STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING AND IRRIGATION
EDWARD HYATT, STATE ENGINEER

BULLETIN No. 13

The Development of the Upper Sacramento River

By PAUL BAILEY

An Appendix to the Summary Report
to the Legislature of 1927
on the
Water Resources of California
and a
Coordinated Plan for Their Development

Containing
Cooperative Report with U. S. Bureau of Reclamation
on
Iron Canyon Project
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CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO, 1928

50667

KENNETT DAM SITE IN SACRAMENTO CANYON.

TABLE OF CONTENTS.

FOREWORD.

This bulletin is one of a series appended to the "Summary Report on the Water Resources of California and a Coordinated Plan for their Development" that was presented to the Legislature of 1927. It is part of the investigation of the water resources of the State commenced in 1921. This investigation comprised a survey of water supplies and flood flows throughout the State, a determination of their characteristics, an estimate of the present and future needs for water, and the formulation of a comprehensive and coordinated plan for future development in order to insure adequate water supplies for all purposes. The 1927 report concludes this investigation. The entire series of bulletins pertaining to the 1927 report are:

Bul. 12—"Summary Report on the Water Resources of California and a Coordinated Plan for their Development." (A report to the Legislature of 1927.)
BUL. 13—"THE DEVELOPMENT OF THE UPPER SACRAMENTO RIVER."
Bul. 14—"The Control of Floods by Reservoirs."
Bul. 15—"The Coordinated Plan of Water Development in the Sacramento Valley."
Bul. 16—"The Coordinated Plan of Water Development in the San Joaquin Valley."
Bul. 17—"The Coordinated Plan of Water Development in Southern California."

Other bulletins pertaining to these investigations published prior to the 1927 report are:
Bul. 4—"Water Resources of California." (A report to the Legislature of 1923 on the first two years of investigation.)
Bul. 5—"Flow in California Streams."
Bul. 6—"Water Requirements of California Lands."
Bul. 9—"A Supplemental Report on the Water Resources of California." (A report to the Legislature of 1925.)
Bul. 11—"Ground Water Resources of the Southern San Joaquin Valley."

The first appropriation for the investigation of the water resources of California was made by Chapter 889 of the 1921 Statutes, in the amount of $200,000. This resulted in the publication of Bulletins Nos. 4, 5 and 6. These contain a complete inventory of all the waters within the State's boundaries, an estimate of the future needs of water for all purposes, and a preliminary comprehensive plan for ultimate development that will secure the greatest public service from the State's limited water supply.

No provision was made for the continuance of the investigations by the 1923 Legislature, but at the urgent request of the farmers of the southern San Joaquin Valley the Chambers of Commerce of San Francisco and Los Angeles advanced $90,000 for the study of a first unit of the comprehensive plan that would relieve the stress in a section of the State most in need of an imported water supply. With this money, works were planned that would transport the surplus waters of the

Sacramento drainage basin into the San Joaquin Valley and make a new supply available for the southern half of the valley. An account of this work is published in Bulletin No. 9, a report to the Legislature of 1925.

Chapter 477 of the 1925 Statutes made $150,000 available to the Division for completion of the work.

Parallel with the water resources investigation, the Division entered into a contract with the United States Bureau of Reclamation in January, 1924, for further study of the Iron Canyon project. Although this study has been pursued as an individual project for irrigating a portion of the Sacramento Valley floor and generating incidental power, since it concerns a reservoir site on an accessible stream containing a large surplus of water, it is of material interest to a "Coordinated Plan" of development for the Great Central Valley. Therefore, the entire report on the Iron Canyon project has been included in this volume.

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This bulletin has been prepared in consultation with a committee of engineers, who advised in the preparation of the "Coordinated Plan." They are:

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With the exception of the cooperative report on the Iron Canyon project which was made by the organization of the United States Bureau of Reclamation, Walker R. Young in charge, this bulletin and the "Summary Report on the Water Resources of California and a Coordinated Plan for their Development" have been prepared by:

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LIST OF PLATES.

PLATES ACCOMPANYING REPORT ON UPPER SACRAMENTO RIVER BY DIVISION OF ENGINEERING AND IRRIGATION.

PLATES ACCOMPANYING REPORT ON IRON CANYON PROJECT BY WALKER R. YOUNG.

PLATES ACCOMPANYING REPORT OF THE BOARD OF ENGINEERS ON IRON CANYON PROJECT, MAY 7, 1920.

CHAPTER I.

INTRODUCTION AND SUMMARY.

The Sacramento River, upstream from the mouth of the Feather, is the most important of all streams tributary to the Great Central Valley of California. With 12,100 square miles of mountain and foothill drainage area, it produces a mean seasonal run-off of 12,400,000 acre-feet, one-half of the run-off from the entire Sacramento drainage area and one-third of all the waters of the Great Central Valley. The bulk of the waters surplus to the future needs of the Sacramento Valley lies in this stream. Large reservoir capacity will be required to equalize its flow in order that this surplus may become available for use. Therefore, a major project to develop the surplus waters of the Sacramento Valley is contingent upon the feasibility of constructing storage works of large capacity on the main Sacramento River.

A reconnaissance survey was run the entire length of the main channel in search of possible reservoir sites. Only one site of large capacity was found. Its dam lies five miles below the confluence with the Pit River and backs water up the upper Sacramento, the Pit, the McCloud, Squaw Creek and numerous small streams and gulches so that, although the reservoir is comparatively narrow, it has a large capacity. The dam foundations have been explored with the diamond drill and have been found adequate for the construction of a reservoir up to 10,000,000 acre-feet capacity. Such a reservoir would yield each year, in addition to present use, 4,600,000 acre-feet of water equalized for the requirements of irrigation and would warrant a power plant of 500,000 k.v.a. capacity below the dam. This site is called Kennett, from the nearby town of that name. Two other sites were located in the Sacramento Canyon, but the cost of storage would exceed that at Kennett and they would overlap the larger Kennett reservoir.

Fifty miles downstream from the Kennett site on the main channel of the Sacramento River is the proposed Iron Canyon reservoir. Topographically this reservoir could be constructed to a capacity of 3,000,000 acre-feet. However, the none too favorable foundations for a dam limit its capacity to 1,120,000 acre-feet. The Iron Canyon project, including both the reservoir and the lands to be irrigated from it, has been under investigation at intervals since 1902 by the United States Bureau of Reclamation and the State Engineer in cooperation. The latest report, recently completed by Walker R. Young, engineer of the Bureau of Reclamation, is included in this volume. This report estimates the yield of a 1,120,000 acre-foot reservoir at 800,000 acre-feet of water per year additional to present use and equalized for the needs of irrigation. It finds that a power plant of 100,000 k.v.a. capacity would be warranted at the foot of the dam. One-third of the area of the Anderson-Cottonwood Irrigation District would be flooded by this reservoir.

Both the Kennett and the Iron Canyon reservoir sites lie upstream from the main body of agricultural land on the floor of the Sacramento Valley and are in the physical position to serve any part of these lands with irrigation water. Both of these reservoirs are included in the preliminary comprehensive plan* for ultimate development of the State's waters presented to the 1923 Legislature. They both will be required ultimately because the Iron Canyon site, being 50 miles downstream, has 2609 square miles of drainage area tributary to it that is not controlled by Kennett. This produces an average run-off of 2,536,000 acre-feet per year.

The Iron Canyon reservoir is not included in the "Coordinated Plan" presented to the 1927 Legislature, however, since its capacity is insufficient to meet the needs of this plan. The "Coordinated Plan" selects the units of the comprehensive plan for ultimate development from which the greatest public service may be obtained through the next half century. It provides for coordinating the operation of these units to secure the solution of the outstanding water problems that threaten future growth. It provides for all the needs for water on the floor of the Sacramento Valley during the next half century, including irrigation, navigation and salt water control, together with a surplus for use in the San Joaquin Valley. It would cut flood flows in half on the upper part of the Sacramento River and develop a large amount of electric power. All these things could not be accomplished were the smaller Iron Canyon reservoir substituted in the "Coordinated Plan" in place of Kennett. Further, the dam foundations are more favorable at Kennett than at Iron Canyon and no agricultural lands are flooded, while the unit cost of producing water and power is about the same. Therefore, the interests of the State are best served by giving preference to the Kennett site. Undoubtedly at some time in the future the run-off from the drainage area between these two reservoirs will be needed. The only way it can be obtained is through the construction of the Iron Canyon reservoir.

The "Coordinated Plan" proposes the construction, amongst others, of a dam at the Kennett site to the initial height of 420 feet. At this height the reservoir would have a capacity of 2,940,000 acre-feet, large enough to yield annually, over and above present use, 2,838,000 acre-feet of water equalized for irrigation needs when operated primarily for this purpose. A power plant of 400,000 k.v.a. capacity would be constructed below the dam. Sluiceways would be constructed in the dam for controlling floods. Operated in accordance with the "Coordinated Plan," the Kennett reservoir would reduce the maximum flood flow in the Sacramento River at Red Bluff from 278,000 to 125,000 second-feet.

The locations of the Kennett and Iron Canyon reservoirs are shown on Plate A, "Three Units of Comprehensive Plan on Upper Sacramento River." The third unit is the diversion of the upper section of the Trinity River into the Sacramento Valley. This diversion is also a unit of the "Coordinated Plan" for development of the State's waters. It would introduce an annual supply of 870,000 acre-feet into the Great Central Valley that would otherwise flow through a mountainous country into the Pacific Ocean unused except for the generation of electric power. The Trinity diversion is fully described in Bul. No.

* Chap. VI, Bul. No. 4, "Water Resources of California," a report to the Legislature of 1923 by the Division of Engineering and Irrigation, State Department of Public Works.

PLATE A

50667—pages 14-15

15, "The Coordinated Plan of Water Development in the Sacramento Valley."

In addition to the foregoing possibilities of developing water on the main Sacramento River, there are several large reservoir sites on the Pit, a tributary of the Sacramento River, and quite a number of smaller ones on the lesser tributaries, particularly to the upper Pit. Some of these will be useful and necessary in the complete development of the Sacramento River; however, the volume of water controlled is much too small to make them part of a comprehensive scheme of development without the construction of a large reservoir on the main channel. These smaller reservoirs will be useful principally in development of the 260,000 acres of irrigable land in the basin of the upper Pit River.

CHAPTER II.

THE MAIN SACRAMENTO RIVER DRAINAGE BASIN.

Drainage area between Red Bluff and mouth of Feather River.

The Sacramento River, upstream from its confluence with the Feather, has a mountainous drainage area of 12,100 square miles. Of this, the run-off from 9258 square miles concentrates in the main channel upstream from the city of Red Bluff. The run-off from the other 2842 square miles enters the channel at intervals from a large number of smaller streams along the entire length of 168 miles from Red Bluff to the mouth of the Feather River. Although these streams drain areas extending into considerable altitude on the easterly side of the Coast Range and the westerly slope of the Sierra, their descent to plains level is steep and direct so that the run-off of each is comparatively small and subject to large variation. Reservoir sites for conserving their waters are few and generally costly. The waters of these streams can be used most advantageously on foothill and plains areas adjacent to their canyon mouths. Therefore, these streams do not enter into a state-wide plan of development.

Drainage area upstream from Red Bluff.

The 9258 square miles of the Sacramento watershed whose run-off concentrates in the main river channel upstream from Red Bluff is the part of great importance to a state-wide plan of conservation. Because the run-off from this area concentrates in the main channel before the river debouches on the valley floor, physical conditions are favorable for equalizing these waters in reservoirs and making them available for use in large quantities.

The drainage basin upstream from Red Bluff is bounded on the west by the Trinity Mountains, which rise to an elevation of 9000 feet on the divide separating it from the Pacific slope of the Coast Range Mountains. To the north the mountains separating this basin from the Klamath River culminate in Mount Shasta, a peak having a crest 14,162 feet above sea level. To the east and south of Mount Shasta is an extensive plateau varying from four to five thousand feet in elevation. This plateau extends easterly to the Warner Mountains, near the State's border, that rise to elevations of 9000 feet or more.

With the exception of the plateau areas east and southeast of Mount Shasta, practically the entire area is mountainous. The agricultural lands are 350,000 acres scattered in parcels along the upper Pit River and 490,000 acres of foothill and plains lands lying in the vicinity of the cities of Redding and Red Bluff. In the latter area is located the Anderson-Cottonwood Irrigation District of 31,400 acres, in which lies nearly all of the land now intensively farmed.

Elevations within the drainage basin vary from 300 feet near Red Bluff to 14,162 feet at the top of Mount Shasta. One-half of the area lies between the elevations of 2500 and 5000 feet above sea level, as shown by the following table:

ELEVATION OF DRAINAGE AREA—MAIN SACRAMENTO RIVER BASIN.
Upstream from Red Bluff.

Elevation:	Drainage area in square miles
Below 2500 feet	2,100
Between 2500 and 5000 feet	4,620
Above 5000 feet	2,538
Total	9,258

Precipitation in the main Sacramento basin varies widely between the mountainous area north of Redding, where the mean seasonal rainfall ranges from 50 to 65 inches, and the plateau region east and southeasterly from Mount Shasta. Here the mean seasonal rainfall approximates 15 inches.

The principal streams are the upper Sacramento, Pit and McCloud rivers. These, in draining the absorbent lava formations to the east and south of Mount Shasta, are distinguished from most other California streams in having a well-sustained summer flow. The mean flow for the month of August is more than one-half of the mean rate throughout the entire year, whereas the state-wide average is only one-quarter.

Water supply.

Knowledge of the run-off from this area is gained through gagings that have been made at several points along the main channels by the United States Geological Survey in cooperation with the State of California. The station that has been maintained through the greater period of time is near Red Bluff. It was established at Jelly's Ferry in 1895, but was moved eight miles downstream to the lower end of Iron Canyon in 1902. The records at these stations furnish data over a period of 30 years, one of the longest continuous records of run-off in California. The daily discharge at this and the several other stations in this basin is published* in the Water Supply Papers of the United States Geological Survey. The stations for which data are available, their tributary drainage area and the period of record are listed in the following table:

* The run-off computations of this volume employed data of the last several years that are in preparation for publication, as well as the published tables of previous years.

UNITED STATES GEOLOGICAL SURVEY GAGING STATIONS IN THE MAIN SACRAMENTO BASIN ABOVE RED BLUFF.

Stream	Station	Location	Period of discharge record	Drainage area in square miles
Upper Sacramento River	Castella	½ mile below Castle Creek	Oct. 1910–Sept. 1922	257
Upper Sacramento River	Antler	200 feet above Gregory Creek	Nov. 1910–Dec. 1911 Apr. 1919–Sept. 1926	463
Main Sacramento River	Kennett	Opposite town of Kennett	Nov. 1925–Sept. 1926	6,603
Main Sacramento River	Jelly's Ferry	12 miles above Red Bluff	Apr. 1895–June 1902	9,093
Main Sacramento River	Red Bluff	4 miles above Red Bluff	Jan. 1902–Sept. 1926	9,258
Pit River	Canby	Above mouth of Ash Creek	Dec. 1903–Dec. 1905	1,460
Pit River	Bieber	4 miles above Horse Creek	Jan. 1904–Sept. 1908 Dec. 1913–Aug. 1914 Sept. 1921–Sept. 1926	3,086
Pit River	Fall River Mills	Below mouth of Fall River at Fall River Mills	Mar. 1921–Sept. 1926	4,152
Pit River	Pecks Bridge	At Pecks Bridge	June 1922–Aug. 1924	4,623
Pit River	Lindsay Flat	3 miles below Rock Creek	Nov. 1922–Sept. 1926	4,858
Pit River	Henderson or Big Bend	1 mile above Kosk Creek	Sept. 1910–Sept. 1926	4,922
Pit River	Ydalpom	4 miles above mouth McCloud River	Nov. 1910–Sept. 1926	5,346
South Fork Pit River	Ivy	6 miles above West Valley Creek	Jan. 1904–Dec. 1905	91
West Valley Creek	Likely	Above junction with South Fork of Pit River	Jan. 1904–Dec. 1905	140
Pine Creek	Alturas	6 miles above mouth	May 1918–Sept. 1926	31
Ash Creek	Adin	½ mile above Adin	Mar. 1904–Dec. 1905	252
Fall River	Fall River Mills	600 feet above mouth	Jan. 1912–Aug. 1913 May 1921–Oct. 1922	600
Fall River	Glenburn	1½ miles below Tule River and ½ mile east of Glenburn	Jan. 1922–Sept. 1922	....
Bear Creek	Dana	2 miles north of Dana	Apr. 1921–May 1926	....
Hat Creek	Hawkins Ranch	6 miles above town of Hat Creek	Aug. 1911–Aug. 1913	265
Hat Creek	Wilcox Ranch	12 miles southwest of Cassel	Aug. 1921–Sept. 1922	....
Hat Creek	Hat Creek	1 mile north Hat Creek post office	Sept. 1910–July 1917	326
Hat Creek	Hat Creek	11 miles southeast of town of Hat Creek and 5 miles below the Big Springs	July 1926–Sept. 1926	....
Hat Creek	Carbon	3 miles above mouth at highway bridge at Carbon	Mar. 1921–Sept. 1922	384
Rising River	Cassel	½ mile above mouth	Aug. 1911–Mar. 1914 Mar. 1921–Sept. 1922	....
Burney Creek	Burney (above)	300 feet below junction of two main forks, 7 miles south of Burney	Oct. 1921–Nov. 1922	44
Burney Creek	Burney (near)	3 miles above Goose Creek and ¾ mile southwest of Burney	Aug. 1911–Aug. 1913 Mar. 1921–Sept. 1922	92
Burney Creek	Burney (below falls)	½ mile below Burney Falls and 10 miles north of Burney	Mar. 1921–Nov. 1922	25
Kosk Creek	Henderson	3½ miles above mouth	Oct. 1910–Aug. 1916	54
Montgomery Creek	Montgomery Creek	Montgomery Creek post office	Aug. 1911–Aug. 1913	42
Squaw Creek	Ydalpom	¾ mile southwest of Ydalpom	Oct. 1911–Aug. 1913	112
McCloud River	Gregory	14 miles east of Gregory post office	Mar. 1902–June 1908	608
McCloud River	Baird	2 miles above mouth	Dec. 1910–Sept. 1926	669
Clear Creek	Shasta	Footbridge at Whiskytown	Aug. 1911–Sept. 1913	182
Cow Creek	Millville	¾ mile above mouth	Aug. 1911–Mar. 1914	185
Clover Creek	Millville	¼ mile above mouth	Aug. 1911–Jan. 1914	48
Little Cow Creek	Palo Cedro	¼ mile east of Palo Cedro	Aug. 1911–Jan. 1914	148
Bear Creek	Millville	5 miles above mouth	Aug. 1911–Mar. 1914	106
North Fork Cottonwood Creek	Ono (near)	At Forester dam site, 4 miles northwest of Ono	Feb. 1919–Dec. 1919	....
North Fork Cottonwood Creek	Ono (at)	1 mile above Eagle Creek	Oct. 1907–Dec. 1913	52
Moon Creek	Ono	4 miles northwest of Ono	Feb. 1919–Dec. 1919	....

The total run-off from the main Sacramento basin is furnished by the records of the Red Bluff and Jelly's Ferry gaging stations. The seasonal run-off obtained from these records was projected into the previous years by comparison of rainfall data. By this method values of the mean seasonal run-off were estimated for the twenty-four years prior to the establishment of the United States Geological Survey gaging station. This work is described in Chapter IV, Bul. No. 5, "Flow in California Streams." The results of the computations are tabulated on p. 191 of Bulletin No. 5 and are repeated in the following table with extensions through the year 1925. The figures entered in the column "Estimated values in acre-feet" are the values without storage or use of water for irrigation on the lands upstream from Red Bluff. They are larger than the entries in the column "Values measured at gaging station near Red Bluff in acre-feet" by the estimated net amount of upstream diversions for that season.

SEASONAL RUN-OFF—MAIN SACRAMENTO DRAINAGE BASIN.

Drainage Area, 9258 Square Miles.

Season (Oct. 1 to Sept. 30)	Seasonal run-off			
	Depth on drainage area in inches	Acre-feet per square mile	Estimated values in acre-feet	Values measured at gaging station near Red Bluff in acre-feet
1871-72	20.7	1,102	10,200,000	
1872-73	9.7	516	4,780,000	
1873-74	14.8	789	7,300,000	
1874-75	8.9	474	4,390,000	
1875-76	29.3	1,566	14,500,000	
1876-77	20.0	1,066	9,870,000	
1877-78	36.1	1,923	17,800,000	
1878-79	17.0	905	8,380,000	
1879-80	25.0	1,329	12,300,000	
1880-81	31.2	1,663	15,400,000	
1881-82	16.2	864	8,000,000	
1882-83	13.5	720	6,670,000	
1883-84	23.0	1,231	11,400,000	
1884-85	13.1	698	6,460,000	
1885-86	29.2	1,555	11,400,000	
1886-87	13.5	720	6,670,000	
1887-88	11.0	587	5,430,000	
1888-89	21.5	1,145	10,600,000	
1889-90	46.0	2,452	22,700,000	
1890-91	13.1	698	6,460,000	
1891-92	14.7	783	7,250,000	
1892-93	25.2	1,339	12,409,000	
1893-94	17.5	933	8,640,000	
1894-95	25.0	1,329	12,300,000	[1]3,347,000
1895-96	23.0	1,225	11,343,200	11,170,400
1896-97	21.0	1,122	10,391,400	10,216,800
1897-98	10.4	555	5,135,800	4,959,300
1898-99	12.1	646	5,977,400	5,799,200
1899-00	17.6	941	8,712,500	8,532,500
1900-01	18.3	974	9,020,900	8,835,700
1901-02	23.1	1,229	11,380,600	11,107,100
1902-03	20.1	1,074	9,941,800	9,756,300
1903-04	32.6	1,739	16,095,800	15,908,900
1904-05	21.9	1,164	10,775,200	10,586,300
1905-06	22.9	1,220	11,294,300	11,103,400
1906-07	28.1	1,500	13,883,700	13,691,300
1907-08	16.0	856	7,921,100	7,726,800
1908-09	29.6	1,574	14,568,700	14,372,800
1909-10	18.4	984	9,106,300	8,908,100
1910-11	20.4	1,092	10,108,300	9,908,800
1911-12	13.3	710	6,577,800	6,369,200
1912-13	14.3	761	7,049,100	6,831,600
1913-14	27.7	1,484	13,737,900	13,511,100
1914-15	25.5	1,359	12,582,900	12,347,400
1915-16	21.6	1,158	10,719,600	10,474,800
1916-17	14.5	774	7,167,100	6,913,600
1917-18	10.9	582	5,388,500	5,125,500
1918-19	15.7	840	7,779,700	7,507,600
1919-20	8.2	439	4,068,800	3,888,100
1920-21	23.1	1,234	11,421,700	11,131,800
1921-22	13.4	715	6,617,800	6,328,000
1922-23	10.7	572	5,298,800	5,009,000
1923-24	6.6	352	3,261,800	2,972,000
1924-25	16.3	867	8,028,800	7,739,000
Mean, 1871-1921, 50 years	20.1	1,072	9,929,000	
Mean, 1871-1925, 54 years	19.5	1,039	9,623,300	

[1] Partial year, May 1 to September 30.

The mean seasonal run-off from the main Sacramento basin upstream from Red Bluff through the fifty-year period from 1871 to 1921 is 9,929,000 acre-feet. Including the four years following 1921, the mean is 9,623,000 acre-feet. The season of greatest run-off was 1889-90 when 22,700,000 acre-feet are estimated to have passed down the channel. The season of least run-off was 1923-24 when the yield was only 3,262,000 acre-feet. The great variation between these extremes is indicative of the need of a reservoir of great capacity to hold water over from one season to another if any large fraction of the mean seasonal run-off is to be made available for use.

An examination of the detail records shows an even greater range in the extreme values of the mean daily flow at the gaging station during the period of record. The greatest value was on February 3, 1909, when the flow averaged 254,000 second-feet, the greatest flood of record on this stream. The highest rate on this day was 278,000 second-feet. The least mean daily flow occurred in August, 1924, with a value of 2810 second-feet.

As disclosed by thirty years of measurement, the seasonal run-off is distributed through the months of the year as shown in the following table:

DISTRIBUTION OF SEASONAL RUN-OFF BETWEEN MONTHS OF YEAR MAIN SACRAMENTO DRAINAGE BASIN.

Upstream from Red Bluff.

1895-1925.

Month	Average run-off in acre-feet	Run-off in per cent of mean seasonal
January	1,250,700	13.6
February	1,488,700	16.2
March	1,501,300	16.4
April	1,118,300	12.2
May	832,400	9.1
June	534,500	5.8
July	377,700	4.1
August	322,300	3.5
September	263,600	2.9
October	328,700	3.6
November	494,800	5.4
December	665,600	7.2
Totals	9,178,600	100.0

Based on the stream gaging records of the United States Geological Survey stations upstream from Red Bluff, the fifty-year mean seasonal run-off from the several sections of the main Sacramento drainage basin is estimated as follows:

MEAN SEASONAL RUN-OFF FROM DIVISIONS OF MAIN SACRAMENTO DRAINAGE BASIN.

Division	Drainage area in square miles	Mean seasonal run-off	
		In acre-feet	In acre-feet per square mile of drainage area
Pit River Basin (Pit River upstream from Bieber)	3,086	753,000	244
Pit River Gorge (from Bieber to confluence with Sacramento)	2,287	3,483,000	1,523
McCloud River	675	1,598,000	2,368
Sacramento River (upstream from confluence with the Pit)	535	1,448,000	2,706
Sacramento River (from mouth of the Pit to Red Bluff)	2,675	2,647,000	990
Totals and average	9,258	9,929,000	1,072

The foregoing figures represent the run-off from the main Sacramento drainage basin unimpaired by diversions of any character. Through the irrigation of a gross area, estimated in 1920 to be about 127,000 acres in the Pit River basin, with some along Burney and Hat creeks, there are now net diversions approximating a couple of hundred thousand acre-feet in the upper part of the basin. This use is growing slowly and undoubtedly will expand ultimately to the limits of available land and water supply. There are about 350,000 acres of agricultural land upon which water could be placed to advantage if an economic supply could be obtained. The mean seasonal run-off tributary to this land is 753,000 acre-feet.

It is estimated that, of the 350,000 acres of available agricultural land, 260,000 ultimately may be brought under irrigation through the construction of canals and reservoirs at known sites. The remainder lies in positions or at elevations too high to be easily watered from available supplies. The 260,000 acres that may be irrigated within the horizon of future economies will require about 500,000 acre-feet annually or seventy per cent of the mean seasonal run-off from this part of the Sacramento drainage basin.

Run-off from this area in any quantity, after the 260,000 acres are placed under irrigation, would reach the lower part of the basin only in seasons of abundant run-off, when the lower basin would be well supplied. It would be too irregular in character to equalize through storage and so would have little value as a water supply. Believing that the best interests of the State will be subserved by the full development of the agricultural resources of the Pit River basin, the entire run-off from the tributary drainage area has been allotted to this use in these investigations. All estimates of water supply available for irrigation, power or other purposes in the Sacramento and San Joaquin valleys have been made after deducting from the total run-off of the main Sacramento basin the entire flow at the Bieber gaging station, estimated at 753,000 acre-feet in the average year. The reservation of this water provides for the future development of all the agricultural land upstream from the Kennett reservoir in a position to be irrigated.

TABLE OF RESERVOIR SITES ON MAIN SACRAMENTO RIVER.

