-06	345,900	77,800	140,100	965,800	1,529,60
1906-07				115,900	115,90
1908-09	292,000	72,200	32,900	298,000	695,10
1909-10		24,600		10,600	35,20
1910-11				166,200	166,20
1913-14				18,000	18,00
1915-16	1,007,300	83,200		341,800	1,432,30
1921-22				124,200	124,20
Totals	1,703,300	257,800	329,500	4,651,900	6,942,50

PLATE LXVII



OPERATION OF UNDERGROUND RESERVOIRS
IN
UPPER SAN JOAQUIN VALLEY
UNDER PLAN OF ULTIMATE DEVELOPMENT
SOUTH OF SAN JOAQUIN RIVER
1889-1929

amounts of water to build up the underground storage. In each hydrographic division, substantial amounts of water would have remained in storage in the underground reservoirs at the end of the forty-year period considered, the net accumulation in all four divisions combined amounting to over 6,000,000 acre-feet after meeting the full water requirements of the area. Assuming an empty underground reservoir at the beginning of the season of 1889–1890, the storage on hand under conditions of ultimate development would have mounted from zero to 10,000,000 acre-feet by 1897. From 1897 to 1900 it would have been drawn down to 6,000,000 acre-feet, to mount almost continuously to 15,000,000 in 1911. From 1911 to 1913 it would have decreased to 12,000,000, to increase again to nearly 18,000,000 in 1917. From 1917 to the end of the period in the fall of 1929, the decrease of storage on hand would have been almost continuous to 6,000,000 acre-feet.

The distribution of the portion of the water supply made available through ground water utilization in each hydrographic division might be somewhat nonuniform with respect to the degree of its accessibility to meet the requirements over the entire area of a particular division. However, it is considered that local pumping and conveyance facilities would be provided to control and distribute the supply so that all lands to be served in each division would receive ample water. No plans have been prepared for such local pumping and distribution facilities as a part of the ultimate State Water Plan. The plan as formulated provides the required water supply for each hydrographic division as a whole, leaving the detailed plans of local distribution to later consideration when necessary. However, sufficient investigations have been made in each area to demonstrate that the water supplies furnished under the plan of operation proposed could be distributed by practicable and feasible methods to meet the requirements of all lands to be served in each hydrographic division.

The available underground capacity in each of the hydrographic divisions and in the entire area, as heretofore presented in Table 100 in Chapter VI, would have been sufficient to provide for the maximum storage regulation required, amounting to about 18,000,000 acre-feet in the entire area. The maximum underground storage capacity that would have been required at any time during the forty-year period is equal to the maximum amount of accumulated ground water storage shown in Table 133. If it were assumed that the utilizable water supply furnished on the average during the forty-year period had only been sufficient to meet the full water requirements and there had been no net accumulation of stored water in the underground reservoirs at the end of the forty-year period, the capacity of underground storage required would have been considerably less than the capacity required for complete regulation and conservation of the entire utilizable water supply provided under the plan. The required underground storage capacities and the corresponding maximum ground water fluctuations, for underground storage regulation of the utilizable water supplies provided under the plan and for regulation of an average water supply equal to water requirements only, are shown in Table 134.

The required underground storage capacities shown in Table 134 for conservation and regulation of the entire utilizable water supply are of about the same magnitude as the utilizable undergound storage

TABLE 134

REQUIRED STORAGE CAPACITY AND MAXIMUM GROUND WATER FLUCTUATION FOR UNDERGROUND STORAGE REGULATION OF UTILIZABLE WATER SUPPLIES IN UPPER SAN JOAQUIN VALLEY SOUTH OF SAN JOAQUIN RIVER UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Hydrographic division	Required underground storage in acre-feet		Gross absorptive area, in acres	Assumed drainage factor, in per cent	Maximum ground water fluctuation below a depth of 10 feet below ground surface, in feet	
	For conservation and regulation of entire utilizable water supply	With average 40-year water supply equal to water requirements			For conservation and regulation or entire utilizable water supply	With average 40-year water supply equal to water requirements
1[2]	3,535,000	3,000,000	525,000	[1]15	47	40
2[2]	3 711,000	3,000,000	322,000	15	77	62
3	1,911,000	1,850,000	308,000	15	42	40
4	8 517,000	5,500,000	996,000	15	57	37
Totals	17,674,000	13,350,000	2,151,000	15	[3]55	[3]42

[1] Except for area north of the seventh parallel in Hydrographic Division 1 where a drainage factor of 12½ per cent was used.
[2] Exclusive of West Side Rim Lands.
[3] Average for entire absorptive area considered.

capacities shown in Table 100 between a depth of 10 feet below ground surface and the assumed economic limit of pumping lift. The capacities required for conservation and regulation of a water supply sufficient only on the average to meet the water requirements are considerably less than these utilizable underground storage capacities. It should be noted, however, that the drainage factors used are conservative, inasmuch as a considerably larger drainage factor was found in many of the principal absorptive areas as shown by the studies presented in Chapter IV. In other words, the required underground storage capacity could probably be obtained within a considerably smaller range of ground water fluctuation than that shown in the table based upon the assumed drainage factor. It is safe to conclude that the required underground storage regulation could have been provided with the water supplies made available, well within the limits of economic pumping lift in all areas.

The large amount of cyclic storage required for the regulation and seasonal distribution of local and imported waters in the upper San Joaquin Valley under conditions of ultimate development can be obtained only by utilization of ground water reservoirs. Possible surface reservoirs would provide only a fraction of the required capacity. Evaporation losses from surface reservoirs utilized for cyclic storage are very great while in underground reservoirs these losses are a minimum. The only feasible method of adequate conservation of water supply produced in wet cycles for use in dry cycles, in this area, consists of the utilization of the large available underground storage space. This utilization would require the installation of ample pumping capacity and the lowering of the water planes in dry cycles.

The results of the detailed study of the operation of underground reservoirs within the area on the east side of the upper San Joaquin

Valley south of the San Joaquin River demonstrate that the proposed plan of service for the ultimate development of this area is adequate. By means of the combined regulation afforded by the proposed surface storage reservoirs and by underground storage and pumping, the study shows that a water supply would have been provided during the forty-year period 1889–1929 more than sufficient to meet the ultimate water requirements of the areas to be served; and that, in addition, water in excess of the net use requirements would have been available for storage in the underground reservoirs, with a substantial net amount of storage accumulated at the end of the forty-year period. The proposed plan of development and operation is the only one which is practicable and economical of accomplishment to meet the demands of this section of the basin. Its dependability is demonstrated by the detailed studies presented.

Operation of Underground Reservoirs in Lower San Joaquin Valley.

Along the eastern slope of the lower San Joaquin Valley, there is available for utilization about 3,000,000 acre-feet of underground capacity with a gross absorptive area of 558,000 acres. However, the utilizable water supplies which would have been available with the proposed major surface storage units for ultimate development during the forty-year period 1889–1929 would have provided an adequate surface irrigation supply for the area to be served, without the use of underground storage and pumping, except in Hydrographic Division 8, where underground storage was utilized to a limited extent.* Under present conditions of development with generally plentiful water supplies, liberal irrigation applications on the lands result in relatively high ground water levels. As a result, the chief problem with respect to ground water is now one of drainage. Ground water levels are being controlled in some areas by use of wells and pumping plants. By utilizing pumped water to meet the peak demands of the irrigation season in these areas, effective use could be made of the underground storage capacity and a more uniform draft upon surface reservoirs could be made. This method of operation would have advantages on a system where hydroelectric power is generated.

In Hydrographic Division 8, it is proposed to utilize the underground reservoir for storage and pumping to supply a portion of water requirements for the area to be served therein. The present constructed Exchequer Reservoir of 279,000 acre-feet capacity on the Merced River would regulate the supply for the major portion of the area to be served with Merced River water but it would not provide a full surface irrigation supply. By means of underground storage and pumping, an average seasonal supply of 294,000 acre-feet from reservoir spill would have been made available for utilization during the forty-year period 1889–1929, in addition to the safe surface irrigation yield of 440,000 acre-feet per season from the reservoir. The tota

*Since the preparation of the studies in this report based upon the run-off up t 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yiel have been extended to include the period 1929–1931 and are presented in Appendix D. In order to provide the required water supplies with the available run-off from 192 to 1931, including the dry season, 1930–1931, the studies presented in Appendix I show that it would be necessary to utilize the available underground storage in severa additional areas in the lower San Joaquin Valley.

utilizable water supply from combined regulation by surface and underground storage is adequate to meet the water requirements for the portion of the area to be served by Merced River water in this hydrographic division.

Operation and Accomplishments of Conveyance Units in San Joaquin River Basin.

The chief function of the proposed conveyance units of the ultimate State Water Plan in the San Joaquin River Basin is the conveyance and distribution of surplus Sacramento River Basin water to the areas of deficient local water supply in the San Joaquin Valley. These units, described in detail in Chapter VI and shown on Plate XXVI, provide in effect a continuous conveyance system for carrying water from the Sacramento River to the southerly end of the San Joaquin Valley. However, in accord with the proposed plan of development found to be most practicable and economical, no physical connection is provided between the San Joaquin River Pumping System and the Madera and San Joaquin River-Kern County canals but the equivalent to a physical connection is effected by the substitution of Sacramento River water at Mendota for San Joaquin River water which would be diverted at Friant Reservoir through the Madera and San Joaquin River-Kern County canals. By means of this exchange of supplies, a saving of about 300 feet in pumping lift is effected as compared to a plan wherein Sacramento River water would be directly conveyed and lifted to the levels of the Madera and San Joaquin River-Kern County canals for serving the easterly slope of the upper San Joaquin Valley. A similar exchange of water for the purpose of saving pumping lift would be made on the Kern River where supplies brought in through the San Joaquin River-Kern County Canal would be substituted for Kern River water which in turn would be diverted through the Kern River Canal to higher lying rim lands along the southerly extremity of the San Joaquin Valley.

Madera and San Joaquin River-Kern County Canals—The operation and accomplishments of the Madera and San Joaquin River-Kern County canals have been set forth in detail previously in this chapter in connection with the presentation of the operation and accomplishments of Friant Reservoir and of the utilization and operation of the underground reservoirs in the upper San Joaquin Valley. These canals would be operated to deliver water from Friant Reservoir on the San Joaquin River to supplement the supplies made available from local sources on the easterly slope of the upper San Joaquin Valley. The total water supply delivered through these canals during the forty-year period would have averaged 361,500 acre-feet per season for the area served by the Madera Canal and 1,364,600 acre-feet for the areas served by the San Joaquin River-Kern County Canal, or a total average seasonal supply of 1,726,100 acre-feet. With the supplemental supplies delivered by these canals from San Joaquin River added to the supplies made available from local sources, the water requirements for the areas to be served under the ultimate plan of development on the easterly slope of the upper San Joaquin Valley would have been fully met; and, in addition, water in excess of the net use requirements would have accumulated in the underground storage reservoirs over the forty-year period 1889–1929.

San Joaquin River and Mendota-West Side Pumping Systems—The San Joaquin River and Mendota-West Side pumping systems would be operated primarily to furnish the required water supply for the areas to be served on the westerly slope of both the upper and lower San Joaquin Valley. The source of water supply would be chiefly surplus Sacramento River Basin water conveyed through these systems by successive pumping lifts from the delta to the southerly terminus of the Mendota-West Side Pumping System near Elk Hills. An additional source of supply would be the return flows from irrigated lands in the lower San Joaquin Valley and unregulated surplus water of the San Joaquin River and its east side tributaries. In the portion of the pumping system utilizing the San Joaquin River channel are located five dams, from Dam No. 1 below the mouth of the Stanislaus River to Dam No. 5 below the mouth of the Merced River. These dams, at varying elevations, would intercept the return flows from irrigated lands and unregulated surplus waters tributary to the channel above them. The dam at Mendota would also intercept return flow from the tributary irrigated areas above and surplus flows of the San Joaquin River passing Friant Dam. Those portions of the return flows and surplus waters available during the period of pumping would be intercepted and combined with Sacramento River water pumped from the Sacramento-San Joaquin Delta channels to supply the lands to be served by the San Joaquin River and Mendota-West Side pumping systems. The result would be lower capital and annual costs than could be obtained by pumping the entire supply from the Sacramento-San Joaquin Delta channels with a lift from approximateley sea level. However, although a portion of the supply for these lands would be furnished from the intercepted surplus and return waters of the lower San Joaquin Valley, any water so intercepted would have reached the delta under natural conditions and must therefore be replaced with Sacramento River water to provide for irrigation and salinity control uses in the delta and the water requirements of adjacent delta uplands. Therefore, considering necessary replacement of intercepted return flow and surplus waters from the lower San Joaquin Valley by Sacramento River water, the water provided in the delta from the Sacramento River for use in the San Joaquin Valley necessarily would be sufficient in amount to furnish the water requirements for all lands to be served therein by the San Joaquin River and Mendota-West Side pumping systems.

The areas and water requirements to be served under the ultimate State Water Plan in the San Joaquin River Basin by water conveyed through the San Joaquin River and Mendota-West Side pumping systems are shown in Table 135, by hydrographic divisions.

The water requirements shown in Table 135 would be furnished partly from return and surplus waters from the San Joaquin River Basin but for the most part from Sacramento River water. The return flow and surplus water intercepted by the San Joaquin River Pumping System would be utilized on certain lands in the area to be served b

TABLE 135

AREAS AND WATER REQUIREMENTS OF LANDS TO BE SERVED BY SAN JOAQUIN RIVER AND MENDOTA-WEST SIDE PUMPING SYSTEMS UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Area served	Hydrographic division	Net irrigable area, in acres	Seasonal water requirements (gross allowance), in acre-feet
West side area north of Merced River	7	62,000	124,000
West side rim lands north of Mendota	7a	143,000	286,000
Areas south of Merced River, now served from San Joaquin River	7	203,000	670,000
	8	69,000	226,000
Columbia Canal area	6	13,000	26,000
Mendota to Kettleman Hills	5	260,000	520,000
Mendota to Kettleman Hills	5B	221,000	442,000
West side rim lands, upper San Joaquin Valley	2e	74,000	148,000
West side rim lands, upper San Joaquin Valley	1f	217,000	434,000
Totals		1.262,000	2,876,000

the pumping system, so allocated as to save as much pumping of Sacramento River water as possible. The west side area at present receiving a pumped supply derived from the east side tributaries of the San Joaquin River would be allotted a full supply from this source under the State Plan for ultimate development. The west side rim lands in Hydrographic Division 7a would also be served from the return flow and surplus water of the lower San Joaquin Valley. Lands south of Merced River now served from the San Joaquin River in hydrographic divisions 7 and 8 would receive a partial supply from this source supplemented by Sacramento River water. In certain months in every season, there would be more than sufficient water from return flows and surplus waters to meet the demands of this area and in other months a considerable portion of the required supply would be imported from the Sacramento River Basin. An adequate supply with a maximum deficiency of less than 35 per cent in an exceptionally dry season would be received. The amounts of surplus and return waters in any month in excess of the demands of these lands in the lower San Joaquin Valley would be available for areas on the west side of upper San Joaquin Valley south of Mendota. However, the major portion of the required supply for this latter area would be imported from the Sacramento River Basin, resulting in an adequate supply with a maximum deficiency of less than 35 per cent in an exceptionally dry season. Return and surplus waters not utilizable for irrigation demands, including those occurring in the winter months especially, would flow into the Sacramento-San Joaquin Delta.

The utilizable water supply provided from return and surplus waters in the San Joaquin River Basin and from importations from the Sacramento River Basin for delivery through the San Joaquin River and Mendota-West Side pumping systems, to satisfy the water requirements as set forth in Table 135, is shown for each season of the twelve-year period 1917–1929 in Table 136. The amounts from each source for each hydrographic division and in total for the entire area served are set forth. There also are shown the estimated amounts and sources of return and surplus flows in the San Joaquin River Basin, and, lastly, the residual flow into the Sacramento-San Joaquin Delta after deduction of the amounts of return and surplus water intercepted and utilized.

Based upon the data presented in Table 136 showing the areas served and the amounts and sources of the water supply conveyed through the San Joaquin River Pumping System, the seasonal amounts of water which would have been pumped through each pumping plant of the system are shown for the twelve-year period 1917–1929 in Table 137. The data set forth in this table form the basis for the estimated cost of electric energy for pumping presented in the estimates of annual cost of this pumping system in Chapter VI.

TABLE 137

WATER PUMPED THROUGH SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Season	Seasonal quantities, in acre-feet					
	Plant 1	Plant 2	Plants 3 and 4	Plant 5	Plants 6, 7 and 8	Plants 9 and 10
1917–18	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1918–19	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1919–20	1,901,800	1.918,800	2,247,100	2,212,300	2,526,000	2,303,800
1920–21	1,897,400	1 915.700	2,247,100	2,212,300	2,526.000	2,303,800
1921–22	1,515,100	1,532,100	1,821,200	1,793,300	2,187,500	2,004,700
1922–23	1,814,000	1,831,800	2,165,200	2,130,400	2,526,000	2,303,800
1923–24	1,257,900	1,274,200	1,548,600	1,513,800	1,835,600	1,681,900
1924–25	1,907,600	1,929,200	2,247,100	2,212,300	2,495,900	2,274,600
1925–26	1,999,900	2,007,200	2,287,000	2,252,200	2,526,000	2,303,800
1926–27	1 933,200	1,951,300	2,267,400	2,232,600	2,526,000	2,303,800
1927–28	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1928–29	2,027,700	2,033,900	2,321,900	2.287,100	2,526,000	2,303,800
Average, 1917–29	1,828,000	1,845,000	2,158,000	2,124,000	2,438,000	2,225,000
Installed capacity, in second-feet	7,000	7,000	7,500	7,500	8,000	6,500

The area to be served by the Mendota-West Side Pumping System comprises hydrographic divisions 5, 5B, 2c, and 1f, embracing 772,000 acres of good lands on the westerly slope of the upper San Joaquin Valley extending from Mendota to Elk Hills. The seasonal water requirements for these lands aggregate 1,544,000 acre-feet. The local streams tributary to this area have an erratic or flashy flow and are not considered as furnishing an appreciable supply. The underlying formations are so heavily impregnated with the chemical constituents of the adjacent west side mountain range that shallow ground waters even if made available through the generous application of surface irrigation, would be rendered unfit for irrigation use. Therefore, such underground reservoir capacity as may exist within these hydrographic divisions is not considered as available for utilization. The total water requirements for the entire area would therefore be furnished as a surface irrigation supply. The required supply, delivered through the Mendota-West Side Pumping System, would be obtained from return flow and surplus water of the lower San Joaquin Valley and from Sacramento River water, delivered to Mendota by means of the San Joaquin River Pumping System. A safe surface irrigation supply of the amount required would be furnished from these sources with a maximum deficiency of 35 per cent in exceptionally dry seasons. Th

UMPING SYSTEMS

	…le rim lands, Divisions 1f and 2e		Total from Sacramento River Basin	Total from San Joaquin River Basin	Seasonal return flow and unregulated surplus from east side tributaries of San Joaquin River, in acre-feet	Seasonal return flow, in acre-feet		Residual flow into Sacramento-San Joaquin Delta, in acre-feet
	From Sacramento River Basin	Total				From west side area north of Merced River, Division 7	From San Joaquin River areas south of Merced River Divisions 7 and 8	
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
19	507,900	582,000	1,731,700	1,144,000	1,034,200	18,600	313,500	222,300
19	508,100	582,000	1,725,700	1,150,000	1,036,100	18,600	313,500	218,200
19	414,300	582,000	1,369,100	1,506,600	1,291,200	18,600	*682,400	485,600
19	507,400	582,000	1,641,700	1,234,000	1,124,200	18,600	313,500	222,300
19	315,600	402,600	1,090,300	1,025,500	970,900	18,600	258,300	222,300
19	508,300	571,800	1,726,100	1,118,700	988,200	18,600	272,100	160,200
19	508,000	582,000	1,860,200	1,015,500	905,700	18,600	313,500	222,300
19	521,100	582,000	1,760,500	1,115,200	936,000	18,600	313,500	152,900
19	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
19	508,000	582,000	1,891,200	984,500	874,700	18,600	313,500	222,300
	485,100	566,200	1,663,900	1,145,900	1,024,000	18,600	*336,200	232,900

and, lastly, the residual flow into the Sacramento-San Joaquin Delta after deduction of the amounts of return and surplus water intercepted and utilized.

Based upon the data presented in Table 136 showing the areas served and the amounts and sources of the water supply conveyed through the San Joaquin River Pumping System, the seasonal amounts of water which would have been pumped through each pumping plant of the system are shown for the twelve-year period 1917–1929 in Table 137. The data set forth in this table form the basis for the estimated cost of electric energy for pumping presented in the estimates of annual cost of this pumping system in Chapter VI.