Stream	Name of reservoir site	Location of dam Sec. M. D. B. & M.	T.	R.	Drainage area in square miles	Dimensions for maximum size: Height of dam in feet	Capacity of reservoir in acre-feet	Type of dam	Cubic yards of material in dam	Cubic yards of material in dam per acre-foot of storage
Sacramento River	Iron Canyon	2	27N	3W	9,258	152.5	1,121,900	Gravity-concrete Earth-fill	836,730 763,000	0.7 0.7
Sacramento River	Kennett	15	33N	5W	6,649	420	2,940,000	Gravity-concrete	2,650,000	0.9
Sacramento River	Keswick	17	32N	5W	6,690	255	267,000	Gravity-concrete	567,500	2.1
Sacramento River	Coram	29	33N	5W	6,660	300	872,000	Gravity-concrete	962,000	1.1
Elder Creek	Gallatin	14	25N	6W	146	190	96,000	Earth-fill	1,288,000	13
Red Bank Creek	Red Bank	16	26N	6W	14	165	21,100	Gravity-concrete	77,700	3.7
Northeast Fork of Cottonwood Creek	Forester	29	31N	7W	....	70	740	Rock-fill	24,800	34
Northeast Fork of Cottonwood Creek	Misselbeck*	31	31N	7W	12	106	5,460	Earth-fill	....	....
Hoover Creek	Hoover	28	31N	7W	....	90	1,900	Rock-fill	42,000	22
Cottonwood Creek	Cottonwood	{16, 17}	30N	6W	97	165	53,300	Gravity-concrete	120,200	2.3
Sacramento River	Wagon Valley	29	40N	4W	117	213	34,800	Concrete-arch.	130,300	3.7
Sacramento River	Sims	18	37N	4W	287	305	128,000	Gravity-concrete	1,121,200	8.8
Sacramento River	Delta	35	36N	5W	390	186	32,900	Gravity-concrete	211,700	6.4
Sacramento River	Castle Lake	19	39N	4W	1	35	1,300	Earth-fill	85,300	66
Castle Creek	Lower Echo Lake	4	38N	5W	1	85	2,000	Rock-fill	222,000	111
Castle Creek	Upper Echo Lake	5	38N	5W	1	45	230	Rock-fill	42,000	183
McCloud River	Old Bartle	30	40N	1W	58	127	21,000	Rock-fill	505,000	24
McCloud River	Upper Falls	7	39N	1W	300	87	20,600	Rock-fill	459,000	22
McCloud River	Rinckle	15	38N	2W	415	200	22,300	Gravity-concrete	183,000	8.2
McCloud River	Whittier	{5, 8}	37N	2W	435	215	20,900	Gravity-concrete	245,000	12
McCloud River	Squaw Valley	27	37N	3W	577	240	36,000	Gravity-concrete	451,000	13
McCloud River	Ellery	9	35N	3W	619	285	116,200	Gravity-concrete	477,400	4.1
Tributary North Fork Pit River	Crowder*	7	44N	14E	....	12	400	Earth-fill	20,000	50
North Fork Pit River	Joseph Creek	36	44N	13E	73	104	15,600	Rock-fill	316,000	20
Tributary North Fork Pit River	Round Mountain	34	44N	13E	....	10	2,000	Earth-fill	12,000	6.0
Shields Creek	Plum Canyon*	32	42N	14E	....	24	180	Earth-fill	11,000	61
North Fork Pit River	Cubalo	5	42N	13E	193	44	12,400	Gravity-concrete	13,100	1.1
Between Pine and Parker Creeks	Dorris*	{17, 8}	42N	13E	114	28	12,500	Earth-fill	....	....
South Fork Pit River	Jess Valley	11	39N	14E	91	62	110,000	Earth-fill	219,000	2.0
Near South Fork Pit River	Flourney*	{30, 34}	40N	13E	....	10	250	Earth-fill	41,000	164

South Fork Pit River	Cable*	28	40N	13E	....	12	120	Earth-fill	27,000	225
South Fork Pit River	Nelson*	24	38N	12E	....	16	420	Earth-fill	6,000	14
Crooks Canyon	Graven	23	40N	11E	....	13	840	Earth-fill	46,000	55
Crooks Canyon	Crooks Canyon	32	40N	12E	34	45	11,500	Earth-fill	118,000	10
Crooks Canyon	Potter and Carpenter	3 4	40N	12E	....	21	1,800	Earth-fill	252,000	140
Rattlesnake Creek	Government Corral*	26 27	45N	11E	....	20	550	Earth-fill	41,000	75
Rattlesnake Creek	Big Sage*	7	43N	12E	104	50	77,000	Earth-fill	....	....
Tributary to Rattlesnake Creek	Big Dobe, north and south*	22 26 27	44N	12E	20	13 14	6,500 3,900	Earth-fill Earth-fill	....	....
Emigrant Creek	Emigrant Creek*	31	44N	13E	....	8	560	Earth-fill	11,000	20
Near Pit River	Kelley or Greiner	21 17	43N	13E	....	10	280	Earth-fill	20,000	71
Near Canyon Creek	Portugee Flat*	6 7 7	41N 41N 41N	11E 11E 11E	....	10 11 6	1,400	Earth-fill	18,000	13
Near Canyon Creek	Mary Elvory	11	43N	10E	....	13	1,600	Earth-fill	27,000	17
Clover Swale	Essex*	6	42N	11E	....	45	5,100	Earth-fill	115,000	23
Tributary to Pit River	White*	26	41N	10E	....	8	150	Earth-fill	7,000	47
Howard Gulch	Kane*	26 24	42N 42N	9E 9E	....	15 19	1,400	Earth-fill	108,000	77
Howard Gulch	Williams*	29	43N	9E	....	8	1,500	Earth-fill	9,000	6.0
Howard Gulch	Duncan No. 1*	33	43N	9E	....	18	1,500	Earth-fill	41,000	27
Pit River	Stone Coal Valley	25	41N	7E	1,461	115	117,000	Gravity-concrete	95,500	0.8
Pit River	Mead Flat*	27	40N	6E	....	10	870	Earth-fill	3,000	3.4
Pit River	Antelope Flat* or Roberts	30 29	40N 40N	7E 7E	....	8 6	950	Earth-fill	19,000	20
Pit River	Old Roberts	11	39N	7E	....	18	4,000	Earth-fill	17,000	4.2
Ash Creek	Ash Valley	18 19	38N	11E	134	113	314,500	Gravity-concrete	130,600	0.4
Unnamed	Homer C. Jack	10 23	36N 36N	9E 9E	....	10 8	3,900	Earth-fill	22,000	5.6
Unnamed	Dry Lake	3	36N	8E	....	30	4,200	Earth-fill	53,000	13
Pit River	Big Valley	27	37N	7E	3,086	80	1,300,000	Gravity-concrete	42,500	0.03
Horse Creek	Dixie Valley	18	35N	8E	91	74	166,100	Rock fill	76,000	0.5
Pit River	Fall River	31	37N	5E	4,151	146	1,200,000	Rock-fill	....	....
Hat Creek	Big Springs	12	32N	4E	98	155	48,300	Gravity-concrete	148,900	3.1
Hat Creek	Lake Logan	2	32N	4E	6	55	7,300	Rock-fill	33,000	4.5
Burney Creek	Tamarack	1	33N	2E	62	51	51,000	Earth-fill	153,000	3.0
Pit River	Pit River No. 3	30	37N	3E	4,821	140	67,500	Gravity-concrete	88,000	1.3
Squaw Creek	Winni Bulli	6	34N	3W	85	255	25,500	Gravity-concrete	570,000	22
Squaw Creek	Medin	4	35N	2W	39	226	34,600	Gravity-concrete	306,000	8.8

*Reservoir constructed

Reservoir sites.

Prior to 1921, the only reservoir site in the Sacramento River Canyon that had been given serious consideration was that at Iron Canyon near Red Bluff. Although this site is favorably situated to equalize the run-off of the Sacramento River, its capacity is insufficient for the purpose.

Other sites exist on the Pit River capable of being developed to large capacity at reasonable costs but, being located on a tributary, have only a small fraction of the run-off of the main Sacramento basin passing their dam sites. The water that does reach these sites will be reduced by the future growth in demand for irrigation water in the Pit River basin.

The 1921–23 Water Resources Investigations made a reconnoissance survey in the Sacramento River Canyon from Redding to the mouth of the Pit River, a distance of 18 miles, in search of possible reservoir sites at a low elevation with capacity large enough to equalize the major portion of the run-off from the tributary drainage area. Three sites were found, the Keswick, Coram and Kennett, named from the towns in whose proximity the dam sites are located. Preliminary cost estimates revealed that storage could be constructed at the Kennett site with less cost than at either of the other two, both of which overlap the more favorable Kennett site. The Keswick site can be utilized in conjunction with the Kennett reservoir, as an afterbay to reregulate the discharge of the power turbines at the Kennett dam for irrigation use. The discharge from these turbines will fluctuate with the variation in power demand through the day and will need smoothing out before being turned loose in the river channel.

The foregoing table sets forth the salient information collected concerning reservoir sites in the main Sacramento River drainage basin. This information has been collected from various sources. It is presented without relation to the feasibility of the individual sites. Its accuracy is not known. It was assembled and used only for preliminary considerations in formulating the "Coordinated Plan" of development.

CHAPTER III.

KENNETT RESERVOIR SITE.

General.

The Kennett reservoir would be created by a dam across the canyon of the Sacramento River in section 15, township 33 north, range 5 west, M. D. B. and M., about 5 miles below the confluence with the Pit and 13 miles upstream from the city of Redding. A dam at this point would back the river up the upper Sacramento, the Pit, the McCloud, Squaw Creek and numerous canyons and gulches so that, although the reservoir is comparatively narrow, it would have a large capacity.

The site is naturally favorable for a high dam. Massive spurs converge from the mountain ranges on either side of the canyon to form a dam site for one of the most promising reservoirs in the entire State. A topographic survey of the dam site, made in 1924, discloses that the width of the stream channel at this point is only 150 feet. The canyon walls on either side rise on an average of 33 feet per 100 feet of distance. At a height of 610 feet above low water in the river, the canyon width is 3600 feet and the reservoir capacity is 10,000,000 acre-feet.

Were it not that the main line of the Southern Pacific Railroad, several miles of state highway, and improvements serving adjacent mines, traverse the reservoir site, it would yield stored water at a very low cost. The expense of flooding improvements constitutes from 31 to 64 per cent of the estimated construction cost of the reservoir, according to the height of dam considered.

Although the expense of relocating the Southern Pacific Railroad and state highway is large, these properties could function just as advantageously in other locations. There is no agricultural land within the reservoir site and for the most part the rather steep slopes have a value for grazing purposes only.

The Kennett dam site has tributary to it 72 per cent of the drainage area of the main Sacramento basin upstream from Red Bluff. The average seasonal run-off is 1100 acre-feet per square mile, a very excellent yield. Two of the tributary streams, the upper Sacramento and McCloud, that drain the slopes of Mount Shasta, have a run-off in relation to the size of their drainage areas that is exceeded in California only by a few of the smaller streams in the north Pacific Coast region. The average seasonal run-off of the Sacramento River above the confluence with the Pit is equivalent to 49 inches of depth on its drainage area and that of the McCloud River is equivalent to 45 inches. The average depth of seasonal run-off on the drainage areas of these two streams is approximately double that of any of the other tributaries upstream from the mouth of the Feather River.

Reservoir capacity.

A preliminary survey of the Kennett reservoir site was completed in 1924 to the 1200-foot contour, which is 615 feet above low water in the river at the dam site. The 1200-foot contour extends 33 miles up the main channel of the Sacramento River and 35 miles up the Pit. The surface area of a reservoir at this elevation would be 54,400 acres, which is unusually small for its large storage capacity. At this elevation there are 194 acre-feet capacity for each acre of water surface. This is more than double the capacity per acre of exposed water surface of many reservoir sites in California and there are few that exceed it. This relatively small area exposed to evaporation makes the Kennett reservoir an ideal site for over-year storage.

A working map was plotted from the preliminary surveys on a scale of 1 inch equals 1000 feet, showing contour intervals of 25 feet. The area and capacity of the reservoir at the several heights of dam were planimetered from this map and found to be as follows (see Plate C for Area-Capacity Curves):

CAPACITY OF KENNETT RESERVOIR.

Height of dam in feet (5 feet freeboard)	Water surface elevation of reservoir in feet	Area of water surface in acres	Capacity of reservoir in acre-feet
100	680	900	30,000
120	700	1,260	52,000
140	720	1,800	82,000
160	740	2,460	124,000
180	760	3,250	181,000
200	780	4,200	257,000
220	800	5,490	353,000
240	820	6,590	471,000
260	840	7,780	618,000
280	860	9,060	785,000
300	880	10,500	983,000
320	900	12,370	1,209,000
340	920	14,150	1,476,000
360	940	16,110	1,774,000
380	960	18,230	2,122,000
400	980	20,500	2,510,000
420	**1,000**	**23,030**	**2,240,000**
440	1,020	25,810	3,430,000
460	1,040	28,700	3,980,000
480	1,060	31,650	4,578,000
500	1,080	34,700	5,242,000
520	1,100	37,820	5,967,000
540	1,120	40,920	6,759,000
560	1,140	44,080	7,600,000
580	1,160	47,390	8,516,000
600	1,180	50,800	9,501,000
620	1,200	54,430	10,555,000

Water supply.

The drainage area upstream from the Kennett dam site is 6649 square miles, 2609 square miles less than that tributary to the Red Bluff gaging station of the United States Geological Survey. Although a gaging station is now established near the town of Kennett a few miles above the dam site, there is only a single season's measurement at this point. All water supply computations for the Kennett reservoir, therefore, have been based upon the records at the Red Bluff gaging station.

Estimates of the run-off of the separate tributaries to the main Sacramento basin have been published in Bulletin No. 5, "Flow in California Streams," pages 179 to 191. Applying these data, it is found that there is a mean seasonal run-off (50-year mean) of 2,536,000 acre-feet on the 2609 square miles of drainage area between the Kennett dam site and the Red Bluff gaging station. This is distributed between the several streams as set forth in the following table:

RUN-OFF FROM AREA BETWEEN RED BLUFF GAGING STATION AND KENNETT DAM SITE.

Stream	Drainage area in square miles	Mean seasonal run-off in acre-feet (50-year mean)
Cottonwood Creek	937	913,000
Clear Creek	251	295,000
Churn Creek Group	100	83,000
Cow Creek	444	510,000
Bear Creek Group	137	104,000
Ink's Creek	34	28,000
Paynes Creek	80	84,000
Battle Creek	367	422,000
Backbone Creek Group (partial)	113	97,000
Direct area	146	0
Totals	2,609	2,536,000

The mean seasonal run-off (50-year mean) at Red Bluff, unimpaired by upstream diversions, is 9,929,000 acre-feet. Subtracting the run-off from the area between Red Bluff and the dam site, the unimpaired mean seasonal run-off (50-year mean) at the Kennett dam site is found to be 7,393,000 acre-feet. This is 74 per cent of the run-off at the Red Bluff gaging station. This factor was used in estimating the monthly and seasonal run-off values at Kennett from the corresponding values at Red Bluff during the period of measurement. The estimates prior to 1895, the year of establishing the Red Bluff gaging station, were made by subtracting from the estimated values at Red Bluff, tabulated on page 19, the monthly and seasonal values for the 2609 square miles of drainage area between the gaging station and the Kennett dam site. The monthly and seasonal values for this area were taken from the estimates for the partial areas in the main Sacramento drainage basin published in Bulletin No. 5.*

The entire flow so estimated, with the exception of the water diverted for agricultural use in the Pit River basin, would be available for generating power at the Kennett dam site. However, due to prior rights established for agricultural use downstream from the Kennett reservoir site, only part of this water is available for new agricultural development.

In 1920 there were 127,000 acres under irrigation on the upper Pit River. This area is expanding from year to year and will eventually require practically the entire flow of the stream. In order to allow for the full development of the agricultural lands upstream from the Kennett reservoir site, the entire run-off of the Pit River basin, as measured at the Bieber gaging station of the United States Geological Survey, was deducted from the unimpaired run-off at the Kennett dam site to obtain the water available in the future for both power and irrigation development.

The seasonal run-off at Bieber was computed by developing a run-off curve from the several seasons' record of gagings, following the

* Pages 182 to 191, Bul. No. 5, "Flow in California Streams," Division of Engineering and Irrigation, State Department of Public Works.

methods described in Chapter IV, Bulletin No. 5, "Flow in California Streams," and taking off the values for the seasons other than those during which measurements were made by the use of the indices of wetness for Precipitation Division A (p. 82, Bul. No. 5). The unimpaired mean seasonal run-off (50-year mean) so obtained is 753,000 acre-feet. Therefore, the mean seasonal run-off at the Kennett dam site available for generating power is 6,640,000 acre-feet.

It is difficult to estimate the prior rights to water passing the Kennett dam site, since these rights have never been adjudicated. However, for the purpose of this investigation, it was assumed that the entire flow of the stream up to 5000 second-feet would be required between March 1st and October 31st in order to satisfy the rights of users downstream from the Kennett dam site. One-fourth of this was assumed to originate below the dam. On this basis, had these rights been in existence during the 50-year period, 1871 to 1921, and fullly exercised, they would have required for their satisfaction from the water passing the Kennett dam site an average of 1,737,000 acre-feet per season. The mean seasonal run-off at Kennett available for new agricultural development is, therefore, 4,903,000 acre-feet.

The following table sets forth these estimates by seasons, beginning in 1871:

SEASONAL RUN-OFF AVAILABLE FOR USE AT KENNETT DAM SITE.

Season (Oct. 1 to Sept. 30)	Estimated seasonal run-off in acre-feet				
	Sacramento River at Kennett dam site (unimpaired flow)	Pit River at Bieber	Available for power development at Kennett dam site	Prior rights downstream from Kennett dam site	Available at Kennett dam site for new irrigation use
1871-72	7,308,000	393,000	6,915,000	1,784,000	5,131,000
1872-73	4,341,000	330,000	4,011,000	1,496,000	2,515,000
1873-74	5,742,000	283,000	5,459,000	1,741,000	3,718,000
1874-75	3,996,000	189,000	3,807,000	1,447,000	2,360,000
1875-76	9,676,000	299,000	9,377,000	1,784,000	7,593,000
1876-77	8,186,000	2,753,000	5,433,000	1,784,000	3,649,000
1877-78	11,819,000	441,000	11,378,000	1,784,000	9,594,000
1878-79	6,324,000	393,000	5,931,000	1,773,000	4,158,000
1879-80	9,009,000	1,636,000	7,373,000	1,784,000	5,589,000
1880-81	11,103,000	2,360,000	8,743,000	1,784,000	6,959,000
1881-82	6,434,000	1,038,000	5,396,000	1,775,000	3,621,000
1882-83	5,373,000	315,000	5,058,000	1,692,000	3,366,000
1883-84	8,643,000	1,825,000	6,818,000	1,784,000	5,034,000
1884-85	5,623,000	1,007,000	4,616,000	1,655,000	2,961,000
1885-86	10,334,000	1,967,000	8,367,000	1,784,000	6,583,000
1886-87	5,711,000	991,000	4,720,000	1,676,000	3,044,000
1887-88	4,840,000	535,000	4,305,000	1,561,000	2,744,000
1888-89	7,800,000	960,000	6,840,000	1,784,000	5,056,000
1889-90	15,227,000	1,904,000	13,323,000	1,784,000	11,539,000
1890-91	5,433,000	598,000	4,835,000	1,668,000	3,167,000
1891-92	5,812,000	503,000	5,309,000	1,738,000	3,571,000
1892-93	8,866,000	1,180,000	7,686,000	1,784,000	5,902,000
1893-94	6,602,000	566,000	6,036,000	1,782,000	4,254,000
1894-95	8,575,000	677,000	7,898,000	1,784,000	6,114,000
1895-96	8,406,000	960,000	7,446,000	1,784,000	5,662,000
1896-97	7,701,000	897,000	6,804,000	1,784,000	5,020,000
1897-98	3,806,000	252,000	3,554,000	1,759,000	1,795,000
1898-99	4,430,000	267,000	4,163,000	1,756,000	2,407,000
1899-00	6,457,000	566,000	5,891,000	1,743,000	4,148,000
1900-01	6,685,000	708,000	5,977,000	1,738,000	4,239,000
1901-02	8,434,000	456,000	7,978,000	1,737,000	6,241,000
1902-03	7,368,000	346,000	7,022,000	1,717,000	5,305,000
1903-04	11,928,000	1,367,000	10,561,000	1,759,000	8,802,000
1904-05	7,985,000	390,000	7,595,000	1,769,000	5,826,000
1905-06	8,370,000	844,000	7,526,000	1,782,000	5,744,000
1906-07	10,289,000	1,254,000	9,035,000	1,784,000	7,251,000
1907-08	5,870,000	279,000	5,591,000	1,766,000	3,825,000
1908-09	10,796,000	708,000	10,088,000	1,784,000	8,304,000
1909-10	6,749,000	346,000	6,403,000	1,775,000	4,628,000
1910-11	7,491,000	897,000	6,594,000	1,784,000	4,810,000
1911-12	4,875,000	236,000	4,639,000	1,784,000	2,855,000
1912-13	5,224,000	393,000	4,831,000	1,752,000	3,079,000
1913-14	10,181,000	748,000	9,433,000	1,763,000	7,670,000
1914-15	9,325,000	189,000	9,136,000	1,776,000	7,360,000
1915-16	7,945,000	472,000	7,473,000	1,774,000	5,699,000
1916-17	5,311,000	488,000	4,823,000	1,737,000	3,086,000
1917-18	3,993,000	173,000	3,820,000	1,669,000	2,151,000
1918-19	5,765,000	267,000	5,498,000	1,700,000	3,798,000
1919-20	3,015,000	189,000	2,826,000	1,595,000	1,231,000
1920-21	8,464,000	802,000	7,662,000	1,659,000	6,003,000
1921-22	4,904,000	524,000	4,380,000	1,633,000	2,747,000
1922-23	3,927,000	267,000	3,660,000	1,605,000	2,055,000
1923-24	2,417,000	255,000	2,162,000	1,268,000	894,000
1924-25	5,950,000	323,000	5,627,000	1,573,000	4,054,000
Mean seasonal, 1871-1921, 50 years	7,393,000	753,000	6,640,000	1,737,000	4,903,000
Mean seasonal, 1871-1925, 54 years	7,164,000	722,000	6,442,000	1,721,000	4,721,000

Water yield for irrigation.

Due to the great irregularity in the values of seasonal run-off in successive years, storage facilities do not yield the same equalized flow in all years or through all periods of years. The foregoing tabulation of the seasonal run-off available for new irrigation use shows a minimum seasonal value of 894,000 acre-feet for 1923–24 and a maximum value of 11,539,000 acre-feet in 1889-90, thirteen times larger than the minimum.

If it were proposed to provide storage only for holding winter water over for the following summer use, 894,000 acre-feet of reservoir capacity would make the available run-off of the minimum year usable for new irrigation supplies. Such a reservoir would deliver a perfect supply through all seasons, but the average yield would be only about 20 per cent of the mean seasonal run-off available for new irrigation supplies. Eighty per cent of the available run-off would be wasted.

If it were desired to utilize in each season the entire available run-off of that season, the reservoir should be constructed to store the winter water of the maximum season for use during the following summer. This would require a capacity of 7,905,000 acre-feet, about nine times larger than is necessary to equalize the minimum season. If such a reservoir had been constructed in 1871 and emptied each season, it would have been put to full use only once in the following 54 years. On the average only 50 per cent of its capacity would have been utilized, and the yield in successive seasons would have varied 1300 per cent. Obviously, it would be useless to develop such an irregular supply, for there is no type of agriculture that could survive its uncertainties. To obtain practical results in the use of much more than the minimum seasonal run-off, it is necessary to store water over from one season to another. The extent to which this should be done to secure a reasonably uniform draft from the reservoir requires an extended investigation.

Analyses of the yield of the Kennett reservoir, operating primarily for irrigation, were made for five heights of dam. The irrigation draft was determined for each height that could be sustained through the 54-year period of run-off estimates with a deficiency in supply not oftener, on an average, than one year in ten. These analyses were made by applying the assumed rate of draft to the 54 seasons of run-off record and noting the progressive results. The application was made month by month through the entire period, starting from a full reservoir at the close of the year 1871, and using the estimated monthly values of unimpaired run-off at the Kennett dam site reduced by the flow of the Pit River at Bieber. The analyses were made both with and without the deduction of estimated prior rights downstream from the dam site.

The irrigation draft from the reservoir was assumed to be distributed through the season in accordance with the desirable monthly irrigation demand determined for the Sacramento Valley floor in previous studies.* It is as follows:

* See p. 63, Bul. No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, State Department of Public Works.

DISTRIBUTION OF IRRIGATION DEMAND THROUGH THE SEASON.

Month:	Irrigation demand in per cent of total seasonal use
January	0
February	0
March	1
April	5
May	16
June	20
July	22
August	20
September	12
October	4
November	0
December	0
Total	100

The water in storage in the reservoir was reduced month by month by the estimated evaporation from the water surface. This was taken at 3.5 feet net per annum, distributed between the months from April to December as in the following table. It was assumed that the gain from precipitation on the reservoir surface from December to April compensates the loss by evaporation during these months.

ESTIMATED NET EVAPORATION FROM KENNETT RESERVOIR.

Month	Depth in feet	Per cent of seasonal total
April	0.32	9.2
May	0.44	12.6
June	0.52	15.0
July	0.62	17.8
August	0.58	16.6
September	0.45	12.7
October	0.34	9.6
November	0.23	6.5
Totals	3.50	100.0

These computations show that a 420-foot dam would produce each season 2,838,000 acre-feet of new water equalized for irrigation use, or 4,276,000 acre-feet, including prior-right water equalized to the irrigation demand. The seasonal yields for five heights of dam are shown in the following table, together with the average and maximum amounts of their deficiencies. It may be noted that the magnitude of the deficiencies in supply increases for the larger reservoirs, although the frequency with which they occur averages one year in ten for all heights of dam. The value of the maximum deficiency ranges from 50 to 81 per cent for the three highest dams. Such deficiencies would be disastrous if they occurred very often. However, reference to the tables on pages 37 and 38 shows that these maximum deficiencies occurred in 1924, a year of 33 per cent normal run-off, terminating a series of three years that averaged 51 per cent normal, a most unusual occurrence. (See table, page 29.) The deficiencies in the year 1920 were also rather large, but the maximum deficiencies during the 48-year period prior to 1920 ranged in the several computations from only 1 to 22 per cent.

If, in order to avoid the large deficiencies here shown in the yields for the higher dams, a moderate limit had been placed on the maximum deficiency in supply when computing the yields for the several heights of dam compared, the high dams would have shown almost perfect supply through the 48-year period prior to 1920 and would have had only moderate deficiencies in 1924. Such supplies would be uneconomically perfect and superior to the yields for the lower dams which would have had a larger number of deficiencies approaching the moderate limit during the same period. Therefore, while the system adopted for making the comparisons, of computing yields on the basis of equal frequency of deficiencies, does not produce exactly comparable results, it is believed that they are more nearly comparable than would have been obtained had a moderate limit been placed on the allowable deficiency. To obtain exactly comparable results would have required placing a different limit on the maximum deficiency in the computations of yield for each height of dam. This limit would have been fixed by weighing the relative consequence of the magnitude and frequency of the several deficiencies. The labor involved in accomplishing this through a series of trial computations was judged to be greater than was warranted by the small difference that it would have made in the results.

SEASONAL IRRIGATION YIELD—KENNETT RESERVOIR.

Operating primarily for irrigation.

Deficiency in Supply on Average of One Year in Ten.

Height of dam in feet (5 feet freeboard)	**Without** deduction for prior rights			**With** deduction for prior rights		
	Irrigation yield in acre-feet per season	Deficiency in per cent		Irrigation yield in acre-feet per season	Deficiency in per cent	
		Average of all seasons	Maximum season		Average of all seasons	Maximum season
220	1,468,000	0.6	18	466,000	0.7	26
320	2,559,000	0.6	16	1,418,000	0.9	38
420	**4,276,000**	**1.6**	**50**	**2,838,000**	**2.8**	**69**
520	5,486,000	2.8	61	3,858,000	3.6	77
620	6,372,000	3.2	66	4,686,000	4.1	81

It is interesting to observe the part of the seasonal irrigation yield that is supplied from stored water. This varies for the several heights of dam and from season to season for the same height. For the 420-foot dam without deduction for prior rights 50 per cent of the average yield is water taken from storage, and with deduction for prior rights 71 per cent of the average yield is taken from storage. The remainder is supplied direct from the flow in the stream. The average use of the reservoir space each season is 74 and 68 per cent, respectively. The following table presents these figures for all heights of dam:

DRAFT ON STORED WATER IN KENNETT RESERVOIR.

Operating Primarily for Irrigation, with Deficiency in Supply on Average of One Year in Ten.

Height of dam in feet (5 feet freeboard)	Capacity of reservoir, in acre-feet	Seasonal irrigation yield, in acre-feet	Seasonal draft on stored water: Average, 1871-1925			Maximum		Minimum	
			In acre-feet	In per cent of seasonal irrigation yield	In per cent of reservoir capacity	Year	Acre-feet	Year	Acre-feet
				Without Deduction for Prior Rights					
220	353,000	1,468,000	141,000	9.6	39.9	[1]1873	353,000	1890	0
320	1,209,000	2,559,000	812,000	31.7	67.2	[2]1873	1,209,000	1890	0
420	2,940,000	4,276,000	2,151,000	50.5	73.5	1875	2,914,000	1890	614,000
520	5,967,000	5,486,000	3,171,000	57.8	53.1	1873	3,979,000	1924	1,040,000
620	10,555,000	6,372,000	3,967,000	62.3	37.6	1873	4,854,000	1924	1,031,000
				With Deduction for Prior Rights.					
220	353,000	466,000	197,000	42.3	55.8	[3]1873	353,000	1876	0
320	1,209,000	1,418,000	855,000	60.3	70.7	[4]1873	1,209,000	1878	34,000
420	2,940,000	2,838,000	2,008,000	70.8	68.3	1873	2,576,000	1890	529,000
520	5,967,000	3,828,000	2,908,000	75.4	48.7	1898	3,665,000	1924	894,000
620	10,555,000	4,686,000	3,665,000	78.2	34.7	1898	4,539,000	1924	894,000

[1] Other years giving maxima, 1875, 1888, 1920, 1923, 1924.
[2] Other years giving maxima, 1875, 1888, 1920, 1923.
[3] Other years giving maxima, 1875, 1901, 1920, 1923, 1924.
[4] Other years giving maxima, 1918, 1923.

The foregoing computations of seasonal irrigation yield of the Kennett reservoir are based on shortages occurring on an average of one year in ten. Past experience has demonstrated that farming enterprises, particularly in the developmental stage, can better survive occasional deficiencies in their water supply than to accept the burden of paying for deliveries perfect in the regularity of their full volume.* Extended studies were made to ascertain the variance in volume of yield with different average frequencies of deficiency.

The irrigation yield from the Kennett reservoir, when operating primarily for this purpose, would increase as much as 60 per cent over a perfect supply according to the amount and frequency of deficiencies that might be endured. From these studies it was concluded that, for practical purposes, an irrigation supply having deficiencies on an average not oftener than one year in ten would be the economic type of supply to provide during the developmental period in northern California. In later years, after the heavy initial construction costs have been paid off, greater regularity in supply could be obtained if desired by enlarging the reservoir. The selection of a draft with deficiencies in supply on an average of one year in ten increases the area of service from a reservoir of given size from 22 to 43 per cent over that for a draft that would carry through the driest year without a shortage.

The following table sets forth the area of service (net) from a 420-foot dam for several average frequencies of deficiency in supply based upon a net consumptive use of 2.5 acre-feet per acre. It may be observed that, if a deficiency in supply is sustained on an average of one year in ten, 34 per cent greater area may be served with an equalized irrigation supply inclusive of prior rights and 43 per cent greater area exclusive of prior rights, and that the average deficiency in seasonal supply would be small, although deficiencies as large as 50 and 69 per cent, respectively, would have to be endured at long intervals. The magnitudes of all the deficiencies, had the reservoir been in operation from 1871 to 1925, are tabulated in the tables on pages 37 and 38. Reference to these tables shows that the largest deficiency during the 49-year period, 1871–1920, while operating with a deficiency in yield on the average of one year in ten, was 4 per cent without deduction for prior rights and 15 per cent with deduction for prior rights. The years 1920 and 1924 brought deficiencies in yield of 27 and 50 per cent, respectively, without deduction for prior rights, and 41 and 69 per cent, respectively, with deduction for prior rights. They are the only serious shortages during the entire 54 years of test. Although these deficiencies are large and would seriously impair agricultural production during the season in which they occur, they would not inflict permanent damage. An inspection of the table of seasonal run-off available for use at the Kennett dam site on page 29 is convincing that it would be uneconomical at this time to construct over-year storage in order to obtain a full supply in such seasons. The shortages in supply, although large, must be endured in this type of season because the records disclose that they occur too infrequently, only twice in the 54 years, to warrant large expenditures for reservoir space

* See p. 73, Bul. No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, State Department of Public Works.

that would be so seldom used. The cost of additional storage space in the Kennett reservoir that would be sufficiently large to hold over flood waters from previous years of plenteous run-off in amounts that would furnish a perfect supply in the lean years of 1920 and 1924, under present conditions, would exceed the benefit accruing to agricultural production in having the full irrigation supply during these seasons.

AREA OF IRRIGATION SERVICE FROM KENNETT RESERVOIR.

420-Foot Dam.

With Varying Average Frequency of Deficiency in Supply.

Average frequency of deficiency in supply in period 1871-1925	**Without** deduction for prior rights				**With** deduction for prior rights			
	Area in acres (net)	Area in per cent of service with no deficiency in supply	Deficiency in seasonal supply, in per cent		Area in acres (net)	Area in per cent of service with no deficiency in supply	Deficiency in seasonal supply, in per cent	
			Average of all years	Maximum year			Average of all years	Maximum year
No deficiency	1,278,000	100	0	0	794,000	100	0	0
1 year in 50 years	1,463,000	114	0.4	24	891,000	112	0.4	20
1 year in 25 years	1,672,000	131	1.3	49	1,027,000	129	1.4	52
1 year in 10 years	1,710,000	134	1.6	50	1,135,000	143	2.8	69
1 year in 5 years	1,828,000	143	3.1	53	1,289,000	162	5.3	72

The data concerning the varying yield for different frequencies of deficient supply are so interesting that they are given complete in the following tables. First, the irrigation yield in acre-feet per season is given for several average frequencies of deficiency and heights of dam, both with and without deductions for estimated prior rights. The second table gives the net area in acres that could be irrigated under the same conditions of supply. These areas were computed on a duty of 2.5 acre-feet per acre per season, which includes the full use of return waters. Actual deliveries over much of the area would exceed this amount. The third table expresses the irrigation yield for the several average frequencies of deficiency in per cent of that having a deficiency on an average of one year in ten. The fourth and fifth tables set forth the amount of the deficiencies under the several different conditions and the years in which they would have occurred. In reviewing the latter tables, it will be noticed that the amounts of the deficiencies for a specific frequency vary considerably in the several computations for different heights of dam. In general, they tend to increase with the size of the reservoir. Limitations on the amounts of the deficiencies as well as their frequency should be included for a complete definition of the quality of a supply. The comparison of supplies in these tables is based only upon equal average frequency of deficiencies without regard to their amount because of the difficulty of including two criteria in the computations. A few minor inconsistencies in the tables may be explained by this omission.

IRRIGATION YIELD—KENNETT RESERVOIR.
ACRE-FEET PER SEASON.
Operating Primarily for Irrigation.

Average frequency of deficiency in supply during period 1871-1925	Height of dam in feet (5 feet freeboard)				
	220	320	420	520	620
	Without Deduction for Prior Rights.				
No deficiency	1,166,000	2,102,000	3,196,000	4,411,000	5,142,000
1 year in 50 years	1,322,000	2,404,000	3,658,000	4,915,000	5,551,000
1 year in 25 years	1,374,000	2,441,000	4,181,000	5,154,000	5,574,000
1 year in 10 years	1,468,000	2,559,000	4,276,000	5,486,000	6,372,000
1 year in 5 years	1,598,000	2,723,000	4,570,000	5,878,000	6,615,000
	With Deduction for Prior Rights.				
No deficiency	343,000	1,115,000	1,986,000	2,962,000	3,562,000
1 year in 50 years	431,000	1,329,000	2,227,000	3,298,000	3,927,000
1 year in 25 years	443,000	1,381,000	2,567,000	3,521,000	3,996,000
1 year in 10 years	466,000	1,418,000	2,838,000	3,858,000	4,686,000
1 year in 5 years	497,000	1,513,000	3,222,000	4,191,000	4,994,000

AREA OF IRRIGATION SERVICE—KENNETT RESERVOIR.
IN ACRES.
Operating Primarily for Irrigation.

Average frequency of deficiency in supply during period 1871-1925	Height of dam in feet (5 feet freeboard)				
	220	320	420	520	620
	Without Deduction for Prior Rights.				
No deficiency	466,000	841,000	1,278,000	1,764,000	2,057,000
1 year in 50 years	529,000	962,000	1,463,000	1,966,000	2,220,000
1 year in 25 years	550,000	976,000	1,672,000	2,062,000	2,230,000
1 year in 10 years	587,000	1,024,000	1,710,000	2,194,000	2,549,000
1 year in 5 years	639,000	1,089,000	1,828,000	2,351,000	2,646,000
	With Deduction for Prior Rights.				
No deficiency	137,000	446,000	794,000	1,185,000	1,425,000
1 year in 50 years	172,000	532,000	891,000	1,319,000	1,571,000
1 year in 25 years	177,000	552,000	1,027,000	1,408,000	1,598,000
1 year in 10 years	186,000	567,000	1,135,000	1,543,000	1,874,000
1 year in 5 years	199,000	605,000	1,289,000	1,676,000	1,998,000

IRRIGATION YIELD—KENNETT RESERVOIR—IN PER CENT OF YIELD WITH DEFICIENCY IN SUPPLY ON AVERAGE OF ONE YEAR IN TEN.
Operating Primarily for Irrigation.

Average frequency of deficiency in supply during period 1871-1925	Height of dam in feet (5 feet freeboard)				
	220	320	420	520	620
	Without Deduction for Prior Rights.				
No deficiency	79.4	82.1	74.7	80.4	80.7
1 year in 50 years	90.1	93.9	85.6	89.6	87.1
1 year in 25 years	93.6	95.3	97.8	94.0	87.5
1 year in 10 years	100.0	100.0	100.0	100.0	100.0
1 year in 5 years	108.9	106.3	106.9	107.2	103.8
	With Deduction for Prior Rights.				
No deficiency	73.6	78.7	70.0	76.8	76.0
1 year in 50 years	92.5	93.8	78.5	85.5	83.8
1 year in 25 years	95.1	97.4	90.5	91.3	85.3
1 year in 10 years	100.0	100.0	100.0	100.0	100.0
1 year in 5 years	107.0	106.7	113.6	108.6	106.6

KENNETT RESERVOIR.
AMOUNT AND YEAR OF DEFICIENCY IN SEASONAL IRRIGATION YIELD DURING PERIOD 1871-1925.
Without Deduction for Prior Rights.
Operating Primarily for Irrigation, with Yields Shown in Tables on Page 36.

Height of dam in feet (5 feet freeboard)	Frequency of deficiency in supply							
	1 year in 50 years		1 year in 25 years		1 year in 10 years		1 year in 5 years	
	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply
220	1924	11	1875	3	1888	1	1887	1
			1924	14	1920	1	1918	2
					1873	5	1885	2
					1875	7	1925	4
					1924	18	1923	6
							1920	7
							1888	7
							1873	10
							1875	13
							1924	24
Average	....	11	....	8.5	....	6.4	....	7.6
320	1924	11	1875	1	1923	2	1887	1
			1924	12	1873	3	1925	2
					1920	4	1885	2
					1875	5	1918	5
					1924	16	1888	5
							1923	7
							1873	8
							1920	9
							1875	10
							1924	21
Average	....	11	....	6.5	....	6	....	7
420	1924	24	1920	23	1898	2	1922	1
			1924	49	1899	4	1873	4
					1923	4	1888	6
					1920	27	1899	10
					1924	50	1918	10
							1875	12
							1898	14
							1923	20
							1920	37
							1924	53
Average	....	24	....	36	....	17.4	....	16.7
520	1924	42	1920	22	1875	10	1900	1
			1924	58	1899	14	1898	3
					1923	18	1925	5
					1920	49	1919	8
					1924	61	1918	18
							1899	29
							1875	34
							1923	36
							1920	52
							1924	64
Average	....	42	....	40	....	30.4	....	25
620	1924	61	1923	3	1925	11	1899	5
			1924	65	1922	13	1875	8
					1920	42	1900	12
					1923	43	1901	12
					1924	66	1888	14
							1925	16
							1922	20
							1923	45
							1920	58
							1924	68
Average	....	61	....	34	....	35	....	25.8

KENNETT RESERVOIR.
AMOUNT AND YEAR OF DEFICIENCY IN SEASONAL IRRIGATION YIELD DURING PERIOD 1871-1925.
With Deduction for Prior Rights.
Operating Primarily for Irrigation, with Yields Shown in Tables on Page 36.

Height of dam in feet (5 feet freeboard)	Frequency of deficiency in supply							
	1 year in 50 years		1 year in 25 years		1 year in 10 years		1 year in 5 years	
	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply	Year	Deficiency in per cent of full supply
220	1924	20	1920 1924	3 22	1901 1923 1873 1920 1924	1 1 4 7 26	1888 1887 1918 1919 1875 1901 1923 1873 1920 1924	2 2 3 3 4 5 6 8 12 31
Average	....	20	....	12.5	....	7.8	....	7.6
320	1924	30	1920 1924	4 36	1873 1918 1923 1920 1924	1 1 2 8 38	1899 1887 1901 1875 1898 1873 1918 1923 1920 1924	1 1 2 4 6 6 7 8 19 42
Average	....	30	....	20	....	10	....	9.6
420	**1924**	**20**	**1920 1924**	**25 52**	**1898 1923 1899 1920 1924**	**12 14 15 41 69**	**1873 1922 1888 1875 1918 1899 1898 1923 1920 1924**	**2 9 11 16 23 25 33 37 59 72**
Average	....	**20**	....	**38.5**	....	**30.2**	....	**28.7**
520	1924	54	1920 1924	30 75	1875 1899 1923 1920 1924	1 22 25 68 77	1900 1901 1925 1919 1918 1875 1899 1923 1920 1924	1 2 5 11 19 30 42 47 71 79
Average	....	54	....	52.5	....	38.6	....	30.7
620	1924	77	1923 1924	13 78	1925 1922 1920 1923 1924	15 16 50 57 81	1919 1900 1901 1925 1922 1888 1899 1923 1920 1924	1 17 18 20 27 33 35 59 76 82
Average	....	77	....	45.5	....	43.8	....	36.8

Power yield.

Electric power may be generated at the Kennett reservoir by constructing a power plant below the dam, through which would pass, under reservoir pressure, all or part of the water released. The amount and character of power that could be so generated will depend upon the manner in which water is released from storage. Ultimately, the State's interests will be served best by releasing this water in conjunction with that from the Iron Canyon reservoir, in accord with the demand for irrigation use modified to fit the necessities of navigation and salt water control in the Sacramento River.

The demand for irrigation water varies in volume from month to month with the necessity of irrigating crops, but follows nearly the same fluctuations each season. The table on page 31 presents these estimated average fluctuations. While the demand for electric power increases during the summer months similarly to the demand for irrigation water, the increase is not nearly so large. The following table shows that, while the irrigation demand increases during the summer months 164 per cent of the average rate, the state-wide demand for power increases only 14 per cent of the average rate.

COMPARISON OF MONTHLY DEMAND FOR ELECTRIC POWER AND IRRIGATION WATER IN TERMS OF THE AVERAGE DEMAND.

Month	Electric power consumption in per cent of annual total (state-wide average)	Irrigation water consumption in per cent of annual total (Sacramento Valley)
January	7.3	0
February	6.9	0
March	7.8	1
April	7.9	5
May	8.8	16
June	9.0	20
July	9.4	22
August	9.5	20
September	8.7	12
October	8.5	4
November	8.0	0
December	8.2	0
Totals	100.0	100.0

Although the foregoing table shows that, at the time the demand for irrigation water would absorb the entire capacity of the reservoir for equalizing the stream flow, power can not be generated from the released water in accordance with the need for this commodity, nevertheless, there will be a period when it can, while the area to be irrigated is changing over to intensive farming and the full capacity of the reservoir is not required for irrigation service. The ultimate irrigation service, especially from the larger reservoirs, is so great that many years will pass before the demand for water equals the total available supply. During this period of irrigation development, considerable advantage may be obtained in the generation of power by modifying the time of release of water from the reservoir to best suit the needs of power generation. A more satisfactory power output may be obtained prior to the ultimate use of the water for irrigation than could be generated from the water if released at the present time in accordance with its ultimate disposition.

Analyses have been made of the power that could be generated under two methods of release, the one primarily for power generation and the other for maximum irrigation use. The latter analysis approximates the way in which water would be released ultimately from the reservoir under the "Coordinated Plan," however, some modification would be made in order that Kennett could contribute its part in maintaining navigation and salt water control in the Sacramento River.

The power output, while releasing stored water primarily for the generation of power, was computed for a plant serving its individual system of power distribution. Operating for this service, it would be desirable to secure the maximum production of continuous power in order to minimize duplicate steam stand-by service. The estimated maximum continuous output was classed as primary power. Power that could be generated at intervals economically, in addition to the continuous output, was classed as secondary power. If the installation were connected into an extended system with many generating plants, its operation would be adjusted to the particular needs of that system and the output of secondary power might vary from the estimates of this report. The primary output, however, would remain the same.

The estimates of yield operating primarily for power generation were carried forward month by month as in the analyses of water yield, commencing with a full reservoir at the close of 1871. The water draft through the turbines was varied with the altering reservoir level to maintain a uniformly constant primary power output throughout the entire 54-year period, 1871–1925. Secondary power was included in the estimates during those periods in which water was available in excess of the needs for generating primary power. There was no secondary output during the critical seasons that determined the volume of primary power that could be generated. Since secondary power requires stand-by generating capacity in some other plant for use during the periods in which the secondary power is not available, its value is much less than primary power. For this reason, a standard method was adopted for computing secondary power that would permit completion with the means at hand of the great bulk of such computations incident to formulating the "Coordinated Plan." This method yields results adequate for comparing values of reservoir sites and alternate reservoir capacities but, as later pointed out, requires modification for other purposes.

The standard method adopted for computing secondary power included quantities in the estimates only during those periods in which the reservoir was full and to the extent it was economical to increase the capacity of the installation to use water that otherwise would have wasted over the spillway. The plant efficiency used in the estimates, including entrance, penstock and draft-tube losses, fluctuated above and below 75 per cent for the varying conditions of head and efficiency of turbines and generators. The greatest drawdown during the 54 years of computation was to seven-tenths depth. Deductions in head acting on the turbines were made for the raised level of the tail race during seasons of flood or large discharge from the reservoir.

When operating primarily for the needs of irrigation, the power yield was computed for the same installation as in the first set of computations. Instead, however, of varying the draft through the turbines to maintain a uniform output of primary power, the draft was limited to water released for irrigation plus spill when the reservoir was full and the power was computed on a 100 per cent load factor. In the first set of computations, operating primarily for the generation of power, the production was obtained from the same installation on a 75 per cent load factor but in the second set the entire installed capacity of the plant was utilized when water was available. At times in the second set of computations when the available water was less than the capacity of the turbines, the plant could have operated on other than a 100 per cent daily load factor but the average power output would have been the same. Between the months of October and March, there was no water available for power generation except when the reservoir had filled to overflowing. The average period of plant idleness was four-tenths of a month for the lowest dam height to five months for the 620-foot dam. No power was entered in the computations when the reservoir level was below half depth. While there would be some output under these conditions, the low head, the poor efficiencies and the infrequent occurrence would make it relatively small in amount.

The power output at five heights of dam was estimated as follows:

POWER YIELD—KENNETT RESERVOIR.

Height of dam in feet (5 feet freeboard)	Installed capacity in k. v. a. P. F.=0.80	Average yield in kilowatts—Operating primarily for power. Load factor=0.75			Average yield in kilowatts—Operating primarily for irrigation. Load factor=1.00
		Primary	Secondary	Total	Secondary
220	315,000	37,800	60,600	98,400	105,600
320	395,000	69,500	67,600	137,100	143,900
420	**400,000**	**113,400**	**47,100**	**160,500**	**159,400**
520	450,000	175,600	28,200	203,800	165,500
620	500,000	248,800	0	248,800	160,100

The primary power of the foregoing table is a steady continuous output but the secondary is intermittent. The characteristics of the secondary power may be best described by tabulating the average monthly values together with the monthly values of the maximum, minimum and several recent years. The method of computing secondary power employed in the preparation of the foregoing table, however, limits the time of year for the generation of secondary power to the periods during the winter and spring when the reservoir is full. A part of this secondary power could be generated in the summer months and thus secure a more useful distribution through the year. The amount would be limited to that which would not draw the reservoir level below its cycle in generating primary power during critical seasons. The power output at the 420-foot dam, therefore, was recomputed on this basis. A change was also introduced in the computation of primary power. It was generated in accord with the average state-wide variation through the season in the demand for power instead of at a uniformly constant rate as was assumed for convenience in the first set of computations. The state-wide average demand for power increases from 10 to 14 per cent above the average during the midsummer months. The results of the second set of computations are incorporated in the first of the two following tables which show the characteristics of the power that could be generated at the Kennett dam site. The average primary power output of 113,400 kilowatts is identical with that of the first set of computations but the average secondary output increased from 47,100 kilowatts to 56,600 kilowatts with a larger proportion during the summer months. The characteristics of the secondary power shown in the first table are those while operating primarily for power generation. The second of the two following tables shows the characteristics of the secondary power (the entire output) if operating primarily for irrigation.

CHARACTERISTICS OF POWER OUTPUT.
KENNETT RESERVOIR—420-FOOT DAM.
Operating Primarily for Power.

Installed capacity 400,000 k. v. a. (P. F. -0.80).
Load factor, 0.75.
Primary power in accord with state-wide demand.
Reservoir level drawn down each year to 1923 levels.

Month	Primary power in kilowatts	Secondary power in kilowatts				
		Average for 54-year period, 1871-1925	Maximum year, 1878	Minimum year, 1924	1916	1920
January	97,400	41,100	112,600	0	112,600	0
February	101,900	82,900	108,100	0	111,600	0
March	104,200	91,500	105,800	0	105,800	0
April	109,000	91,800	101,000	0	101,000	0
May	117,500	72,900	92,500	0	84 000	0
June	124,200	14,300	85,800	0	50,800	0
July	125,400	37,?00	84,600	0	55,200	0
August	126,700	32,800	83,300	0	32,500	0
September	120,000	29,600	90,000	0	23,800	0
October	113,400	33,700	96,600	0	19,900	0
November	110,300	57,600	99,700	0	27,500	30,700
December	109,400	65,300	100,600	0	44,500	100,600
Average	113,400	56,600	96,600	0	64,000	11,000

CHARACTERISTICS OF POWER OUTPUT.
KENNETT RESERVOIR—420-FOOT DAM.
Operating Primarily for Irrigation.

Installed capacity 400,000 k. v. a. (P. F. -0.80).
Load factor, 1.00.
Seasonal irrigation draft 4,276,000 acre-feet.
Deficient in supply one year in ten.
Without deduction for prior rights.
Draft from reservoir in accord with the demand for irrigation water.

Month	Primary power in kilowatts	Secondary power in kilowatts				
		Average 1871-1925	Maximum year, 1890	Minimum year, 1924	1916	1920
January	0	73,200	280,000	0	149,600	0
February	0	164,300	280,000	0	280,000	0
March	0	210,200	280,000	13,400	280,000	14,300
April	0	235,100	280,000	70,700	280,000	80,100
May	0	277,000	280,000	191,400	280,000	243,300
June	0	272,900	280,000	0	280,000	233,300
July	0	267,500	280,000	0	280,000	0
August	0	240,800	280,000	0	266,900	0
September	0	130,200	212,600	0	151,800	0
October	0	38,700	69,200	0	47,000	0
November	0	0	0	0	0	0
December	0	3,300	42,700	0	0	0
Average	0	159,400	213,400	23,100	190,900	47,500

Although, in generating the power listed in the first of the two foregoing tables, the reservoir would be operating primarily for the generation of power, nevertheless, a very considerable area could be irrigated from the water in the turbine discharge. The amount of water that could be diverted in accord with the demand for irrigation water and the area that it would irrigate are set forth in the following tabulation. It shows, for a 420-foot dam, 38.1 per cent of the ultimate area could be irrigated from the turbine discharge while operating primarily for power without deduction for prior rights and 19.5 per cent with deduction for prior rights.

In computing the volume of irrigation water entered in this table, approximately the same average deficiency was allowed in the supply that is contained in the estimates of water yield from the reservoir for like heights of dam when operating primarily for irrigation with a deficiency in supply on an average of one year in ten.

Comparisons in this instance are made on the basis of the amount of average deficiencies rather than on the basis of the frequency of deficiencies because the range in value of the deficiencies in supply taken from the turbine discharge is small. The range in value of deficiencies operating the reservoir primarily for irrigation use is large. To compare the two on the basis of frequency of deficiencies would not compare equivalent supplies. The comparison upon the basis of equal values for average deficiencies as made in the following table is not entirely of equivalent supplies but more nearly so than if the comparison were made on the former basis.

IRRIGATION SERVICE FROM KENNETT RESERVOIR.

Operating Primarily for Generation of Power.

Height of dam in feet (5 feet freeboard)	Water available in turbine discharge for diversion in accord with irrigation demand				Net area irrigable (net consumptive use 2.5 acre-feet per acre)	
	Acre-feet per season	Deficiency in seasonal irrigation supply in per cent of perfect supply		Average flow in month of August in second-feet	In acres	In per cent of area irrigable if operating primarily for irrigation
		Average of all years	Maximum year			
		Without Deduction for Prior Rights.				
220	1,116,000	0.6	14.6	5,000	446,000	76.0
320	1,221,000	0.6	5.2	5,300	488,000	47.7
420	**1,631,000**	**1.6**	**7.9**	**6,200**	**652,000**	**38.1**
520	1,986,000	2.8	6.9	7,300	794,000	36.2
620	2,285,000	3.2	5.2	7,900	914,000	35.9
		With Deduction for Prior Rights.				
220	106,000	0.7	33.8	1,600	42,000	22.6
320	*73,000	0.9	15.9	1,900	29,000	5.1
420	**552,000**	**2.8**	**17.0**	**2,800**	**221,000**	**19.5**
520	853,000	3.6	10.0	3,900	341,000	22.1
620	1,170,000	4.1	8.2	4,500	468,000	25.0

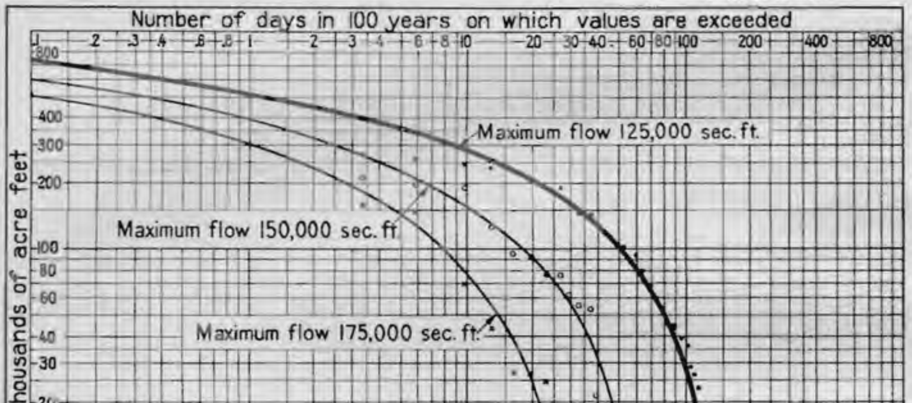
*It would appear by comparison with the quantities for other dam heights that this value should be larger than 73,000. An examination of the detail power computations shows that, for this height of dam, there is less draw down in the reservoir during the month of June than for other heights. This is purely a circumstance of the application of uniform assumptions to the computations for all heights of dam. In this instance the computations carried through with smaller relative turbine discharges in the generation of power during June than for other dam heights and hence there was relatively less water available for new irrigation use if the average deficiency were not allowed to exceed that occurring when operating primarily for irrigation with a deficiency on the average of one year in ten. If this average deficiency were allowed to reach 2.0 per cent instead of only 0.9 per cent, the water available in the turbine discharge for new irrigation use would have been 171,000 acre-feet.

Flood control.

The value of the Kennett reservoir for controlling floods depends upon its ability to absorb the volume of flow that constitutes a flood as it debouches from the mountainous areas onto the Sacramento Valley floor. This volume is very large on the main Sacramento River. The largest flood since measurements were started, in 1895, occurred on February 3, 1909. The crest flow was 278,000 second-feet. The mean flow for the day was 254,000 second-feet. A reservoir of small capacity at the Kennett site would have little value for controlling such floods. The degree of control that could be established would increase with the size of the reservoir constructed. The limit of this ability would lie in the size of flood that might develop upon the drainage area downstream from the dam site but tributary to the channel before it emerges from the mountainous areas upon the valley floor.