TABLE 137

WATER PUMPED THROUGH SAN JOAQUIN RIVER PUMPING SYSTEM UNDER CONDITIONS OF ULTIMATE DEVELOPMENT

Season	Seasonal quantities, in acre-feet					
	Plant 1	Plant 2	Plants 3 and 4	Plant 5	Plants 6, 7 and 8	Plants 9 and 10
1917–18	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1918–19	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1919–20	1,901,800	1,918,800	2,247,100	2,212,300	2,526,000	2,303,800
1920–21	1,897,400	1 915,700	2,247,100	2,212,300	2,526,000	2,303,800
1921–22	1,515,100	1,532,100	1,821,200	1,793,300	2,187,500	2,004,700
1922–23	1,814,000	1,831,800	2,165,200	2,130,400	2,526,000	2,303,800
1923–24	1,257,900	1,274,200	1,548,600	1,513,800	1,835,600	1,681,900
1924–25	1,907,600	1,929,200	2,247,100	2,212,300	2,495,900	2,274,600
1925–26	1,999,900	2,007,200	2,287,000	2,252,200	2,526,000	2,303,800
1926–27	1 933,200	1,951,300	2,267,400	2,232,600	2,526,000	2,303,800
1927–28	1,895,900	1,913,700	2,247,100	2,212,300	2,526,000	2,303,800
1928–29	2,027,700	2,033,900	2,321,900	2,287,100	2,526,000	2,303,800
Average, 1917–29	1,828,000	1,845,000	2,158,000	2,124,000	2,438,000	2,225,000
Installed capacity, in second-feet	7,000	7,000	7,500	7,500	8,000	6,500

The area to be served by the Mendota-West Side Pumping Systen comprises hydrographic divisions 5, 5B, 2e, and 1f, embracing 772,00 acres of good lands on the westerly slope of the upper San Joaquin Valley extending from Mendota to Elk Hills. The seasonal wate requirements for these lands aggregate 1,544,000 acre-feet. The loca streams tributary to this area have an erratic or flashy flow and ar not considered as furnishing an appreciable supply. The underlyin formations are so heavily impregnated with the chemical constituent of the adjacent west side mountain range that shallow ground waters even if made available through the generous application of surfac irrigation, would be rendered unfit for irrigation use. Therefore, sucl underground reservoir capacity as may exist within these hydrographi divisions is not considered as available for utilization. The tota water requirements for the entire area would therefore be furnished a a surface irrigation supply. The required supply, delivered throug the Mendota-West Side Pumping System, would be obtained fror return flow and surplus water of the lower San Joaquin Valley an from Sacramento River water, delivered to Mendota by means of th San Joaquin River Pumping System. A safe surface irrigation suppl of the amount required would be furnished from these sources with maximum deficiency of 35 per cent in exceptionally dry seasons. Th

TABLE 136

UTILIZABLE WATER SUPPLY FOR LANDS SERVED BY SAN JOAQUIN RIVER AND MENDOTA-WEST SIDE PUMPING SYSTEMS UNDER CONDITIONS OF ULTIMATE DEVELOPMENT—1917-1929

Season	Seasonal supply in acre-feet (gross allowance): Lands north of Mendota: West side area north of Merced River, Division 7: From San Joaquin River Basin	Lands north of Mendota: West side rim lands, Division 7a: From San Joaquin River Basin	Lands north of Mendota: San Joaquin River areas south of Merced River, Divisions 7 and 8: From San Joaquin River Basin	San Joaquin River areas south of Merced River, Divisions 7 and 8: From Sacramento River Basin	San Joaquin River areas south of Merced River, Divisions 7 and 8: Total	Columbia Canal area, Division 6: From San Joaquin River Basin	Columbia Canal area, Division 6: From Sacramento River Basin	Columbia Canal area, Division 6: Total	Lands south of Mendota: Mendota to Kettleman Hills below elevation 350, Division 5: From San Joaquin River Basin	Mendota to Kettleman Hills below elevation 350, Division 5: From Sacramento River Basin	Mendota to Kettleman Hills below elevation 350, Division 5: Total	Mendota to Kettleman Hills above elevation 350, Division 5B: From San Joaquin River Basin	Mendota to Kettleman Hills above elevation 350, Division 5B: From Sacramento River Basin	Mendota to Kettleman Hills above elevation 350, Division 5B: Total	West side rim lands, Divisions 2d and 2e: From San Joaquin River Basin	West side rim lands, Divisions 2d and 2e: From Sacramento River Basin	West side rim lands, Divisions 2d and 2e: Total	Total from Sacramento River Basin	Total from San Joaquin River Basin	Seasonal return flow and unregulated surplus from east side tributaries of San Joaquin River, in acre-feet	Seasonal return flow, in acre-feet: From west side area north of Merced River, Division 7	Seasonal return flow, in acre-feet: From San Joaquin River areas south of Merced River Divisions 7 and 8	Residual flow into Sacramento-San Joaquin Delta, in acre-feet
1917-18	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1918-19	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1919-20	124,000	286,000	534,000	361,700	895,700	3,300	22,700	26,000	66,300	453,700	520,000	56,300	385,700	442,000	74,100	507,900	582,000	1,731,700	1,144,000	1,034,200	18,600	313,500	222,300
1920-21	124,000	286,000	540,800	354,900	895,700	3,200	22,800	26,000	66,000	454,000	520,000	56,100	385,900	442,000	73,900	508,100	582,000	1,725,700	1,150,000	1,036,100	18,600	313,500	218,200
1921-22	124,000	286,000	644,100	251,600	895,700	7,500	18,500	26,000	149,900	370,100	520,000	127,400	314,600	442,000	167,700	414,300	582,000	1,369,100	1,506,600	1,291,200	18,600	*682,400	485,600
1922-23	124,000	286,000	622,700	273,000	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,641,700	1,234,000	1,124,200	18,600	313,500	222,300
1923-24	124,000	286,000	380,800	239,000	619,800	3,900	14,100	18,000	77,700	282,000	359,700	66,100	239,600	305,700	87,000	315,600	402,600	1,090,300	1,025,500	970,900	18,600	258,300	222,300
1924-25	124,000	286,000	537,400	354,900	892,300	2,800	22,800	25,600	56,800	454,100	510,900	48,200	386,000	434,200	63,500	508,300	571,800	1,726,100	1,118,700	988,200	18,600	272,100	160,200
1925-26	124,000	286,000	406,000	489,700	805,700	3,200	22,800	26,000	66,100	453,900	520,000	56,200	385,800	442,000	74,000	508,000	582,000	1,860,200	1,015,500	905,700	18,600	313,500	222,300
1926-27	124,000	286,000	540,800	354,900	895,700	2,700	23,300	26,000	54,500	465,500	520,000	46,300	395,700	442,000	60,900	521,100	582,000	1,760,500	1,115,200	936,000	18,600	313,500	152,900
1927-28	124,000	286,000	540,800	354,900	895,700	3,300	22,700	26,000	66,700	453,300	520,000	56,700	385,300	442,000	74,600	507,400	582,000	1,723,600	1,152,100	1,042,300	18,600	313,500	222,300
1928-29	124,000	286,000	375,000	520,700	895,700	3,200	22,800	26,000	66,100	453,900	520,000	56,200	385,800	442,000	74,000	508,000	582,000	1,891,200	984,500	874,700	18,600	313,500	222,300
Mean, 1917-1929	124,000	286,000	517,000	355,400	872,400	3,600	21,700	25,300	72,500	433,400	505,900	61,700	368,300	430,000	81,100	485,100	566,200	1,663,900	1,145,900	1,024,000	18,600	*336,200	232,900

* Includes waste from Friant Reservoir.

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TABLE 138

SUMMARY OF WATER REQUIREMENTS AND WATER SUPPLY FOR ULTIMATE STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN BY HYDROGRAPHIC DIVISIONS

Hydrographic Division	Description of area served	Net irrigable area served, in acres	Seasonal water requirements, in acre-feet			Sources of water supply			Seasonal utilizable water supply, in acre-feet					
									From San Joaquin River Basin				From Sacramento River Basin[5]	Totals
			Gross allowance	Net allowance	Net use	Local	Return flow and unregulated surplus	Imported	San Joaquin River at Friant	Local streams	Return flow and unregulated surplus	Totals		
1a	North of Poso Creek, to be served by pumping lifts above the San Joaquin River-Kern County Canal	17,000	34,000	34,000	34,000			San Joaquin River	(1)36,000			36,000		36,000
1b	Between Kern River and Poso Creek, within pumping lifts of 200 feet above Beardsley and Lerdo canals	36,000	72,000	72,000	72,000	Kern River and Poso Creek				(1)74,000		74,000		74,000
1d	South of Kern River within pumping lifts of 350 feet above Kern River Canal	58,000	116,000	116,000	116,000	Kern River and minor streams				(1)119,000		119,000		119,000
1f	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	217,000	434,000	434,000	434,000		Lower San Joaquin Valley	Sacramento River			(3) (4)72,000	72,000	(2)362,000	434,000
1	Valley lands, including municipal areas, and excluding areas in 1a, 1b, 1d and 1f	463,000	926,000	926,000	926,000	Kern River and minor streams		San Joaquin River	(1)387,000	(1)567,000		954,000		954,000
	Totals, Hydrographic Division 1	791,000	1,582,000	1,582,000	1,582,000				423 000	760,000	72,000	1,255,000	362,000	1,617,000
2a	East side rim lands within pumping lifts of 250 feet above San Joaquin River-Kern County Canal	78,000	156,000	156,000	156,000			San Joaquin River	(1)159,000			159,000		159,000
2b	East side rim lands to be served jointly by pumping lifts from San Joaquin River-Kern County Canal and gravity diversions from Tule River	31,000	62,000	62,000	02,000	Tule River		San Joaquin River	(1)23,000	(1)39,000		62,000		62,000
2c	Land served entirely by gravity diversions from Tule River	10,000	20,000	20,000	20,000	Tule River				(1)20,000		20,000		20,000
2d	Lands served by pumping lifts from Tule River diversion conduits	13,000	26,000	26,000	26,000	Tule River				(1)27,000		27,000		27,000
2e	West side rim lands above elevation 250 feet, to be served by Mendota-West Side Pumping System	74,000	148,000	148,000	148,000		Lower San Joaquin Valley	Sacramento River			(3) (4)25,000	25,000	(2)123,000	148,000
2	Valley lands, excluding areas in 2a, 2b, 2c, 2d and 2e	360,000	720,000	720,000	720,000	Tule River and Deer Creek		San Joaquin River	(1)692,000	(1)56,000		748,000		748,000
	Totals, Hydrographic Division 2	566,000	1,132,000	1,132,000	1,132,000				874,000	142,000	25,000	1,041,000	123,000	1,164,000
3	Valley lands, including municipal areas	270,000	540,000	540,000	540,000	Kaweah River and minor streams		San Joaquin River	(1)68,000	(1)477,000		545,000		545,000
4	Valley lands, including municipal areas	830,000	1,660,000	1,660,000	1,660,000	Kings River				(1)1,764,000		1,764,000		1,764.000
5	Kettleman Hills to Mendota, below elevation 350 feet	260,000	520,000	520,000	520,000		Lower San Joaquin Valley	Sacramento River			(3) (4)87,000	87,000	(2)433,000	520,000
5B	Kettleman Hills to Mendota, above elevation 350 feet	221,000	442,000	442,000	442,000		Lower San Joaquin Valley	Sacramento River			(3) (4)74,000	74,000	(2)368,000	442,000
	Totals, hydrographic divisions 5 and 5B	481,000	962,000	962,000	962,000						161,000	161,000	801,000	962,000
6	Valley lands, exclusive of Columbia Canal area	184,000	368.000	368,000	368,000	Chowchilla, Fresno and San Joaquin rivers			(1)361,000	(1)100,000		461,000		461,000
6	Columbia Canal area	13,000	26,000	26,000	26,000		Lower San Joaquin Valley	Sacramento River			(3) (4)4,000	4,000	(2)22,000	26,000
	Totals, Hydrographic Division 6	197,000	394,000	394,000	394,000				361,000	100,000	4,000	465,000	22,000	487,000

(1) Average for 40-year period 1889-1929, made available by combination of surface storage and underground storage and pumping.
(2) Safe surface irrigation supply with a maximum allowable deficiency not exceeding 35 per cent in an exceptionally dry season.
(3) Average for 11-year period 1918-1929, the combination of local and imported waters providing a safe surface irrigation supply with a maximum allowable deficiency not exceeding 35 per cent in an exceptionally dry year.
(4) To be replaced in delta by Sacramento River Basin water.
(5) Does not include water from Sacramento River Basin which would be required to replace in the delta the return flow and unregulated surplus water from the lower San Joaquin Valley intercepted and utilized before reaching the delta.
(6) Exclusive of 64,000 acre-feet, exported to foothill area in American River Basin and diverted from Cosumnes River above Nashville Reservoir.

capacity, pumping lift, and seasonal amount of water pumped by each pumping plant of the Mendota-West Side Pumping System are shown in Table 113 in Chapter VI.

The location of the Mendota-West Side Pumping System is in general along the lower edge of the lands to be served. The utilization of most of the water supplies delivered through this conduit would require the construction and operation of local pumping projects having total lifts varying from 250 to 500 feet. These projects would be similar in plan to existing pumping projects on the westerly slope of the lower San Joaquin Valley north of Merced River. The weighted average lift of all local pumping projects would be about 220 feet.

Summary of Operation and Accomplishments.

Based upon the foregoing presentation of the operation and accomplishments of the physical units of the ultimate State Water Plan in San Joaquin River Basin, there is summarized in Table 138 the sources and amounts of the water supplies that would be furnished to meet the water requirements of the areas to be served in each hydrographic division of the basin. For each hydrographic division and special subdivisions thereof, the table shows:

First—The net irrigable area to be served in acres.

Second—The seasonal water requirements in acre-feet, including the amounts for gross allowance, net allowance and net use.

Third—The sources of water supply, including local major and minor streams, surplus and return flows available for reuse and imported supplies from outside the particular hydrographic divisions.

Fourth—The total seasonal utilizable water supply in acre-feet made available from each source of supply.

The basic data with respect to the areas to be served and the water requirements are presented in Chapter V. The sources and amounts of utilizable water supply and the methods of obtaining these supplies through the operation of the major physical units of surface storage, underground storage and conveyance have been presented in detail previously in this chapter. In general, the water supply required for the areas to be served would be obtained from local sources up to the fullest practicable development of the amounts available, regulated by means of both surface and underground storage, where available.

On the east side of the upper San Joaquin Valley including hydrographic divisions 1, 2, 3 and 6, the local water supplies capable of being developed would be insufficient to meet the requirements and the supplemental water supplies required would be furnished from the San Joaquin River. In the entire area on the east side of the upper San Joaquin Valley, comprising hydrographic divisions 1, 2, 3, 4 and 6, the water provided from both local and outside sources would be furnished as far as possible as a surface irrigation supply, but a considerable portion of the supply required would be obtained through ground water storage and pumping. The utilization of underground storage in this portion of the upper San Joaquin Valley is most essential. The bulk of the utilizable water supply would be obtained from the major streams, the amounts of which are set forth in Table 122. The minor streams in general would furnish but a small amount. In Division No. 1, Poso and Caliente creeks and other minor streams would furnish a mean seasonal supply, based on the forty-year period 1889–1929, sufficient to serve about 45,000 acres. In Division No. 2, the minor streams Deer Creek and White River would furnish a mean seasonal supply of about 14,000 acre-feet for the same period. In Division No. 3, the minor streams Limekiln and Yokohl creeks would furnish a mean seasonal supply of about 42,000 acre-feet for the same period.

In the area on the east side of the lower San Joaquin Valley embraced within hydrographic divisions 8, 8A, 9, 9A, 11 and 11A, adequate water supplies would be obtained for practically the entire area to be served from the local sources of supply comprising Merced, Tuolumne and Stanislaus rivers. One exception to this would be in Hydrographic Division 8 where a portion of the area adjacent to the San Joaquin River would be served by return flow and surplus water and Sacramento River water diverted from the San Joaquin River Pumping System. The total utilizable supply which could be made available from Merced River would not be sufficient for the entire area to be served in hydrographic divisions 8 and 8A and hence the service of a portion of the area from the San Joaquin River Pumping System is required. Most of this area in Hydrographic Division 8 that would be served from the San Joaquin River Pumping System under ultimate development is now served from return flows and crop land waters of the San Joaquin River and hence the ultimate plan of service would be similar to the present. A portion of the utilizable supplies for Hydrographic Division No. 8 would be obtained from ground water storage and pumping of surplus Merced River water, but the bulk of the water would be furnished as a surface irrigation supply. The supplies for hydrographic divisions 9, 9A, 11 and 11A would be surface irrigation supplies entirely, based upon the utilizable supply for the forty-year period 1889–1929.

In the remaining portion of the east side of the lower San Joaquin Valley, comprising hydrographic divisions 12, 12A, 13 and 13A, the water supplies would be obtained chiefly from the local streams but would be supplemented partly by supplies obtained from the American River in the Sacramento River Basin. Based upon the utilizable supplies that would have been available during the forty-year period 1889–1929, ground water storage utilization is not contemplated in these divisions, and an adequate supply would be furnished from the local streams and the American River for surface irrigation.

The major portion of the irrigable area in Hydrographic Division 10 now receives its supply through local pumping projects diverting Sacramento and San Joaquin river waters from delta channels. Under conditions of ultimate development the entire area to be served in this division would be supplied in a like manner for the most part with Sacramento River water.

For the areas to be served on the westerly slope of both the upper and lower San Joaquin valleys, the water supply would be obtained chiefly by importation from the Sacramento River Basin. However, a substantial amount of the required supply would be obtained from the

	Seasonal utilizable water supply, in acre-feet					
	From San Joaquin River Basin				From Sacramento River Basin[5]	Totals
Imported	San Joaquin River at Friant	Local streams	Return flow and unregulated surplus	Totals		
oaquin River---	(1)36,000			36,000		36,000
		(1)74,000		74,000		74,000
		(1)119,000		119,000		119,000
mento River---			(2) (4)72,000	72,000	(2)362,000	434,000
oaquin River---	(1)387,000	(1)567,000		954,000		954,000
	423 000	760,000	72,000	1,255,000	362,000	1,617,000
Joaquin River---	(1)159,000			159,000		159,000
Joaquin River---	(1)23,000	(1)39,000		62,000		62,000
		(1)20,000		20,000		20,000
		(1)27,000		27,000		27,000
mento River---			(2) (4)25,000	25.000	(2)123,000	148,000
Joaquin River---	(1)692,000	(1)56,000		748,000		748,000
	874,000	142,000	25,000	1,041,000	123,000	1,164,000
Joaquin River---	(1)68,000	(1)477,000		545,000		545,000
		(1)1,764,000		1,764,000		1,764.000
mento River---			(2) (4)87,000	87,000	(2)433,000	520.000
mento River---			(2) (4)74,000	74,000	(2)368,000	442,000
			161,000	161,000	801,000	962,000
	(1)361,000	(2)100,000		461,000		461,000
mento River---			(2) (4)4,000	4,000	(2)22,000	26,000
	361,000	100,000	4,000	465,000	22,000	487,000

the delta.

return flow and surplus waters originating in the lower San Joaquin Valley and intercepted for reuse behind the dams of the San Joaquin River Pumping System. All of the water furnished in this area would be a surface irrigation supply, with none of the supply obtained through utilization of underground storage.

The data presented in Table 138 demonstrate that, under the proposed ultimate State Water Plan in the San Joaquin River Basin, the water requirements of the areas to be served under ultimate development would be adequately met in each hydrographic division, based upon the forty-year period of run-off considered from 1889 to 1929. In addition, the supplies made available for the areas on the east side of the upper San Joaquin Valley south of the San Joaquin River would have resulted in a net accumulation of 6,000,000 acre-feet of water stored in the underground reservoirs at the end of the forty-year period considered. The average seasonal amount of water that would have been required to be imported from the Sacramento River Basin would have been about 2,000,000 acre-feet, exclusive of an average seasonal amount of about 1,000,000 acre-feet of return flow and surplus water from the lower San Joaquin Valley intercepted by the San Joaquin River Pumping System and utilized in the areas served by the San Joaquin River and Mendota-West Side pumping systems, which would be replaced in the delta by Sacramento River water.

Summarizing the accomplishments with respect to water supply and water requirements, the operation of the ultimate State Water Plan would furnish for the San Joaquin River Basin:

1. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of a net area of 1,810,000 acres of irrigable land in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley, after deducting from the full natural run-off of the lower San Joaquin River tributaries, 565,000 acre-feet per season for an adequate and dependable irrigation supply for 205,000 acres of land embracing all of the net irrigable mountain valley and foothill lands situated in the lower San Joaquin Basin at elevations too high to be irrigated by gravity from the major reservoir units.