The Kennett reservoir site has 6649 square miles of drainage area tributary to it upon which originates about three-fourths of the run-off from the main Sacramento basin. Between the dam site and Red Bluff, which is at the edge of the valley floor, there are 2609 square miles of drainage area that, it is estimated, might produce a flood as great as 125,000 second-feet. Therefore, the greatest control that could be

PLATE B



SPACE REQUIRED IN KENNETT RESERVOIR
TO CONTROL FLOODS ON SACRAMENTO RIVER
CONTROLLED FLOW MEASURED AT RED BLUFF

obtained through the Kennett reservoir would be to limit the flood flow at Red Bluff to 125,000 second-feet. This would require the complete absorption of the flow entering the Kennett reservoir during the passage of the maximum flood crest.

An extensive study of the possibilities of controlling floods by reservoirs has been undertaken by these investigations. The detail of the various considerations are so great that the subject is presented in a separate volume, Bulletin No. 14, "The Control of Floods by Reservoirs." Here it is demonstrated that the Kennett reservoir could be utilized for reducing the maximum flood flow at Red Bluff from 278,000 to 125,000 second-feet in harmony with the conservation of water and the generation of power. This would require at times the use of 454,000 acre-feet of reservoir space for detention of flood flows. The larger the reservoir, the easier it would be to secure a harmonious method of operation that would control floods without detriment to the conservation values of the reservoir. To secure these combined benefits, it is essential that a specially prepared schedule of operation be instituted.

The degree of control that may be effected by the utilization of various amounts of space in the Kennett reservoir is expressed on Plate B, "Space Required in Kennett Reservoir to Control Floods on Sacramento River." This diagram is constructed from data taken from Bulletin No. 14, "The Control of Floods by Reservoirs." It is empirically constructed from run-off records. Its purpose is to ascertain the amount of reservoir space that may be needed to detain flood flows in excess of a desired maximum controlled flow and the probability that this space will be adequate under the most severe conditions. The following tabulated values are taken from this chart:

SPACE REQUIRED IN KENNETT RESERVOIR TO CONTROL FLOODS ON SACRAMENTO RIVER.

Maximum controlled flow at Red Bluff in second-feet	Space required in reservoir in acre-feet				
	Exceeded on the average one day in 10 years	Exceeded on the average one day in 25 years	Exceeded on the average one day in 50 years	Exceeded on the average one day in 100 years	Exceeded on the average one day in 1000 years
125,000	286,000	385,000	454,000	518,000	731,000
150,000	158,000	252,000	326,000	395,000	597,000
175,000	79,000	163,000	237,000	306,000	504,000

Improvements flooded by reservoir.

The lands flooded and the marginal areas above the flow line that would have to be acquired if the Kennett reservoir were constructed are rough and mountainous and have no agricultural value. The slopes are mostly steep and rocky and are used only for grazing purposes. The assessed values range from \$0.50 to \$10 per acre and average \$3.75 over the entire reservoir.

No towns of importance are located within the reservoir area, and very few ranch improvements. Kennett, the largest town, has recently suffered a loss in population and property values by the closing of the Mammoth mine. For years this mine was a large producer, but was shut down in 1925 upon exhaustion of its ore bodies. Its smelter and bag house have been salvaged. Other towns are Copper City on Squaw Creek, and Delmar, Pollock, Antler and Delta, along the state highway. None of these have an assessed valuation exceeding $4,000.

The principal properties that would be affected by the construction of the Kennett reservoir are the Southern Pacific Railroad, the state highway, and the Bully Hill mine and smelter. The railroad and highway could be moved to new locations without detriment to their public service. The cost of doing this is large and constitutes a substantial part of the total cost of the reservoir. It ranges from 40 per cent for the low heights of dam to 20 per cent for the greatest height.

The moving of the main line track of the Southern Pacific Railroad through the Sacramento Canyon would be the largest single item of cost for rights of way. It extends the entire length of the reservoir and would have to be relocated for all heights of dam. Twelve miles of line would be submerged by a 220-foot dam, 20 miles by a 420-foot dam, and 26 miles by a 620-foot dam. In order to secure good alignment and avoid heavy grades it probably would be necessary to start the relocation at the city of Redding. A tentative route has been reconnoitered on the easterly side of the river. Although this route would shorten the line about eight miles for the 420-foot dam, it is costly because of several tunnels and major bridge crossings. For dam heights greater than 420 feet, the crossing at the Pit River becomes awkward and very expensive.

The second largest item in the cost of rights of way would be the relocation of 3 to 15.5 miles of the Pacific Highway northerly from the Pit River. This would involve heavy grading and the construction of several major bridges. Preliminary studies indicate that the length of the new route for some heights of dam would be slightly greater than the present one, however, present grades would be elminated, as the new road would skirt the reservoir for several miles.

The most important mining property affected by the construction of the Kennett reservoir is the Bully Hill mine and smelter on Squaw Creek, a tributary of the Pit. This was originally a copper-producing property, but after remaining idle for several years the mine was re-opened in 1924 for the production of zinc oxide. Ore from this and the Afterthought mine, on the south side of the Pit River near Ingot, is shipped to the Southern Pacific main line in the Sacramento Canyon over a standard-gauge track located on the right bank of the Pit River. Ore from the Afterthought mine is conveyed to the branch railroad by an aerial tram. A part of the tram and all of the branch railroad would be flooded for heights of dam over 300 feet. The smelter is not now in use. It would be flooded only for dam heights greater than 600 feet. Both mines are above the flow line for all heights. In 1924, the county assessed valuation of the Bully Hill properties was $100,000. In 1925, the Bully Hill smelter and mine, together with the railroad, were sold at public auction for $788,827.24 in foreclosure proceedings.

Other mining properties affected are the Herault smelter, located on the right bank of the Pit River, between the McCloud River and Squaw Creek, and the Arps mine, near Copper City on Squaw Creek. The Herault smelter would be flooded by heights of dam greater than 200 feet. The mine is located about 700 feet higher than the smelter, well above the flow line of the largest reservoir. At the present time both smelter and mine are inactive. The county assessed valuation of the smelter in 1924 was $32,000. The Arps mine is a copper and zinc prospect. It lies at an elevation that would be flooded by a 400-foot dam. In 1924 the county assessed valuation of this property was $28,500.

The state fish hatchery at Baird, on the McCloud River, at an elevation of 750 feet, would be flooded by all heights of dam.

The estimated cost of acquiring the lands and marginal areas, relocating the Southern Pacific Railroad and the state highway, compensating the owners of all mines and other improvements for the loss incurred by the construction of the Kennett reservoir, is set forth in the following table for five heights of dam:

ESTIMATED COST OF FLOODING LANDS AND IMPROVEMENTS BY KENNETT RESERVOIR.

Height of dam in feet (5 feet freeboard)	Cost in dollars	Cost in per cent of total cost of reservoir
220	$14,370,000	64
320	16,780,000	50
420	22,970,000	42
520	32,710,000	37
620	40,000,000	31

Type of dam.

Foundation conditions at the Kennett dam site, as disclosed by the diamond drill borings and the geologic report of Prof. George D. Louderback, are suitable for a high dam of any type. Topographic features and the absence of earth in large quantities, however, limit considerations to a gravity-concrete or a rock-fill dam. An ample supply of suitable rock adjoins the dam site at high elevations so that the construction of a rock-fill dam could proceed under unusually favorable conditions. Preliminary estimates indicate that a rock-fill dam may be constructed for somewhat less cost than a gravity-concrete dam. The added cost of power and flood control outlets through the thicker rock-fill dam, however, makes the total cost about the same for either type. The estimates in this report are based upon a gravity-concrete dam.

Layout at dam.

Several trial layouts were made of the dam, power plant and flood control outlets at the Kennett dam site. These preliminary studies indicate that, in general, it is desirable to locate the power plant a distance downstream from the dam and convey the water to it in pressure tunnels leading from the reservoir through the canyon walls. This arrangement relieves serious congestion in the narrow gorge at the foot of the dam. It also leaves the space about the dam for the convenient location of spillways and flood control outlets. These take up so much room, because of the large volume of water to be cared for, that no suitable arrangement could be found in the time allotted to this study, with the power plant at the foot of the dam.

The most advantageous and economic layout varies with each height of dam. Tentative plans were made for five heights. While differing in detail, the layout for the 420-foot height is typical and is described herein for illustration. It is also delinated on Plate C, "Layout at Kennett Dam and Reservoir Area and Capacity Curves." The position of the dam shown on this plate is the one most advantageous for a height of 420 feet. The most advantageous position changes for each height. A dotted line on Plate C indicates the position of the upstream face most favorable for the ultimate raising of the dam to a height of 620 feet.

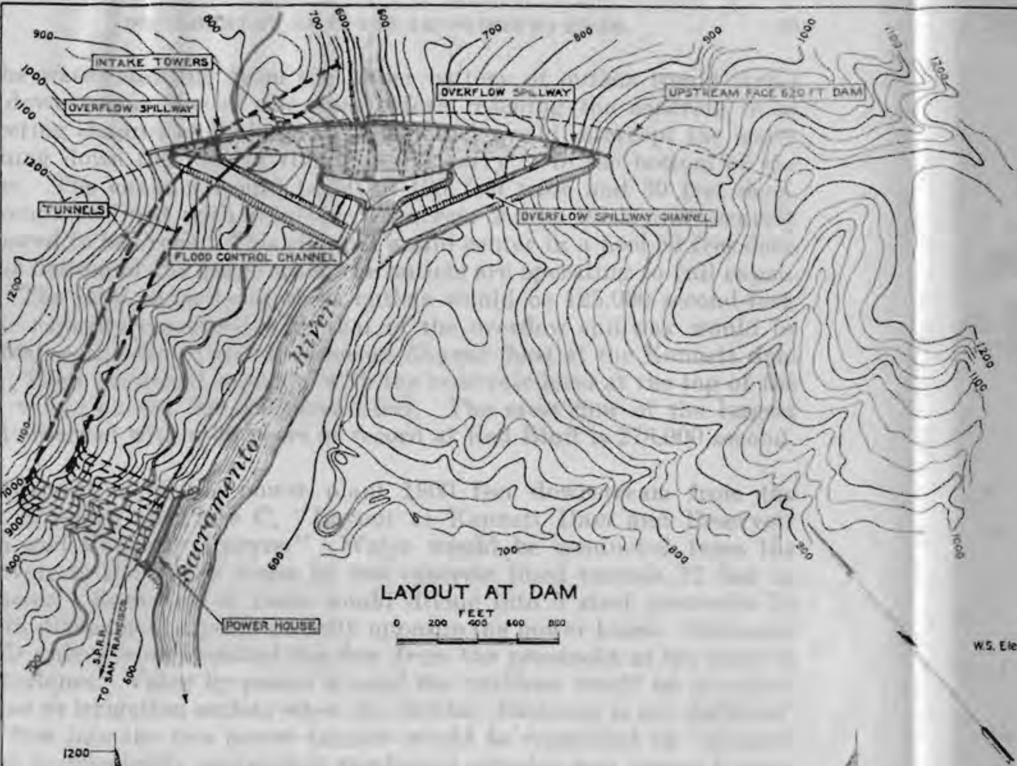
A cross-section of the dam is also shown on Plate C. It has a top width of 20 feet, a freeboard of 5 feet above the highest water, a slightly inclined upstream face and a slope on the downstream face of $\frac{2}{3}$ to 1 on the upper 390 feet and a 1 to 1 slope below this. The dam would rest on foundations stripped to firm rock. Seal would be made by grouting from two rows of holes along the upstream face of the dam, extending as deep into the foundation as may be advisable. Drain pipes along the full length of the dam downstream from the grout holes would connect through vertical pipes to drainage tunnels in the dam.

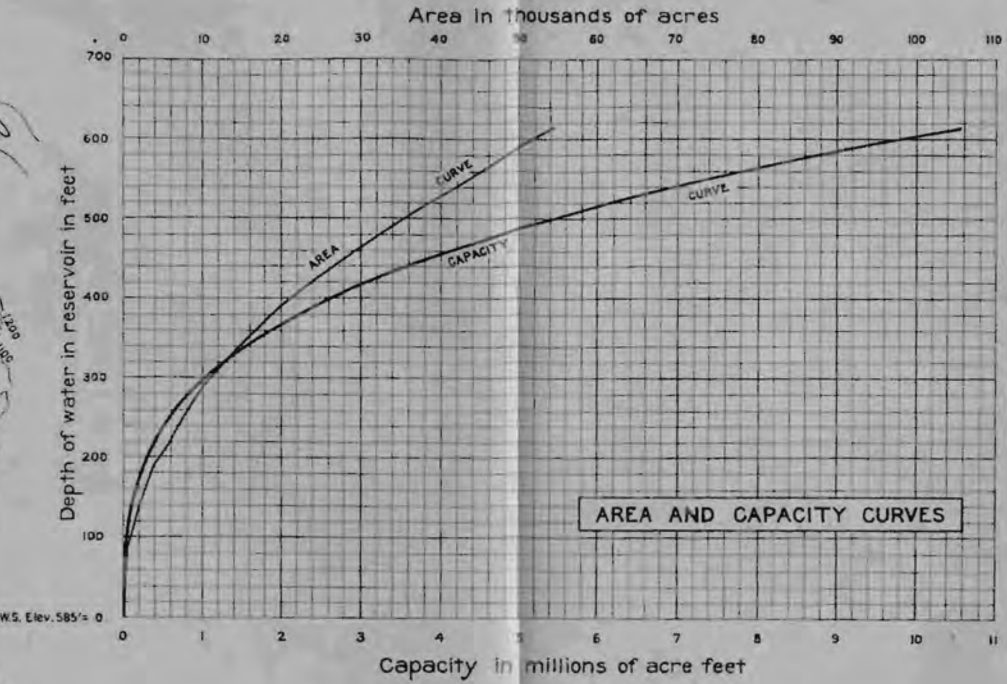
The overflow spillway would be divided in two parts, half at either end of the dam crest. Each section would have a length of 222 feet and a waterway 20 feet deep. The outflow from the reservoir would be controlled by hydraulically operated drum gates. The two sections together would have a capacity of 125,000 second-feet without encroaching on the five-foot freeboard of the dam. About 190,000 second-feet could be passed without its being overtopped.

Water flowing over the spillway would be intercepted in a concrete waterway 40 to 70 feet wide and 35 to 40 feet deep and be conducted to the river channel 300 feet downstream from the toe of the dam. The channel would be lined with 2 feet of concrete heavily reinforced and anchored to bed rock. Under drains would relieve upward pressure from percolating water below the concrete lining should there be any. The waterway area of these channels was computed for a 50 per cent increase in volume for entrained air. The sides would extend twenty feet above this.

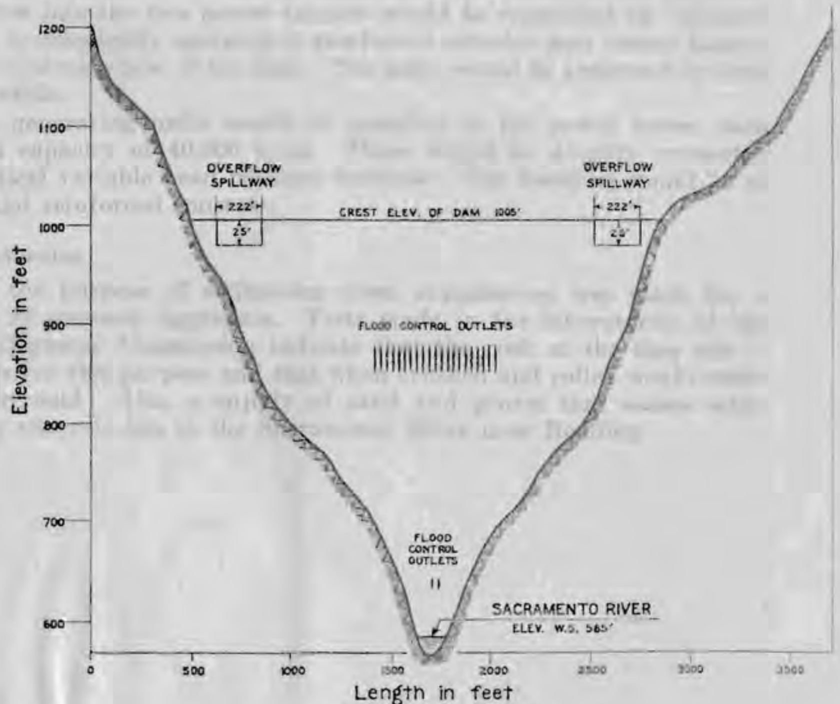
Flood control outlets through the dam would be provided in addition to the overflow spillway. These would be arranged in two batteries. The upper one would consist of 21 outlets each 166 inches in diameter. They would be spaced 30 feet in the central part of the dam with their inlets 60 feet below the top. The greatest drawdown in the reservoir for flood control would be 21 feet below the top of the dam. The outlets would be lined with three-eighths inch steel plate. Flow would be controlled through each outlet at the upstream face of the dam by a roller sluice gate mechanically operated from the top. The gates would be protected by steel trash racks.

The lower battery of outlets would consist of two 118-inch pipes with inlets 350 feet below the top of the dam. In this position they would be useful in draining the reservoir should this ever become desirable. They would be constructed similar to the upper battery of outlets except that the steel plate would increase to seven-eighths inch thickness toward the downstream end where a balanced needle valve would be placed.





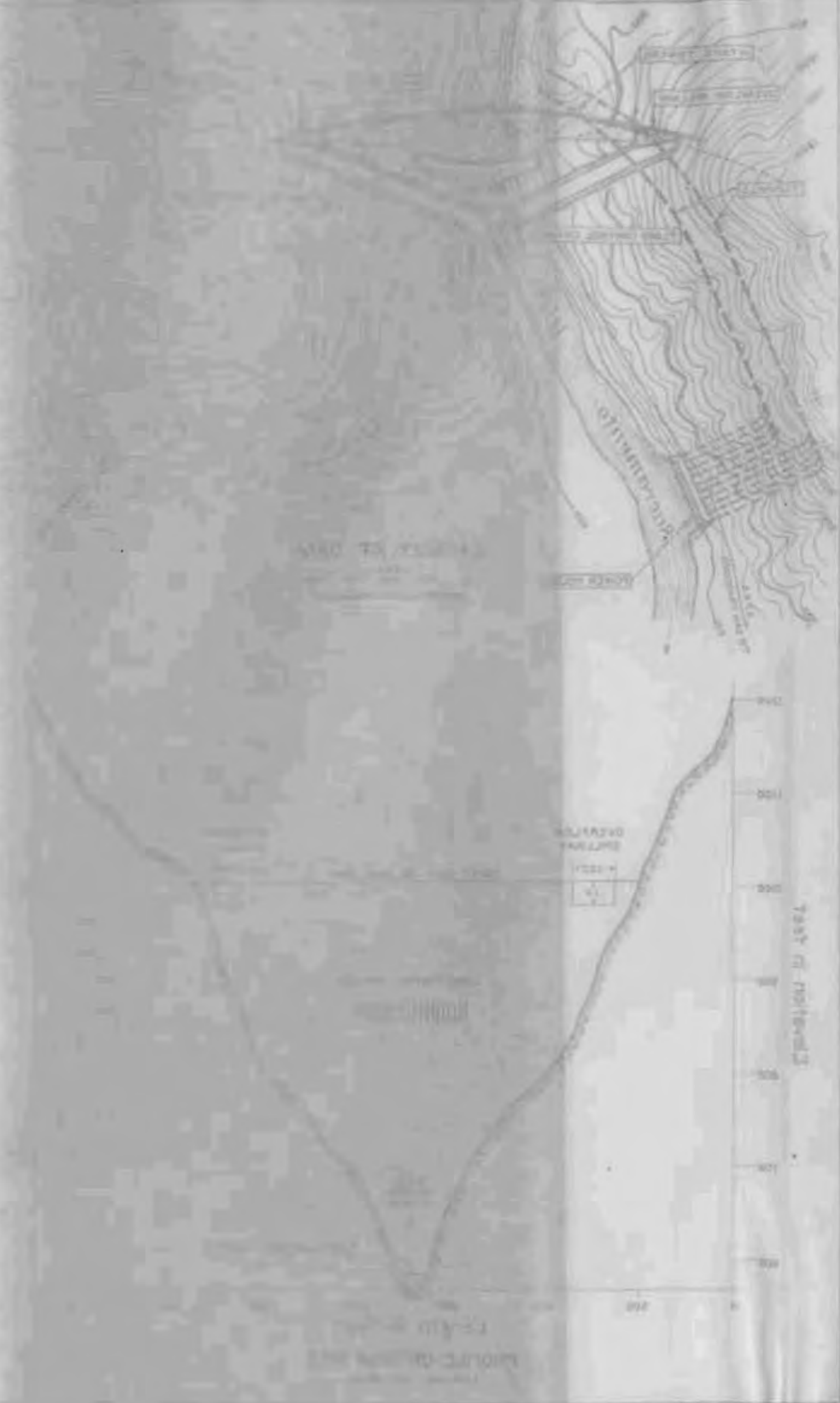
Height of Dam (above low water level)	420 Ft.
Capacity of Reservoir	2,940,000 Ac. Ft.
Capacity of Flood Control Outlets	125,000 Sec. Ft.
Capacity of Overflow Spillways	125,000 Sec. Ft.
Installed Capacity of Power Plant	400,000 K.V.A.



PROFILE OF DAM SITE
LOOKING UPSTREAM

MAXIMUM
CROSS SECTION OF DAM

Layout at Kennett Dam and Reservoir Area and Capacity Curves



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The water escaping from the upper battery of outlets would strike the downstream face of the dam before reaching the concrete lined collecting channel at its base. This channel would intercept the water running down the face of the dam and carry it to the bottom of the gorge. The channel would be 50 to 100 feet wide and 30 feet deep. It would be lined with reinforced concrete 2 feet thick and securely anchored to bed rock. This channel would center in a pool 50 feet deep in the bottom of the gorge when the outlets are operating to full capacity. The total capacity of these outlets would be 125,000 second-feet. Their capacity combined with that of the overflow spillway would be 250,000 second-feet, twice the once-in-25-year flood at the Kennett dam site. Their combined capacity with the reservoir level at the top of the dam would exceed 300,000 second-feet. The crest flow of the largest flood observed within 30 years of record at Red Bluff is 278,000 second-feet.

The position of the power plant 1800 feet downstream from the dam is shown on Plate C, "Layout at Kennett Dam and Reservoir Area and Capacity Curves." Water would be conducted from the reservoir to the power house in two concrete lined tunnels 22 feet in diameter. Each one of these would divide into 5 steel penstocks 10 feet in diameter at a point directly opposite the power house. Balanced needle valves would control the flow from the penstocks at the inlet to the turbines. Valve by-passes around the turbines would be provided for use as irrigation outlets when the turbine discharge is not sufficient. The flow into the two power tunnels would be controlled by balanced valves hydraulically operated in reinforced concrete gate towers located at the upstream face of the dam. The gates would be protected by steel trash racks.

Ten generating units would be installed in the power house, each with a capacity of 40,000 k.v.a. These would be directly connected to vertical variable head reaction turbines. The building would be of steel and reinforced concrete.

Cost estimates.

For the purpose of estimating costs, examination was made for a source of concrete aggregate. Tests made in the laboratories of the State Highway Commission indicate that the rock at the dam site is suitable for this purpose and that when crushed and rolled would make suitable sand. Also, a supply of sand and gravel that makes satisfactory concrete lies in the Sacramento River near Redding.

The unit prices used in preparing the estimates of cost are:

Item	Unit price
EXCAVATION—	
In dam foundations above river level	$1.50 per cubic yard
In dam foundations below river level	4.00 per cubic yard
For spillway channel	1.50 per cubic yard
For collection channel at base of dam $1.50 to	4.00 per cubic yard
In pressure tunnels	6.00 per cubic yard
In penstock tunnels	8.50 per cubic yard
Backfill	1.25 per cubic yard
CONCRETE—	
Mass concrete in dam	7.00 per cubic yard
Reinforced concrete in parapets	19.50 per cubic yard
Reinforced concrete in spillway piers	16.00 per cubic yard
Reinforced concrete in bridge over spillway	24.00 per cubic yard
Reinforced concrete in spillway and collection channels	12.50 per cubic yard
Reinforced concrete in gate towers	24.00 per cubic yard
Concrete lining in pressure and penstock tunnels	20.00 per cubic yard
Concrete in penstock cradles	12.50 per cubic yard
STEEL—	
Reinforcing steel	0.05\frac{3}{4}$ per lb.
Pipe and outlet lining	.08$\frac{3}{4}$ per lb.
Trash racks	.08$\frac{3}{4}$ per lb.
Drum gates in spillway	.10 per lb.
Balanced valves—inlet tower	.20 per lb.
Balanced needle valves	.28 per lb.
Sluice gates	$12,000 to $17,000 each
POWER PLANT EQUIPMENT—	
Buildings and all generating, hydraulic, switching and miscellaneous equipment including balanced needle valves at the turbines	$35.00 per k.v.a.
OVERHEAD—	
Administration and engineering	10 per cent
Contingencies	15 per cent
Interest during construction	6 per cent compounded semi-annually

Based upon the foregoing unit prices and quantities computed from the preliminary layouts and designs, the cost of the five heights of dam was estimated as in the following table succeeded by the detail of the estimate for the 420-foot dam.

COST OF KENNETT RESERVOIR AND POWER PLANT.

Height of dam in feet (5 feet freeboard)	Dam	Lands and improvements flooded by reservoir and reservoir clearing	Power plant	Additional cost for flood control features	Total cost
220	$7,840,000	$14,520,000	$19,810,000	(No flood control)	$42,170,000
320	16,370,000	17,120,000	24,670,000	$1,100,000	59,260,000
420	**31,190,000**	**23,610,000**	**24,980,000**	**270,000**	**80,000,000**
520	54,370,000	33,770,000	28,020,000	0	116,160,000
620	87,710,000	41,560,000	31,060,000	0	160,330,000

DETAIL COST ESTIMATE OF KENNETT RESERVOIR AND POWER PLANT.

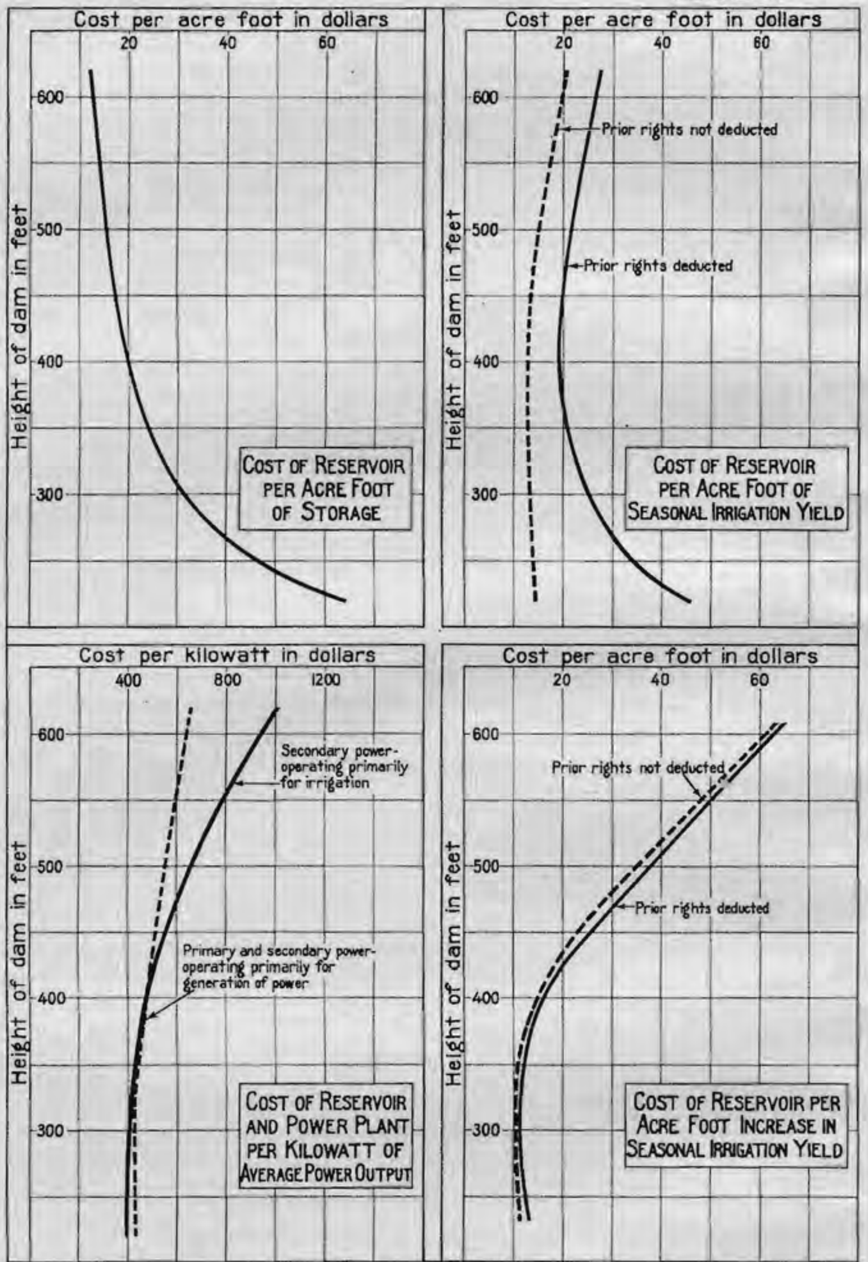
Height of dam, 420 feet.
Reservoir capacity, 2,940,000 acre-feet.
Capacity of overflow spillway, 125,000 second-feet.
Capacity of flood control and irrigation outlets, 125,000 second-feet.
Installed capacity of power plant, 400,000 k.v.a.

DAM AND RESERVOIR—		
Exploration and core drilling		$30,000
Diversion of river during construction by coffer dams and power tunnels		270,000
Clearing of reservoir site, 23,000 acres at $20		460,000
Excavation for dam and spillways:		
Below river level, 24,000 cubic yards at $4	$96,000	
Above river level, 1,050,000 cubic yards at $1.50	1,575,000	
Mass concrete 2,650,000 cubic yards at $7	18,550,000	
Reinforced concrete, 20,000 cubic yards at $12.50 to $24	265,000	
Drum gates, 2,500,000 lbs. at $0.10	250,000	
Backfill, 120,000 cubic yards at $1.25	150,000	
Sealing foundation and drainage	60,000	
		20,946,000
Lands and improvements flooded		14,960,000
Miscellaneous:		
Gravel spur railroad	$25,000	
Construction and permanent camps	320,000	
		345,000
Flood control and irrigation outlets:		
Trash racks and steel lining, 3,555,000 lbs. at $0.08¾	$311,000	
Sluice gates, 2 at $17,000	34,000	
21 at 12,000	252,000	
Balanced needle valves, 500,000 lbs. at $0.28	140,000	
Excavation for channel:		
Below river level, 23,000 cubic yards at $4	92,000	
Above river channel, 58,000 cubic yards at $1.50	87,000	
Concrete channel lining, 19,000 cu. yds. at $7 and $12.50	158,000	
		1,074,000
Subtotal, dam and reservoir		$38,085,000
Contingencies		5,713 000
Administration and engineering		3,808,000
Interest during construction		7,414,000
Total cost of dam and reservoir		$55,020,000
POWER PLANT—		
Gate Towers:		
Concrete, 2000 cubic yards at $12.50 and $24	$43,000	
Trash racks, 620,000 lbs. at $0.08¾	54,000	
Balanced valves, 666,000 lbs. at $0.20	133,000	
		$230,000
Penstocks:		
Tunnel excavation, 81,000 cubic yards at $6	$486,000	
47,000 cubic yards at $8.50	399,000	
Concrete tunnel lining, 36,000 cubic yards at $20	720,000	
Temporary tunnel timbering	97,000	
Steel reinforcing in lining, 390,000 lbs. at $0.05¾	22,000	
Steel penstock pipes, 20,620,000 lbs. at $0.08¾	1,804,000	
Concrete pipe cradles, 550 cubic yards at $12.50	7,000	
		3,535,000
Building and equipment, 400,000 k.v.a. at $35		14,000,000
Keswick afterbay		500,000
Subtotal, power plant and afterbay		$18,265,000
Contingencies		2,740,000
Administration and engineering		1,827,000
Interest during construction		2,148,000
Total cost of power plant and afterbay		$24,980,000
GRAND TOTAL COST OF DAM, RESERVOIR, POWER PLANT AND AFTERBAY		$80,000,000

Dam height selected for "Coordinated Plan."

The most desirable capacity of the Kennett reservoir as a unit of the "Coordinated Plan" is not subject to an exact analysis. Necessarily,

PLATE D



COST OF RESERVOIR CAPACITY AND UNIT YIELD OF WATER AND POWER FROM KENNETT RESERVOIR it must bear some relation to the size of the other units of the plan and to their cost. Since the main Sacramento is the largest of the several tributaries and the Kennett reservoir offers the least expensive storage facilities, this unit should be large. It would be economic to develop at Kennett the largest possible part of the total water required for the purposes of the plan. The plan proposes to develop the water needed for future irrigation and domestic use on the floor of the Sacramento Valley together with a surplus for navigation and salt water control. Half or more of this surplus, after use for navigation in the Sacramento River, would be diverted into the San Joaquin Valley for relief of their deficient local supplies. Therefore, the total water required by the plan is much dependent upon the length of the period for which provision should be made at this time. This in turn would vary with the costs. In conclusion, therefore, it would seem that the desirable size of the Kennett reservoir in the "Coordinated Plan" is the one of greatest capacity commensurate with reasonable production costs.

Plate D, "Cost of Reservoir Capacity and Unit Yield of Water and Power from Kennett Reservoir," sets forth the costs of producing water and power at the Kennett reservoir. The upper left graph on this plate shows the average cost of an acre-foot of storage behind all heights of dam. It may be noted that storage is costly for low heights. At 220 feet, it is $64 per acre-foot. It decreases sharply to $24 per acre-foot at a height of 350 feet. For greater heights it gradually decreases to $12 for a dam 620 feet high. These costs are for a reservoir complete for irrigation use. They do not include the cost of a power plant or of flood control features.

The upper right graph shows the average cost of an acre-foot of seasonal irrigation yield for all heights of dam with the reservoir similarly equipped. Two lines are shown on the graph. The full line is the cost per acre-foot of yield after the estimated prior rights below the dam site are deducted from the water supply. The dashed line is the average cost of equalizing all water, including that passed for prior rights below the dam site. Both curves indicate that a dam height of 420 feet would have the largest capacity commensurate with reasonable costs of water production. The cost at this height would be $19 per acre-foot of new water equalized for irrigation use. For greater heights, as well as for heights more than 50 feet lower, the average cost per acre-foot of yield increases substantially. The rates at which these costs increase for a change in height at the several heights of dam are shown on the lower right graph. The curves on this graph show the cost of each additional acre-foot of yield that would be gained by slightly raising the dam. It may be noticed that for heights greater than 400 feet the unit increase in yield gained by raising the dam enlarges rapidly in cost. At 420 feet height of dam the cost of an additional unit of supply is $19 per acre-foot. This is identical with the average cost of the entire new supply at this height of dam. Therefore, as an irrigation reservoir, the economic height, so far as production costs are concerned, is 420 feet.

The graph in the lower left corner, Plate D, delineates the cost per kilowatt of average power output for a reservoir equipped to generate power. These costs include the reservoir and power plant, with all appurtenances, but do not include flood control features. Two curves are shown. The dashed-line curve indicates the cost of average output of both primary and secondary power when operating primarily for power generation. The full-line curve indicates the cost of average output when operating for ultimate irrigation needs. This curve shows a slightly less cost for low heights of dam than the one representing operation primarily for power generation. In the latter case the full installation is not employed in generating power when water is available, the load factor being 0.75, while in the first instance it is. This gives a slightly greater total output and hence the slightly less unit cost of production for low heights of dam operating primarily for irrigation.

Both curves indicate that about 320-foot height of dam is most advantageous so far as power production is concerned if primary and secondary power have the same value. Since primary power has a greater value than secondary, and the proportion of primary to secondary power output increases rapidly with higher dams when operating primarily for power generation, the true economic height so far as power production is concerned is greater than 320 feet. At 420 feet the cost is $500 per kilowatt average production, about 17 per cent greater than the cost at a height of 320 feet, but the proportion of primary power is 20 per cent larger. The true economic height would, therefore, approach 420 feet, according to the relative values assigned to primary and secondary power. The cost does not increase very rapidly with greater dam heights when operating primarily for power generation. At a 620-foot height, the cost is $644 per kilowatt. At the same height, the cost operating primarily for irrigation mounts to $1,000 per kilowatt.

The studies on the control of floods by reservoirs indicate that the greatest space needed for detention of flood flows at the Kennett reservoir is 454,000 acre-feet. They also indicate that this is too large a fraction of the total capacity of the reservoir behind dams much less than 420 feet in height for flood control to harmonize with the production of water and power. Since the 420-foot height is most economical for water production, practically so for power production and favorable for flood control, it was selected as the initial dam height for the Kennett reservoir in the "Coordinated Plan."

CHAPTER IV.

GEOLOGY OF KENNETT DAM SITE.

Diamond drill explorations.

Because of the importance of the Kennett reservoir to any scheme for developing the surplus waters of the Sacramento drainage basin, the site was explored in 1924–25 with a diamond drill. Prof. George D. Louderback, geologist of the University of California, advised in this work. The site was drilled with both vertical and inclined holes to ascertain the presence of zones of weakness, if any should exist in the massive formation at the dam site. In all, 4299 lineal feet of hole were drilled, 8 vertical holes aggregating 1112 feet in length, and 12 inclined holes totaling 3187 feet in length. The core saved was 45 per cent of the entire length of the holes drilled. All cores have been preserved.

This series of holes pierced the surface covering of the dam site to a general depth of 151 feet below the ground surface. At from 10 to 108 feet below the surface a firm, greenish-gray rock was encountered in every hole. The cores show the seams and crevices of this underlying rock to be unusually tightly filled by secondary depositions of quartz or calcite, sometimes associated with other minerals. The overlying material was found to be badly weathered. Narrow belts of badly weathered material extend to depths as great as 100 feet. As shown by the drill cores and surface indications, the depth to which this weathered material will have to be removed in constructing a high dam varies from a few feet in a belt five or six hundred feet wide along the gorge to about 108 feet on a very limited area at the deepest point on the right abutment. In general, less stripping will be required on the left abutment than on the right. Here the maximum depth will be about 60 feet. The average depth of stripping to uncover firm foundations over the entire dam site is estimated to be 45 feet.

The location of the diamond drill holes is shown on Plate E, "Location of Diamond Drill Borings at Kennett Dam Site." The holes are plotted on this plate, showing their relative positions on cross-sections of the canyon. Their horizontal positions are spotted on a topographic map of the dam site, also contained on this plate. A complete log of the diamond drill borings is delineated on Plate F, "Log of Diamond Drill Borings at Kennett Dam Site."

Report of Prof. George D. Louderback, Geologist.

Based upon a field examination of the surrounding terrain, a study of the drill cores, the driller's logs, field engineer's notes, and maps, Prof. George D. Louderback of the University of California rendered the following report:

UNIVERSITY OF CALIFORNIA
GEOLOGICAL SCIENCES
BERKELEY

George D. Louderback,
103 Bacon Hall.

December 28, 1926.

State Engineer,
Department of Public Works,
Sacramento, Cal.

Geologic Features of Kennett Dam Site.

Dear Sir:

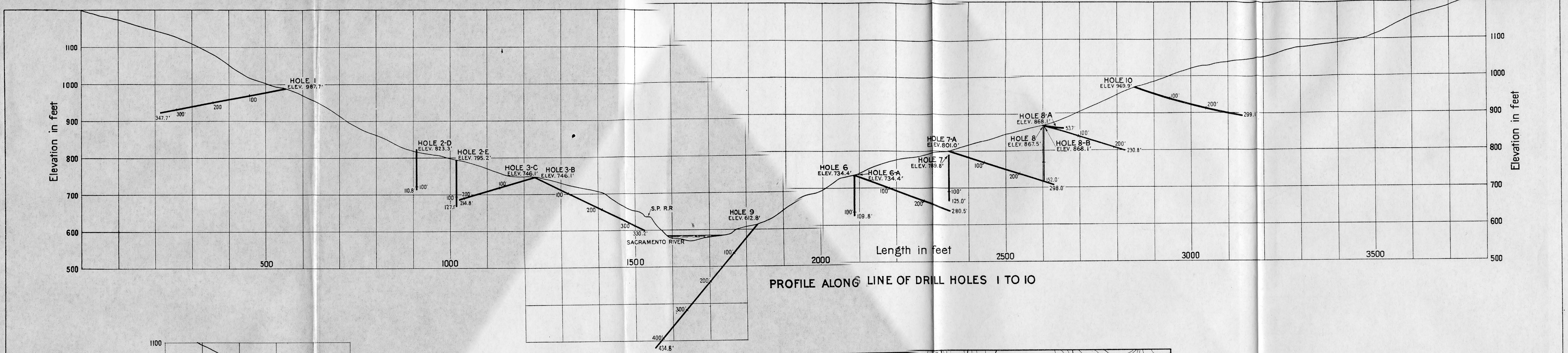
The following report is the result of a study in the field of the immediate area of the Kennett dam site, and the examination of a series of core samples taken from a series of bore holes along and near the proposed location of the dam, and representing a total of 4299 feet of subsurface exploration.

THE ANDESITIC SERIES.

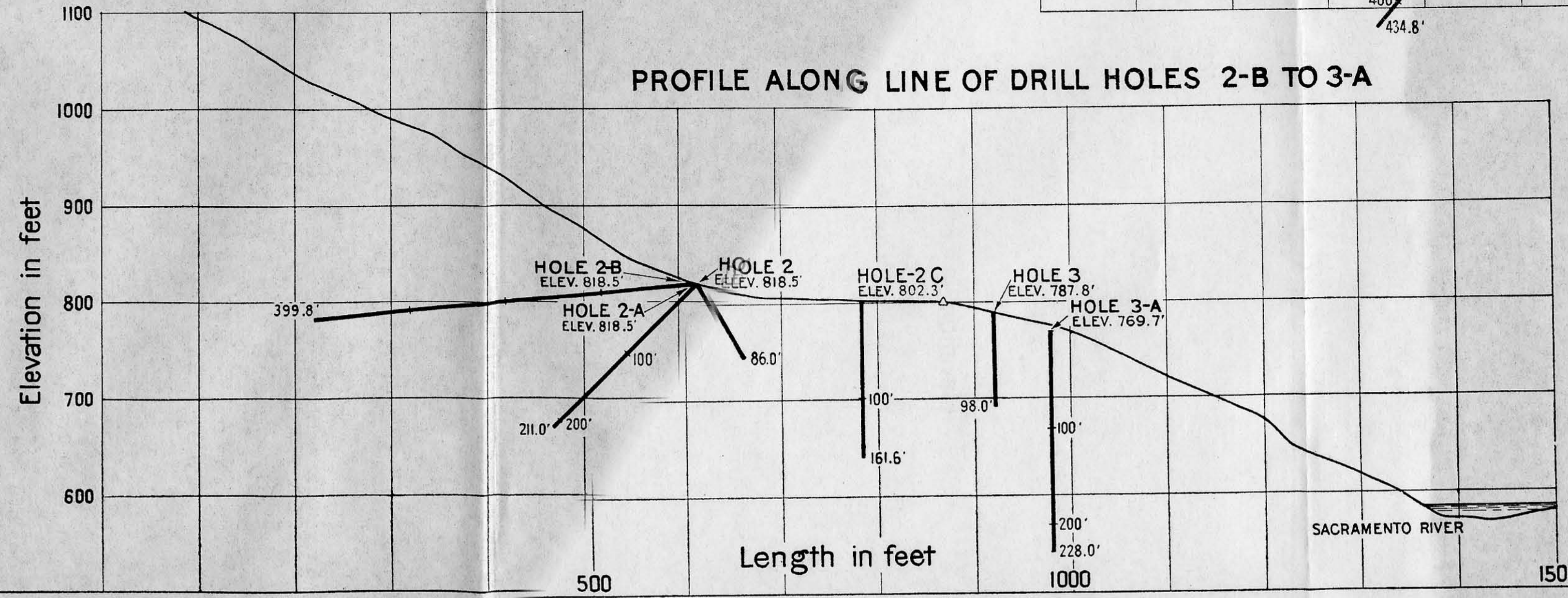
By far the greater part of the rocks encountered represent an old volcanic series made up originally of a succession of lava flows, and the products of explosive eruptions (tuffs and agglomerates). Earth movements have turned these rocks up into attitudes not far from vertical so that on traversing the proposed line of the dam, one is crossing in almost the shortest possible distance, the successive members of the series. While the different layers originally varied in texture and in chemical composition, they appear to belong to the same general rock group—pyroxene andesite. This series has been determined by Mr. Diller of the U. S. Geological Survey to be pre-Devonian in age, and he named it the "Copley Metaandesite."

All of the rocks of the Copley group have undergone alteration to a greater or less extent. There has been a widespread alteration of the ferro-magnesian constituents (chiefly pyroxene) to chlorite. This has given the unweathered parts of the rocks a light or dark green color, dependent largely on the amount of chlorite present, and they may all properly be referred to as greenstones. Much of the feldspar has been changed to sericitic products with the concomitant development of epidote or calcite. During the alteration a certain amount of secondary quartz also developed. These forms of alteration are more or less variable, sometimes much of the original minerals remaining, sometimes all of the original minerals being replaced by alteration products. A high development of epidote gives the rock the peculiar greenish yellow tint characteristic of certain forms of that mineral.

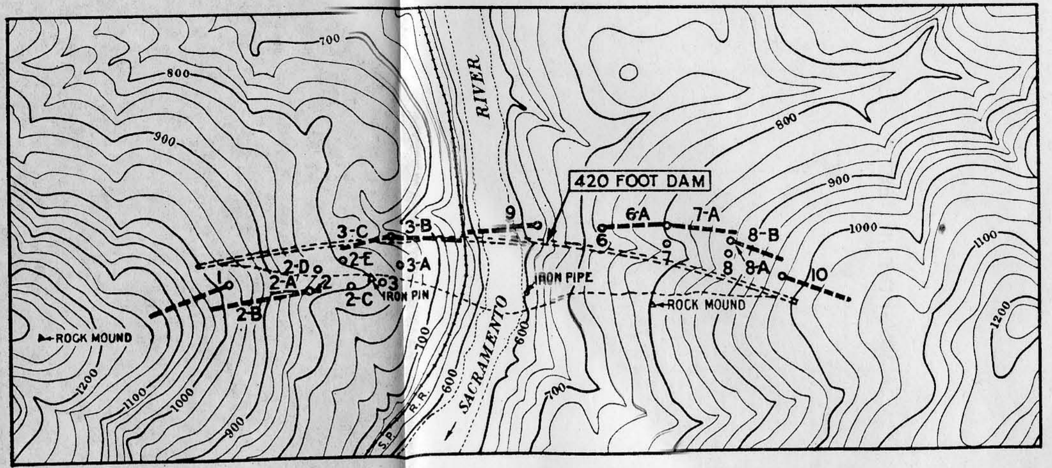
Another form of alteration that is found in streaks or belts, is the development of schistosity by recrystallization under lateral pressure (stress). In some places this is developed along minor shear lines closely spaced, the rock substance between not partaking of the schistose structure. In the core samples from the bore holes, rock thus altered, breaks into short sections with rather lustrous surfaces due to the small



PROFILE ALONG LINE OF DRILL HOLES 1 TO 10



PROFILE ALONG LINE OF DRILL HOLES 2-B TO 3-A



PLAN OF DRILL HOLES

0 400 800
FEET

LOCATION OF DIAMOND DRILL BORINGS AT KENNETT DAM SITE

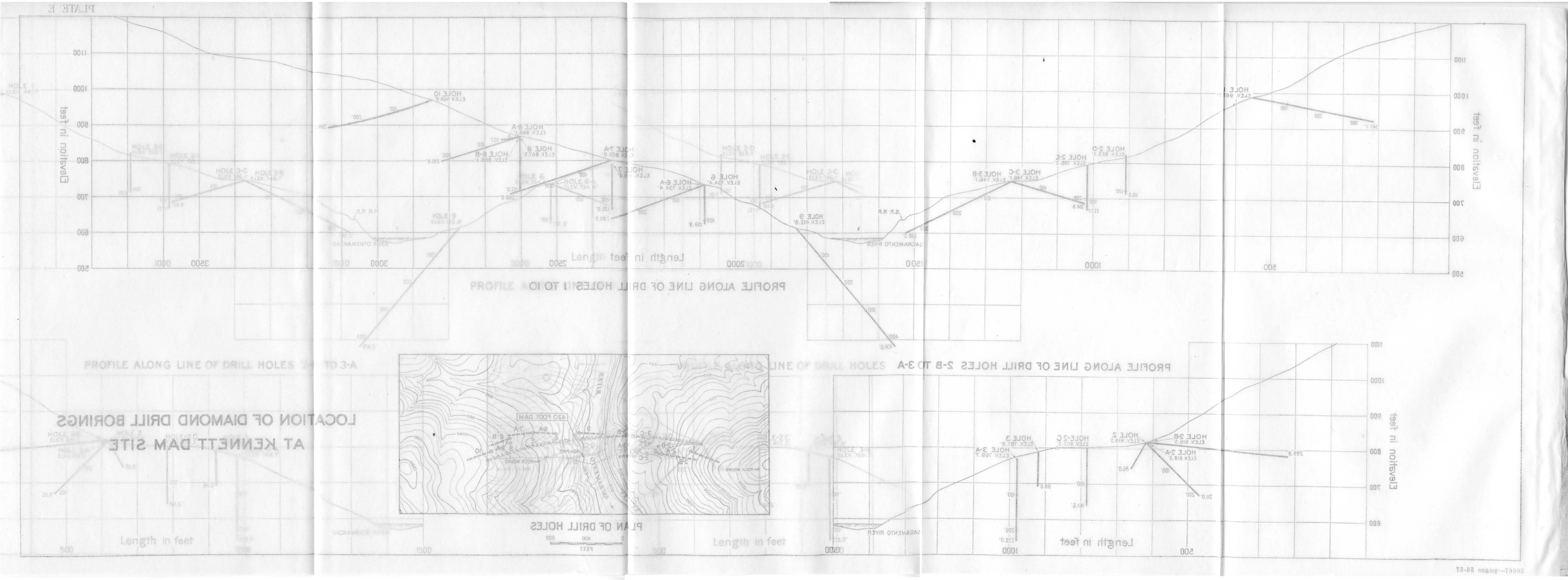


PLATE E
LOCATION OF DIAMOND DRILL BORINGS
AT KENNETT DAM SITE
PLAN OF DRILL HOLES
PROFILE ALONG LINE OF DRILL HOLES 2-B TO 3-A
PROFILE ALONG LINE OF DRILL HOLES 1 TO 10
Length in feet
Elevation in feet

PLATE F

LOG OF DIAMOND DRILL BORINGS AT KENNETT DAM SITE

new crystals being arranged in planes. In certain belts the whole rock has been given a marked parallel structure and may be called a schist (chloritic schist or greenstone schist). Many of the layers that do not show either of the above phenomena, show a certain general parallelism of constituents, in part due to original flow structure, in part developed under lateral compression. This is brought out best by weathering and gives the flaky appearance called by the drillers "shale."

In texture the andesites originally varied from those with a glassy groundmass, through those with fluidal microcrystalline groundmass to those of very fine crystalline, in part granular, intersertal texture and without recognizable flow structure. All the glasses have of course been devitrified. Some of the flows are of fine uniform grain and dense, while some carry in the microcrystalline or aphanitic groundmass disseminated visible crystals (phenocrysts) of feldspar, less frequently pyroxene, or both. A number of the flows and most of the fragments of the fragmental layers were originally more or less charged with steam holes (vesicular structure) but these have everywhere been filled by secondary deposition, usually with quartz, sometimes with calcite, both often being associated with chlorite or other minerals. Sometimes in the zone of weathering, this secondary calcite has been leached out, leaving the rock with empty roundish holes.

In the unweathered portions of the rocks, not only are the steam holes filled with mineral matter, but the original spaces between the grains of the fragmental rocks have been obliterated by compression and deposition, a very fortunate alteration for the rocks of a dam site, as originally they were probably very porous.

Veining is very common in the unweathered samples. Thin stringers up to veins several inches across have been observed. Such veining is rather widespread but some belts are much more heavily veined than others. The commonest vein minerals are quartz and calcite. Each may occur alone, or both may appear in the same vein. The quartz may be associated with epidote. Scattered grains, groups of grains, and druses of pyrite are very common throughout the series. These generally weather to limonite in the oxidation zone. A few rotten streaks have been found where a marked red color prevails. These are probably the result of the oxidation of zones of concentrated pyrite.

Other Rocks.

Aside from the various facies of the andesitic series above described, the only other rocks found were occasional dikes of younger intrusive igneous rocks, as follows:

In Hole 1 at about 30 feet, a medium grained quartz diorite.

In Hole 1 between 180 and 187 feet occurs a more basic quartz diorite.

In Hole 1 216 feet, a dacite porphyry.

In Hole 2A about 74 feet, a dacite porphyry.

In Hole 6A 30–59 feet, diabase or augite-diorite.

In Hole 7A 198–246 feet, dacite porphyry.

General Distribution of Rock Types.

On the west side at, or near, the Sacramento River, the rock is an agglomerate. As there is little soil, and the exposed rocks are fairly fresh, the structure is easily observed. The andesite fragments lie in a green base in which the original open pores have evidently been obliterated by compression and mineral reorganization.

At about 750–755 feet in elevation, a fine grained rock comes in, that has become more or less schistose and in part may be called chlorite schist. It does not stand out in prominent outcrops above the soil as does the agglomerate.

Near Hole 3 and the triangulation station occurs an amygdaloidal andesite.

Commencing at the road and running up to 860–870 feet in elevation, the exposures are mostly dull ochreous friable "shaly" meta-andesites, which are followed by more amygdaloidal andesites rather badly weathered.

At about 930 feet greenstone schists are again encountered, followed in the high shoulder at 1000 to 1200 feet by rocks showing rather prominent outcrops of agglomerate weathering out like the "gravestone-slates" of the foothill belt of the Sierra Nevada. Some of the projecting masses are 25–30 feet high.

The quartz diorite and dacite porphyry dikes were not observed on the surface but found in the drill cores.

To the east of the river the rocks are at first well exposed and with little soil. Distinct porphyritic and amygdaloidal forms of andesite occur, and near the river, a band of chlorite schist. Farther up from the river the rocks are more soil-and-vegetation-covered than on the west side, and the types are harder to follow, although occasional outcrops occur. As one goes up, however, fragmental types become more and more dominant, to the end of the surveyed section.

A thick diabase (or augite diorite) dike was observed both at the surface and in core samples, and also, one of dacite-porphyry.

Physical Characteristics of the Rocks.

In the unweathered state most of the rocks of the dam site zone are firm and their textures tight. The only slightly schistose types and the massive types, which together make up the greater part of the section are strong and tough. The more schistose, especially the best developed chlorite schists are comparatively weak, but held firmly between the stronger layers, are sufficiently resistant for dam purposes, considering the thickness that will be involved. There are no readily permeable, or typical water-bearing strata in the series.

As the series is built up of layers which have been tilted up to not far from vertical (usually 20° or less), these layers lie in belts, and these belts run in general roughly parallel to the Sacramento River. On the high shoulder (1200 feet in elevation) in the west they strike N. 40° E.; at about 1000 feet in elevation, N. 46° E.; at 930 feet, about N. 50° E.; near the river, N. 15° E. to N. 18° E. Going north from the line of drill holes the strike turns more to the east, and carries the formations on the west side across the river. Values of N. 53° E. and N. 60° E. were obtained on this turn.

This structure is not as favorable as one at right angles to the river would be, as the lines of the layers and of shearing are in general transverse to the dam and the water pressure is exerted along these lines. However, the filling of the seams and crevices by secondary deposition makes leakage along these structural planes improbable below the weathered zone.