2. A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of Classes 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley.

3. A supply of 1,570,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent in an exceptionally dry year, for the irrigation of all of the net irrigable area of 772,000 acres of Classes 1 and 2 lands lying on the western slope of the upper San Joaquin Valley and 13,000 acres of Classes 1 and 2 lands in the Columbia Canal area.

In addition to the water supplies furnished, an average annual electric energy output of 728,500,000 kilowatt hours would be generated at the major reservoirs in the San Joaquin River Basin incidental to their primary operation for irrigation; additional flood protection would be effected on several of the major streams (see Chapter IX); and navigation would be improved on the San Joaquin River above Stockton (see Chapter X).

CHAPTER VIII

INITIAL DEVELOPMENT OF STATE WATER PLAN IN SAN JOAQUIN RIVER BASIN

The initial development of the State Water Plan in the San Joaquin River Basin is proposed as the first progressive step in the consummation of the plan for ultimate development set forth in Chapters VI and VII. It is designed primarily to meet the immediate pressing needs of existing developments. Certain areas in the basin, especially in the upper San Joaquin Valley and in the San Joaquin Delta region, in recent years have been and are now experiencing serious problems of water shortage, the adequate solution of which would require the construction and operation of initial units of the State Water Plan if the productive resources and investment in present developments are to be maintained. The basic objective of the initial development is to furnish additional water to meet the present deficiencies between supply and demand in these developed areas. Added to this is the desirability of providing additional flood protection and improving navigation on the San Joaquin River above Stockton.

As in the plan for ultimate development, the initial developmen in the San Joaquin River Basin is closely related to and interdependen with that in the Sacramento River Basin because the San Joaqui Valley is dependent upon the Sacramento River Basin for supple mental water supplies required to fully meet the present demands The initial units in the two basins constitute a unified project for th immediate development of the State Water Plan in the entire Grea Central Valley and would be operated coordinately to adequately an completely meet the present needs for the development, regulation distribution and utilization of the water resources.

In evolving a plan for initial development in the San Joaqui River Basin, the following criteria have been adopted:

1. The plan must be so designed as to furnish an adequate sup plemental supply to those developed areas with a permanen deficiency, not remediable by the development of their loca water supplies.
2. The physical works of the plan must be so designed as to perm of economical enlargement and extension to a capacity an degree required under the provisions of the plan of ultimat development.

The procedure in the evolution of the plan for initial developme was as follows:

1. The location and extent of the present developed areas of pe manent deficiency of water supply were determined.
2. The amounts of deficiency in the areas of inadequate supp and the amounts of supplemental water required were estimate
3. The economic and logical sources of supplemental supply we determined and the amounts of water obtainable from tho sources estimated.

4. The physical works necessary for furnishing this supplemental supply to the areas of deficiency were determined with careful consideration of the future additional water requirements of the areas.
5. Capital and annual costs of the physical works and revenues anticipated from sale of water and power were estimated.

Immediate Water Problems in San Joaquin River Basin.

A study of present irrigation development in the San Joaquin River Basin reveals that the lower San Joaquin Valley, with the exception of the San Joaquin Delta Region, has an adequate and dependable water supply for present requirements.

In the Sacramento-San Joaquin Delta, the available inflow from the Sacramento and San Joaquin river systems during recent years of generally subnormal run-off has been insufficient during certain months in several years to meet the consumptive demands in the delta and to keep the water fresh as against the invasion of saline water from the bay. Invasion of saline water has rendered the water in the delta channels unfit for irrigation and other uses, not only for the delta lands but also for the adjacent uplands and in the area adjacent to Suisun Bay. The immediate water problems in the delta and adjacent areas and the methods for their solution are presented in detail in other reports.* A few relatively small areas in hydrographic divisions 12 and 13 are in need of some additional water to meet present water requirements, but it appears that the amount of water required can be obtained from local sources through the development of facilities by local interests.

In the upper San Joaquin Valley, a study of existing conditions of irrigation development reveals an area in which many of the local supplies are inadequate to support existing development. On all the streams tributary thereto, there long since has been effected a very high degree of utilization of run-off without surface storage regulation. For many years, therefore, while the irrigated areas devoted to annuals have varied with surface water supplies, the expansion of the irrigated areas devoted to permanent crops has occurred chiefly through the development of ground water supplies. With limited or no surface supplies, the replenishment of ground water storage, commonly resulting from the use of ample surface applications, is lacking in many of these areas. In some localities, expansion of the irrigated areas has continued to such an extent that the net draft on ground water storage exceeds the average seasonal replenishment from whatever local sources are available. The result has been a depletion of ground water storage, which is indicated by a continuously receding water table.

Determination of Developed Areas with Deficient Water Supply and Amounts of Water Shortage.

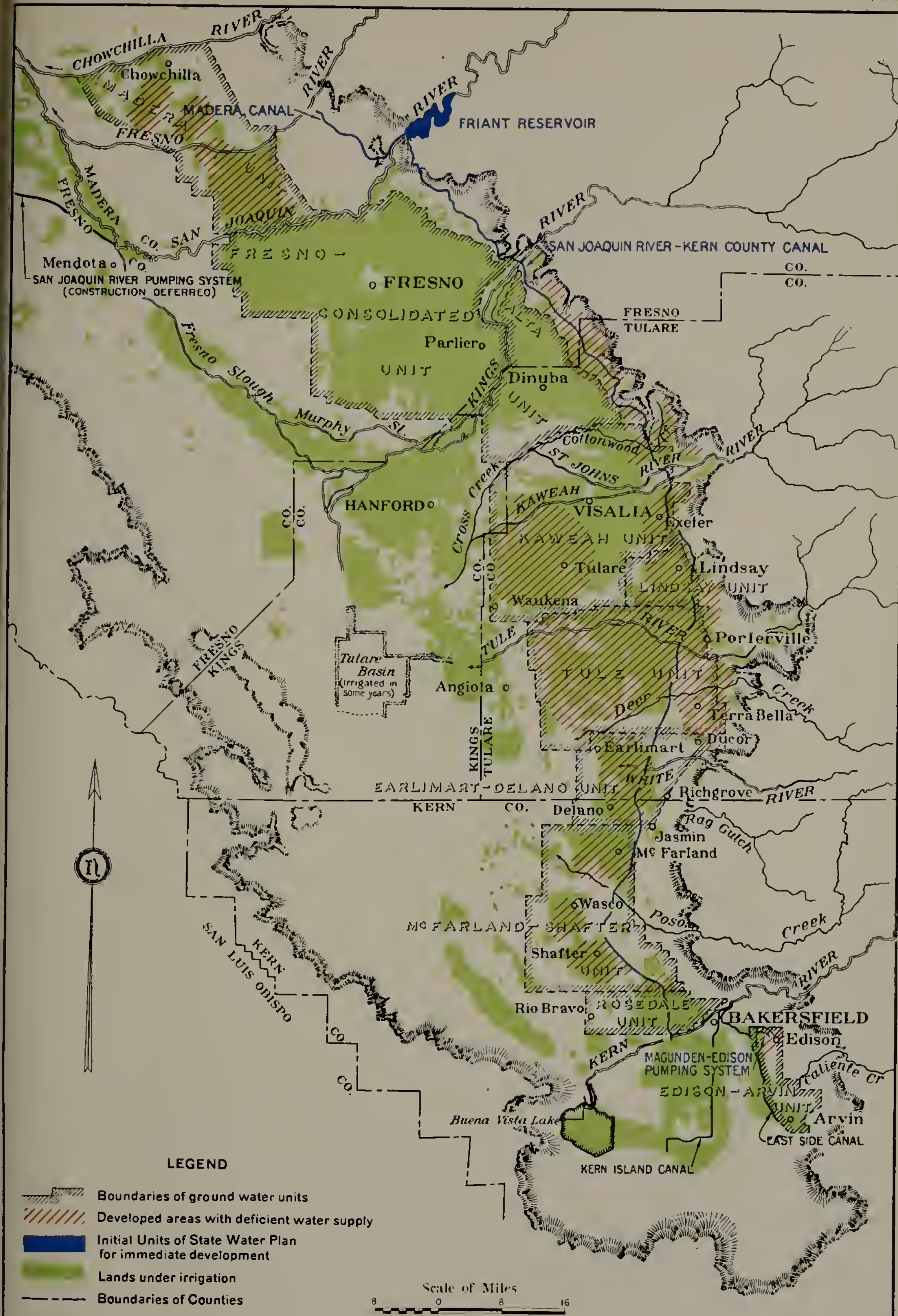
In order that the location and extent of the developed areas of deficient water supply in the upper San Joaquin Valley could be determined, a detailed study of existing development was made involving the elements of the available local water supplies, the irrigated

* Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.
Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay," Division of Water Resources, 1931.
Bulletin No. 28, "Economic Aspects of a Salt Water Barrier below Confluence of Sacramento and San Joaquin River," Division of Water Resources, 1931.

areas and the conditions of ground water storage. The results have been presented in Chapter IV. This study covered the area in the five southern counties of the valley, namely, Madera, Fresno, Tulare, Kern and Kings. For convenience of study, areas within the first four counties were divided into ten smaller units, designated as the Madera, Fresno-Consolidated, Alta, Kaweah, Lindsay, Tule-Deer Creek, Earlimart-Delano, McFarland-Shafter, Rosedale and Edison-Arvin ground water units. The term "ground water unit" was applied to these areas as the study dealt primarily with an analysis of the ground water conditions underlying each. The location of these units, described in detail in Chapter IV, is shown on Plate LXVIII, "Ground Water Units and Developed Areas with Deficient Water Supply in Upper San Joaquin Valley." Lands under irrigation, developed areas with deficient water supply and initial units of the State Water Plan for immediate initial development in upper San Joaquin Valley also are shown on this plate. Kings County and other areas not included in the above named ground water units also were studied but on a different basis.

An analysis was made for each ground water unit to determine as closely as possible the deficiency of supply, if any, that has been experienced for the lands already under irrigation. This analysis covered the eight year period 1921–1929 for which the complementary data were available on surface water supply to the unit, irrigated areas and ground water levels. The length of the period was fixed by the length of continuous records of ground water conditions. In the Kern County units, the records covered the 9–year period 1920–1929 but, in order to make the studies in all units comparable, the 8-year period was used throughout. Data on some 4000 wells, distributed over the entire area, were available for the study.

The boundaries of ground water units were selected in each case to include irrigated lands with a common source of water supply, whether from surface or underground development. Based upon a year by year study for the period 1921–1929 of the collected data on surface inflow, irrigated area and change in ground water level for each ground water unit, it has been possible to estimate the average seasonal inflow required to support the existing irrigation development and prevent a continuous recession of the ground water. The seasonal inflow into any particular area is defined as that part of the tributary run-off actually entering the area, less known exportations and surface outflow from the area. Since ground water is a form of cyclic storage, fluctuations in level are permissible from year to year so long as the minimum levels do not increase pumping lifts beyond the economic limit. The fact that, during a period of subnormal inflow, a lowering in the ground water has occurred in an area of pumping development does not necessarily mean that it is an area with a supply inadequate to meet existing irrigation demands. If, however, the long-time available mean seasonal inflow to the ground water unit is less than the estimated mean seasonal water requirements, it is concluded the area is one of deficient local supply as now utilized. On this basis, the conditions in each ground water unit have been studied and the period of depletion and the total and mean seasonal amounts of depletion of ground water storage estimated. Estimates of depletion in each unit are for the entire area of the unit, regardless of the percentage actually



GROUND WATER UNITS

AND

DEVELOPED AREAS WITH DEFICIENT WATER SUPPLY

IN

UPPER SAN JOAQUIN VALLEY

irrigated. In some units, portions of the area, due to their favorable position on the schedule of utilization of local surface supplies, are without deficiency, even in periods of subnormal run-off. In such units, the ground water contour maps for each year of record show clearly, by cones of depression in the water table, where the overdraft upon the ground water is greatest. It is not feasible, however, to define exactly the boundary of the area of deficiency or to say what part of the overdraft is due to pumping in adjacent areas. For these reasons no attempt has been made to lay down the exact boundaries of the areas of deficiency within each ground water unit, but only to indicate their general location and to estimate the amount of deficiency between supply and present draft.

Utilizing all the available data, there has been presented in Chapter IV a year by year analysis of ground water conditions in each unit for the period 1921–1929. The results of this analysis are summarized in Table 139. In this table are set forth for each unit its total area, the average area irrigated for the period studied, and the total and average seasonal depletion of ground water.

TABLE 139

CHANGE IN VOLUME OF GROUND WATER IN UPPER SAN JOAQUIN VALLEY. SUMMARY BY GROUND WATER UNITS, 1921-1929

Unit	Area of unit, in square miles	Average area irrigated, in acres	Depletion of ground water, in acre-feet	
			Total	Average per season
Madera	343	69,000	487,000	61,000
Fresno-Consolidated	700	319,900	566,000	71,000
Alta	191	79,000	161,000	20,000
Kaweah	468	133,700	732,000	92,000
Lindsay	64	22,000	148,000	19,000
Tule-Deer Creek	373	67,400	447,000	56,000
Earlimart-Delano	150	21,200	400,000	50,000
McFarland-Shafter	310	50,100	491,000	61,000
Rosedale	79	12,000	69,000	9,000
Edison-Arvin	51	18,600	103,000	13,000

The depletion of ground water for the period 1921–1929 in the several ground water units, as set forth in Table 139, reflects the relation between the inflow and the net draft during the period of ground water record. It so happens that the entire range of continuous observations of ground water conditions falls within a period of subnormal run-off. The occurrence of a season of normal run-off during this dry period is sharply reflected in the ground water conditions in some of the units.

It is not sufficient to use the data of a series of dry years, alone, in determining which of the ground water units have inadequate local supplies. Examination also must be made of the relation between average seasonal inflow during the recent period of depletion and the seasonal inflow for various other periods. In this investigation, the seasonal inflow for each ground water unit was taken as that part of the estimated tributary run-off practicable of utilization through the full use of existing physical works and underground storage, less exportation and surface outflow from the area, as under present conditions of development. The records of exportation and surface outflow considered were obtained from outflow data for seasons of corresponding run-off during the period of measurement. Estimates of inflow were made for the 40-year period 1889–1929, the 20-year period 1909–1929, the 8-year period 1921–1929 for which ground water depletion was determined and the 5-year period 1924–1929.

A comparison of the seasonal inflow for the period of depletion and other periods, with the average seasonal depletion in ground water for each unit is set forth in Table 140. The average seasonal inflows shown in the table for the Tule-Deer Creek unit for the various periods include a supply for about 5000 acres of developed lands lying east of the unit and for which no records of ground water or diversion are available. Similarly for the Kaweah unit, the figures of average seasonal inflow include a supply for 3600 acres lying east of the unit. It was impracticable to segregate the use on these two particular areas from the total inflow which should be done to obtain exact figures for the inflow into these respective units. However, this approximation does not affect the conclusions as to the deficiencies in supply in these units.

TABLE 140

COMPARISON OF DEPLETION OF GROUND WATER STORAGE WITH AVAILABLE LOCAL SUPPLIES IN UPPER SAN JOAQUIN VALLEY. SUMMARY BY GROUND WATER UNITS

Ground water unit	Average seasonal depletion in ground water during period 1921-1929, in acre-feet	Average seasonal inflow to ground water unit, in acre-feet				Required average seasonal inflow to prevent depletion, in acre-feet[1]
		40-year period, 1889-1929	20-year period, 1909-1929	8-year period, 1921-1929	5-year period, 1924-1929	
Madera	61,000	144,200	121,000	111,400	101,400	172,400
Fresno-Consolidated	71,000	770,000	680,000	537,000	568,200	608,000
Alta	20,000	225,000	182,000	133,900	145,300	153,900
Kaweah	92,000	370,000	297,000	250,800	248,200	342,800
Lindsay	19,000	(2)	(2)	13,900	14,000	[1]44,000
Tule-Deer Creek	56,000	155,000	130,000	92,300	87,100	148,300
Earlimart-Delano	50,000	4,000	3,500	2,800	2,800	52,800
McFarland-Shafter	61,000	86,000	79,000	38,900	27,100	99,900
Rosedale	9,000	87,000	81,000	46,700	41,200	55,700
Edison-Arvin	13,000	37,000	29,000	23,600	22,100	36,600

[1] Sum of average seasonal depletion and average seasonal inflow for eight-year period, 1921-1929, excepting Lindsay unit. In this unit the sum of these items does not represent an adequate supply and therefore a net use of two acre-feet per acre is assumed.

[2] Inflow to Lindsay unit is an importation from the Kaweah River of about 14,000 acre-feet annually, beginning in 1918. This was taken into consideration in estimating the net inflow to the Kaweah unit.

It is obvious that the depletion of the underground storage represents an overdraft upon the available supply and, therefore, the sum of the average seasonal depletion and the average seasonal inflow during the period of depletion should represent the amount of average seasonal inflow which would have been adequate to maintain stable ground water conditions during that period. The summations of average seasonal inflow and depletion for the 8-year period of record are shown in the last column of Table 140 for the purpose of determining whether each unit is one of permanent deficiency in local supply as related to the available inflow for periods other than the period of depletion. By comparing the quantities in the last column with the average seasonal inflow for each of the five, eight, twenty and forty-year periods ending in 1929, the condition as to permanent deficiency is indicated.

The results of the detailed studies as to deficiency or adequacy of water supply for the present irrigation development in each ground water unit and other areas in the upper San Joaquin Valley are presented in the following paragraphs:

The Madera Unit—The Madera unit is one in which the present average draft upon the ground water evidently exceeds the replenishment that would be effected even with the average utilizable water supply over a 40-year period including both wet and dry periods. During the 8-year period, the irrigated area in this unit increased from 60,000 acres in 1921 to 81,000 acres in 1929, segregated as follows: Deciduous fruits 8200 acres, vines 25,300 acres, alfalfa 16,200 acres, field crops 2000 acres, cotton 27,400 acres, pasture 1300 acres and truck 600 acres. The sources of water supply now utilized in this area are the Chowchilla and Fresno rivers, augmented by an importation of about 10,000 acre-feet each year from the Merced and San Joaquin River drainage areas. The average seasonal inflow available during this period was 111,400 acre-feet. With this inflow, the average seasonal depletion of ground water was 61,000 acre-feet and that during the season 1928–1929 was 146,000 acre-feet. The 40-year average seasonal inflow available is estimated as 144,200 acre-feet, or 32,800 acre-feet in excess of that during the period of ground water record. Comparing this excess with the 61,000 acre-feet of average seasonal depletion, it is obvious present development could not have been supported without an overdraft on the ground water storage.

The Fresno-Consolidated Unit—The data on the Fresno-Consolidated unit indicate no permanent depletion of its ground water storage. The Fresno and Consolidated irrigation districts, which are included within this unit, have been under practically full irrigation development for many years. The area irrigated in 1929 consisted of 1100 acres of citrus and 40,700 acres of deciduous fruits, 168,700 acres of vines, 35,300 acres of alfalfa, 31,700 acres of field crops, 9600 acres of cotton, 34,500 acres of pasture and 200 acres of truck, totalling 321,800 acres. The Fresno District has extensive diversion rights of relatively early priority on Kings River and receives a more dependable water supply, both in amount and in distribution through the season, than other large areas served from Kings River. From the inception of irrigation in this area to the beginning of the period of this study, the ground water had risen from 30 to 60 feet above its position prior to irrigation. This resulted in the water-logging of a considerable portion of the area now in the district and it is only with the development of pumping and the recent series of dry years that conditions favorable to the proper production of crops in the portions of the district formerly water-logged have been reached. The depth to ground water over the greater part of the Fresno District varies from 10 to 25 feet. At the extreme northern edge of the district the depth to ground water ranges from 50 to 70 feet. The average total lowering in different parts of the district for the 8-year period of record was 6.5 feet. The water rights of the Consolidated District furnish only a limited supply at medium to low stages of Kings River, but yield a large flow during the short period of high water. This condition results in an unfavorable distribution of the season's total supply and for this reason practically all canal-irrigated lands are equipped for supplemental pumping. The average depth to ground water varies from 10 to 25 feet, and is about 50 feet in an area of two or three square miles along the bank of Kings River, just east of Parlier. The average total lowering during the 8-year period varied from 5 to 10 feet, with a small area near Kings River having a lowering of 15 feet.

The quantities in Table 140 show that, while the seasonal inflow has been somewhat inadequate during the recent years of subnormal run-off, the average seasonal inflow of utilizable water supply for either the 20 or 40-year periods preceding 1929 would have supported the present development of the unit. For the 5 and 8-year periods, the average deficiency in seasonal inflow into this unit was about one-tenth of the full requirement.

Lying northeast of and irregularly situated within a strip of territory from one to two miles in width and 20 miles in length adjacent to and paralleling the Enterprise Canal of the Fresno Irrigation District, are small pump-irrigated areas totaling 3300 acres and having no water rights in said canal. The irrigated areas contain 180 acres of citrus and 80 acres of assorted deciduous fruits, 1750 acres of figs, 40 acres of alfalfa and 1250 acres of vines. The source of supply for ground water replenishment in these areas consists of drainage from the lower foothills of the Sierra between the Kings and San Joaquin rivers through Dry, Dog and Fancher creeks and Sales Creek, a tributary of Dog Creek. The average seasonal run-off of these streams for the 8-year period, 1921–1929, is estimated at 7900 acre-feet, which amount is sufficient to support existing development without permanent overdraft on ground water.

The Alta Unit—The Alta unit, which consists principally of the Alta Irrigation District, is similar to the Fresno-Consolidated as to the sufficiency of its water supply, in that, for the long-time average, the inflow of utilizable water supply is adequate to support the present irrigation development, with the possible exception of an area of 5000 acres along its eastern rim in which a total lowering of ground water of from 25 to 35 feet occurred during the period of observation. The total area irrigated in 1929 was 68,450 acres, consisting of 800 acres of citrus and 8800 acres of deciduous fruits, 47,300 acres of vines, 1900 acres of grain, 6000 acres of alfalfa, 450 acres of field crops, 1800 acres of cotton, 1100 acres of pasture and 300 acres of truck. In the central portion of the district, the total lowering has been from 5 to 15 feet and 25 feet in a very limited area. The present depth to ground water varies from 15 to 35 feet. The data for this unit show that, with proper distribution of local supplies, the average seasonal inflow for either the 20- or 40-year periods would have been adequate to meet the present needs of the unit.

Lying east of and immediately adjacent to the Alta district is the Foothill Irrigation District, some 50,000 acres in extent and with a present developed area of 11,000 acres which in 1929 consisted of 3600 acres of citrus and 3000 acres of deciduous fruits and 4400 acres of vines. This district was organized under a plan calling for the exchange of a supply pumped from ground water along Murphy Slough for a gravity diversion right on Kings River. The plan has never been consummated and, with practically no run-off tributary to the area, the district is entirely without a water supply. No continuous record of ground water observations has been maintained in the Foothill District, but a few recent observations indicate that such ground water supply as originally underlay the area is practically exhausted. The present developed area of 11,000 acres, combined with the 5000 acres of the higher rim lands of the Alta unit, is considered to be one of practically zero water supply and has been so treated in estimating the requirements for importation of supplemental water supplies under initial development.

The Kaweah Unit—The Kaweah unit, including all of the area naturally dependent upon the Kaweah River for its water supply, is apparently one in which, over the 40-year period, the local sources of supply are adequate. However, the higher eastern portion of the unit around Exeter is so situated that it receives no portion of the available surface flow so that its principal source of ground water replenishment must be from the west through relatively impervious materials. A deep trough of depression in the ground water is revealed by a study of ground water levels in this area near Exeter. The total lowering during the period of record has been from 20 to 50 feet. The present depth to ground water is from 50 to 110 feet. This portion of the unit has relatively nonabsorptive soils and it is concluded additional water must be provided, chiefly in the form of a surface irrigation supply. At the extreme north edge of the unit, but slight lowering of the water table has occurred during the period of record. In the areas served by canals the lowering has been from 5 to 15 feet. Farther from canal service and near the town of Tulare, extensive pumping development has resulted in a lowering of from 25 to 35 feet. While the tabular quantities show that the 40-year average seasonal inflow is adequate to support existing development, it is judged that its unequal distribution throughout the area in accordance with existing diversion rights probably would result in some permanent depletion.

The irrigated area, which in 1929 totaled 128,500 acres, consisted of 12,000 acres of citrus and 23,500 acres of deciduous fruits, 22,000 acres of vines, 2000 acres of grain, 38,000 acres of alfalfa, 6000 acres of field crops, 14,500 acres of cotton, 9500 acres of pasture and 1000 acres of truck.

The Lindsay Unit—The Lindsay unit lies between the deltas of the Kaweah and Tule rivers in a locality of small tributary inflow. It is devoted largely to citrus culture and is one of the oldest pumping areas in the San Joaquin Valley. The irrigated area in 1929 consisted of 13,000 acres of citrus and 4000 acres of deciduous fruits, 2800 acres of vines, 500 acres of alfalfa, 400 acres of field crops, 1200 acres of cotton and 100 acres of truck, totaling 22,000 acres. This unit is relatively distant from the Tule and Kaweah rivers and out of the line of ground water movement from the deltas of these streams. The lack of any active source of ground water replenishment is shown by the rapid rate of lowering which has occurred. Practically the only source of inflow to this area during the period of record has been the seasonal importation of about 14,000 acre-feet pumped from a well field at the head of the Kaweah Delta by the Lindsay-Strathmore Irrigation District. The total ground water lowering during the period 1921–1929 averaged 55 feet, with a range of 25 to 75 feet. The present depth to ground water varies from 25 to 175 feet. The data show that an imported supplemental water supply is required to meet the present needs of this area.

The Tule-Deer Creek Unit—The Tule-Deer Creek unit includes lands dependent upon the Tule River and Deer Creek for their ground water replenishment. The irrigated area in 1929 consisted of 3700 acres of citrus and 5800 acres of deciduous fruits, 8000 acres of vines, 1100 acres of grain, 9500 acres of alfalfa, 2400 acres of field crops, 34,000 acres of cotton, 5200 acres of pasture and 500 acres of truck, totaling 70,200 acres. The total average lowering of ground water during the 8-year period of record has been 23 feet. Along the main line of the Southern Pacific Railroad the depth to ground water varies from 50 to 70 feet. At the westerly edge of the unit the depth is about 30 feet and at the eastern rim of the unit southeast of Terra Bella the depth to ground water is 200 feet. Although the forty-year average seasonal inflow shows a slight excess above the average requirement for this area, the average seasonal inflows for the 20, 8 and 5-year periods show marked deficiencies. It is concluded that this area is one requiring an imported supplemental water supply. Over the southeastern portion of this unit the soil types are considered nonabsorptive and an imported water supply, delivered chiefly in accordance with a surface irrigation demand, will be required.

Area East of Tule-Deer Creek Ground Water Unit—East of and adjacent to the Tule-Deer Creek Unit are small nonabsorptive irrigated areas totaling 6000 acres, about 1000 acres of which have an adequate surface supply. The irrigated areas in 1929 consisted of 5000 acres of citrus and 600 acres of deciduous fruits and 400 acres of vines.

The Earlimart-Delano Unit—The Earlimart-Delano unit includes the east side valley lands from Earlimart and Ducor on the north to the southern limit of the Delano development in northern Kern County. This is an area of extremely limited tributary run-off. White River is the only stream draining higher foothill areas. Rag Gulch drains additional low foothill areas. All irrigation development is by pumping. The irrigated area increased from 11,600 acres in 1921 to 30,500 acres in 1929, segregated as follows: Citrus fruits, 500 acres; deciduous fruits, 1000 acres; vines, 13,000 acres; alfalfa, 1000 acres; field crops, 1000 acres and cotton, 14,000 acres. The figures in Table 140 show the great contrast between available inflow and the overdraft to date. East of Delano a maximum lowering of the water table of 70 feet has occurred in the 8-year period, with a lowering of 50 feet shown for a large area. At the north end of the unit, depths to ground water range from 50 feet at Earlimart to 200 feet just east of Ducor, with a midway depth of 100 feet. At the south limit of the unit, the range is from 25 feet at the west to 200 feet near Jasmin on the east, with a midway depth of 125 feet just east of Delano. An examination of the seasonal inflows and the depletion of ground water in this unit shows that it requires an additional supply almost equal to its total irrigation needs for present development.

The McFarland-Shafter Unit—The McFarland-Shafter unit, bordering the Earlimart-Delano unit on the south, extends southward 21 miles and includes within its boundaries the highly developed areas around the towns of McFarland, Wasco and Shafter. The areas irrigated in the vicinity of these towns totaled 49,800 acres in 1929 and consisted of 8400 acres of deciduous fruit, 11,700 acres of vines, 10,000 acres of alfalfa, 7500 acres of field crops and 12,200 acres of cotton. These irrigated areas are dependent entirely upon a supply pumped from the underlying ground water. Included within this unit also are some 60,000 acres of Class 1 land lying for the most part above the pumping developments, which are properly located to receive surface irrigation from existing canals of large capacity but with diversion rights of late priority on the Kern River. The irrigated area devoted chiefly to annuals varies from year to year with the water supply. With the exception of Poso Creek, which is estimated to contribute a long-time mean seasonal replenishment of 17,000 acre-feet to the ground water of this unit, the only source of replenishment for the ground waters underlying the pump-developed areas are the losses of conveyance and distribution from the supplies delivered through canals to the large area dependent upon surface irrigation. These canal-irrigated lands are largely in one ownership and, in past periods of high run-off, have been liberally supplied with water, the effect of which during the period from 1880 to 1920 was to raise the natural water table from 50 to 60 feet. Pumping development began about 1910 and has continued steadily ever since. At approximately the same time the pumping draft reached an amount about equal to the average seasonal replenishment, a period of subnormal run-off began. The effect of these two conditions of steadily increasing draft and diminishing inflow is sharply reflected in the data for this unit. The maximum total lowering of the water table during the period of ground water record has been 40 feet at McFarland, about the same near Wasco, and about 30 feet at Shafter. The depths to ground water at these points as of October 1929, were from 50 to 100 feet at McFarland and from 50 to 75 feet in the vicinity of Wasco and Shafter. If auxiliary pumping were practiced in the adjoining canal-served area, from which replenishment is now largely received, these declines in water level would be further increased.

The data for this unit indicate that even the 40-year average seasonal inflow under present conditions of water supply development and utilization would have been entirely inadequate to meet the water requirements of this area. The propriety of including these pumping areas in an immediate initial project for importing supplemental water supplies to this unit may be questioned inasmuch as earlier studies of the Kern River area for a local project indicate that, if properly utilized through the combined medium of surface and ground water storage, the run-off of Kern River is adequate to serve all the area lying within the outlines of existing canal systems and dependent more or less directly thereon for a water supply. However, the existing status of the recognized diversion rights on this stream is such that, without construction of a complete system of regulatory works and some adjustment of present rights, no additional water could be furnished to remedy the conditions of receding ground water underlying the pumping areas of McFarland, Wasco and Shafter, which lie outside the Kern River alluvial fan and within that of Poso Creek.

Moreover, as will be shown subsequently, no additional utilizable water supply could have been obtained by the additional provision of storage regulation on Kern River during the period 1917–1929; and the cost of water imported from the San Joaquin River would be less than the cost of new water which would be developed on Kern River from the run-off that would have been available during the 40-year period 1889–1929 by combining the fullest practicable amount of surface storage regulation with underground storage and pumping. It is concluded, therefore, that this area is one requiring an imported supplemental water supply.

The Rosedale Unit—The Rosedale unit, lying between the McFarland-Shafter unit and Kern River, is one served by supplemental gravity and pumped supplies. Being adjacent to Kern River and traversed by an extensive canal system, it is subject to heavy recharge and large outflow to the west. While some lowering of the water table has occurred during the recent dry years, the long-time average available inflow is far in excess of that required to support existing development. In earlier years of plentiful water supply, a considerable portion of this unit was subject to water-logging. After a lowering of about 10 feet during the 8-year period of record, the depth to ground water in the main portion of the area is about 20 feet. The data show that there is no permanent shortage of supply in this unit.

Canal-Irrigated Area South of Kern River—South of the Kern River lies an agricultural area of some 100,000 acres which for forty years has been in the same general state of irrigation development. This area is served from Kern River under diversion rights of varying priorities with a water supply which, if uniformly distributed and intensively utilized, would be adequate to support existing development. The ground water problem in this area is one of drainage. With the recent series of dry years the ground water is at a depth 10 feet from the ground surface.

At the eastern edge of the foregoing canal-irrigated area, but separated from the main body of that area by the alkali-impregnated topographic trough of the old South Fork channel, lies the East Side Canal area of 16,000 acres. Of this area, some 6200 acres of service right lands in the past 30 years have received by diversion from Kern River an average gross water supply of four acre-feet per acre. A similar area is served solely from ground water sources and supplemental pumping is practiced on much of the service right area. While lowering of from 5 to 10 feet in the water table has occurred during the period of record, due to subnormal inflow, the average supply is considered adequate to maintain existing irrigation development under both canal and pumping service. Therefore, it is not considered as an area requiring a supplemental supply.

The Edison-Arvin Unit—Contiguous on the east to the area served by the East Side Canal lies the Edison-Arvin unit. This unit includes in its southern portion the entire area developed under pump irrigation on the cone of Caliente Creek and around the town of Arvin. In its northern portion it includes the citrus development around Edison and the area devoted to both citrus and deciduous fruits extending o both sides of the Southern Pacific Railroad from Edison westward past Magunden toward Bakersfield. The area irrigated in 1929 totaled 20,000 acres, consisting of 1000 acres of citrus and 4000 acres of deciduous fruits, 7500 acres of vines, 4000 acres of alfalfa, 3000 acres of cotton and 500 acres of truck. The principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek. The existence of a cone of depression under this area, caused by heavy pumping draft during the past 5 years, has lowered the water table to an elevation below that under the East Side Canal 3 miles away. This condition can not long continue without appreciable movement of ground water probably occurring from the canal area to the Arvin area. The total irrigation development under pumping on the Caliente Creek fan is 17,400 acres and the long-time mean yield of the tributary drainage area is 37,000 acre-feet. During the period of ground water record, 1920–1929, the average seasonal inflow from Caliente Creek is estimated as 22,900 acre-feet and under these conditions there has occurred a lowering of from 10 feet to 30 feet with resulting depths, as of October 1929, varying from 70 feet near the East Side Canal to 200 feet at the eastern limit of the development. The data indicate that, while the 40-year average inflow shows a slight excess over the mean requirement, the 20-year average inflow is inadequate for a full supply. The northern portion of this unit, the area of permanent deficiency, can not avail itself of any of the local supply from Caliente Creek because of its relative elevation and impervious subsoil. The lack of ground water movement from the developed area around Arvin to that around Magunden and Edison is indicated on Plate VIII, which shows a slight raise in the water table underlying the unirrigated area which separates the cones of depression underlying each of the developed areas.

A study of the geologic, run-off and ground water conditions of the Magunden-Edison area indicate that the principal source of replenishment is from the apex of the delta cone of the Kern River as that stream passes beyond the impervious toe of Kern Bluffs at Bakersfield, and from the East Side Canal. From Bakersfield to the bottom of the ground water depression underlying this development, the water table descends 50 feet in 7 miles. From the East Side Canal the fall is about 6 feet in 2 miles. These slopes indicate some movement of ground water, but they have been created by a total lowering of 20 feet for the period of record, 1920–1929. This movement, however, is inadequate to support the existing development. It is estimated that a net area, consisting of 1000 acres of citrus fruits and 1600 acres of olives and deciduous fruits in the Magunden-Edison area, is in need of a supplemental supply of 2 acre-feet per acre, or a seasonal total of 5200 acre-feet.

Other Areas Studied—In selecting areas in need of immediate relief, those used for annual crops under canal irrigation varying in adequacy from year to year and those of high ground water, where good opportunities are afforded for pumping development, have not been included. Within these excluded classes fall Kern County areas in the Buena Vista Water Storage District, Pioneer Canal area, Buttonwillow and Semitropic ridges and the canal-irrigated areas above discussed in the McFarland-Shafter unit.

The Kings County Canal area also falls in these classes. It lies immediately south of the Kings River channel and contiguous to the Kaweah unit on the west. The gross area is 159,000 acres served by gravity waters from the Kings River under the diversion rights of the Peoples, Last Chance and Lemoore canals. The water supply has been sufficient to cause high ground water under much of the area. Some supplemental pumping of ground water supplies has been practiced in recent years, but has not attained proportions comparable with the upper Kings River areas. During the recent years of subnormal run-off the water table has receded somewhat. In the fall of 1929, depths to ground water varied from 10 to 15 feet. In normal years drainage would be beneficial to this area.

The Tulare Lake area, which is here used to include the total area of the Corcoran and Lakelands irrigation districts and Tulare Lake Water Storage District, for the most part also falls in these classes. It is served by water diverted from the Kings and Kaweah rivers mainly at high stages. Due to the deficiency of water supply during the recent series of years of subnormal run-off and the menace of floods in years of large run-off, the bed of Tulare Lake, which has for the most part been reclaimed by levees, is devoted chiefly to grain farming. On the higher lands lying principally in the Corcoran District, cotton is the predominating crop with smaller areas of alfalfa and grain. The cropped areas vary considerably from year to year. The area irrigated in 1929 totaled 71,300 acres, consisting of 12,650 acres of grain, 2960 acres of alfalfa, 360 acres of field crops and 15,850 acres of cotton in the Corcoran District; 4320 acres of grain and 160 acres of alfalfa in the Lakelands District; and 34,100 acres of grain, 200 acres of alfalfa and 700 acres of cotton in areas outside of these districts. Ground water supplies in the Tulare Lake area are obtained mainly from the deeper strata. In this area artesian wells formerly were obtainable. The formation is considered relatively nonabsorptive and a definite natural barrier along the eastern rim seems to resist ground water movement into the area from the east. The depth to ground water in wells in June of 1929 was about 100 feet, as compared with that of 30 feet in the area just east of Corcoran on the outer Tule Delta. This area could be adequately served either from the Kings River, if regulated, by means of pumping and surface supplies or from the excess ground water supplies which could be made available on the lower edge of the Kaweah and Tule deltas under the plan of immediate initial development.

There is a large irrigated area lying north of the lower Kings River and southwesterly of the Fresno and Consolidated irrigation districts which also comes within the classes noted. It is supplied by gravity diversion chiefly from Kings River and by pumping from wells and natural drains. This area is divided into organized districts and groups namely, Laguna Irrigation District, Riverdale Irrigation District, Crescent Irrigation District, Cuthbert-Burrel lands, Stinson Irrigation District, Residual Murphy Slough group, James Irrigation District and Tranquillity Irrigation District. The total gross area included within these districts and groups is about 135,000 acres. The area irrigated in 1929 was 69,000 acres.

The Laguna and Riverdale irrigation districts include the lands between the north bank of Kings River and Murphy Slough. Pumping was begun in this area in recent years and the former high water table appears to be under control. The average depth to ground water in the fall of 1929 was from 10 to 15 feet. The Crescent Irrigation District is situated west of the Riverdale area. Cuthbert-Burrel lands, Stinson Irrigation District and Residual Murphy Slough group are to the north of these areas. Farther north, and adjacent to Fresno Slough, are the James and Tranquillity irrigation districts. All of these areas divert water from Kings River at the higher stages of flow. Supplemental pumping from ground water is practiced when river water is not available. The James and Tranquillity irrigation districts also exercise diversion rights on the San Joaquin River by pumping water backed up Fresno Slough by the Mendota Weir. The James Irrigation District operates both deep wells within the district and shallow wells in the general area of undeveloped land between Fresno Slough and the Fresno Irrigation District. With an estimated mean seasonal pumping draft of 17,000 acre-feet from a battery of shallow wells during the period 1921–1929, a maximum lowering of ground water of 10 feet and an average depth to water table of 20 feet has resulted. The draft of 1929 has been estimated at 24,000 acre-feet. The obvious source of replenishment of these underground supplies is the ground water outflow from the Fresno Irrigation District.

Within the foregoing areas lying north of the lower Kings River, notably under some canals of late priority of diversion right on Kings River serving lands adjacent to the valley trough, are developed lands dependent in part upon ground waters of considerable mineral content. During recent years of deficient canal supply (normally depended on to counteract the toxic effect of the use of mineralized ground waters) some portions of these areas have been insufficiently supplied with fresh water. It is considered possible that portions of these areas may require relief, both for the restoration of soil conditions and relief of ground water draft. This could be afforded through additions of fresh water to their present available surface supplies to overcome the harmful effects of recent increases in the use of ground water.

Estimation of Relative Deficiencies in Water Supply—The depletion of ground water storage during a certain period of years, the amount of which can be ascertained, for an area under irrigation development is not an absolute measure of the degree of water supply shortage, nor is it proof that the area is one of deficient water supply. Several other factors influence the determination of the adequacy of the available supply. A comparison must be made of all elements of supply and demand for the period during which the estimated depletion took place, with similar elements for other periods of record. Continuous records during the 8-year period 1921–1929 of ground water elevations, irrigated areas and water inflow, for the various units of the upper San Joaquin Valley, have made it possible to estimate the depletion of ground water storage for each, and the average seasonal inflow required to maintain the balance between supply and draft.