The effect of the structure is very noticeable near the surface especially on the west side where the rock is weathered more deeply than on the east side, as for example about Hole 2 rotten and friable streaks are shown down to a depth of 50 feet and the rock is weathered and oxidized to a depth of 60 to 70 feet. Such belts run parallel or roughly parallel to the strike.

These highly oxidized and weathered streaks are the weakest parts of the whole belt. Fortunately their extent is limited and they may readily be recognized by their color, and the ease by which they can be dug or picked out in a crumbling mass. They are both physically weak and subject to percolation. In most places they are shallow, and near the river, where the water pressure would be greatest, the erosion is too recent for such weathered products to have formed. This material should all be removed in stripping the dam site.

CONCLUSIONS.

In my opinion the geological and topographic conditions combine to produce a very satisfactory dam site. The massive spurs that extend out toward the river, are underlain by firm rock, the original molar spaces of which have been closed by pressure and mineral deposition and offer good foundations for a dam.

A certain amount of percolation may take place along shear zones and other structure lines in the formation, but as far as the firm, unweathered rock is concerned, it will probably be negligible. Care will have to be used in the handling of the badly weathered belts, and zones of shear as indicated above, but there is no reason to believe that any difficulty from this source can not be overcome by reasonable precautions. The desirable depth of stripping will be irregular over the dam site, varying from a minimum of a few feet in a belt 250 to 300 feet on either side of the stream channel to a maximum of 108 feet on a very limited area on the right abutment but in general it will range from 10 to 50 feet.

The location of the Kennett dam as proposed in the engineering report is the most suitable one in the vicinity of Kennett.

Yours very sincerely,

George D. Louderback

CHAPTER V.

REPORT ON IRON CANYON PROJECT—CALIFORNIA

by

WALKER R. YOUNG

Engineer, U. S. Bureau of Reclamation.

OCTOBER, 1925.

United States Department of the Interior
Bureau of Reclamation
in cooperation with
California State Department of Public Works
Division of Engineering and Irrigation

and

Sacramento Valley Development Association.

LETTER OF TRANSMITTAL.

Berkeley, California,
October 31, 1925.

From: Walker R. Young, Engineer,

To: Chief Engineer, Denver, Colorado.

Subject: Report upon Iron Canyon Project in Sacramento Valley, California.

1. Transmitted herewith is report upon investigations made of the Iron Canyon project as provided for in the Cooperative Agreement of January 26, 1924, between the United States Department of the Interior; the Department of Public Works, Division of Engineering and Irrigation of the State of California; and the Sacramento Valley Development Association.

2. Many courtesies have been extended by those with whom the writer and his associates have come in contact in the prosecution of the work. The writer wishes to express his sincere appreciation of these courtesies, and to acknowledge the very valuable assistance given, particularly by Mr. Wm. Durbrow, President, Glenn-Colusa Irrigation District; Mr. Frank Adams, Professor of Irrigation Investigations and Practice, University of California; and Mr. R. C. E. Weber, Superintendent of the Orland Project.

3. In connection with the preparation of material for the report, credit is due Mr. W. A. Perkins, Associate Hydraulic Engineer, Division of Engineering and Irrigation, State Department of Public Works, who made the principal office studies, and to Mr. Paul A. Jones, Assistant Engineer, of this Bureau, who had charge of all field work and of the preparation of designs and estimates for the canal system.

4. Whether the best project to be found in the Sacramento Valley, which may be watered from Iron Canyon reservoir, has been selected for investigation is doubtful. The studies made have therefore been presented in considerable detail in order that duplication of work may be avoided in future investigations. Appendix A * accompanies three copies of the report only as the supply has been exhausted.

(Signed) WALKER R. YOUNG,
Engineer, U. S. Bureau of Reclamation.

* Not included in printed report, to save space. Copy on file at office of Division of Engineering and Irrigation and may be consulted there.

TABLE OF CONTENTS.

BODY OF REPORT.

EXHIBITS.

TABLES.

PRELIMINARY ESTIMATES.

APPENDICES.

PHOTOGRAPHS.

PLATES.

SYNOPSIS.

Project considered. The project considered in this report contemplates the irrigation of a gross area of 276,900 acres of land in Sacramento Valley, California, as indicated on Plates 1 and 2. With the exception of 7000 acres located on the east side of the valley opposite the city of Red Bluff, the lands lie on the west side between Red Bank Creek on the north and the Colusa-Yolo county line on the south. Storage of surplus flood waters from the upper Sacramento drainage area for the irrigation of the project is to be provided in a reservoir, having a gross capacity of 1,121,900 acre-feet, created by the construction of a concrete gravity dam in Iron Canyon, at a point about four miles upstream from Red Bluff. The dam would raise the water surface 152.5 feet above low water in the river. Under the proposed plan, 757,300 acre-feet of this storage, less evaporation, is annually available for irrigation of the project which, augmented by natural stream flow in the early months, provides a net annual irrigation draft of 800,000 acre-feet.

The proposed project is long and narrow, having an airline length of about 100 miles and an average width of but four and one-half miles, the latter varying from one-half to eleven miles.

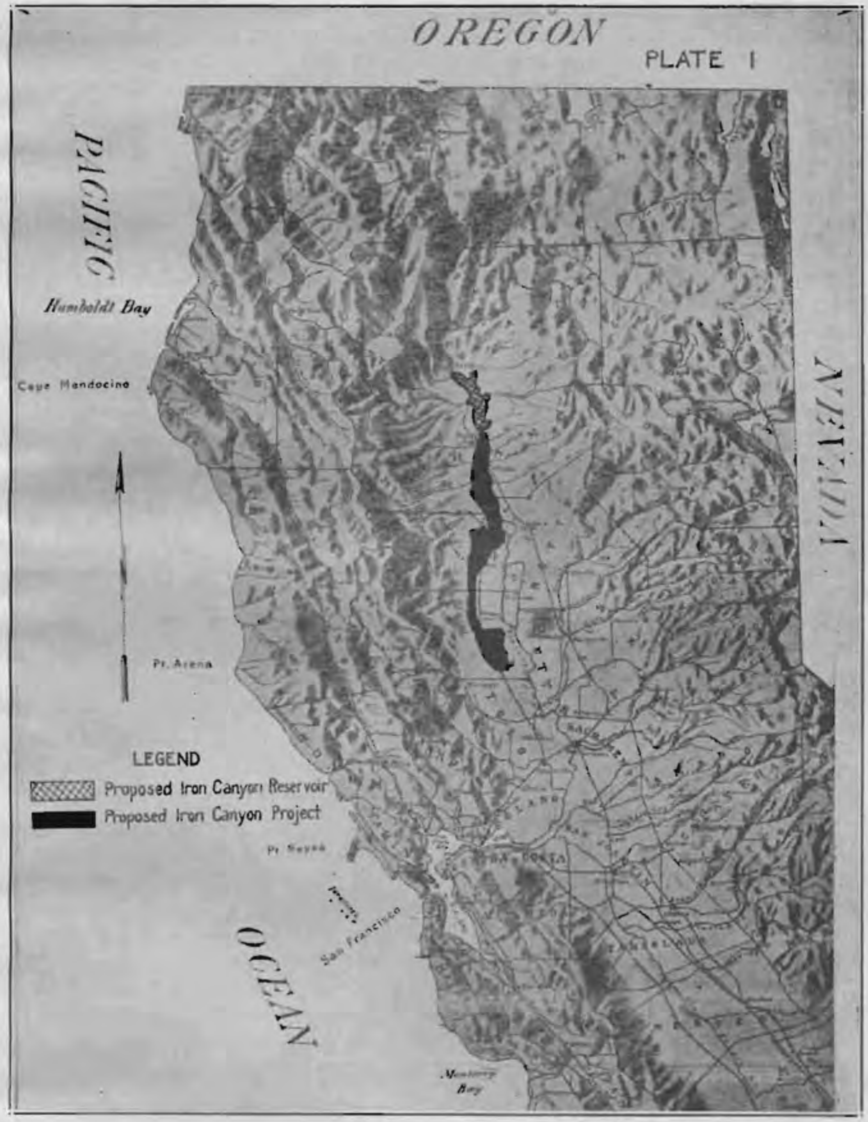
It is proposed to irrigate the small area east of Red Bluff by direct diversion from Iron Canyon reservoir, while lands on the west side are to be served by diversion from the Sacramento River at the mouth of Red Bank Creek, six and one-half miles downstream from the storage dam, diversion being effected through the construction of a movable crest type of dam at that point. Ninety-four thousand four hundred sixty-six acres of the gross area on the west side of the valley will be served by pumping from the main gravity canal.

Development of power, while of secondary consideration, is an important phase of the report, since it affords a means of partially financing the undertaking. The plan proposed includes the construction, at the storage dam, of a hydro-electric plant of 110,000 h.p. installed capacity and a smaller plant of 10,400 h.p. capacity on the main canal at Mooney Island Slough, 4.7 miles below the diversion dam.

Purpose of investigation. The investigations were made, at the request of the Sacramento Valley Development Association and the Iron Canyon Project Association, for the purpose of determining the feasibility and probable cost of a project supplied by a low-line canal receiving its water from the Sacramento River at some point downstream from the storage dam, rather than through a high-line canal diverting from Iron Canyon reservoir as proposed in previous reports. Copy of the request, dated November 4, 1922, is attached as Exhibit 1.

Authority for investigation. Authority for the investigation is contained in a cooperative contract of January 26, 1924, entered into by the United States of America, Department of the Interior; the Department of Public Works, Division of Engineering and Irrigation of the State of California; and the Sacramento Valley Development Association; attached as Exhibit 2. The agreement covering the plan of procedure to be followed in the investigation is attached as Exhibit 3.

Cooperation received. The State Department of Public Works, Division of Engineering and Irrigation, has cooperated in the investi-


OREGON
PLATE I
PACIFIC
Humboldt Bay
Cape Mendocino
NEVADA
Pt. Arena
LEGEND
Proposed Iron Canyon Reservoir
Proposed Iron Canyon Project
Pt. Reyes
San Francisco
OCEAN
Monterey Bay

gations made, a representative of that department having been assigned to the work. This report, although made in cooperation with the State Department of Public Works, has been prepared independently of the State's comprehensive investigations of its water resources. Due to the necessary limitations of the endeavor, it has not been possible for engineers of the Bureau of Reclamation to study the State's plan for coordinated development and control of water for irrigation, navigation, flood control, salt water control and the generation of electric power in the Sacramento and San Joaquin valleys. It is believed, however, that whatever is done should follow a carefully coordinated plan.

Office work. Headquarters for the investigation of the Iron Canyon project, and of the proposed salt water barrier below the confluence of the Sacramento and San Joaquin rivers, were established in Berkeley, California, on April 19, 1924, the writer being in direct charge.

Mr. W. A. Perkins, associate hydraulic engineer, representing the State of California, Department of Public Works, Division of Engineering and Irrigation, was assigned to the Berkeley office on July 21, 1924, at which time the office studies were taken up. The principal studies made were those of irrigable area, soil classification, water supply, feasibility of increased storage, and power development. Although studies of water supply had been made in the earlier investigations, it was necessary to make a complete new study for the reason that conclusions drawn from the former reports should be modified to include the season 1923–24 during which the run-off from the Sacramento River drainage basin was the lowest of record.

Field work. Field work in connection with the investigations was started on July 29, 1924, with Mr. Paul A. Jones, assistant engineer, U. S. Bureau of Reclamation, in charge. A preliminary stadia survey was made of a total of 232 miles of canal line and, in addition, a topographic survey of the diversion dam site was made. The field work was completed on November 30, 1924, while the estimates, on account of more urgent work on the salt water barrier, were not completed until October, 1925.

Cost of investigation. Through the provisions of the contract, the sum of $10,000 was made available for the investigation. A statement of cost of investigations to date will be found in Exhibit 4. A detail statement of the cost of the investigation covered by this report will be found in Exhibit 5.

Data filed. Original computations, maps, reports, and correspondence relative to the investigations, are filed in the office of the Chief Engineer, U. S. Bureau of Reclamation, at Denver, Colorado. Miscellaneous field note books, canal profiles and cross sections used for estimating purposes, as well as copies of computations made in the preparation of this report, are filed with the State Department of Public Works, Division of Engineering and Irrigation, at Sacramento, California.

Diamond drill cores, obtained in former investigations of foundation conditions at the various dam sites in Iron Canyon, are stored at the Orland project headquarters office at Orland, California.

SUMMARY OF RESULTS.

Duty of water. The irrigable area is assumed as 85 per cent of the gross area within the project. The general classification of crops, and the assumed net duty of water on the land, are as follows:

Crop	*Net duty of water*
Rice	5.0 acre-feet per acre
General crops	2.7 acre-feet per acre
Orchards	1.5 acre-feet per acre

Of the rice area, it is assumed that not more than 75 per cent will actually be planted to rice in any one year, the remaining 25 per cent being either fallow, or planted to crops not requiring irrigation, in order to prevent a ruinous growth of aquatic plants.

The average net duty on the total irrigable area is 2.58 acre-feet per acre, while the gross duty, including transportation losses, is 3.4 acre-feet per acre.

The rainfall in the vicinity of the proposed project is normally about 20 inches. The rainy season usually begins in November and ends in April or May, with practically no rain during the summer months.

Water supply. The water supply for the project will be derived from the 9258 square miles of Sacramento River drainage area above the storage dam site in Iron Canyon. The average seasonal run-off measured at that point is roughly 10,000,000 acre-feet. During the 1923–24 season, the measured run-off was 2,972,000 acre-feet, the least of record and only about 30 per cent of normal. Filings for diversion and for storage in behalf of the Iron Canyon project have been made with the Division of Water Rights, State Department of Public Works.

The irrigation season is assumed to begin in March and end in October, the maximum demand for water being in July when 22 per cent of the seasonal supply would be delivered. The main canals are designed with a capacity of 115 per cent of the average July flow to allow for daily peaks.

In the study of water supply, it has been assumed that the monthly distribution of water to supply prior rights would be upon the same basis as for the proposed project; and that the demand in July would be at the rate of 6000 second-feet, provided that amount were in the river above the storage reservoir. Upon this basis, the amount of water required annually to supply prior rights is shown to be 1,677,000 acre-feet. The run-off, and the assumed requirements of prior rights and of the Iron Canyon project, are shown graphically on Plate 7.

Studies indicate that in the season of 1923–24, there would have been a shortage of less than 4 per cent in the water supply for irrigation of the project, the only shortage which would have occurred in the 29 years of record.

No advantage is taken of the auxiliary water supply which might be derived from Coast Range streams crossed by the main canal, pumping from wells, or utilization of return water.

Power. The assumed average monthly demand for power, in per cent of the annual demand, as shown on Plate 9, is based upon data furnished by the Pacific Gas and Electric Company for Sacramento Valley.

According to the proposed plan, all water to satisfy prior rights and the project requirements becomes available for power development at Iron Canyon dam. Of the total reservoir capacity, 364,600 acre-feet are reserved for the purpose of creating a minimum static head of 115 feet at the dam, the maximum being 152.5 feet.

Had a plant been in operation during the 29 years for which there is a record of run-off, the average amount of power gained by passing the project irrigation water through the plant would have been 94,313,700 k.w.h. per year, with 80 per cent efficiency at the switchboard. The total average annual output of the proposed Iron Canyon plant would have been 584,890,000 k.w.h. and the plant would have been in operation, at full capacity, an average of 53 per cent of the time.

The proposed plan contemplates the diversion of 3640 second-feet of the prior rights water to be carried in the enlarged main project canal to Mooney Island Slough, 4.7 miles below the diversion dam, where 31 feet of static head may be developed. An average annual output of 59,333,000 k.w.h. would have been possible had a plant at this point been operated at 80 per cent efficiency during the 29-year period studied.

The combined average annual gross output of the two plants, therefore, would have been at the rate of 644,223,000 k.w.h., had they been in operation in connection with the proposed irrigation project under conditions of full development. Of this amount, about 60 per cent would have been primary power and 40 per cent secondary. In the estimates, the assumption is made that 90 per cent of the primary and 55 per cent of the secondary power could be sold at the switchboard to one of the distributing companies whose transmission lines pass within a few miles of the proposed plants. At 4 mills per k.w.h., the average annual revenue from the combined output of the two plants is estimated to be $1,963,400.

Distribution system. It is assumed that 60 per cent of the lateral system, the larger pump canals, and all but the upper 4.7 miles of the main canal will ultimately be lined; but the cost of lining the main canal might be deferred for several years, operating the canal during the early development of the project at about two-thirds of its capacity lined. Estimates are based upon the assumption that all structures are of the highest type of concrete and steel construction. Siphons to carry the canal under water courses will be an expensive item of construction because of their number and the shallowness of the channels, which are proportionately wide.

Probably the most difficult problem presented is that of wasteways, for the reason that most of the water courses crossed are only shallow depressions which in many cases are cultivated. There are no well-defined natural channels between miles 64 and 120, making it necessary to provide artificial waste channels. As the main canal parallels that of the Glenn-Colusa Irrigation District, means must be provided for carrying waste water from the Iron Canyon canal under the district canal.

Project drainage. It is probable that none of the area north of Stony Creek, and that only a part of the area to the south will require drainage, but, in the absence of accurate classification of areas, it is assumed that the cost will be distributed equally over the whole project. Perhaps 75 per cent of the cost of the drainage system could be deferred during the first few years of project operation.

Cost analysis, assuming noninterest bearing money. In all that follows, it is assumed that there will be a market for that portion of the power which, in the studies, is assumed to be salable. The demand for power is increasing rapidly and it is believed that, in normal development, the increase will continue.

It is shown that the revenue from power, gained by raising the water surface in the storage reservoir, is more than sufficient to pay the cost of installing gates on the spillway crests for that purpose.

It is shown that the saving in excavation of the first 4.7 miles of main canal, made by building the diversion dam to raise the water surface 15 feet, is more than sufficient to pay the increased cost of the diversion dam. The saving is estimated at about $568,000.

Building the diversion dam to raise the water surface 15 feet, results in a saving of about $20,000 per year in pumping to the Red Bank unit, if it be assumed that power for that purpose is bought at $0.01 per k.w.h.

The saving, effected by building the first 4.7 miles of main canal unlined, is shown as about $316,000.

The power gained annually by passing the project irrigation water through the power plant at the storage dam, which was not possible in the plan proposed in former reports, is estimated to be about 94,300,000 k.w.h. Project pumping requires 18,900,000 k.w.h. The average annual surplus is estimated at $166,000.

The increased cost of construction to provide for development of power at Mooney Island Slough, is shown as about $1,591,000; but the net annual revenue derived from the sale of power generated at that plant, at 4 mills per k.w.h., is about $166,000, or over 10 per cent return on the investment.

It is shown that the revenue to be derived from the sale of power would, after deducting operating expense, repay the construction cost of all power, storage and diversion features in 20 years; and, in addition, furnish a surplus which might be used to help repay the cost of the distribution system. The surplus is as follows:

Sale price per k. w. h.	$0.0035	$0.004	$0.0045	$0.005	$0.006
Annual surplus	$2,987	$248,409	$493,831	$739,253	$1,230,097

A—Estimated project cost, assuming noninterest bearing money, and repayment of construction cost in 20 years. Cost assessed against 95 per cent of the gross area within the project.

(a) Gross cost, neglecting revenue to be derived through the sale of power:

Total cost	Cost per acre, 263,055 acres	20 annual installments		
		Construction	Operation and maintenance	Total
$56,140,317	$213.41	$10.67	$3.00	$13.67

(b) Net cost, crediting the revenue from the sale of power to the project:

Sale price of power per k. w. h.	Net construction repayments		20 annual installments		
	Total	Per acre, 263,055 acres	Construction	Operation and maintenance	Total
4 mills	$23,123,582	$87.90	$4.40	$3.00	$7.40
4½ mills	18,215,142	69.24	3.46	3.00	6.46
5 mills	13,306,702	50.59	2.53	3.00	5.53

(c) Comparison of net cost per acre, including O. and M. charges on various project units:

Project unit	Area assessed in acres	Annual repayment per acre after crediting power at rates per k. w. h. indicated		
		4 mills	4½ mills	5 mills
Whole project	263,055	$7.40	$6.46	$5.53
West side gravity	166,660	6.30	5.36	4.43
Red Bank pump unit	37,380	9.17	8.23	7.30
Pump units near Orland	33,060	10.26	9.32	8.39
Pump unit south of Willows	19,300	9.59	8.65	7.72
East side gravity	6,650	4.19	3.25	2.32

(d) Deferred charges. The charges which might be deferred by postponing construction of 75 per cent of the project drainage system and the lining of the main canal, is estimated at $41.11 per acre, equivalent to $2.06 per acre per year, which, considering the whole project, would reduce the annual payments during the first few years of project operation to the following:

Sale price of power:	Net annual repayment per acre after deducting deferrad charges
4 mills per k. w. h.	$5.34
4½ mills per k. w. h.	4.40
5 mills per k. w. h.	3.47

B—Estimated project cost, assuming that the storage and power features are constructed with interest bearing money, thus reducing the amount of noninterest bearing money to that required in the construction of the balance of the project. Cost assessed against 95 per cent of the gross area within the project.

Estimated cost of project	$56,140,317
Estimated cost of Iron Canyon reservoir, power plant, and Mooney Island power development	26,363,810
Estimated cost of canal, distribution and drainage systems, to be built with noninterest bearing money	29,776,507

In the report it is shown that upon the assumption that construction of the Iron Canyon reservoir, power plant, and Mooney Island power development would cover a period of five years; that money would be available at 5 per cent interest, compounded semi-annually; that the cost would not exceed $26,363,810; and that the Iron Canyon reservoir would be permitted to exercise a water right for generating power prior to any upstream reservoirs not yet constructed; and that the net revenue derived from the sale of power at 4 mills per k.w.h. would be applied in the repayment of construction costs; the entire indebtedness ($26,363,810) could be repaid in fifty-three years after beginning construction.

Estimated cost of the balance of the project:

Total cost	Cost per acre, 263,055 acres	20 annual installments		
		Construction	Operation and maintenance	Total
$29,776,507	$113.20	$5.66	$3.00	$8.66
With deferred charges deducted	72.09	3.60	3.00	6.60

CONCLUSIONS.

1. There is need for a supplementary water supply for the successful growing of most crops in Sacramento Valley.

2. It is apparent that further irrigation development in Sacramento Valley without storage facilities is not feasible.

3. The proposed Iron Canyon reservoir is so located that it may serve any part of the Sacramento Valley. Therefore, the selection of a project should be made only after studies of alternative areas have been completed. The project studied is planned with the idea of distributing water stored in Iron Canyon reservoir over the nearest available area on the west side of the valley.

4. The project studied is essentially a water conservation project, since in a dry year approximately 90 per cent of its water supply is drawn from storage.

5. The relatively high duty of water assumed in the studies is believed to be justified by the comparatively large rainfall, and by the fact that some crops have been raised in the vicinity of the proposed project for the past 50 years, or more, without irrigation. The duties assumed are based upon a fully developed project and are not to be expected on individual tracts during their development.

6. The question of prior rights and the possible outcome of an overruling of section 11 of the Water Commission Act, dealing with riparian rights, is one for serious consideration in the study of any project in the Sacramento Valley.

7. Although during a low season, such as that of 1923–24, about 90 per cent of the project's supply would come from storage, the adequacy of the supply will depend upon decisions of the courts relative to the right of riparian owners to store flood waters by exercising their riparian rights, and upon what action the federal government may take relative to the release of water for navigation on the Sacramento River.

8. On account of the long carriage system, without regulating reservoirs along the line, the rotation system of irrigation is the most practicable for adoption on the project studied.

9. Without power development as a means to repay the construction cost, the project appears to be infeasible under present conditions, on account of its high initial cost.

10. Potential primary power at the Iron Canyon plant should increase as additional reservoirs farther upstream are built in the process of normal irrigation and power development; provided, the Iron Canyon reservoir is permitted to exercise a water right prior to any upstream reservoirs not yet constructed. Indications are that the demand for power will continue to increase.

11. Estimates of cost are based upon present prices of material and labor. The effect of a change in the amount and value of power which it is assumed can be marketed is an important consideration.

12. It is probable that in the final location of the main canal to serve the area studied, adoption of canal sections and grades other than those used in the preliminary location would result in a saving in cost.

13. Floods for some distance below the storage dam could be reduced materially through skillful operation of the gates. Bearing in mind, however, that the use of the reservoir for flood control should

be secondary to its primary use for storage of irrigation water and for power development, it is doubtful whether less precaution should be taken in maintaining protective works. Improper operation of the gates might, and in a dry season would, result in serious shortages in water to supply the requirements of both irrigation and power development. Some of the dangers attendant upon an endeavor to use the reservoir for flood control are demonstrated in the report but conclusions as to the flood control values of the Iron Canyon reservoir are deferred until the completion of the general study by the State of California on the control of floods by reservoirs.

14. Although it is evident that the construction and use of Iron Canyon reservoir in the manner proposed would be of no direct benefit to navigation on the Sacramento River, it is not apparent that the effect would be seriously detrimental.

15. By sacrificing the power feature at Iron Canyon dam, the reservoir could be used to prevent the encroachment of salt water into the delta region. If the reservoir were used for this purpose, the water, which with the power feature included is reserved in dead storage to create power head, could be released during the critical period in the amount necessary to act as a natural barrier against the encroachment of salt water. Such use would benefit navigation to some extent, but would make the development of power infeasible, thus destroying the power value of the reservoir as a means of partially repaying the construction cost.

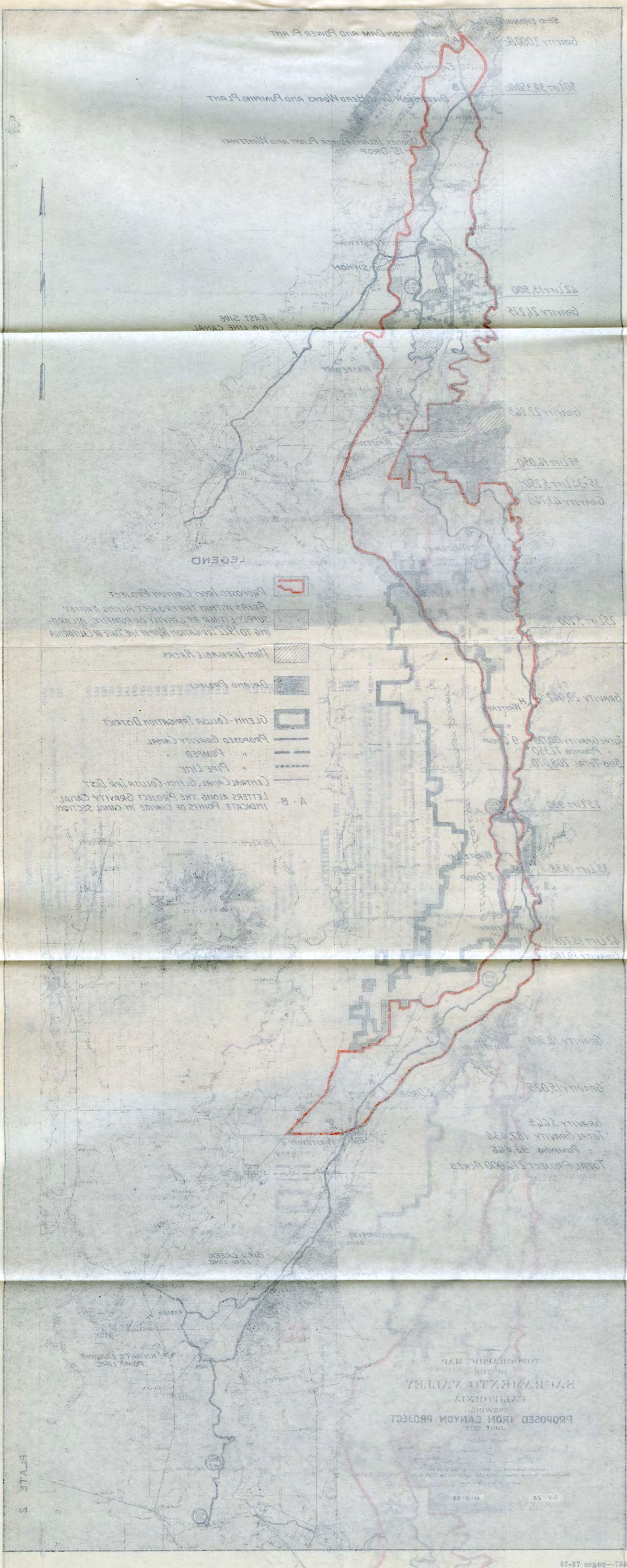
16. For several years, during the development of the irrigation project and power market, it might be practicable to utilize the reservoir to the benefit of navigation and for the partial, if not complete, control of the salt water menace in the delta.