This period is established by records as one of subnormal run-off in all local streams. As the estimated ground water depletion occurred under conditions of subnormal supply, it is necessary also to determine how much depletion, if any, would have occurred during periods of more plentiful supply, and what the average conditions of supply and draft would have been during longer periods of stream flow record.

In Table 140 there have been set forth for each ground water unit, the average seasonal depletion of ground water which occurred during the 8-year period 1921–1929, the estimated average seasonal inflow which would be required to prevent continuous depletion or in other words the total seasonal water requirements under present conditions, and, for comparison with that requirement, the estimated average utilizable seasonal inflow to each ground water unit for each of the 40, 20, 8 and 5-year periods. The factors used in estimating the relative deficiencies in water supply of the various ground water units are shown in Table 141. For each unit there are set forth for the period 1921–1929 the average irrigated area, the average seasonal lowering of ground water, the required average seasonal inflow to prevent depletion and the average seasonal ground water depletion, expressed in total acre-feet, acre-feet per acre of irrigated area and in per cent of required average seasonal inflow to prevent depletion.

Units now under development having comparatively small lowering of their ground water levels and an average seasonal inflow for the 20-year period 1909–1929 adequate for complete replenishment thereof, are considered to have no permanent deficiencies of water supply even

TABLE 141

FACTORS USED IN ESTIMATING RELATIVE DEFICIENCIES IN WATER SUPPLY OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY, 1921-1929

Unit	Average area irrigated, in acres	Average seasonal lowering of ground water, in feet	Required average seasonal inflow to prevent depletion, in acre-feet[1]	Average seasonal ground water depletion		
				Total acre-feet	Acre-feet per acre of irrigated area	Per cent of required average seasonal inflow to prevent depletion
Madera	69,000	1.4	172,400	61,000	0.88	3[illegible]
Alta-Foothill[3]	16,000	------------	32,000	32,000	2.00	10[illegible]
Kaweah	133,700	2.3	342,800	92,000	0.69	2[illegible]
Lindsay	22,000	6.9	44,000	19,000	0.86	4[illegible]
Tule-Deer Creek	67,400	2.8	148,300	56,000	0.83	3[illegible]
Earlimart-Delano	21,200	4.2	52,800	50,000	2.36	9[illegible]
McFarland-Shafter	50,100	3.1	99,900	61,000	1.22	6[illegible]
Magunden-Edison	2,600	------------	5,200	5,000	2.00	10[illegible]
Fresno-Consolidated	319,900	0.8	608,000	[2]71,000	0.22	1[illegible]
Alta—						
Including 5,000 acres of rim land	79,000	1.4	153,900	20,000	0.25	1[illegible]
Excluding 5,000 acres of rim land	74,000	------------	143,900	10,000	0.14	
Rosedale	12,000	1.3	55,700	9,000	0.75	1[illegible]
Edison-Arvin—						
Including 2,600 acres in Magunden-Edison	18,600	2.9	36,600	13,000	0.70	3[illegible]
Excluding 2,600 acres in Magunden-Edison	16,000	------------	31,400	8,000	0.50	[illegible]

[1] Sum of average seasonal depletion and average seasonal inflow.

[2] Includes present known outflow of about 17,000 acre-feet supplying lands in James Irrigation District, for whic a supplementary supply is provided in plan of proposed immediate initital development.

[3] Comprises area of 11,000 acres in Foothill Irrigation District and 5,000 acres of rim lands in Alta Unit.

though the records of the 1921–1929 period indicate ground water depletion. A study of the data in Tables 140 and 141 shows that the Fresno-Consolidated Unit, Alta Unit (excluding 5000 acres of rim land) and Rosedale Unit fall under this criterion. The Edison-Arvin Unit, excluding 2600 acres in the Magunden-Edison area, also is placed in this classification although the estimated average inflow into the unit for the 20-year period is slightly less than the estimated required average inflow to prevent depletion under present requirements. However, the average inflow, as estimated for a 25-year period, 1904–1929, appears adequate to support existing development.

Units underlain with impervious material and having practically no means of replenishment of ground waters are considered as having a deficiency of a total net use of two acre-feet per acre of irrigated land. An area of 11,000 acres in the Foothill Irrigation District, 5000 acres on the eastern rim of the Alta Irrigation District and 2600 acres in the Edison-Arvin ground water unit, designated as the Magunden-Edison unit, are considered in this class. These areas have no local inflow. The Lindsay Unit of 22,000 acres also falls in this classification, but its requirement is partially met by the annual importation of about 14,000 acre-feet of water pumped from the Kaweah Delta.

Units for which the records show a lowering of ground water levels and a net use or a required average seasonal inflow to prevent depletion exceeding the 20-year average seasonal inflow are considered as areas of permanent deficiency in local supply. The units in this classification are Madera, Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter.

Areas and Amounts of Deficient Water Supply and Required Importations of Supplemental Water—Based upon the foregoing considerations, it is concluded that the ground water units in the upper San Joaquin Valley requiring an imported supplemental water supply to meet the deficiencies in supply for present developed areas therein are those given in Table 142 and delineated on Plate LXVIII. The table sets forth the amount of average seasonal deficiency during the period 1921–1929 for each unit. The figures in the table for irrigated areas are for 1929, except those for the Kaweah and Tule-Deer Creek units, which are the average areas irrigated during the eight-year period 1921–1929.

TABLE 142

DEFICIENCIES IN WATER SUPPLY IN GROUND WATER UNITS IN UPPER SAN JOAQUIN VALLEY REQUIRING IMPORTED SUPPLIES

Ground water unit	Irrigated area, in acres	Average seasonal deficiency, 1921-1929, in acre-feet
Madera	81,000	61,000
Alta-Foothill	16,000	32,000
Kaweah	133,700	92,000
Lindsay	22,000	30,000
Tule-Deer Creek	67,400	56,000
Earlimart-Delano	30,500	50,000
McFarland-Shafter	49,800	61,000
Magunden-Edison	2,600	5,000
Totals	403,000	387,000

Lands under canal service of late priority in the Kings River area lying north of the Kings River along the valley trough and partially dependent upon ground water of considerable mineral content are omitted from the summary, but are included in the area for immediate relief in the allotment of imported water supplies as subsequently presented, not because of a shortage of water particularly, but because of the harmful quality of the ground water supply. These lands need an additional surface supply of fresh water for the restoration of soil conditions and relief of ground water draft.

The average total seasonal deficiency in supply for the period 1921–1929, as set forth in the summary, is estimated at 387,000 acre-feet. The maximum deficiency in one season was about 680,000 acre-feet in 1928–1929. The minimum seasonal deficiency was about 100,000 acre-feet in 1921–1922, excluding the figures for the Madera and Kaweah units which had a surplus in that season.

The provision of imported supplemental water supplies in amounts equal to the average seasonal deficiencies for each unit would meet the water requirements during a period of run-off the same as that of 1921–1929 and would result in ground water conditions the same at the end of the period as at the beginning thereof. However, if the run-off were more subnormal than that of the period 1921–1929, there would be a further lowering of ground water levels unless larger amounts of supplemental water supplies were imported. Looking ahead to the consummation of a plan of relief, it appears evident that the importation of supplemental water supplies sufficient only to meet the present average deficiencies would not be an adequate remedy for the areas of deficiency because it would not correct the present unfavorable conditions of excessive pumping lift. In addition to meeting present deficiencies, economic considerations point to the necessity of providing for replenishment of underground reservoirs and the reduction of present pumping lifts. Although local supplies would increase in amount with more normal run-off than during the period 1921–1929, the possibility of the occurrence of wet years can not be anticipated with certainty. It is desirable that plans for relief should provide for importation of supplemental water supplies sufficient in amount not only to meet the average deficiency based upon a subnormal period of run-off such as 1921–1929 but also to furnish additional water sufficient in amount to provide with certainty for substantial ground water replenishment. Furthermore it might be desirable and economical to provide for supplemental supplies in those areas not classed as ones of permanent deficiency, as for example the Fresno-Consolidated and Alta units. Therefore, to meet the deficiency in supply and to provide for ground water replenishment, it is estimated that average seasonal importations of supplemental water amounting to from 500,000 to 600,000 acre-feet should be provided as a minimum requirement.

Progressive Steps in Plan for Initial Development.

The plan for initial development in the San Joaquin River Basin has been considered in two steps:

First—A plan of development which would provide an average seasonal supplemental supply to the upper San Joaquin Valley of 500,000 to 600,000 acre-feet during the period 1921–1929, which is considered to be the minimum amount of supplemental water supply which would adequately meet the needs of present developed areas. This first step in the initial development has been designated as the "immediate initial" development.

Second—A plan of development which would furnish a greater amount of supplemental water supply than the minimum amount considered necessary in the "immediate initial" development, and which would provide with greater certainty for the complete relief of present developed areas in the upper San Joaquin Valley, for more substantial ground water replenishment and for expansion of irrigated areas on lands adjacent to present developments in accord with reasonable anticipations of growth in the near future. This second step in initial development has been designated as the "complete initial" development.

For the first step designated the "immediate initial" development, supplemental water supplies in the amount required as a minimum for present developed areas in the upper San Joaquin Valley could be obtained, as studies subsequently presented will show, either from the San Joaquin River alone by regulation of surplus water and water now put to inferior use on this stream, or from the combined sources of surplus water regulated on the San Joaquin River and water imported from Sacramento River Basin sources.

For the "complete initial" development however, imported supplemental water supplies would be required from the Sacramento River Basin because it is the only dependable source of surplus water adequate in amount during a subnormal period of run-off such as 1917–1929 to provide the amount of supplemental water supply required for complete initial development.

In the following portion of this chapter, consideration is given first to alternate plans for "immediate initial" development followed by the presentation of plans for a "complete initial" development.

Alternate Sources of Supplemental Water Supply and Plans for Immediate Initial Development.

In the formulation of a plan to furnish the foregoing estimated average seasonal supplemental supply of 500,000 to 600,000 acre-feet required to meet the deficiencies and to provide for ground water replenishment in the developed areas in need of immediate relief in the upper San Joaquin Valley, many alternative plans have been investigated and studied. These studies have involved estimates of water yield from various sources, estimates of cost and economic analyses of cost of supplemental water supplies delivered to the land.

The following sources of supplemental supply and plans for obtaining the same were investigated:

1. Surplus waters of east side tributaries of the lower San Joaquin River.
2. Development and regulation of local surface supplies on major streams of upper San Joaquin Valley.
3. Supply from San Joaquin River obtained by means of exchange for water imported from Sacramento River Basin.
4. Supply from San Joaquin River obtained from surplus waters and by purchase of "grass land" rights along San Joaquin River.

Inquiry was made as to the possibility and feasibility of obtaining a supply from the surplus waters of the east side tributaries of the lower San Joaquin River. After a study of the conditions on these streams, it appeared evident that it would not be feasible to export water from those sources because all existing surplus water on these streams is a part of the present supply for salinity control and consumptive use in the San Joaquin Delta. Furthermore, such amounts of surplus water now existing on these streams as could be made available for use in other localities by the substitution of a new water supply in the San Joaquin Delta would be required ultimately for the irrigation of the undeveloped lands in the lower San Joaquin Valley. Therefore, further consideration was not given to the possibility of obtaining a supply from those sources.

Study was given to the possible further development and regulation of the local water supplies of major streams in the upper San Joaquin Valley as contemplated under the plan for ultimate development. Utilizable water supplies in addition to the amounts now available without surface storage regulation could be obtained on the average over a long period of years from the Kern, Tule, Kaweah and Kings rivers by the construction of surface storage reservoirs on those streams, operated in combination with underground storage and pumping. However, a detailed study of the water supplies for the critical period 1917–1929 shows that the utilizable supply which could have been made available during that period by provision of surface storage regulation would be increased only a relatively small amount on Kings River; and, on the other three streams, would not be increased but, on the contrary, would be decreased because of reservoir evaporation. Table 143 shows the average seasonal amounts and the costs per acre-foot of new utilizable yield which could have been made available by surface storage regulation on these streams, both for the 40-year period 1889–1929 and for the shorter period 1917–1929. The total new utilizable yield from the four local sources practicable of development is 433,000 acre-feet per season, on the average, for the 40-year period 1889–1929 and only 45,000 acre-feet for the 12-year period 1917–1929. During the shorter period, no new water could have been developed for utilization on the Kern, Tule and Kaweah rivers and only 50,000 acre-feet per season on the average on Kings River. Based on the average

TABLE 143

AMOUNTS AND COSTS OF NEW UTILIZABLE YIELD BY SURFACE STORAGE REGULATION ON LOCAL MAJOR STREAMS IN UPPER SAN JOAQUIN VALLEY

Stream	Reservoir	Capacity of reservoir, in acre-feet	Seasonal new utilizable yield, in acre-feet		Cost per acre-foot of new utilizable yield			
			Average for period, 1889-1929	Average for period, 1917-1929	For period, 1889-1929 Capital	For period, 1889-1929 Annual	For period, 1917-1929 Capital	For period, 1917-1929 Annual
Kern River	Isabella	338,000	58,000	—1,000	$98 28	$5 86		
Tule River	Pleasant Valley	39,000	26,000	—3,000	111 54	6 58		
Kaweah River	Ward	100,000	43,000	—1,000	188 37	11 33		
Kings River	Pine Flat	400,000	306,000	50,000	31 37	1 88	$192 00	$11 48
Totals		877,000	433,000	45,000				

new utilizable yield for the 40-year period 1889–1929, the capital cost per acre-foot of new water ranges from $31.37 for the Kings River to $188.37 for the Kaweah River. For the 12-year period 1917–1929, the capital cost for the Kings River is $192.00 per acre-foot. The annual costs per acre-foot range from $1.88 for the Kings River to $11.33 for the Kaweah River, based on the 40-year period. Based on the 12-year period, the annual cost for the Kings River is $11.48.

In evolving the plan for the ultimate development of the Great Central Valley, including the upper San Joaquin Valley, the water supply studies were based on the run-off of the streams for the 40-year period 1889–1929 because the run-off for this period was considered to be representative of the probable water supply that might be expected over a long period of years and it was concluded that it was proper that such a long period should be considered in analysis for the estimation of the yield of the reservoirs, both surface and underground. For the plan of immediate development in the upper San Joaquin Valley, on the other hand, it was concluded that the period 1917–1929, a period of subnormal run-off, should be used as the basis of water supply studies because an emargency exists in that area which demands immediate attention and relief; and therefore, regardless of the run-off character of the seasons of the immediate future, the water supply should be estimated on the basis of a dry period of record. Hence, in comparing available amounts and unit costs of supplemental water supplies from the several alternate sources considered, the run-off of each stream for the 12-year period 1917–1929 has been used instead of that for the 40-year period 1889–1929 as the basis of water supply. With the foregoing criteria as a guide, it may be seen that the amount of new utilizable water obtainable by surface storage development on the four major streams of the upper San Joaquin Valley south of the San Joaquin River is less than one-tenth of that required to meet the needs of the irrigated areas in distress in that region. Furthermore, the utilizable supply would be entirely from the Kings River. The annual cost of the new utilizable yield from this source would be $11.48 per acre-foot at the dam, including no costs for conveyance to areas of use. It will be shown in a later discussion that this figure exceeds the cost of water from other sources. Under a great number of diversion rights, Kings River water is used now to irrigate more than a half million acres of highly developed lands which are experiencing a temporary deficiency in surface supplies. It would appear, therefore, to be infeasible and probably legally impracticable to divert any water from the Kings River for use on other areas. Due to these conditions it is concluded that surface storage development and regulation of local surface water supplies on the four major streams of the upper San Joaquin Valley would not solve the problem of immediate relief.

Two other sources of supplemental supply were investigated. One is Sacramento River and other waters tributary to the Sacramento-San Joaquin Delta and the other is the surplus and "grass land" waters in the San Joaquin River. The use of water from the San Joaquin River alone or from the San Joaquin and Sacramento rivers combined, as a source of supplemental water supply for importation into the areas of deficiency in the upper San Joaquin Valley, involves units for initial development of the State Water Plan in the Sacramento River Basin which would be required to provide for immediate requirements in the

Sacramento River Basin as well as required supplemental water supplies for the San Joaquin River Basin. As previously stated, the use of existing surplus water supplies from the San Joaquin River which are now available to the Sacramento-San Joaquin Delta would require the replacement in the delta of such supplies by Sacramento River water. Moreover, although the amount of water that will be subsequently shown could be made available from regulation of surplus waters and waters now put to inferior use on the San Joaquin River probably would provide an adequate supply to satisfy the immediate needs for supplemental water in the upper San Joaquin Valley, it could not be certain in the future that there will not be seasons or periods of run-off even more subnormal than during the period 1917–1929 on which water supply studies have been based. Water in addition to the amounts that could be made available from the San Joaquin River from existing surpluses and water now put to inferior use may be required to meet the needs of present developed areas and provide for adequate ground water replenishment. Furthermore, it appears proper that some provision in the plan should be made for expansion of irrigated areas on lands adjacent to present developments which may be reasonably anticipated in the future. Therefore, provision should be made for exportation of supplemental water supplies from the Sacramento River Basin in order to make available a full and dependable water supply which will completely and adequately meet the immediate future needs of the upper San Joaquin Valley. In addition to the supplemental water supplies required from Sacramento River Basin for completely and adequately meeting the needs of the upper San Joaquin Valley, the requirements of the San Joaquin Delta region in the lower end of the San Joaquin River Basin must be supplied under initial development from Sacramento River sources. Whether or not water is exported from Sacramento River Basin sources to the San Joaquin Valley, the requirements of the San Joaquin Delta and adjacent uplands, together with the Sacramento Delta, would be supplied under the plan of initial development from the Sacramento River Basin. Under the proposed initial plan of development, regulated supplies would be released from the initial storage unit, Kennett Reservoir on the Sacramento River, to supplement the unregulated inflow into the delta from both the Sacramento and San Joaquin river systems to provide a full supply for the consumptive needs of the delta and adjacent upland areas and to maintain fresh water at all times in the delta channels by controlling saline invasion from the bay at the lower end of the delta. The supply furnished would provide for the replacement of any surplus water of the San Joaquin River now available to the delta which the initial plan of development would divert for use in the upper San Joaquin Valley.

The controlling elements governing the selection of a plan of immediate initial development for the upper San Joaquin Valley are:

1. The quantity and characteristics of water supply to be secured thereby.
2. The cost of water, delivered to the land.
3. The degree of provision for expansion by enlargement and extension, as may be required, in accordance with the provisions of the complete initial and ultimate plans of development.

Alternate Plans Investigated. Many plans have been studied and analyzed for importing supplemental water supplies from San Joaquin and Sacramento river sources into the areas of deficiency in the upper San Joaquin Valley for an immediate initial development. Of these, six have been chosen for presentation. Two plans, Nos. I and II, would import water from the Sacramento-San Joaquin Delta in combination with regulation and utilization of San Joaquin River water. Four plans, Nos. III, IV, V and VI, would utilize certain surplus and "grass land" waters of the San Joaquin River. In all of these plans, it is assumed that adequate storage would be provided in the Sacramento River Basin, and operated to provide the water requirements for consumptive use and control of saline invasion in the Sacramento-San Joaquin Delta; and, in the case of Plans Nos. I and II, to provide adequate additional supplies in the delta for exportation to the San Joaquin Valley. In the financial comparison of the six plans, no costs are included for the Sacramento River Basin storage, which would be required to be constructed before exportation from the delta could be effected. Also, it is assumed that such storage necessarily must be constructed and operated for salinity control and consumptive use requirements in the delta before any exportation of surplus and "grass land" water would be permitted from the upper San Joaquin River.

A brief description and an enumeration of the units included in the six alternate plans considered for immediate initial development are given in the following paragraphs. The data briefly summarized herewith are based upon detailed month by month studies of water supply and operation of the units, cost estimates of all units of each plan, and cost of delivery and utilization of water.