RECOMMENDATION.

If a large project in Sacramento Valley is considered feasible, and desirable, it is recommended that further investigations be made of other areas which might be served by Iron Canyon reservoir in order that a judicial selection of the area to be included within the project may be made. Several projects which may have merit are described in the report.

WALKER R. YOUNG,
Engineer, U. S. Bureau of Reclamation.


BEND EMBANKMENT
IRON CANYON DAM AND POWER PLANT
GRAVITY 7,000 AC.
EARTH DIKE
50' LIFT 39,350 AC.
DIVERSION DAM, HEAD WORKS AND PUMPING PLANT
MOONEY ISLAND POWER PLANT AND WASTEWAY
15' DROP
WASTEWAY
SIPHON
42' LIFT 13,500
GRAVITY 21,275
EAST SIDE LOW LINE CANAL
WASTEWAY
GRAVITY 22,263
ORLAND PROJECT
WASTEWAY
35' LIFT 16,050
35'+34' LIFT 5,250
GRAVITY 43,760
WASTEWAY
LEGEND
PROPOSED IRON CANYON PROJECT
AREAS WITHIN THE PROJECT HAVING A WATER SUPPLY EITHER BY GRAVITY OR PUMPING - ACCORDING TO 1922 IRRIGATION MAP OF THE STATE OF CALIFORNIA
NON-IRRIGABLE AREAS
ORLAND PROJECT
GLENN-COLUSA IRRIGATION DISTRICT
PROPOSED GRAVITY CANAL
" PUMPED "
" PIPE LINE
CENTRAL CANAL, GLENN-COLUSA IRR. DIST.
A - B. LETTERS ALONG THE PROJECT GRAVITY CANAL INDICATE POINTS OF CHANGE IN CANAL SECTION
25' LIFT 3,200
GRAVITY 29,962
WASTEWAY
GLENN-COLUSA IRRIGATION DISTRICT
TOTAL GRAVITY 130,720
PUMPING 77,350
SUB-TOTAL 208,070
9' DROP
25' LIFT 930
WASTEWAY
35' LIFT 1,458
2' DROP
WASTEWAY
42' LIFT 14,728
GRAVITY 19,180
MARYSVILLE BUTTES
GRAVITY 18,304
WASTEWAY
GRAVITY 15,025
2' DROP
GRAVITY 5,665
TOTAL GRAVITY 182,434
" PUMPING 94,466
TOTAL PROJECT 276,900 ACRES
WASTEWAY
6879+39
0+00
BIRD CREEK LOW LINE
1064
833+60
KNIGHTS LANDING PUMP LINE
402
WOODLAND
TOPOGRAPHIC MAP OF THE SACRAMENTO VALLEY CALIFORNIA SHOWING PROPOSED IRON CANYON PROJECT JUNE 1925
Contour interval 25 feet excepting that on Marysville Buttes above 500, the interval is 250 feet.
S.V. 28
41-D-93
PLATE 2


LEGEND
Proposed Iron Canyon Project
Non-irrigable Areas
Orland Project
Glenn-Colusa Irrigation District
Proposed Gravity Canal
Pumped
Pipe Line
TOPOGRAPHIC MAP
OF THE
SACRAMENTO VALLEY
CALIFORNIA
SHOWING
PROPOSED IRON CANYON PROJECT
JUNE 1925
PLATE 2

KEY TO PROJECT MAP—PLATE 2.

The figures shown on the left side of the map represent the available gross irrigable area within a pumping unit, or that under the gravity canal between points indicated by italics on the line of the proposed canal. Subtotals are shown at the Glenn-Colusa county line with the idea that the narrow area south of there, might, in future studies, be replaced by other areas.

Italics on the canal line indicate the points at which a change in canal cross-section is made. The designed capacities of the various features are as follows:

Letter	Feature	Designed capacity, second-feet
A	East side canal diverting at Iron Canyon dam	87
B	Intake gates at diversion dam	7,000
B	Pumping plant	371
B-C	Main canal	6,578 normal
C	Mooney Island power plant	3,640 normal
C-D	Main canal	2,869
D	Pumping plant	131
D-E	Main canal	2,446
E-F	Main canal	2,170
F	Pumping plant	206
	Auxiliary pumping plant second lift	51
F-G	Main canal	2,094
G-H	Main canal	1,486
G-H	Pumping plant	35
H-I	Main canal	1,029
H-I	Pumping plant	9
H-I	Pumping plant	23
I	Pumping plant	172
I-J	Main canal	535
J-K	Main canal	279
K-L	Main canal	64
L	End of main canal for project studied.	

Cross-sections of the canals, except that on the east side, are shown on Plate 25.

INTRODUCTION.

Early investigations. A large project in Sacramento Valley has been under consideration by the Bureau of Reclamation since its inception in 1902. In all, five investigations have been made, from which the proposed Iron Canyon project is the outgrowth. Four of the investigations were made under cooperative agreements with the State of California, development associations, or both.

Investigations made during the period 1902–1904 included a general reconnaissance of the entire river basin, the search for reservoir sites, the gaging of streams, and the approximate determination of the areas of irrigable land. The work was carried on in cooperation with the State of California and in harmony with the work done by the topographic branch of the Geological Survey in mapping the valley lands, and also in harmony with the Bureau of Forestry of the Department of Agriculture.

Work was taken up again in 1909, but not completed. The results and conclusions reached at that time are contained in Report No. 1281, U. S. Senate Committee on Irrigation and Reclamation of Arid Lands, Sixty-first Congress, third session. The project included approximately 100,000 acres of irrigable land. It was proposed to provide at Iron Canyon a reservoir having a maximum capacity of about 260,000 acre-feet, of which approximately 150,000 acre-feet only would be available for irrigation. This storage, however, was to be supplemented by a reservoir on the upper Pit River in Big Valley, bringing the total available for irrigation purposes up to about 400,000 acre-feet. The average estimated cost per irrigable acre is given as $111. The possibility of developing power at the Iron Canyon dam was recognized although no advantage was taken of it to reduce the estimated per acre cost of the project.

1914 Report. In the summer of 1913 certain citizens of Sacramento Valley again took up the matter, urging further investigations for a more definite estimate, and at that time it was proposed to increase the height of the dam in Iron Canyon to provide storage for a larger area. An agreement was entered into between the United States and the Iron Canyon Project Association which provided for further investigations. The results of these investigations appear in published report of November, 1914. The project proposed contemplated the irrigation of as much as 300,000 acres of land in the upper Sacramento Valley and a reservoir of 709,000 acre-feet gross capacity to be created by a dam in Iron Canyon near Payne's Creek. Development of approximately 50,000 horsepower of electrical energy was an incidental feature. The estimated cost per acre irrigated is given as from $37 to $73 for the various alternatives, depending in part on certain assumed values to be given for water power development.

1920 Report. The investigations and drilling done at the dam site in 1913–14 indicated foundation conditions not altogether satisfactory and among other things a board of review recommended a more complete investigation of the project. On May 5, 1919, an agreement was entered into by the United States, the State of California and the Iron Canyon Project Association which provided for continuing the investigations. The results of the work are contained in report dated May, 1920. This report contemplates a project of 225,000 acres net irrigable area and a reservoir of 640,000 acre-feet storage available for irrigation, created by a dam at what is known as the lower site in Iron Canyon. The lands were to be supplied with water diverted at the reservoir at an elevation of 87 feet above the water surface in the river and carried to the lands in what is known as the West Side high line canal. Development of power at the dam site was again incidental to the plan, it being proposed to install generating equipment of 60,000 horsepower capacity. The cost per acre was estimated at $133.70.

1925 Report. Hoping that the cost could be reduced, proponents of the project again urged investigation of a plan substituting a low line canal diverting from the river downstream from the dam for the high line canal, which it was said was expensive on account of the difficult country traversed. It was further expected that the cost of the project could be reduced through the sale of additional power which might be developed at the dam by reason of the fact that all irrigation water for the proposed project, as well as that to supply prior rights and water for navigation, could, contrary to plans previously considered, be passed through the power house.

GENERAL DESCRIPTION.

Sacramento Valley. Very complete discussions of the Sacramento Valley relative to geography, topography, population, markets, climate, and agriculture are contained on pages 1 to 27 of a report of the United States Department of Agriculture, in cooperation with the University of California Agricultural Experiment Station, "Reconnaissance Soil Survey of the Sacramento Valley, California," by L. C. Holmes, J. W. Nelson and party, which is attached as Appendix A.* Other discussions appear on pages 60 to 63 of Bulletin No. 6, "Irrigation Requirements of California Lands" published by the State of California, Department of Public Works, Division of Engineering and Irrigation and in Water Supply Paper 495 published by the United States Geological Survey which is a report upon the "Geology and Ground Water Resources of Sacramento Valley, California" by Kirk Bryan.

Project considered. The project selected for investigation was adopted with a view to distributing the water to be impounded in Iron Canyon reservoir over the nearest available area on the west side of the valley, with the exception noted. It is recognized that while the east side of the Sacramento Valley may be supplied with water from Sierra Nevada streams, the west side must depend chiefly upon the Sacramento River as a source of irrigation supply.

As shown on Plate 2 the project, with the exception of 7000 acres opposite Red Bluff, lies on the west side of the valley, being bounded on the west by the foothills of the Coast Range and on the east by the

* Not included in printed report, to save space. Copy on file at office of Division of Engineering and Irrigation and may be consulted there.

Sacramento River north of Stony Creek, and by the main canal of the Glenn-Colusa Irrigation District south of that creek.

Lands. The lands included within the project are privately owned, and in some cases have been cultivated for fifty years or more without irrigation. The major part of these lands was originally embraced within large land grants of several thousand acres each. These grants have been divided and sold until, at the present time, the proposed project consists mainly of small farms. There still remain, however, a few farms of from five hundred to a thousand acres each.

Drainage. The topography and natural drainage of the area included within the proposed project are such that practically all of the lands can be irrigated. The entire area slopes toward the Sacramento River, and with the exception of the high area east of Corning, which is excluded from the project as nonirrigable, the lands are well adapted to irrigation by ordinary methods. Natural drainage north of Stony Creek flows directly into the Sacramento River, but south of Stony Creek it flows into the Colusa Basin, eventually reaching the river through an extensive system of artificial drains.

Timber. Nearly all of the lands have been cleared of their natural vegetation, except some of the bottom lands near the river, along the first forty miles of canal line, which still retain patches of willows, oaks and sycamores.

Crops. On the irrigated lands, there is a wide diversity of crops, including alfalfa, barley, oats, wheat, rice, melons, garden truck, oranges, lemons, grapefruit, walnuts, almonds, olives, pears, prunes, grapes, etc. Experiments in the production of cotton have been made in the past few years and there is a growing impression, as a result of these experiments, that there will soon be a thriving cotton industry in the Sacramento Valley. On the unirrigated, or dry lands, wheat and barley are raised with fair success. The rice, alfalfa and grain fields afford pasture in the fall for large bands of sheep and cattle.

Present irrigation. The present irrigation consists mainly in pumping from wells, with some diversions from small side streams early in the spring.

Growing season. Under average conditions the growing season may be considered as beginning in March and closing in October. In some years, however, water deliveries are made in February and occasionally as late as November.

Transportation facilities and markets. The proposed project is well located, regarding transportation and markets, and has a fairly well developed system of roads and highways. There are several thriving small towns and cities on, and adjacent to, the area included within the proposed boundaries of the project.

The main line of the Southern Pacific Railroad runs north and south through the project from Red Bank Creek to Tehama, where it divides into two lines, one crossing the river to Chico and Sacramento, and the other continuing south through the project to connect with the main line again at Davis, about forty miles south of the southern extremity of the project. In addition, there are two branch lines that cross the project east and west. No lands within the project are more than five miles from a railroad.

The Sacramento River is navigable for a considerable distance above the city of Sacramento and boats are at present operated on a regular schedule between Sacramento and San Francisco, affording an outlet for products by water.

A paved highway, which is one of the main routes from San Francisco to Portland, Oregon, runs full length of the project. Nearly all other roads within the project have either a gravel or paved surface. The present system of roads is about one-half that needed to fulfill the requirements of a fully developed project.

Market conditions are very favorable, as the center of the project is only 150 miles from San Francisco, which is the center of more than 1,000,000 population living in the San Francisco Bay region.

Cities and towns. The principal cities and towns located within the project are Corning, near the north end; Willows, near the center, and Arbuckle, near the south end. Other important towns on the west side of the river, situated near, or adjacent to, the project, include Red Bluff, Orland, Maxwell, Colusa and Williams.

Based upon the 1920 census, the population of that part of the Sacramento Valley lying between the proposed Iron Canyon project canals and the river is estimated at about 19,000. Of this number approximately 13,000 are on the Glenn-Colusa and Orland projects. It is estimated that of the 6000 remaining, 5000 live in cities and towns within the Iron Canyon project and 1000 on farms.

Industries. The chief industries are farming and dairying. Two large canneries, the Maywood and Heinz, are located at Corning, the chief output being canned olives.

SURVEYS.

Scope of work. Since water impounded in Iron Canyon reservoir may be used for the irrigation of any part of the Sacramento Valley, either by gravity diversion or by pumping, consideration should be given to alternative areas before the project is definitely located, and the survey was planned upon that basis. The contract under which the investigation was made provides for a study of lands on the west side of the valley only. The surveys made were intended to furnish fairly complete preliminary field data for the irrigation of any part of the area on the west side of the valley north of Putah Creek from Iron Canyon reservoir.

Lines surveyed. A stadia location survey was made of the main canal from the mouth of Red Bank Creek to Putah Creek, a distance of 175 miles, including 7 miles of alternate trial lines. As shown on Plate 2, the line held up to pass over the ridge formed by Cache Creek is thrown into the foothills south of the town of Dunnigan. Construction of a canal through these foothills would require heavy excavations and numerous long flumes or siphons as indicated in the accompanying photographs.* To avoid this the "Bird Creek Low Line" was run in the valley floor south of Dunnigan, assuming that water for delivery south of Cache Creek could be pumped over "The Ridge" back to the first line surveyed.

* Not included in printed report. Films on file in office of the Commissioner, Bureau of Reclamation, Washington, D. C.

A similar survey was made of a high line canal from Red Bank Creek to Rice Creek, just north of the Orland project, to serve the area between the foothills and the main gravity canal. The high line canal would receive water by pumping from the Sacramento River at the mouth of Red Bank Creek.

In April, 1921, a survey was made by the State Department of Engineering of a canal on the east side of the valley, diverting by pumping at a point about one mile south of Tehama, to serve an area in the vicinity of Chico. This east side canal could be served by gravity from the west side canal by siphoning under the river, and to furnish data for the determination of the feasibility of this plan a survey was made of a siphon crossing joining the two canal lines.

As an alternative for serving lands in the vicinity of Arbuckle, Woodland and Dixon on the west side by gravity, pumping from the Sacramento River at Knights Landing should be considered. A survey was therefore made of a line from Knights Landing up "The Ridge" to intersect the gravity line where it crosses Cache Creek.

All of the lines located, including that on the east side surveyed by the State Department of Engineering, are shown on Plate 2 although funds were not sufficient to make investigations of areas other than that shown in red. A total of 232 miles of line was surveyed.

Methods used in preliminary location. On account of the preliminary nature of the investigations curves were not run in, an angle survey being considered sufficient for the purpose. The line was cross-sectioned at all changes in transverse slope. The profile as run located the elevation of all important changes in longitudinal slope. The traverse notes were recorded with both magnetic and actual bearings. Ties were made to all important features such as railroads, highways, etc. The location and description of improvements, timber and other features were obtained. In locating the canals the policy was to keep clear of expensive right of way where possible.

Level control. Bench marks, established by the United States Geological Survey at intervals of four and five miles throughtout the valley, were used for level control. Elevations are given in United States Geological Survey Bulletin 342 and Supplementary Bulletin 481, "Spirit Leveling in California." Very close checks were obtained for the first forty miles. From mile 40 to Putah Creek there seemed to be an increasing difference between the levels and those of the Geological Survey, accumulating to the amount of 4.7 feet, the elevation at Putah Creek being 4.7 feet lower than the elevation given by the Geological Survey. One foot of this difference is accounted for between the B. M. one mile east of the line at the Hamilton Branch Railroad and the B. M. 2½ miles north of Germantown, the location survey benches having been checked and found correct. This leaves a difference of 3.7 feet which is not accounted for between stations 3418+00 and 8860+00, approximately .036 of a foot per mile. All other levels have been checked and found correct. The difference of 3.7 feet is not considered of particular importance in the preliminary survey, as neither the area to be included within the project, nor the cost of construction would be affected materially, as the discrepancy occurs principally through a country of fairly steep slopes. The discrepancy is mentioned here only as a guide to what might be encountered in final location should the project be considered further.

Profiles of the lines surveyed, with miscellaneous data noted thereon, are shown on Plates 23 and 24. Typical views along the lines located are shown among the photographs* included at the end of the report.

Topographic surveys. A topographic survey was made of the diversion dam site at the mouth of Red Bank Creek. The profile of the river bottom was determined by soundings. The result of the survey is shown on Plate 16.

PROJECT AREA.

Gravity and pumping areas. Of the total gross area of 276,900 acres within the project considered in this report, 7000 acres lie on the east side of the Sacramento Valley, opposite Red Bluff. This area has been included within the project covered by previous reports and is here included for the reason that it is easy of access, lying immediately below the storage reservoir, and as there is a strong sentiment for its inclusion. Of the remaining area lying on the west side of the valley, 175,434 acres are served by gravity and 94,466 acres by pumping.

To cover the desirable areas of bench lands west of the gravity canal, lying too high to be served by the latter, seven main pumping plants and two auxiliaries are proposed. The location of these units, and the areas of each, are shown on Plate 2. None of the rolling hill lands along the west side of the valley have been included under the pumping system, although much of this area will ultimately be valuable as orchard land.

East side area. The 7000 acres lying on the east side of the valley, opposite Red Bluff, are included in studies made by the State Department of Engineering to determine the feasibility of irrigating lands on that side of the valley from Iron Canyon reservoir. The report is attached as Exhibit 6 and the proposed canals are shown on Plate 2.

The quantity figures given in the report are accepted, but additions are made to the estimates in order that they may be upon the same basis as other estimates made in connection with the investigations just completed.

Lands within the proposed project now irrigated. It is assumed that 50 per cent of the lands within the portion of the project north of mile 70 on the canal line to be served by gravity, but now irrigated principally by pumping from wells, will come into the project and that all other lands within the project, now served by pumping, will come in. None of the lands within the boundaries of the Orland project have been considered as receiving water from the Iron Canyon canals, although this would be feasible if desirable. Areas within the proposed project having a water supply either by gravity or by pumping according to the 1922 irrigation map of the State are shown on Plate 2 in green. Irrigators north of Stony Creek are at present apparently very well satisfied with pumping from wells. Underground water for irrigation of portions of the Iron Canyon project can be secured in varying quantities by this means, but it has not

* Not included in printed report. Films on file in office of the Commissioner, Bureau of Reclamation, Washington, D. C.

been demonstrated that the needs of a fully developed system of agriculture can be supplied in this manner. It is believed that, in general, better results will be obtained under a canal system delivering a predetermined amount of water at a fixed annual charge than under a system of individual pumping, since in the latter case there is an incentive to cut down the amount of water used by reason of the cost of power.

Limiting conditions. The project limits are fixed by the amount of water available from storage rather than by the amount of land available, and if the assumptions as to the acreage now irrigated that would come into the project should prove somewhat in error, there is an abundance of other land to the south, and on the east side of the valley, that could be substituted without materially affecting this estimated acre cost of the project.

Irrigable and assessed area. The percentage of the gross area of 276,900 acres that would actually come under cultivation, excluding roads, building plats, rough and high ground, creek bottoms, canals and laterals is assumed as 85 per cent, or 235,365 acres. The percentage of the gross area upon which return payments should be made, excluding creek bottoms of large dimensions, such as Stony Creek; and high and rough land, classed as either nonirrigable or nontillable, is assumed as 95 per cent, or 263,055 acres. The areas excluded as nonirrigable are shown hatched on Plate 2.

Table 1 shows what has been accomplished on other projects in the way of development of irrigable areas within the project. It should be noted that the projects bracketed are in the Sacramento Valley, adjacent to the proposed Iron Canyon project, and that the net area requiring a water supply is 85 per cent, the same as assumed for the Iron Canyon project.

The following data, submitted by the project superintendent on January 31, 1925, are here given in explanation of the Orland data appearing in Table 1.

ORLAND PROJECT—CALIFORNIA.

Total gross area, including town of Orland, townsites, school sites, and Stony Creek overflow lands	27,257 acres
Gross area, excluding town of Orland, and Stony Creek overflow lands	21,385 acres
Present irrigable area of project	20,659 acres

Irrigable area = 76 per cent of the total gross area.

= 97 per cent of the gross area, excluding town of Orland and Stony Creek overflow lands.

Taking those certain sections entirely included in irrigable area there are 10,345 acres irrigable in a gross area of 10,781 acres, equivalent to 96 per cent.

High land, together with canal and lateral rights of way, are deducted from the gross area. County roads are included in irrigable area; state highway is not included.

Canal and lateral rights of way on project	647 acres
Roads and highways	953 acres

TABLE 1. PORTION OF AGRICULTURAL AREAS THAT REQUIRE A WATER SUPPLY—VALLEY FLOORS, CALIFORNIA.

(Bulletin No. 6, pp. 70, 71.)

Agricultural areas	Gross area within the district boundaries	Land that will not require water being absolutely unfit for irrigation	Irrigable areas occupied by improvements outside of population centers	Net area requiring a water supply	Net area requiring a water supply in per cent of gross area
	Acres	Acres	Acres	Acres	
Consolidated Irrigation District	151,590	3,000	7,425	141,075	93
Fresno Irrigation District	215,205	9,730	11,770	193,705	90
Merced Irrigation District	190,000	10,000	9,400	170,600	90
Turlock Irrigatiot District	178,665	9,100	8,900	160,665	90
Modesto Irrigation District	81,183	7,183	3,700	70,300	86
Orland Project, U. S. R. S.	26,597	4,823	1,809	19,974	75
Imperial Irrigation District	693,840	88,840	25,750	183,250	81
James Irrigation District	27,260	5,260	1,100	20,900	77
Glenn-Colusa Irrigation District; Jacinto Irrigation District; Provident; Compton-Delevan; Maxwell Irrigation District, Williams Irrigation District	167,685	18,400	7,400	141,885	85
South San Joaquin	71,112	11,000	7,112	53,000	75

SOIL CLASSIFICATION.

Studies made. The chief study of soil classification was to determine the areas within the proposed project suitable for rice culture, since the large amount of water required for this crop is an important consideration in balancing water supply against project area. A division of the lands within the proposed project into areas suitable for general crops, alfalfa and orchards, was not considered necessary for the reason that a large percentage of the soil, aside from that classed as rice land, is adaptable to any one of the other crops. The division will be influenced by economic conditions and by the personal choice of the settlers more than by consideration of type of soil.

In the study of rice areas use was made of bulletins published by the United States Department of Agriculture, Bureau of Soils, as follows:

Soil Survey of the Red Bluff Area, California.

Soil Survey of the Colusa Area, California.

Soil Survey of the Woodland Area, California.

These bulletins are summarized in the bulletin accompanying this report as Appendix A,* in which the classification used in the earlier detailed reports has been modified to some extent.

Rice lands. In the studies made, only clays, adobes and clay-adobes were considered as rice land; it being assumed that the large amount of water required for this crop by other soils would gradually cause their elimination from the area devoted to rice culture. The results of the study are shown in the following table:

* Not included in printed report, to save space. Copy on file at office of Division of Engineering and Irrigation and may be consulted there.

TABLE 2. AREAS ASSUMED SUITABLE FOR RICE CULTURE.
Within the Boundaries of the Proposed Iron Canyon Project.

U. S. G. S. quadrangle sheet	Soil classification	Gross area in acres	Accumulated area in acres
Red Bluff area:			
Vina	Ka	1,195	1,195
Colusa area:	Ne	200	1,395
Vina	Wa	1,020	2,415
	Ssc	50	2,465
Hamilton	Ne	45	2,510
Orland	Wa	280	
		(20 acres irr.)	2,790
	Wa	100	2,890
Walker Creek	Ne	125	3,015
Lyman	Wa	10,150	13,165
	We	870	14,035
	Ne	75	14,110
Jacinto	Sse	115	14,225
	Wa	4,470	18,695
Kurand	Wa	3,360	22,055
Logan Creek	We	55	22,110
Logandale	Wa	1,850	23,960
	Wa	2,510	26,470
Sites	Ne	40	26,510
	Wa	1,470	27,980
Delavan	Wa	5,420	33,400
Fairview	We	360	33,760
	Ne	60	33,820
	We	50	33,870
Williams	Wa	600	34,470
Woodland area:	Wla	1,080	35,550
Fairview	We	290	35,840
Williams	Wla	2,630	38,470
	We	255	38,725
Spring Valley	Wla	3,430	
		(70 acres irr.)	42,155
	We	505	42,660
Arbuckle	Wla	6,795	49,455
	Sea	200	49,655
	Wla	280	49,935
Grimes	Sea	600	50,535
	Wla	896	51,431
Hershey	Sea	1,100	52,531

Explanation of Soil Classification.

Ka —Kirkwood silty clay adobe.
Ne —Norman clay adobe.
Wa —Willows clay adobe.
Ssc —Sacramento silty clay.
We —Willows clay.
Wla—Willows clay adobe.
Sea —Sacramento clay adobe.

DUTY OF WATER.

Basis of assumed duty. The net duty of water assumed in the preparation of this report is based on a careful use of water under conditions of a fully developed project, with an efficient distribution system and well prepared land. The duty assumed is not to be expected in the early years of project operation during the period of land leveling, soil reconstruction and development of farm water distribution facilities. The net duty used is slightly higher than that used in the 1920 report on Iron Canyon project, but it is believed that the higher duty is justified by the more recent data gathered by the State Department of Public Works, Division of Engineering and Irrigation, in the preparation of the report to the legislature of 1923, on the Water Resources of California. The duty of water used in the studies included herewith is that shown on page 62 of Bulletin No. 6 of the above report. In case of the duty for rice lands, data were sought which could be applied to the particular soils within the project assumed to be suitable for rice culture. Tables 3 and 4 contain data extracted from pages 58 and 59 of the Proceedings of the Sacramento River Problems Conference, January 25 and 26, 1924, which it is believed is applicable to the proposed Iron Canyon project.

TABLE 3. SUMMARY OF MEASUREMENTS OF DUTY OF WATER IN RICE IRRIGATION IN SACRAMENTO VALLEY, SEASONS OF 1916, 1917 AND 1918, GROUPED BY SOIL TYPES AND ARRANGED IN ORDER OF DEPTH OF WATER APPLIED.

Net use under usual practice.

Soil classification	Number of full season observations	Total area included in obervations, acres	Average net depth of water applied, feet depth	Average area served during full season per cubic foot per second, acres
Capay clay	2	355	3.94	81
Willows clay adobe	7	8,477	4.22	72
Willows clay	7	5,057	5.08	70
Stockton clay adobe	12	2,877	5.13	60
Sacramento clay	4	4,653	5.72	59
Total or average	32	21,419	4.86	

TABLE 4. RESULTS OF MEASUREMENTS OF USE OF WATER ON E. L. ADAMS RICE FIELD, NEAR BIGGS, 1914-1917, AREA 39.5 ACRES; SOIL, STOCKTON CLAY ADOBE.

Net use on small field under the best practice, with soil fully adapted to rice, land well prepared, water completely under control, and water grass kept in check.

Full irrigation season		Net depth of water applied, feet	Average area served per cubic foot per second, acres		Yield per acre in sacks averaging 100 pounds
Year	From		Period of submergence	Whole season*	
1914	Apr. 29 to Oct. 12	4.65	68	56	60
1915	Apr. 21 to Oct. 1	4.87	66	51	45
1916	Apr. 13 to Sept. 30	4.27	70	56	39
1917	Apr. 11 to Sept. 21	4.37	62	51	39
Average		4.53	66	53	46

*Only days water used during pre-submergence period considered in computing whole season.