Plan I

The units included in Plan I are as follows:

1. Sacramento-San Joaquin Delta Cross Channel.
2. San Joaquin River Pumping System—capacity, 3000 second-feet.
3. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
4. Madera Canal—capacity, 1500 second-feet.
5. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the Friant Reservoir, Madera Canal and San Joaquin River-Kern County Canal to Kern River, would be constructed to ultimate capacities and the San Joaquin River Pumping System to the capacity required for complete initial development. Under this plan, the "grass land" rights on the San Joaquin would not be purchased. With this plan in operation, portions of the irrigated areas, both crop and grass lands now served by San Joaquin River water in the lower San Joaquin Valley, would be furnished with an imported water supply by means of the San Joaquin River Pumping System in substitution for water diverted at Friant to the upper San Joaquin Valley, except during periods when there would be excess waters passing Friant dam. The areas of deficiency in the upper San Joaquin Valley would be furnished a full supplemental water supply from Friant Reservoir in accord with the irrigation demand in the amount of 602,000 acre-feet each season, based upon the run-off for the period 1917–1929. The lands now under irrigation along the San Joaquin River above Mendota would be furnished a supply from the Friant Reservoir. The works proposed under this plan would permit the diversion of the entire San Joaquin River at Friant, if the "grass land" rights, on the San Joaquin River above the Merced River, should be purchased, thus making it the same as the plan for "complete initial" development subsequently presented. In estimating the cost of the plan, one-half of the cost of the Sacramento-San Joaquin Delta Cross Channel and a sum of $1,000,000 for general expense and water rights are included.

Plan II

The units included in Plan II are as follows:

1. Sacramento-San Joaquin Delta Cross Channel.
2. San Joaquin River Pumping System—capacity, 1000 second-feet.
3. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
4. Madera Canal—capacity, 1500 second-feet.
5. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek, 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the Friant Reservoir, Madera Canal, San Joaquin River-Kern County Canal and Magunden-Edison Pumping System would have the same respective capacities as under Plan I. The San Joaquin River Pumping System, however, would have a capacity of only 1000 second-feet to Los Banos and 500 second-feet to Mendota. As in Plan I, the "grass land" rights on the San Joaquin River would not be purchased. The supply for the "grass lands" would be furnished by the San Joaquin River Pumping System, making available for regulation at Friant Reservoir the water now used for this purpose. A seasonal irrigation supply of 604,000 acre-feet on the average would be made available based on the run-off for the period 1917–1929. This water, however, would not be in complete accord with the irrigation demand. The characteristics of the supply would be similar to those under Plan VI. A portion of the supply would be delivered outside the irrigation demand for utilization by underground storage and pumping. One-half the cost of the Sacramento-San Joaquin Delta Cross Channel and a sum of $1,000,000 for general expense and water rights, as under Plan I, are included in the cost estimates.

Plan III

The units included in the plan are as follows:

1. Friant Reservoir—gross capacity, 185,000 acre-feet and net capacity, 130,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—Capacity, 500 second-feet.
3. San Joaquin River-Kings River Canal—capacity, 3000 second-feet on low line location, diverting at Friant at elevation 420 feet.
4. Pine Flat Reservoir—gross capacity, 200,000 acre-feet and net capacity, 140,000 acre-feet. Power plant, 34,500 kilovolt-amperes.
5. Kings River-Kern County Canal—capacity, 1000 second-feet, Kings River to Tule River; 750 second-feet, Tule River to Deer Creek; 500 second-feet, Deer Creek to Poso Creek.

Under this plan the "grass land" rights on the San Joaquin River would be purchased. The supplemental supply for the upper San Joaquin Valley would be obtained from that source and the existing surplus in the San Joaquin River at Friant. The San Joaquin River Pumping System is not included as part of this plan. Through the utilization of existing surplus water and water obtained by purchase of the "grass land" rights on San Joaquin River, an average yield of 485,000 acre-feet per season could have been obtained from those sources during the period 1917–1929. Of the water supply which could have been made available, 370,000 acre-feet or 76 per cent would have been in-season and 115,000 acre-feet or 24 per cent, out of season. Of the in-season water, there would have been 140,000 acre-feet of primary yield or 38 per cent in accord with the irrigation demand every season. The water furnished from Friant Reservoir through the San Joaquin River-Kings River Canal would be delivered to the Kings River area, replacing Kings River water now used thereon which would be diverted or stored in Pine Flat Reservoir for subsequent diversion through the Kings River-Kern County Canal serving the areas south of Kings River in the upper San Joaquin Valley. This exchange of supplies would be effected without disturbance of the present Kings River daily flow schedule of diversion rights. The lower diversion elevation from Friant Reservoir decreases the amount of dead storage and the amount of net storage capacity required but decreases the yield of electric energy from the power plant. This plan of lower diversion elevation from Friant Reservoir makes necessary the exchange of supplies at Kings River. The capacities of the Madera and Kings River-Kern County canals in this plan are fixed by the minimum initial delivery requirements. This plan differs from Plans I and II in that the importation canal from Kings River to Kern County terminates at Poso Creek. Therefore, no provision is made for the Magunden-Edison Pumping System. It is assumed that some arrangement would be made locally to supply this area by purchase of water rights now attached to inferior lands or otherwise. A sum of $5,000,000 is included in the cost estimate for the purchase of "grass land" water rights and for general expense.

Plan IV

The units included in this plan are as follows:

1. Friant Reservoir—gross capacity, 325,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—capacity, 1500 second-feet.
3. San Joaquin River-Kings River Canal on low line location diverting at Friant at elevation 420 feet. Capacity, 4000 second-feet.
4. Pine Flat Reservoir—gross capacity, 400,000 acre-feet and net capacity, 340,000 acre-feet. Power plant, 40,000 kilo-volt-amperes.
5. Kings River-Kern County Canal—capacity, 3000 second-feet, Kings River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
6. Magunden-Edison Pumping System—capacity, 20 second-feet.

This plan provides for exchange of water at Kings River as in Plan III. However, greater reservoir capacities are assumed at both Friant and Pine Flat and also larger canal capacities for the Madera, San Joaquin River-Kings River and Kings River-Kern County canals. This plan would effect accomplishments equivalent to those under Plan VI. "Grass land" water rights on the San Joaquin River would be purchased and the water therefrom with surplus supplies regulated by Friant Reservoir. The San Joaquin River Pumping System is not included in the plan. By this plan a greater amount of water would have been obtained than with Plan III. Based on the period 1917–1929, an average of 590,000 acre-feet per season could have been obtained from the "grass land" rights and surplus waters in the San Joaquin River, whereas the comparable figure under Plan III is 485,000 acre-feet. Of this amount, 74 per cent would have been in-season water and 26 per cent out of season. Of the in-season water, there would have been 140,000 acre-feet of primary yield or 32 per cent in accord with the irrigation demand every season. An amount of $5,000,000 is included in the estimates of cost for general expense and purchase of water rights.

Plan V

The units included in Plan V are as follows:

1. Friant Reservoir—Gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilo-volt-amperes.
2. Madera Canal—capacity, 500 second-feet.
3. San Joaquin River-Kern County Canal—capacity, 1000 second-feet, San Joaquin River to Tule River; 750 second-feet, Tule River to Deer Creek; 500 second-feet, Deer Creek to Poso Creek.

In this plan, the "grass land" water rights on the San Joaquin River would be purchased and water therefrom with surplus supplies regulated by Friant Reservoir which would be constructed to ultimate capacity. The Madera and the San Joaquin River-Kern County canals would be constructed to the minimum capacities sufficient to meet the immediate needs. There would be no provision for enlargement in the design of these units. The San Joaquin River-Kern County Canal would terminate at Poso Creek. This plan would serve all areas in immediate need except the Magunden-Edison unit in Kern County. The Magunden-Edison Pumping System would not be constructed. For the 12-year period 1917–1929, the amount of water that could have been supplied from the surplus and grass land waters of the San Joaquin River under this plan would have been 540,000 acre-feet per season on the average. Of this amount, 75 per cent would have been in-season and 25 per cent out of season water. Of the in-season water, there would have been 138,000 acre-feet of primary yield or 34 per cent in accord with the irrigation demand every season. A sum of $5,000,000 is included in the cost estimates to cover general expense and purchase of water rights.

Plan VI

The units included in this plan are as follows:

1. Friant Reservoir—gross capacity, 400,000 acre-feet and net capacity, 270,000 acre-feet. Power plant, 30,000 kilovolt-amperes.
2. Madera Canal—capacity, 1500 second-feet.
3. San Joaquin River-Kern County Canal—capacity, 3000 second-feet, San Joaquin River to Tule River; 2500 second-feet, Tule River to Deer Creek; 2000 second-feet, Deer Creek to Poso Creek; 1500 second-feet, Poso Creek to Kern River.
4. Magunden-Edison Pumping System—capacity, 20 second-feet.

In this plan, the "grass land" rights on the San Joaquin River would be purchased and the water therefrom with surplus supplies regulated by Friant Reservoir. All of the units would be constructed immediately to ultimate capacity. A foundation investment would be made so that future expansion in the upper San Joaquin Valley could take place when it appeared economically desirable.

Based on the 12-year period 1917–1929, 602,000 acre-feet of water per season on the average could have been obtained from the surplus and "grass land" waters of the San Joaquin River with the proposed units of this plan. Of this amount 80 per cent would have been in-season water and 20 per cent out of season water. Of the in-season water, there would have been 138,000 acre-feet of primary yield or 29 per cent in accord with the irrigation demand every season. A sum of $5,000,000 is included in the cost estimates to cover general expense and purchase of water rights.

Capacity of Friant Reservoir for Immediate Initial Development—The capacity of Friant Reservoir for immediate initial development is based upon a detailed month by month study of reservoir operation for the regulation of the water supply that would have been available from surplus waters and grass land rights on the San Joaquin River during the period 1917–1929 to furnish the required supplemental water supplies to the areas of deficiency in the upper San Joaquin Valley and provide the full requirements of present developed areas. The supplemental supplies furnished from Friant Reservoir combined with local supplies would be utilized through the combined means of surface diversion and ground water storage and pumping. The detailed studies of reservoir operation and required storage capacity for initial development were made in a similar manner as those presented for ultimate development in Chapter VI. The reservoir would be operated to deliver as large a surface irrigation supply as possible during the months of peak irrigation demand and in addition provide as much water as possible outside the irrigation season for ground water storage and subsequent pumping. As in the case of ultimate development, the fullest practicable utilization of the underground storage capacity in the upper San Joaquin Valley is essential in order to economically meet the full requirements of present developed areas with the water supplies that would be available. The underground reservoirs afford the only economical and feasible means of providing the cyclic storage required to effect a full utilization of water supplies available for meeting the present requirements.

Briefly summarized, the studies showed that, in order to regulate the available supply from surplus waters and grass land rights on the San Joaquin River during the period 1917–1929 to provide an average seasonal supplemental water supply of from 500,000 to 600,000 acre-feet during this period, a net storage in Friant Reservoir of 110,000 to 130,000 acre-feet would have been required, depending upon the capacity of the San Joaquin River-Kern County Canal. With a capacity of 3000 second-feet for this canal, the required net reservoir capacity would have been 110,000 acre-feet; with a capacity of 1000 acre-feet, 130,000 acre-feet; for approximately equal average seasonal yields of supplemental water. The supplemental supply furnished with these net reservoir capacities would consist largely of out of season water, the utilization of which would require ground water storage and pumping. The amount of in-season water would vary considerably from season to season and would not be sufficient for present needs particularly in nonabsorptive areas.

In order to supply the nonabsorptive areas with the same adequacy as the absorptive areas under a plan for initial development, it was concluded that a full surface irrigation supply should be provided each season in the amount required for the developed lands therein. The nonabsorptive areas would require a surface irrigation supply each season of about 107,000 acre-feet to fully meet the present requirements. In addition it was assumed that the Madera unit, because of rights to acquire San Joaquin River water initiated by the Madera Irrigation District, should be furnished with a surface irrigation supply each season with not less than 31,000 acre-feet in a season of minimum yield. Combining these two requirements for a surface irrigation supply each season designated as a primary irrigation supply, the studies showed that an additional net storage capacity of about 140,000 acre-feet would be required in Friant Reservoir. As stated in the studies presented under ultimate development, the provision of additional storage for obtaining this required amount of primary water supply would not materially increase the average seasonal yield from the reservoir. Based upon this requirement for primary surface irrigation supplies, the required net storage capacity of Friant Reservoir under initial development was determined to be 250,000 and 270,000 acre-feet, respectively, for canal capacities of the San Joaquin River-Kern County Canal of 3000 and 1000 second-feet. The criteria upon which these required net storage capacities in Friant Reservoir are based are particularly applicable to plans II, V and VI. In order to simplify the analyses and also in view of the fact that the net storage capacity of Friant Reservoir found to be required for both complete initial and ultimate development was 270,000 acre-feet, a net storage capacity of this amount was adopted as a basis for estimating the cost and water supply yield of Friant Reservoir under these three plans.

Under Plan I, the same storage capacity was adopted but the water supply considered available for regulation under this plan is larger in amount as it includes some San Joaquin River waters now used on crop lands which would be replaced by waters conveyed through the San Joaquin River Pumping System. Moreover, Plan I differs from plans II, V and VI in that the reservoir was operated to provide a primary surface irrigation supply each year of over 600,000 acre-feet.

Under plans III and IV the capacity of Friant Reservoir is governed to some extent by the proposed plan of exchange on Kings River with storage in Pine Flat Reservoir which involves a different plan of operation for Friant Reservoir than in plans II, V and VI. However, a net storage capacity of 270,000 acre-feet in Friant Reservoir was found necessary under Plan IV to effect accomplishments comparable to plans II and VI.

Cost of Alternate Plans for Immediate Initial Development—Estimates of cost for the six alternate plans for obtaining a supplemental water supply for immediate initial development are presented in summary form in Tables 144 to 149, inclusive, and are consolidated in Table 150. The estimates of the respective plans are strictly comparable both as to type of construction and unit prices used. All estimates are based on the same types of construction as described in Chapter VI for the units of the ultimate State Water Plan. The estimates for the Friant and Pine Flat dams are based on gravity concrete sections, and those of the Madera, San Joaquin River-Kern County canals and canals of the San Joaquin River Pumping System on concrete lined sections. The estimates for the San Joaquin River Pumping System are based on the same type of dams and pumping plants as shown on Plate LVIII. Unit prices for Friant and Pine Flat dams are the same as set forth in Table 66, those of the San Joaquin River Pumping System the same as in Table 105 and those of the Madera and San Joaquin River-Kern County canals the same as in Table 108. The unit prices of construction, set forth in the tables above referred to, are for the items in place and are exclusive of amounts for administration, engineering, contingencies and interest during construction. To each cost estimate there has been added 10 per cent for administration and engineering, 15 per cent for contingencies, and interest for the estimated period of construction at 4.5 per cent, computed on a basis of financing at the beginning of each six months and compounding to the end of the construction period. Annual costs including those for interest and amortization on bonds, depreciation, operation and maintenance have been estimated for each unit. Annual electric energy costs have been estimated for conveyance units having pumping plants. The bases for estimating annual costs are the same as set forth in Chapter VI for storage and conveyance units of the ultimate State Water Plan.

The investment in the Friant power plant is assumed to be amortized in 10 years because, with further possible expansion of irrigation in the upper San Joaquin Valley, the San Joaquin River Pumping System would be installed, and ultimately the entire flow practicable of being utilized would be diverted above the plant.

The values of the electric energy at the power plants of the Friant and Pine Flat reservoirs are based on the cost of producing an equivalent amount of electric energy of the same characteristics with a steam-electric plant located in the area of consumption, taking into account the cost of transmission from point of generation to load centers. The electric energy charges for pumping in the San Joaquin River and Magunden-Edison pumping systems are in accord with the power schedules of the public utilities distributing power in the region in which the systems are located.

The total cost of supplemental water supply at the land under each plan was obtained by adding to the net annual cost at main canal side:

1. The average annual cost of surface distribution of in-season water. A figure has been used of $1.00 per acre-foot for all plans except Plan I. For the latter plan it is assumed that the main distributaries would be concrete lined. This would result in an additional annual cost of $0.25 per acre-foot but would reduce the conveyance losses and pumping installation for reuse. The supply under Plan I is in accord with the irrigation demand every season.

2. The average annual cost of surface distribution of out of season water. This cost is estimated at $0.15 per acre-foot. The cost of operation and maintenance only is included because the same canals would be used for distributing this water as for the in-season water. No charges are included for cost of releasing out of season water into natural channels as it is believed the operation and maintenance charges included in the annual costs of the main canal are adequate to cover any possible costs of such operation.

3. The average annual energy charge for pumping the portion of the supplemental water supply utilized by underground storage and pumping. The unit cost used in the estimates is $0.03 per acre-foot per foot of lift. The total energy charge is calculated on an estimated average lift of 63 feet, including well drawn down, for the absorptive areas of permanent deficiency and the average annual amount which would have been pumped during the 12-year period 1917–1929. The estimated average lift of 63 feet is a weighted average for all areas of deficiency based upon the records of ground water levels during the period 1921–1929. The average gross amount of water pumped is estimated at 125 per cent of the water made available from supplemental supplies for ground water pumping. This factor is based on the assumption that the water

pumped from underground would be applied at a gross rate of 2.5 acre-feet per acre or 25 per cent in excess of the net use requirement. Hence, the energy charges involved in the utilization of water made available for ground water pumping would be based upon the pumping of 125 per cent of the ground water supply for a net use requirement of 2.0 acre-feet per acre. The amount of supplemental water made available for ground water pumping would comprise all the out-of-season water and the amounts of in-season water applied in excess of net use. Under Plan I, with main distributaries concrete lined, the gross application of in-season water is assumed to be at the rate of 2.5 acre-feet per acre. Hence, one-fifth of the gross application would be in excess of net use and would be absorbed underground. Under Plans II to VI inclusive with main distributaries unlined, the gross application of in-season water is assumed to be at the rate of 3 acre-feet per acre, one-third of which would be in excess of net use and would be absorbed underground. These amounts of gross application of in-season water in excess of net use would be utilized by ground water pumping in order to obtain the fullest practicable utilization of supplemental water supply furnished with a resulting net use of 2 acre-feet per acre.

4. The annual fixed charges on wells and pumping plants based on the installation required for a season of minimum ground water pumping. The unit cost used is $0.02 per acre-foot per foot of lift or $1.50 per acre-foot based on a maximum lift of 75 feet, including well draw down, representing a weighted average for all areas of deficiency for the season of lowest ground water levels during the period 1921–1929. The amount of water pumped in a season of maximum ground water pumping which would occur in a season of minimum yield of supplemental water supplies is based upon the assumption that the full net use requirements of the area to be served by supplemental water would be met by pumping from underground all of the supply required that would not be furnished by delivery of in-season water during that season. Under plans II to VI inclusive, the maximum gross amount of water pumped upon which fixed charges are based would be 125 per cent of the difference between the average seasonal supplemental water supply furnished for the entire period and two-thirds of the amount of in-season water actually delivered in the season of minimum yield. Under Plan I, the amount of water pumped would be the same each season.

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TABLE 144

CAPITAL AND ANNUAL COSTS OF PLAN I FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply, 602,000 acre-feet of in-season water each season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Sacramento-San Joaquin Delta Cross Channel (one-half cost)	$2,000,000	$150,000	
San Joaquin River Pumping System. Capacity 3,000 second-feet	15,000,000	1,266,000	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	14,000,900	840,000	
Friant Power Plant—30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
General expense and water rights	1,000,000	56,000	
Totals	$63,400,000	$4,981,000	
Annual costs to main canal side:			
Gross annual cost, exclusive of electric energy for pumping	$4,981,000		
Electric energy for pumping, 147,000,000 kilowatt hours at $0.0055 and 760,000 kilowatt hours at $0.012	818,000		
Gross annual cost, including electric energy for pumping	$5,799,000	$5,799,000	
Revenues from sale of electric energy, 85,500,000 kilowatt hours at $0.0035		300,000	
Net annual cost with deduction for power credit		$5,499,000	
Total cost per acre-foot at main canal side			$9.14
Annual costs main canal side to land:			
Surface distribution of in-season water, 602,000 acre-feet at $1.25 per acre-foot	752,000		
Fixed charges on pumping installation for 150,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	225,000		
Energy charges for pumping 150,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	283,000		
Total annual cost main canal side to land	$1,260,000	1,260,000	
Cost per acre-foot main canal side to land			$2.09
Total annual cost delivered to land		6,759,000	
Total cost per acre-foot delivered to land			$11.23

TABLE 145

CAPITAL AND ANNUAL COSTS OF PLAN II FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply, 484,000 acre-feet of in-season water and 120,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Sacramento-San Joaquin Delta Cross Channel (one-half cost)	$2,000,000	$150,000	
San Joaquin River Pumping System. Capacity 1,000 second-feet	8,000,000	701,000	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	14,000,000	840,000	
Friant Power Plant—30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
General expense and water rights	1,000,000	56,000	
Totals	$56,400,000	$4,416,000	
Annual costs to main canal side:			
Gross annual cost, exclusive of electric energy for pumping	$4,416,000		
Electric energy for pumping 114,400,000 kilowatt hours at $0.0055 and 760,000 kilowatt hours at $0.012	638,000		
Gross annual cost, including electric energy for pumping	$5,054,000	$5,054,000	
Revenues from sale of electric energy, 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$4,687,000	
Total cost per acre-foot at main canal side			$7.76
Annual costs main canal side to land:			
Surface distribution of in-season water 484,000 acre-feet at $1.00 per acre-foot	$484,000		
Surface distribution of out-of-season water 120,000 acre-feet at $0.15 per acre-foot	18,000		
Fixed charges on pumping installation for 488,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	732,000		
Energy charges for pumping 352,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	665,000		
Total annual cost main canal side to land	$1,899,000	$1,899,000	
Cost per acre-foot			$3.14
Total annual cost delivered to land		6,586,000	
Total cost per acre-foot delivered to land			$10.90

TABLE 146

CAPITAL AND ANNUAL COSTS OF PLAN III FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 370,000 acre-feet of in-season water and 115,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost	
Friant Reservoir. Gross capacity 185,000 acre-feet. Net capacity 130,000 acre-feet	$6,500,000	$390,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 500 second-feet	1,500,000	123,000	
San Joaquin-Kings River Low Line Canal. Capacity 3,000 second-feet	5,500,000	448,000	
Pine Flat Reservoir. Gross capacity 200,000 acre-feet. Net 140,000 acre-feet	6,000,000	360,000	
Pine Flat Power Plant. Capacity 34,500 kilovolt-amperes	1,700,000	145,000	
Kings River-Kern County Canal. Maximum capacity 1,000 second-feet	10,800,000	880,000	
General expense and water rights	5,000,000	278,000	
Totals	$38,500,000	$2,846,000	
Annual costs to main canal side:			
Gross annual cost		$2,846,000	
Revenues from sale of electric energy, 90,000,000 kilowatt hours at $0.0035 and 100,000,000 kilowatt hours at $0.0030		615,000	
Net annual cost with deduction for power credit		$2,231,000	
Total cost per acre-foot at main canal side			$4.60
Annual costs main canal side to land:			
Surface distribution of in-season water 370,000 acre-feet at $1.00 per acre-foot	$370,000		
Surface distribution of out-of-season water 115,000 acre-feet at $0.15 per acre-foot	17,000		
Fixed charges on pumping installation for 490,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	735,000		
Energy charges for pumping 298,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	563,000		
Total annual cost main canal side to land	$1,685,000	$1,685,000	
Cost per acre-foot main canal side to land			$3.47
Total annual cost delivered to land		3,916,000	
Total cost per acre-foot delivered to land			$8.07

TABLE 147

CAPITAL AND ANNUAL COSTS OF PLAN IV FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 434,000 acre-feet of in-season water and 156,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Friant Reservoir. Gross capacity 325,000 acre-feet. Net capacity 270,000 acre-feet	$11,100,000	$666,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin-Kings River Low Line Canal. Capacity 4,000 second-feet	6,600,000	538,000	
Pine Flat Reservoir. Gross capacity 400,000 acre-feet. Net capacity 340,000 acre-feet	9,600,000	574,000	
Pine Flat Power Plant. Capacity 40,000 kilovolt amperes	2,000,000	168,000	
Kings River-Kern County Canal. Maximum capacity 3,000 second-feet	19,500,000	1,590,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
General expense and water rights	5,000,000	278,000	
Totals	$57,900,000	$4,258,000	
Annual costs to main canal side:			
Gross annual cost exclusive of electric energy for pumping	$4,258,000		
Electric energy for pumping. 760,000 kilowatt hours at $0.012 per kilowatt hour	9,000		
Gross annual cost, including electric energy for pumping	$4,267,000	$4,267,000	
Revenues from sale of electric energy, 100,000,000 kilowatt hours at $0.0035 and 107,000,000 kilowatt hours at $0.0030 per kilowatt hour		671,000	
Net annual cost with deduction for power credit		$3,596,000	
Total cost per acre-foot at main canal side			$6.09
Annual costs main canal side to land:			
Surface distribution of in-season water 434,000 acre-feet at $1.00 per acre-foot	$434,000		
Surface distribution of out-of-season water 156,000 acre-feet at $0.15 per acre-foot	23,000		
Fixed charges on pumping installation for 621,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	931,000		
Energy charges for pumping 376,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	711,000		
Total annual cost main canal side to land	$2,099,000	$2,099,000	
Cost per acre-foot main canal side to land			$3.56
Total cost delivered to land		5,695,000	
Total cost per acre-foot delivered to land			$9.65

TABLE 148

CAPITAL AND ANNUAL COSTS OF PLAN V FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 407,000 acre-feet of in-season water and 133,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	$14,000,000	$840,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 500 second-feet	1,500,000	123,000	
San Joaquin River-Kern County Canal. Maximum capacity 1,000 second-feet	14,600,000	1,172,000	
Water rights and general expense	5,000,000	278,000	
Totals	$36,600,000	$2,635,000	
Annual costs to main canal side:			
Gross annual cost		$2,635,000	
Revenues from sale of electric energy 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$2,268,000	
Total cost per acre-foot at main canal side			$4.20
Annual costs main canal side to land:			
Surface distribution of in-season water 407,000 acre-feet at $1.00 per acre-foot	$407,000		
Surface distribution of out-of-season water 133,000 acre-feet at $0.15 per acre-foot	20,000		
Fixed charges on pumping installation for 558,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	837,000		
Energy charges for pumping 336,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	635,000		
Total annual cost main canal side to land	$1,899,000	$1,899,000	
Cost per acre-foot main canal side to land			$3.52
Total annual cost delivered to land		4,167,000	
Total cost per acre-foot delivered to land			$7.72

TABLE 149

CAPITAL AND ANNUAL COSTS OF PLAN VI FOR IMPORTING A SUPPLEMENTAL WATER SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Imported supplemental supply 481,000 acre-feet of in-season water and 121,000 acre-feet of out-of-season water, average per season during period 1917-1929

Item	Capital cost	Gross annual cost, exclusive of electric energy for pumping	
Friant Reservoir. Gross capacity 400,000 acre-feet. Net capacity 270,000 acre-feet	$14,000,000	$840,000	
Friant Power Plant. Capacity 30,000 kilovolt amperes	1,500,000	222,000	
Madera Canal. Capacity 1,500 second-feet	2,500,000	213,000	
San Joaquin River-Kern County Canal. Maximum capacity 3,000 second-feet	27,300,000	2,225,000	
Magunden-Edison Pumping System. Capacity 20 second-feet	100,000	9,000	
Water rights and general expense	5,000,000	278,000	
Totals	$50,400,000	$3,787,000	
Annual costs to main canal side:			
Gross annual cost exclusive of electric energy for pumping	$3,787,000		
Electric energy for pumping 760,000 kilowatt hours at $0.012	9,000		
Gross annual cost including electric energy for pumping	$3,796,000	$3,796,000	
Revenues from sale of electric energy 105,000,000 kilowatt hours at $0.0035		367,000	
Net annual cost with deduction for power credit		$3,429,000	
Total cost per acre-foot at main canal side			$5.70
Annual costs main canal side to land—			
Surface distribution of in-season water 481,000 acre-feet at $1.00 per acre foot	$481,000		
Surface distribution of out-of-season water 121,000 acre-feet at $0.15 per acre-foot	18,000		
Fixed charges on pumping installation for 635,000 acre-feet and a maximum average lift of 75 feet at $0.02 per foot acre-foot	952,000		
Energy charges for pumping 352,000 acre-feet for an average lift of 63 feet at $0.03 per foot acre-foot	665,000		
Total annual cost main canal side to land	$2,116,000	$2,116,000	
Cost per acre-foot main canal side to land			$3.51
Total annual cost delivered to land		5,545,000	
Total cost per acre-foot delivered to land			$9.21

TABLE 150

SUMMARY OF CAPITAL AND ANNUAL COSTS OF SIX ALTERNATE PLANS FOR IMPORTING A SUPPLEMENTAL SUPPLY TO AREAS IN UPPER SAN JOAQUIN VALLEY IN NEED OF IMMEDIATE RELIEF

Plan	Capital cost	Average seasonal supplemental water supply for period 1917-1929, in acre-feet			Net annual cost at main canal side		Net annual cost at land	
		In-season	Out-of-season	Total	Total	Per acre-foot	Total	Per acre-foot
I	$63,400,000	602,000	0	602,000	$5,499,000	$9 14	$6,759,000	$11 23
II	56,400,000	484,000	120,000	604,000	4,687,000	7 76	6,586,000	10 90
III	38,500,000	370,000	115,000	485,000	2,231,000	4 60	3,916,000	8 07
IV	57,900,000	434,000	156,000	590,000	3,596,000	6 09	5,695,000	9 65
V	36,600,000	407,000	133,000	540,000	2,268,000	4 20	4,167,000	7 72
VI	50,400,000	481,000	121,000	602,000	3,429,000	5 70	5,545,000	9 21

The foregoing comparison of cost of supplemental water delivered to the land under the six alternate plans considered involves assumptions which are somewhat approximate as related to an actual plan of operation but, since the same approximations are made with respect to each alternate plan, the estimated costs per acre-foot of water delivered to the land are on a fair basis of comparison if due consideration be given to the accomplishments and scope of each plan which differ to some extent. Furthermore, consideration must be given to the fact that certain of the alternate plans do not permit of enlargement readily to meet the demands of ultimate development and, in some cases, even of complete initial development of the upper San Joaquin Valley.

Plan I is not strictly comparable with any of the other plans considered because it provides a supplemental water supply of over 600,000 acre-feet of in-season water in accord with the irrigation demand each season during the period 1917–1929, an entirely different provision than under any of the other plans considered. The result is a higher cost of water delivered to the land than in any of the other plans. It is presented to show how much greater the cost would be if it were considered necessary to furnish the entire amount of required supplemental water every season for utilization chiefly as a surface irrigation supply and with only a minimum amount of ground water pumping.

Plans II, IV and VI are very nearly comparable in accomplishments and scope and, of these, the studies show that Plan VI is the cheapest. If Plan VI were modified so as to terminate the San Joaquin River-Kern County Canal at Poso Creek, the capital cost would be reduced $2,357,000 and the annual cost $195,000. This would reduce the annual cost of water at main canal side to $5.37 per acre-foot and at the land to $8.89 per acre-foot. Moreover, Plan VI is the only one of these three which makes provision for future expansion of irrigation without additional expenditures for enlargement. The capacities of the units provided under Plan VI are the same as those found to be required for both complete initial and ultimate developments and no additional expenditures on these units would be required for future needs.

In Plan II, the San Joaquin River Pumping System would have a maximum capacity of 1000 second-feet as compared to a required capacity for complete initial development of 3000 second-feet. If provision were made in the design of this unit to allow for ready future enlargement, the cost under this plan would increase considerably.

In Plan IV, the units included are adequate to meet the demands for complete initial development but would not suffice for ultimate development. The plan would require modification. This could be accomplished by three possible methods, namely, first: Enlargement of Pine Flat Reservoir to a capacity of about 600,000 acre-feet; second: Enlargement of Friant Reservoir to a gross capacity of 400,000 acre-feet and relocation of the canal between San Joaquin and Kings rivers to the higher location selected for Plans V and VI; third: Importation of additional water from the Sacramento River Basin directly to the upper San Joaquin Valley.

Plans III and V are presented as representing what may be considered "minimum" projects for immediate relief. Neither of these plans make provision for future enlargement to meet the needs of ever complete initial development. In Plan III, no provision is made for the enlargement of the Friant and Pine Flat dams nor for the Madera and Kings River-Kern County Canal, and if such provision were made the cost would be substantially increased. Furthermore, the amount of supplemental water made available under Plan III is smaller than in any of the plans considered and is somewhat less than the minimum amount considered necessary to adequately meet requirements of an initial relief project.

Plan V, although appearing to be the cheapest of any of the plans in cost of water delivered to the land, makes no provision for future enlargement. If provision were made under this plan for initial construction of structures and other facilities which would permit of ready and economical enlargement of the San Joaquin River-Kern County Canal to the capacity required for complete initial development, the capital cost would be increased $5,277,000 and the annual cost $415,000, resulting in an annual cost of water delivered at main canal side of $4.97 per acre-foot and at the land of $8.49.

Plans III and IV differ from all of the other plans considered in one important particular, namely, the provision for exchange of water on Kings River. This plan of exchange was presented in a former report * based upon preliminary studies prior to the more complete investigations and data on which the present report is based. The foregoing economic analyses show that Plan III is greater in cost than the comparable alternate Plan V, and that Plan IV is greater in cost than the comparable alternate Plan VI. However, in addition to the greater cost of Plans III and IV than the alternate plans with comparable accomplishments, these plans also would involve important exchanges of water supplies on Kings River which would be difficult to effect and which are believed at this time to present an insurmountable obstacle in view of the schedule under which the waters of this stream are administered.

Selection of Plan for Immediate Initial Development—The selection of the most desirable plan for immediate initial development in the upper San Joaquin Valley is somewhat complicated because it necessarily involves the consideration of several physical and economic factors relating to future conditions or occurrence which are difficult to evaluate with certainty. The amount of water that would be available for regulation and utilization in future years is uncertain and must be based on past records. If there should occur a series of more subnormal years of run-off than that of the period used, 1917–1929, as a basis for estimating the water supply furnished under each plan, both local and supplemental supplies would be reduced in amount and the accomplishments of relief would be less adequate than estimated. The amount of water supply furnished under each plan involves not only the provision for meeting present deficiencies in water supply, but also and of equal importance the replenishment of the underground reservoirs to decrease pumping lifts and costs which are now excessive. The amount of expansion of irrigated agriculture in the upper San Joaquin Valley and the time at which such expansion may occur are also uncertain. However, studies of past growth and future

* Bulletin No. 9, "Supplemental Report on Water Resources of California—to the Legislature of 1925," Division of Engineering and Irrigation, 1925.

needs of irrigated agriculture in California point to a growth in irrigated agriculture in the future. Finally, it is uncertain by what methods and under what terms an immediate initial project would be financed, and especially what the interest rate and period of bond retirement would be. The cost analyses on the alternate plans were based upon an assumed interest rate of 4½ per cent and amortization of bonds in 40 years. The actual plan of financing effected would have considerable bearing on the choice to be made as between a minimum project for relief such as Plan V, designed to meet only the present needs, or a more adequate project of relief such as Plan VI which would provide with greater assurance for the present needs and allow for future expansion without additional expenditure on the units included therein.

Based upon the data and economic analyses presented with respect to the six alternate plans for immediate initial development and a consideration of present conditions of irrigation development in the upper San Joaquin Valley, the following conclusions are reached with respect to the most desirable plan for adoption.

1. Under Plan V, an adequate supplemental water supply, based upon the period of run-off 1917–1929 considered, could be furnished the 400,000 acres of developed land in need of immediate relief in the upper San Joaquin Valley, excluding the Magunden-Edison area of 2600 acres in Kern County, at a smaller cost than with any other plan investigated.

2. Considering the desirability of providing with greater assurance for adequate and dependable relief to the present developed areas and the reasonable probability of expansion of irrigated agriculture requiring additional water supplies in the future in the upper San Joaquin Valley; and in view of the greater flexibility of operation which would be obtained by the construction of units for immediate initial development of sufficient capacity to meet the needs under complete initial development; it is concluded that Plan VI is the most desirable and meritorious of all plans investigated for immediate initial development. The additional cost of this plan as compared to Plan V is more than balanced by its greater dependability and more assured adequacy for immediate relief and by its provision for probable future growth of irrigated agriculture in the upper San Joaquin Valley without additional expenditures on the units included in the plan.

3. If arrangements could be effected to purchase water rights on the Kern River now attached to inferior lands sufficient in amount to adequately serve the 2600 acres of developed land in the Magunden-Edison unit, the San Joaquin River-Kern County Canal could be terminated at Poso Creek in Kern County. In this manner, the cost of complete relief provided under Plan VI might be decreased. However, due to the present uncertainty of effecting such purchase of water rights, it is concluded that provision should be made for constructing the San Joaquin River-Kern County Canal to a terminus on Kern River in accord with Plan VI thereby insuring a water supply for the relief of the Magunden-Edison area, which would be provided by exchanging water delivered through the canal for Kern River water now used on lower areas served from this stream and thus permitting diversion of Kern River water to the Magunden-Edison unit.

Proposed Plan for Immediate Initial Development.

The plan designated as Plan VI has been selected for immediate initial development. It is the plan which, after careful study, appears to offer the greatest advantage and to be the most desirable for adoption from all viewpoints. The proposed physical units for immediate initial development comprise Friant Reservoir on the San Joaquin River (gross capacity 400,000 acre-feet), the Madera and San Joaquin River-Kern County canals extending northerly and southerly respectively from this reservoir with respective maximum capacities of 1500 and 3000 acre-feet, and the Magunden-Edison Pumping System (capacity 20 second-feet). It is proposed to acquire the "grass land" waters of the San Joaquin River with due consideration for existing rights that may be invaded in the process. Based upon the supplies available during the period 1917–1929, sufficient water would be obtained from this source and the surplus waters of the San Joaquin River, if regulated by surface storage in Friant Reservoir and by underground storage, to provide the supplemental supplies required in addition to available local supplies to meet the immediate needs of the developed areas of deficient water supply in the upper San Joaquin Valley.

The San Joaquin River Pumping System is not included in the immediate initial plan. It is proposed to defer construction of this unit until such time as additional water is found to be required to meet the needs in the upper San Joaquin Valley. The addition of this unit to those proposed for immediate development would complete the project designated as the "complete initial" development subsequently presented in this chapter. However, in setting up a plan of financing for initial development, it is believed that funds should be provided for this unit to insure adequate relief to the upper San Joaquin Valley. It is possible that the run-off occurring in future years might result in a succession of seasons more subnormal than experienced during the period 1917–1929 upon which the studies of water supply have been based. In this event, the amounts of utilizable water, from both local and supplemental sources of supply, that would be available under the proposed plan of immediate initial development might be so much less than the amounts estimated based on the period 1917–1929 that additional supplemental water supplies would be required to adequately meet the needs of present developed areas.* Such additional supplies would have to be obtained from the Sacramento River Basin and would require the construction of the San Joaquin River Pumping System to convey water from the delta to Mendota to supply crop lands in the lower San Joaquin Valley now served from the San Joaquin River, and thus make available more San Joaquin River Water for

* Since the preparation of the studies in this report based upon the run-off up to 1929, the dry season of 1930–1931 has occurred. Studies of water supply and yield under the immediate initial development have been extended to include the period 1929–1931 and are presented in Appendix D. These show that the average amounts of utilizable water supply from Friant Reservoir and from local sources in the upper San Joaquin Valley would be substantially less than those estimated for the period 1921–1929. Of particular importance, the studies showed that ground water replenishment would be inadequate and that present unfavorable conditions of excessive pumping lift and cost would not be permanently improved if a similar period of run-off such as 1921–1931 should be experienced immediately following 1931 and the project were in operation. These studies presented in Appendix D point to the possible necessity of including the San Joaquin River Pumping System in an immediate initial project if adequate relief including ground water replenishment is to be provided.

regulation in and distribution from Friant Reservoir for use in the upper San Joaquin Valley.

The general locations of the physical works both for immediate and complete initial development are shown on Plate XXVI. To further delineate the features of the initial plan, there is presented Plate LXIX, "Profile of Major Conveyance Units of State Plan for Initial Development in San Joaquin Valley. Sacramento-San Joaquin Delta to Kern County."

Operation and Accomplishments in Upper San Joaquin Valley—As in the plan for ultimate development, Friant Reservoir is the key unit in the plan of immediate initial development for the upper San Joaquin Valley. It would be operated primarily to furnish the required supplemental water supplies to meet the deficiencies in local supply for the present developed areas on the east side of the upper San Joaquin Valley, from the Madera unit on the north to the Magunden-Edison unit on the south. The supplemental supplies furnished from Friant Reservoir combined with local supplies would be utilized partly by direct surface diversion and application and partly by underground storage and pumping. The basis of operation and the amounts of water furnished from this reservoir under the plan of immediate initial development are set forth in the following discussion.

A study of the operation of Friant Reservoir under the plan of immediate initial development was made for the 40-year period 1889–1929. The impaired run-off of the San Joaquin River considered available at Friant Reservoir under the plan of immediate initial development was estimated on the assumption that the existing power storage reservoirs above Friant, with an aggregate capacity of 334,000 acre-feet, would have been operated primarily for power purposes during the entire 40-year period but without interference with the existing delivery schedule of crop land rights now served from the San Joaquin River in the lower San Joaquin Valley by diversion above the mouth of the Merced River. It was assumed that the first demand upon the flow of the San Joaquin River would be the supply for these crop lands in accord with the delivery schedule now under operation. The maximum seasonal total of the demand for these crop lands amounts to 895,700 acre-feet. The maximum monthly demands are shown in Table 151.

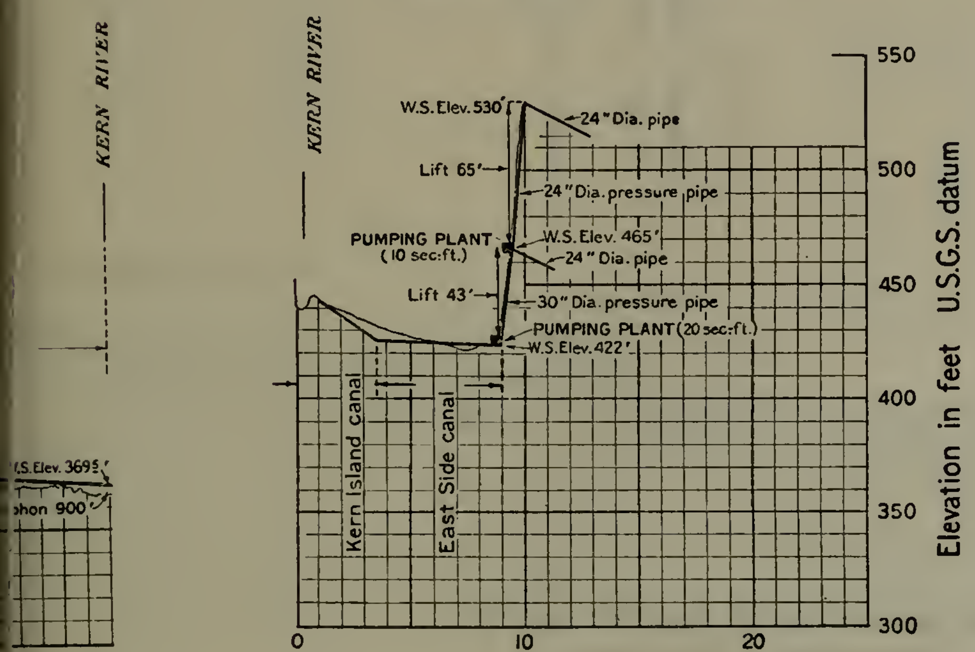
TABLE 151

MAXIMUM MONTHLY DEMAND OF WATER FOR IRRIGATION OF "CROP LANDS" SERVED FROM SAN JOAQUIN RIVER

Month	Maximum demand in acre-feet	Month	Maximum demand in acre-feet
October	27,900	April	114,700
November	8,400	May	158,700
December	6,400	June	163,000
January	10,000	July	142,000
February	27,900	August	108,300
March	51,600	September	76,800
Total			895,700

MAGUNDEN-EDISON PUMPING SYSTEM

Maximum capacity, 20 second-feet



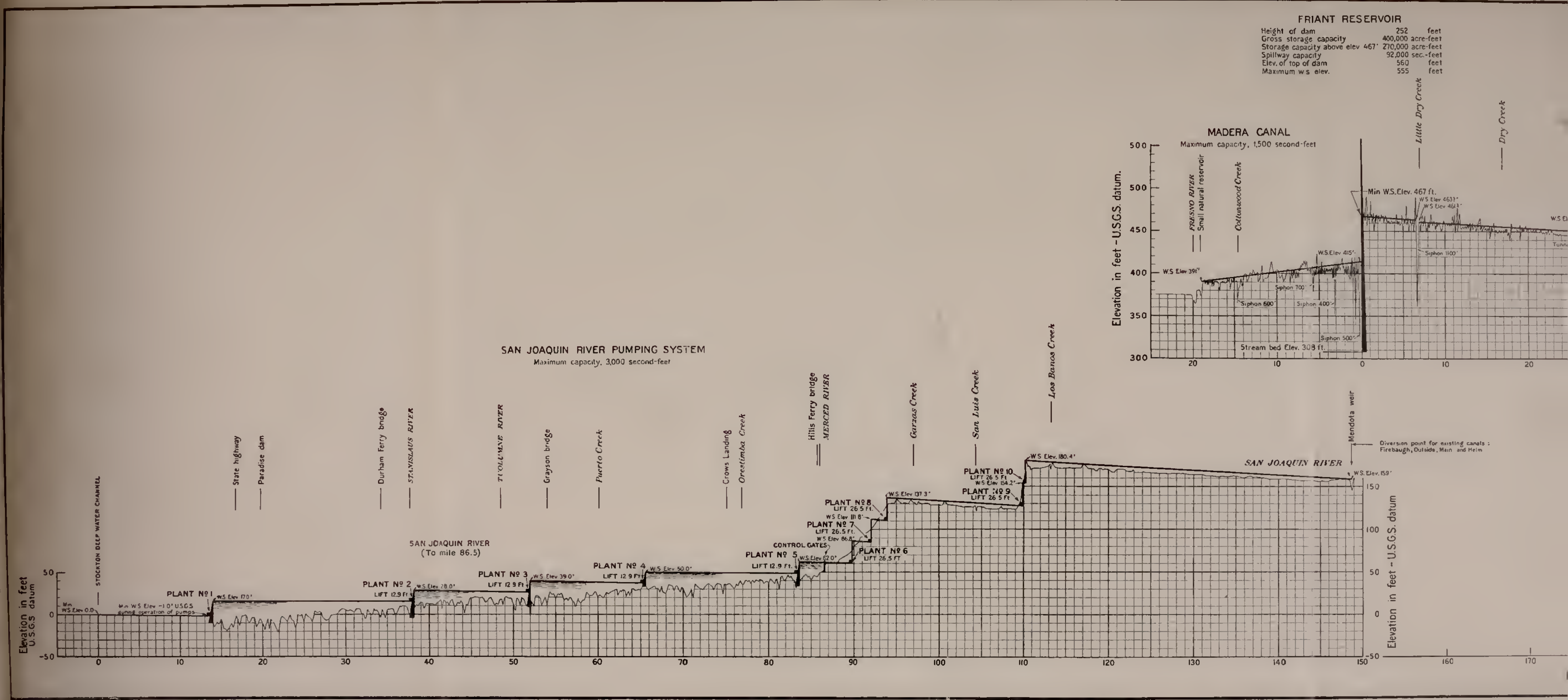
PROFILE OF

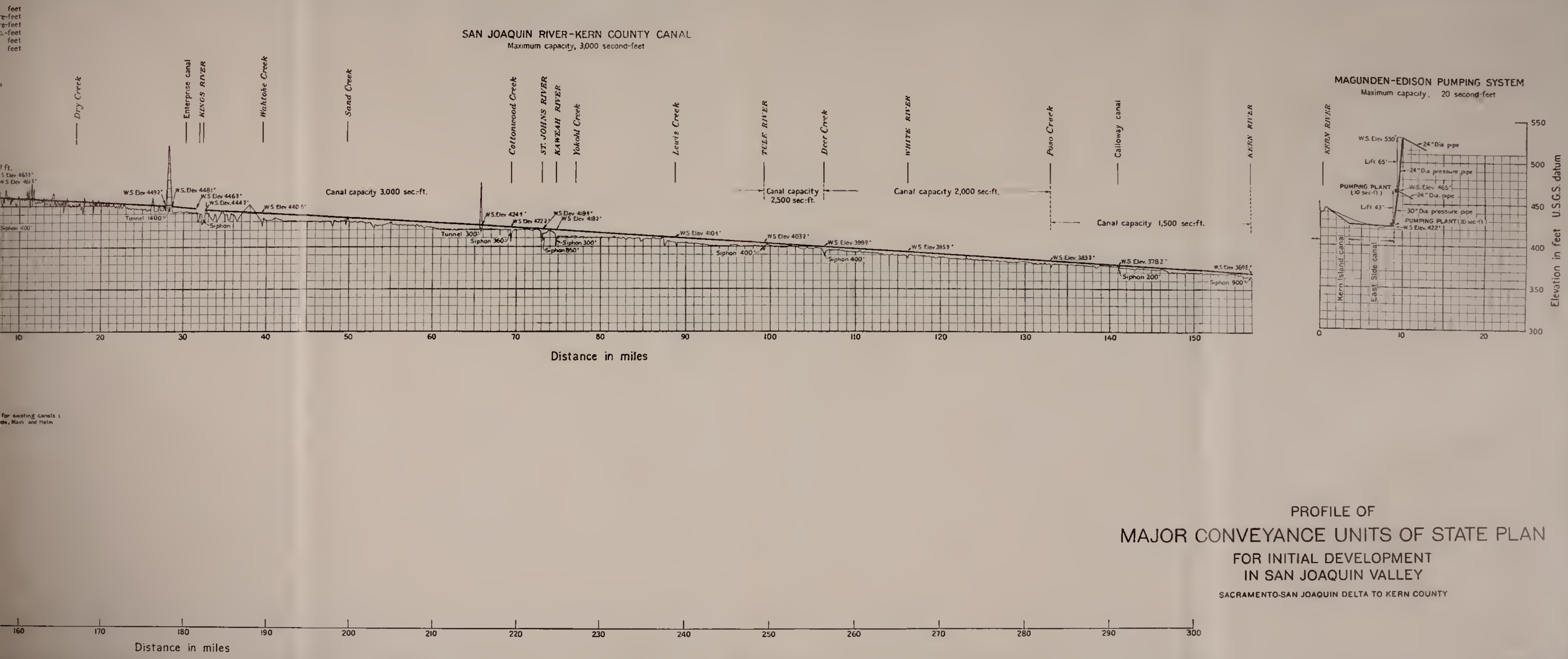
ONVEYANCE UNITS OF STATE PLAN

FOR INITIAL DEVELOPMENT

IN SAN JOAQUIN VALLEY

SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY


FRIANT RESERVOIR
Height of dam 252 feet
Gross storage capacity 400,000 acre-feet
Storage capacity above elev 467' 270,000 acre-feet
Spillway capacity 92,000 sec.-feet
Elev. of top of dam 560 feet
Maximum w.s. elev. 555 feet
MADERA CANAL
Maximum capacity, 1,500 second-feet
FRESNO RIVER
Small natural reservoir
Cottonwood Creek
Little Dry Creek
Dry Creek
Min W.S. Elev. 467 ft.
W.S. Elev 391'
W.S. Elev 415'
Siphon 600'
Siphon 700'
Siphon 400'
Siphon 500'
Siphon 1100'
Stream bed Elev. 308 ft.
Elevation in feet - U.S.G.S. datum.
SAN JOAQUIN RIVER PUMPING SYSTEM
Maximum capacity, 3,000 second-feet
STOCKTON DEEP WATER CHANNEL
State highway
Paradise dam
Durham Ferry bridge
STANISLAUS RIVER
TUOLUMNE RIVER
Grayson bridge
Puerto Creek
Crows Landing
Orestimba Creek
Hills Ferry bridge
MERCED RIVER
Garzas Creek
San Luis Creek
Los Banos Creek
Mendota weir
Diversion point for existing canals : Firebaugh, Outside, Main and Helm
SAN JOAQUIN RIVER
W.S. Elev. 159'
W.S. Elev. 180.4'
PLANT Nº 10
LIFT 26.5 Ft.
W.S. Elev 154.2'
PLANT Nº 9
LIFT 26.5 Ft.
W.S. Elev 137.3'
PLANT Nº 8
LIFT 26.5 Ft.
W.S. Elev 111.8'
PLANT Nº 7
LIFT 26.5 Ft.
W.S. Elev 86.8'
PLANT Nº 6
LIFT 26.5 FT.
CONTROL GATES
PLANT Nº 5
LIFT 12.9 Ft.
W.S. Elev 62.0'
PLANT Nº 4
LIFT 12.9 Ft.
W.S. Elev 50.0'
PLANT Nº 3
LIFT 12.9 Ft.
W.S. Elev 39.0'
PLANT Nº 2
LIFT 12.9 Ft.
W.S. Elev 28.0'
PLANT Nº 1
W.S. Elev 17.0'
Min W.S. Elev 0.0
Min W.S. Elev -1.0' U.S.G.S. during operation of pumps
SAN JOAQUIN RIVER
(To mile 86.5)
Elevation in feet U.S.G.S. datum
Elevation in feet - U.S.G.S. datum



PROFILE OF
MAJOR CONVEYANCE UNITS OF STATE PLAN
FOR INITIAL DEVELOPMENT
IN SAN JOAQUIN VALLEY
SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY

The remaining water supply after satisfying the crop land requirements, comprising surplus waters and waters not attached to areas now devoted to crop production but put to inferior use on grass lands, would be regulated in Friant Reservoir to furnish the supplemental supply required in the upper San Joaquin Valley. The amounts of water available for regulation and utilization from these grass land and surplus waters of the San Joaquin River are shown for each season of the period 1889–1929 in Table 152.

TABLE 152

GRASS LAND AND SURPLUS WATERS OF SAN JOAQUIN RIVER AVAILABLE FOR UTILIZATION UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT IN UPPER SAN JOAQUIN VALLEY, 1889-1929

Quantities in Acre-feet

Season	October	November	December	January	February	March	April	May	June	July	August	September	Totals
1889–90	48,200	82,900	107,700	200,500	200,600	310,900	411,000	866,000	932,400	311,700	34,800	28,200	3,534,900
1890–91	62,700	76,400	86,400	131,700	117,200	152,600	182,100	285,700	309,800	93,500	0	4,900	1,503,000
1891–92	60,500	82,000	91,800	141,200	141,300	194,600	243,000	415,600	487,500	149,200	7,200	8,700	2,022,600
1892–93	59,600	80,100	89,500	142,600	134,600	182,800	227,700	369,200	444,500	133,200	4,800	7,600	1,876,200
1893–94	52,400	70,300	76,900	104,200	93,500	113,100	92,700	178,300	183,800	33,200	0	1,200	999,600
1894–95	55,500	58,900	105,400	165,000	135,000	139,900	178,500	453,800	389,900	143,200	7,100	21,800	1,854,000
1895–96	53,200	66,000	64,400	135,200	76,500	128,600	19,500	90,500	403,600	77,700	0	4,300	1,119,500
1896–97	44,100	76,100	75,500	61,700	116,500	107,400	218,900	487,700	148,300	19,600	0	0	1,355,800
1897–98	46,400	82,900	86,600	54,700	35,900	19,600	27,000	0	0	0	0	0	353,100
1898–99	21,100	21,000	20,600	17,000	4,200	102,700	88,600	24,300	92,300	0	0	0	391,800
1899–00	22,200	54,200	64,600	128,700	11,300	59,900	0	102,400	93,200	0	0	0	536,500
1900–01	31,200	111,000	77,000	192,100	230,000	222,200	149,200	338,700	492,400	78,700	46,100	7,700	1,976,300
1901–02	60,900	77,100	84,400	67,200	40,600	72,500	91,700	139,100	195,500	0	0	0	829,000
1902–03	44,000	65,600	61,100	72,600	44,200	58,000	48,200	267,000	230,400	0	0	0	891,100
1903–04	42,400	55,000	39,800	24,700	22,900	110,100	58,600	301,900	232,900	0	0	9,800	898,100
1904–05	105,300	74,500	63,700	62,200	61,200	104,900	33,700	112,400	127,700	0	0	0	745,600
1905–06	32,800	33,800	26,900	158,600	56,000	306,500	159,000	336,600	808,400	870,500	176,300	32,100	2,997,500
1906–07	63,500	64,800	81,600	121,300	116,000	251,600	259,100	279,700	416,400	335,700	26,700	12,600	2,029,000
1907–08	64,000	66,400	75,600	82,100	55,200	86,100	46,200	0	0	0	0	0	475,600
1908–09	29,100	30,600	29,400	235,400	152,300	100,000	206,800	322,600	588,100	172,800	3,300	7,100	1,877,500
1909–10	53,000	81,500	192,100	183,500	88,800	156,200	199,600	219,000	39,700	0	0	12,900	1,226,300
1910–11	53,000	64,700	72,900	221,900	186,800	290,600	272,900	278,100	712,800	451,600	18,600	16,200	2,640,100
1911–12	53,900	62,800	62,600	52,800	20,300	26,700	0	29,600	103,300	0	0	0	412,000
1912–13	20,000	38,700	27,400	21,500	7,200	0	0	28,900	0	0	0	0	143,700
1913–14	17,500	25,300	28,400	239,700	135,000	191,600	238,300	304,900	353,400	250,700	29,200	13,700	1,827,700
1914–15	57,300	60,800	63,300	65,400	83,400	92,800	109,700	141,100	318,200	119,000	0	5,200	1,116,200
1915–16	43,800	55,200	69,200	170,500	129,000	291,600	302,600	286,500	364,000	145,400	3,800	2,300	1,863,900
1916–17	69,600	67,400	75,200	68,500	121,600	74,700	79,500	127,100	313,800	74,300	0	0	1,071,700
1917–18	44,400	55,400	53,800	24,600	22,900	110,000	43,100	91,800	227,800	0	0	8,100	681,900
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	634,600

1919-20	13,200	20,200	33,100	22,500	6,200	51,300	32,900	186,100	91,500	0	0	0	457,000
1920-21	29,300	57,100	42,200	58,500	55,400	117,600	52,100	121,400	154,100	1,700	0	0	689,400
1921-22	42,400	45,300	61,800	61,200	71,900	59,400	64,900	379,100	476,100	125,300	0	0	1,387,400
1922-23	42,400	65,200	114,600	83,300	52,200	64,400	65,500	214,100	61,400	31,900	0	1,600	796,600
1923-24	54,300	57,800	59,100	22,000	0	0	0	0	0	0	0	0	193,200
1924-25	0	17,700	21,700	14,600	47,700	33,000	60,900	154,500	62,300	0	0	0	412,400
1925-26	44,700	44,000	50,200	18,200	32,300	46,300	161,900	97,500	0	0	0	0	495,100
1926-27	13,100	57,000	48,700	49,200	125,600	99,400	123,000	234,900	216,900	39,100	0	0	1,006,900
1927-28	48,200	90,200	74,200	49,600	31,700	72,500	35,900	87,700	0	0	0	0	490,000
1928-29	22,700	32,100	34,700	20,400	400	5,900	0	31,900	0	0	0	0	148,100
Averages, 1889-1929	45,400	59,700	68,400	94,900	77,700	116,400	116,400	214,700	251,800	91,500	8,900	5,200	1,149,000

With the available supply from surplus and grass land waters, Friant Reservoir would be operated in general to deliver as large a supply as possible during the months of peak irrigation demand for utilization by direct surface application in accord with coincident irrigation needs and for underground storage if in excess of irrigation needs; and in addition provide as much water as possible outside the irrigation season for ground water storage and subsequent pumping. The characteristics of the supply available for regulation would not permit of furnishing the full amount of 500,000 to 600,000 acre-feet of required supplemental water as a surface irrigation supply for direct application. In order to effect the fullest practicable utilization of the available supplies and provide adequately for meeting the immediate water requirements, the storage of water in underground reservoirs and subsequent utilization by pumping are essential. Therefore, the underground storage capacity in the absorptive areas would have to be fully utilized as being the only means of obtaining the large cyclic storage capacity required to regulate the extremely variable amounts of the supplemental water supplies obtained from the San Joaquin River and to regulate the local supplies as well.

However, there are certain nonabsorptive areas with a deficient water supply in the upper San Joaquin Valley for which ground wate storage and pumping would not be a practicable means of providing th required supplies. These are typified by such areas as the Alta-Foot hill, Lindsay and Magunden-Edison units. In order to supply thes nonabsorptive areas with the same adequacy as the absorptive areas, primary surface irrigation supply in accord with the irrigation deman would have to be provided each season in the full amount required For the nonabsorptive areas south of the San Joaquin River it i estimated that a primary surface irrigation supply of 107,000 acre-fee each season would be required. In addition to the primary wate requirements for the nonabsorptive areas, it was assumed that th Madera unit, because of rights to acquire San Joaquin River wate initiated by the Madera Irrigation District, should be furnished with surface irrigation supply each season with a primary supply of no less than 31,000 acre-feet in a season of minimum yield.

This requirement for a primary irrigation supply totaling 138,00 acre-feet in each season was given first consideration in the operatio of Friant Reservoir. In order to insure the furnishing of this amoun of primary water, sufficient water would be held in reserve in the earl part of the season to provide the primary water supply throughout th season. The reservoir would be operated in a specific manner so tha the amount of water held in reserve at any particular time during th season would be sufficient to meet the requirements of primary suppl for the balance of the season. However, in seasons having a run-o above normal, the reservoir would be drawn down below the amount o storage reserve required for primary water in anticipation of subsequent heavy run-off from melting snow which would insure a primar supply for the balance of the season. Such operation would be base upon estimates made prior to March 1st by snow surveys, precipitation and run-off data of the probable total seasonal run-off and of th balance of run-off to be expected in the remaining portion of the seaso