Assumed duty. The duty of water assumed in the studies, exclusive of transportation losses, except as noted, is as follows:

(a) On rice lands served by gravity. Net area irrigated, 85 per cent of gross area. For areas considered adaptable to rice culture it is assumed that 75 per cent of the net irrigable area will be in cultivation in any one year, resulting in an area requiring water of 64 per cent of the gross area. Duty of water, 5 acre-feet per acre on the net area, or 3.2 acre-feet on the gross area.

(b) On lands served by gravity other than rice lands. Net area irrigated, 85 per cent of gross area. Twenty per cent of net area planted to fruit with a duty of 1.5 acre-feet per acre. Eighty per cent of net area planted to alfalfa and general crops with a duty of 2.7

acre-feet per acre. On this basis the net duty on the gross area, exclusive of rice lands, is 2.1 acre-feet per acre.

(c) On rice lands served by pumping. Duty same as for rice lands served by gravity.

(d) On lands served by pumping other than rice lands. Net area 85 per cent of gross area. Sixty per cent of net area planted to fruit with a duty of 1.5 acre-feet per acre. Forty per cent of net area planted to alfalfa and general crops with a duty of 2.7 acre-feet per acre. On this basis the net duty on the gross area, exclusive of rice, is 1.7 acre-feet per acre.

(e) On lands on east side of valley opposite Red Bluff. Net area 85 per cent of gross area. Duty of water, 3.0 acre-feet on the gross area, including transportation losses.

Supporting data. As a check upon the above assumptions, Mr. Frank Adams, Irrigation Investigations, United States Department of Agriculture and University of California, was requested to make an independent study of the project. The results of Mr. Adams' investigation is contained in his letter of March 30, 1925, attached as Exhibit 7. He makes the following estimate of classification and net duty of water:

Gravity system—

Orchard and general crops	25%	1.5 acre-feet
Alfalfa	45%	2.75 acre-feet
Rice	30%	5.0 acre-feet

Pumping system—

Orchard and general crops	50%	1.5 acre-feet
Alfalfa	40%	2.75 acre-feet
Rice	10%	5.0 acre-feet

Excluding the 7000 acres on the east side of the valley opposite Red Bluff, which was not included in Mr. Adams' survey, the water required upon the basis of the duties and classification assumed in the report (exclusive of canal losses) is 589,770 acre-feet. Using the classification and net duty suggested by Mr. Adams, the net water requirement is found to be 586,780 acre-feet.

Although Mr. Adams' estimate of classification and duty of water is not identical with the assumptions made in this report, the total net amount of water required for the project in either case is the same, and this appears to be the important consideration. It is probable that Mr. Adams' estimate is the better.

On page 75 of Bulletin No. 3, "Investigations of the Economical Duty of Water for Alfalfa in Sacramento Valley, California," which is based on data gathered by cooperative agreement between the Department of Agriculture, California State Department of Engineering and the Agricultural Experiment Station of the University of California, it is stated that a depth of water of from 30 to 36 inches annually is the most desirable quantity of irrigation water to apply under general Sacramento Valley conditions for the production of alfalfa. Taking into consideration the fact that a portion of the general field crops will include such annual crops as milo, grains other than rice, melons, truck, etc., which require less water than alfalfa, it appears that the assumption of 2.7 acre-feet per acre as the annual net duty for alfalfa and general crops is reasonable.

It is difficult to predict the relation between areas which will be planted to general field crops and orchards. Data for the Orland Project are given in Table 5.

TABLE 5. RELATION OF ACREAGE OF GENERAL FIELD CROPS TO ORCHARDS—ORLAND PROJECT—1910 TO 1924.

Year	Total acreage irrigated	General field crops		Orchards	
		Acreage irrigated	Per cent of total	Acreage irrigated	Per cent of total
1910	703	503	71.4	200	28.6
1911	2,663	2,390	89.8	273	10.2
1912	4,230	3,878	91.7	352	8.3
1913	6,616	5,877	88.8	739	11.2
1914	7,354	6,362	86.5	992	13.5
1915	8,928	7,426	83.2	1,502	16.8
1916	9,357	7,355	78.6	2,002	21.4
1917	12,927	10,592	82.0	2,335	18.0
1918	14,764	12,060	81.7	2,704	18.3
1919	15,203	12,007	79.0	3,196	21.0
1920	13,872	10,781	77.7	3,091	22.3
1921	14,697	11,121	75.7	3,576	24.3
1922	15,119	11,167	73.9	3,952	26.1
1923	15,500	10,907	70.4	4,593	29.6
1924	11,962	7,742	64.6	4,220	35.3

The large percentage of 28.6 appearing in 1910 is due to the fact that there were several mature orchards, operated in previous years under dry farm methods, which constituted the orchard acreage for that year and which were not a direct result of the project's construction.

The percentage of 35.3 in 1924 is explained by the abnormal drought conditions and water supply shortage which resulted in a less amount of orchard acreage than general crops being omitted from the irrigated area, because of the larger investment represented by the orchards. They were given preference over general crops in the use of the limited water supply available.

It is readily conceivable that a higher percentage than 33⅓ for orchards may be expected on the Orland project, and in comparison, it would appear that the assumption of 20 per cent of the net area of the Iron Canyon project gravity lands, exclusive of rice lands, planted to orchards is somewhat low. However, the assumption, if in error, is on the safe side considering water supply and would tend to offset any error resulting from the assumption that 60 per cent of the net area exclusive of rice lands under pumping will be planted to orchards. The higher percentage assumed in orchard under pumping is predicated upon the assumption that in general there is less danger of frost on the higher bench lands than on lands under the gravity canal.

A comparatively high duty of water is almost certain to result ultimately in the Sacramento and San Joaquin valleys for the reason that there is a very large area of highly desirable land in these valleys with a limited water supply. Managers of irrigation systems have been very active in making the water go as far as possible and in several cases hydrographers have been employed to investigate, and report, any preventable waste.

Comparison with other projects. Table 6 may be convenient in comparing the proposed Iron Canyon project with other well-known projects. The average net duty of 2.58 acre-feet, resulting from the assumptions made, is somewhat lower than the desired net duty of 2.25 acre-feet per acre given on pages 29 and 63 of State Bulletin No. 6. Upon the other hand, the duty is higher than that of 3.00 acre-feet per acre obtaining on the Orland project. The Orland project is hardly a criterion for the Iron Canyon project, since the former is situated upon the gravelly cone of Stony Creek and the soil, in general, is more porous than that included within the Iron Canyon project.

In Table 8 the net duty on the irrigable area within the gravity portion of the proposed project is shown to be 2.79 acre-feet per acre. This compares with 2.75 acre-feet adopted in the 1920 report, in which a project served entirely by gravity is considered. The net duty on the total irrigable pumping area is 2.17 acre-feet per acre, the higher duty being explained by the fact that a larger percentage of the pumping areas is assumed to be planted to orchards than in the lower areas served by gravity.

Rainfall. In comparing the Iron Canyon project with others, the comparatively high rainfall in the locality of the project should be considered. Although the rains occur largely in the nonirrigating season, they would have considerable effect in reducing the necessary supplementary supply of water. The mean seasonal rainfall in the upper Sacramento Valley, in the vicinity of the proposed project, is given in Table 7.

TABLE 7. MEAN SEASONAL RAINFALL—UPPER SACRAMENTO VALLEY IN VICINITY OF IRON CANYON PROJECT.

Rainy season usually begins in November and ends in April or May, with practically no rain during the summer months.

Station	Number of years of record	*Mean seasonal rainfall, inches
Red Bluff	44	25.19
Tehama	44	20.53
Willows	42	16.65
Orland	38	18.02
Corning	34	20.59
Chico	50	23.78
Colusa	40	16.12
Dunnigan	39	20.27

*Season is from July 1 to June 30. Records include the season 1920-21.

Project development. The development of the project will probably be gradual for two reasons: first, the area within the project is large, and, second, the fact that much of the land has, with some success, been dry farmed to grain in large tracts can not be overlooked, and old settlers will probably not be easily convinced that irrigation on smaller tracts would be as easy, or profitable. Studies of irrigation development in California, recently completed by the Irrigation Section of the Commonwealth Club, show that in 1924 the area actually irrigated in California was 76.5 per cent of that for which irrigation works were constructed. The relation for Bureau of Reclamation projects is shown to be 75 per cent, and it is said that in general 70 per cent utilization is reached in about 35 years under normal development.

It is believed that the gradual development anticipated for the Iron Canyon project will give opportunity for the attainment of a comparatively high duty of water, since the lands coming into the project in its early development will have become adapted to a high duty long before the project is fully developed. Gradual development should not be detrimental to the economic feasibility of the project, as the storage dam, diversion dam and power features, should be self-supporting through the development and sale of power; and in the construction of the canal system the concrete lining, and much of the drainage works, can be deferred so that the cost of the ultimate project need not be incurred in the early stage of development.

Water requirements. The water assumed to be required by the project is shown in Table 8.

EXPLANATION OF TABLE 8.

Column 1, Tabulation of the gross irrigable areas, less one-half the areas now under irrigation under the proposed gravity lines to Sta. 3674+00. There is very small amount of irrigated area below this point and it is assumed that practically all this will come into the project. No deductions were made for irrigated lands under proposed pumping units. See Plate 2.

Column 2, Tabulation of the gross areas classified as rice lands.

Column 3, Tabulation of one-half the irrigated areas to Sta. 3674+00 which were deducted from the gross irrigable area.

Column 4, Tabulation of the net areas based on 85% of the gross areas included in the project.

Column 5, Tabulation of net acre-feet duty on gross areas based on 3.2 acre-feet per acre for rice lands and 2.1 acre-feet per acre for other lands under gravity and 1.7 acre-feet per acre for other lands under pumping areas.

Column 6, Tabulation of net duties in second-feet at peak period in July, based on 22% of the seasonal supply delivered during the month, and 15% of average daily flow added to average for peak flow. Refer to Table 10.

Columns 7 and 8, Tabulation of losses in carriage for the several sections. The second-feet losses were determined by allowing 0.3 of a foot depth over the wetted area for 24 hours at peak period. The acre-feet tabulations are obtained by assuming that the loss at peak period is 115% of average daily loss for July and that the loss thus obtained for the month is 22% of the total loss.

Column 9, Tabulation of acre-feet loss in distribution based on 20% under gravity, 25% for the large pumping areas, and 15% for the small pumping areas, of 3200 A, 930 A and 1458 A. The losses for pumping areas include loss for carriage.

Column 10, Tabulation of second-feet losses at peak period.

Column 11, Total water requirement including all losses.

Column 12, Water requirement in second-feet at peak period. It is assumed that the main canal and 60% of the distribution system will ultimately be lined and the quantities shown in the table are based upon the fully developed project.

TABLE 6. WATER REQUIREMENTS ON IRRIGATION PROJECTS.

Data on Federal Projects from Reports by Projects and Correspondence Relative Thereto.

Data for Other Projects from Bulletin 6, California Department of Public Works.

(Compilation by Hydrographic Section, Denver Office, Bureau of Reclamation.)

Project	Soil	Average elevation above sea level	Length of irrigation season, days	Average annual precipitation in inches	Years used in arriving at use of irrigation water	Average annual delivery of irrigation water at the farm in acre-feet per acre	Average precipitation in growing season in feet	Total water applied in growing season, acre-feet per acre	Principal crops ranked by relative acreage	Maximum delivery of irrigation water in one month, acre-feet per acre
United States reclamation projects*:										
Sun River, Montana (Ft. Shaw Division)	Sandy loam, clay and alluvium	3,700	163	10.9	1914-23, inc.	1.53	[1].76	2.29	Alfalfa, grain	.82
Huntley, Montana	Sandy loam and clay	3,000	153	13.1	1914-23, inc.	1.25	[1].82	2.07	Alfalfa, grain, beets	.70
Lower Yellowstone, Montana	Sandy loam	1,900	163	14.9	1914-23, inc.	1.36	[1].85	2.21	Alfalfa, grain, beets	.82
Shoshone, Wyoming (Garland Division)	Sandy loam and clay	4,500	165	5.5	1914-23, inc.	2.55	.37	2.92	Alfalfa, grain, beets, potatoes	.88
Klamath, California-Oregon	Disintegrated basalt, volcanic ash	4,100	168	12.7	1914-23, inc.	1.45	.27	1.72	Alfalfa, grain, vegetables	.47
Okanogan, Washington	Volcanic ash, sand and gravel	1,000	153	11.5	1914-17, 1921-23, inc.	2.61	.46	3.07	Apples, alfalfa, fruit	.81
Yakima, Tieton, Washington	Volcanic ash, decomposed basalt	1,700	164	8.1	1916-24, inc.	2.58	.16	2.74	Alfalfa, apples, grain, potatoes	.58
North Platte, Nebraska-Wyoming	Sandy and clay loams	4,100	182	14.7	1914-23, inc.	2.14	1.09	3.23	Alfalfa, grain, beets, potatoes	.80
Minidoka (gravity), Idaho	Sandy and clay loams	4,200	183	11.8	1913-22, inc.	4.13	.51	4.64	Alfalfa, grain, beets, potatoes	1.28
Minidoka (pumping), Idaho	Volcanic ash	4,200	183	11.8	1914-23, inc.	2.48	.59	3.07	Alfalfa, grain, beets, potatoes	.75
Newlands (Carson), Nevada	Sandy, sandy loam, clay, volcanic ash	4,000	198	4.6	1914-23, inc.	3.00	.24	3.24	Alfalfa, grain	.69
Boise, Idaho	Sandy and clay loams	2,500	200	13.7	1914-23, inc.	3.61	.38	3.99	Alfalfa, grain, potatoes, fruit	.90
Umatilla, Oregon	Sandy and sandy loam	470	210	7.9	1915-24, inc.	5.53	.36	5.89	Alfalfa, fruit	1.50
Yakima, Sunnyside, Washington	Volcanic ash, decomposed basalt	700	214	6.5	1916-24, inc.	3.42	.21	3.63	Alfalfa, apples, grain, potatoes	.65
Uncompahgre, Colorado	Sandy gravel, clay and clay loam	5,500	214	9.5	1914-23, inc.	6.23	.58	6.81	Alfalfa, grain, potatoes, beets	1.34
Grand Valley, Colorado	Sandy loam and clay	4,700	214	8.3	1917-24, inc.	3.87	.45	4.32	Alfalfa, beets, grain	.97
Rio Grande, Texas-New Mexico	Alluvium and sandy loam	3,700	250	10.0	1910-23, inc.	3.23	.57	3.80	Cotton, alfalfa, grain, vegetables, fruit	.55
Carlsbad, New Mexico	Sandy loam	3,100	260	14.3	1914-23, inc.	2.62	[4]1.08	3.70	Cotton, alfalfa	.58
Salt River, Arizona	Sandy loam	1,200	365	8.4	1913-20, inc.	2.82	[4].70	3.52	Cotton, alfalfa, grain, vegetables, fruit	.50
Yuma, Arizona-California	Rich alluvium	100	365	3.6	1914-23, inc.	3.82	[5].30	4.12	Cotton, alfalfa, grain	.57
Orland, California	Sandy, silt and clay loams	250	267	18.4	1917-19, 1921-23, inc.	3.17	.50	3.67	Alfalfa, fruit	.70
Private projects:										
Durham State Land Colony, California	Sandy and clay loams	160	275	24.5	1920	2.70	1.08	3.78	Alfalfa, fruit	.70
Los Molinos Land Company, California	Sandy loam and river silt	200	275	20.1	1916-21, inc.	4.20	.70	4.90	Alfalfa, fruit	1.04
Modesto Irrigation District, California	Sandy and clay loams	100	273	10.2	1914-19[8], inc.	2.6	.38	2.98	Alfalfa, fruit, corn, beets, melons, beans	.50
Riverside Water Company, California	Sandy loam and clay	850	365	10.7	1908-14, 1918	3.0	.90	3.90	Fruit, alfalfa, vegetables	.45
Imperial Irrigation District, California	Sandy loam and clay	—100	365	3.0	1910-21, inc.	3.0	.25	3.25	Alfalfa, grain, cotton, vegetables, fruit	.40
Proposed Iron Canyon, California	Sandy loam, alluvium clay	325	267	20.1	......	2.58	[7].85	3.43	Alfalfa, grain, fruit, nuts, rice, vegetables	.57

*For federal projects the quoted delivery to farms is the amount of water charged to the water user plus allowance for undermeasurement of water from estimate by project superintendent, such allowance averaging about 10 per cent.
[1] April to September, inclusive.
[2] April to October, inclusive.
[3] March to October, inclusive.
[4] February to November, inclusive.
[5] All year.
[6] February to October, inclusive.
[7] Average of February-October, inclusive, at Red Bluff, Tehama, Willows, Orland, Corning, Colusa and Dunnigan.
[8] Includes years of inadequate supply for lack of storage.

TABLE 8. SUMMARY OF LANDS, TRANSPORTATION LOSSES AND WATER REQUIREMENTS.

Unit (Refer to project map, Plate 2)	1 Gross area	2 Rice area, gross	3 Area under irrigation, gross	4 Net area	5 Net water	6	7 Loss in carriage	8	9 Loss in distribution	10	11 Total water	12
					Acre-feet	Second-feet in July	Acre-feet	Second-feet	Acre-feet	Second-feet in July	Acre-feet	Second-feet in July
East side Red Bluff area	7,000	....	....	5,950.0	15,750.0	64.8	....	....	5,250.0	21.6	21,000.0	86.4
Sta. 9+37 to 1175+00	21,275	....	3,175	18,083.75	44,677.5	183.8	7,512.0	30.9	11,169.4	45.9	63,358.9	260.6
Sta. 1175+00 to 2045+00	22,263	1,600	2,417	18,923.55	48,512.0	199.5	4,984.0	20.5	12,128.0	49.9	65,624.0	269.9
Sta. 2106+00 to 2667+00	43,760	1,535	3,805	37,196.0	93,584.5	384.8	2,917.2	12.0	23,396.1	96.2	119,897.8	493.0
Sta. 2667+00 to 3674+00	29,962	14,920	2,228	25,407.7	79,332.0	326.3	4,619.4	19.0	19,833.0	81.6	103,784.4	426.9
Sta. 3674+00 to 4976+00	19,180	9,450	....	16,303.0	50,673.0	208.5	5,057.0	20.8	12,668.25	52.1	68,398.25	281.4
Sta. 4976+00 to 5725+50	11,354	3,610	....	9,650.9	27,814.0	114.4	2,309.7	9.5	6,953.5	28.6	37,077.2	152.5
Lat. 5725+50	6,950	4,330	....	5,907.5	19,358.0	79.6	....	....	4,839.5	19.9	24,197.5	99.5
Sta. 5725+50 to 6060+00	15,025	7,785	....	12,771.25	40,116.0	165.1	729.3	3.0	10,029.0	41.2	50,874.3	209.3
Sta. 6060+00 to 6347+15	5,665	415	....	4,815.25	12,353.0	50.8	364.5	1.5	3,088.25	12.7	15,805.75	65.0
Totals for gravity	182,434.0	43,645.0	11,625.0	155,068.9	432,170.0	1,777.6	28,493.1	117.2	109,355.00	449.7	570,018.1	2,344.5
Pumping at Red Bank Creek	39,350	480	....	33,447.5	67,615.0	278.2	....	....	22,538.3	92.8	90,153.3	371.0
Pumping Sta. 1175+00	13,500	600	....	11,475.0	23,850.0	98.1	....	....	7,950.0	32.6	31,800.0	130.7
Pumping Sta. 2106+00	21,300	740	....	18,105.0	37,320.0	153.5	340.4	1.4	12,440.0	51.2	50,100.4	206.1
Pumping Sta. 3260+00	3,200	1,250	....	2,720.0	7,315.0	30.1	....	....	1,291.0	5.2	8,606.0	35.3
Pumping Sta. 4307+00	930	118	....	790.5	1,758.0	7.2	....	....	310.2	1.3	2,068.2	8.5
Pumping Sta. 4705+00	1,458	1,458	....	1,239.3	4,665.6	19.3	....	....	823.4	3.3	5,489.0	22.6
Pumping Sta. 4976+00	14,728	4,240	....	12,518.8	31,398.0	129.2	....	....	10,466.0	43.0	41,864.0	172.2
Totals for pumping	94,466.0	8,886.0	....	80,296.1	173,921.6	715.6	340.4	1.4	55,818.90	229.4	230,080.9	946.4
Grand totals, pumping and gravity	276,900.0	52,531.0	11,625.0	235,365.0	606,091.6	2,493.2	28,833.5	118.6	165,173.90	679.1	800,099.0	3,290.9

Gross duty on the net irrigable area of 235,365 acres = Col. 5+Col. 7+Col. 9 = 800,099 acre-feet = 3.4 acre-feet per acre.
Net duty on the net irrigable area of 235,365 acres = 2.58 acre-feet per acre.
Net duty on the net irrigable gravity area of 155,069 acres = 2.79 acre-feet per acre.
Net duty on the net irrigable pumping area of 80,296 acres = 2.17 acre-feet per acre.

CANAL LOSSES AND WASTE.

Transportation losses. In calculating transportation losses it was assumed that in concrete-lined sections the loss would be at the rate of 0.3-foot depth in 24 hours over the entire wetted surface of the canal, while in unlined sections the rate of loss was assumed as 1.5 feet per 24 hours.

Waste. In general, waste may be attributed to one or more of four principal causes: leaky structures; waste by the farmer at the end of his lateral; canal breaks; and waste from operation. The type of construction contemplated would insure comparatively tight structures and few breaks. Farm waste will be at the expense of the water user and will, therefore, be held to a minimum. Project waste, although to some extent unavoidable, would, in time of draft on storage, be held to the minimum necessary to convey the project water supply and to comply with the state's avowed policy of efficient use of its waters.

The following is a paragraph copied from "Bulletin No. 4, Proceedings of the Second Sacramento-San Joaquin River Problems Conference, and Water Supervisor's Report, 1924:"

> Early in June, letters to all water users on the Sacramento River above Sacramento were sent out, announcing the establishment and purpose of the water supervisor's office, presenting the critical water situation and warning that where waste should be found on *any project* it would be necessary that the diversion of such project be reduced by the amount of such waste.

Disposition of waste water. A large percentage of any waste from the Iron Canyon project would reach the Colusa Basin to be carried through the main drainage ditch through the basin to Knights Landing, south of the southern extremity of the proposed project, where it can not enter the river by gravity until the low water stage. (Refer to Knights Landing pump line photographs.)* Prior to this time it would be carried on down the Yolo By-pass into the delta region. Thus, return water from the Iron Canyon project below Stony Creek will not reach the river, from which it could be diverted for use in the Sacramento Valley, except in the delta region below Knights Landing. It would, however, become available for use in the by-passes or for transfer to the San Joaquin Valley if such transfer is desirable.

Irrigation method. On account of the long carriage system for the proposed project, without any regulating reservoirs along the line, it appears imperative that the rotation system of irrigation be adopted. If this is done there would probably be no necessity for including a factor for waste, as such, since a very generous allowance has been made in designing the canal sections, as explained later.

Canal designed for irrigation peak. It is quite common practice to increase the carrying capacity of the main canal by about 10 per cent over the average daily demand for the month of maximum demand to allow for the irrigation peak. In localities where the growth of moss and other vegetation in irrigation canals is prevalent, as is the case in the Sacramento Valley, difficulty is often experienced in maintaining a flow that will meet the demands, as the growth of vegetation

* Not included in printed report. Films on file in office of the Commissioner, Bureau of Reclamation, Washington, D. C.

has reached its maximum at the time of maximum demand for both water and labor. In an endeavor to alleviate this condition, and in order that the maintenance cost of the canals might be kept down, the canal sections have been designed with a peak capacity of 15 per cent above the daily average for the month of July, assuming a friction factor of 0.015 for concrete-lined canals. It was not considered necessary to provide for waste during the irrigation peak, which usually only lasts from ten days to two weeks. Data for the Orland project indicates that there has been practically no waste on that project during the past eight years in the months of July and August, when the demand for water is at a maximum.

WATER SUPPLY.

Source. The source of water for use on the proposed project is the Sacramento River and its tributaries entering the river above the city of Red Bluff.

Run-off. Table 9 is extracted from Table 46 appearing on page 191 of Bulletin No. 5, published by the California State Division of Engineering and Irrigation in 1923:

TABLE 9. SUMMARY OF ESTIMATED RUN-OFF OF THE SACRAMENTO RIVER AT RED BLUFF GAGING STATION, 1871 TO 1921.

Drainage Area, 9258 Square Miles.

Season begins on October 1 and ends on September 30.

	Estimated run-off in acre-feet	Depth in inches	Acre-feet per square mile	Season
Mean seasonal	9,929,000	20.10	1,072	....
Maximum seasonal	22,700,000	46.00	2,452	1889-1890
Minimum seasonal	4,068,800	8.20	439	1919-1920
Mean during July	397,200	0.80	43	....
Maximum during July	908,000	1.80	98	1889-1890
Minimum during July	175,900	0.40	19	1874-1875
Mean during August	337,600	0.70	36	....
Maximum during August	771,899	1.60	83	1889-1890
Minimum during August	149,300	0.30	16	1874-1875

Prior to May 1, 1895, the discharge was estimated. From May 1, 1895, to February 1, 1902, the discharge was measured at Jelly's Ferry, 12 miles above Red Bluff, drainage area 9093 square miles. From February 1, 1902, to date the discharge has been measured at the United States Geological Survey gaging station about 4½ miles above Red Bluff and one-half mile above the site of the proposed Iron Canyon dam. The rating curve is shown on Plate 5. In Table 9 the discharge at the two points of measurements is assumed to be the same since the tributary area between them is not productive of appreciable run-off.

The run-off estimated in Table 9 is the total from the drainage area. The discharges as measured at the gaging stations, subsequent to 1895, are somewhat less than the estimated total run-off as the former has been adjusted to take account of storage and irrigation above the points of measurement. As shown in Bulletin No. 5, upstream storage has increased until in 1921 it amounted to 121,900 acre-feet. Irrigation had increased to 161,000 acres in 1920–21. In the season 1919–20, in which the minimum seasonal run-off up to that time occurred, the measured discharge at Red Bluff gaging station was 3,788,100 acre-feet in comparison with the adjusted total of 4,068,800 acre-feet. In the season 1923–24, the measured seasonal discharge from October 1, 1923, to September 30, 1924, was only 2,972,000 acre-feet, the lowest of record and about 30 per cent of normal. The measured run-off in July and August, 1924, was 178,000 acre-feet in each month, somewhat greater than the adjusted minimum run-off shown in Table 9 for the same two months.

Basis of estimated supply. The studies of water supply for the Iron Canyon project have been based upon the *measured discharge* from 1895 to 1924, inclusive, without attempting adjustments for diversions higher up on the river. The records are affected somewhat by diversions and storage above, the correction necessary to adjust the water supply to conditions of present irrigation development gradually decreasing yearly from the date of the earliest records down to the present time. As the most critical years of water supply are recent (1919–20 and 1923–24), when irrigation development approximated very closely that of the present time, depletion due to past upstream diversions have been neglected.

No account has been taken of the effect of future depletion upon the assumption that use will be made of the applications now on file for the Iron Canyon project.

Monthly distribution.

TABLE 10. ASSUMED MONTHLY DISTRIBUTION OF IRRIGATION WATER FOR IRON CANYON PROJECT IN PER CENT OF THE SEASONAL SUPPLY.

From page 63, Bulletin No. 6, State Department of Public Works.

Month	Per cent	Month	Per cent
January	0	July	22
February	0	August	20
March	1	September	12
April	5	October	4
May	16	November	0
June	20	December	0

The distribution is based upon all available records of actual use of irrigation water. The values shown are those which are believed to be most adaptable to plant requirements, upon the assumption that the schedule can be attained through an adequate storage system.

Iron Canyon project filings. Applications on file on behalf of the Iron Canyon project are as follows:

Application No. 1279 filed by W. A. Beard for the Iron Canyon Project Association May 16, 1919. Asks for 2500 cubic feet per second from March 1st to November 30th and for 775,100 acre-feet per annum between November 30th and May 1st, all for agricultural purposes, to be used on approximately 284,000 acres of land in Sacramento Valley in Tehama, Glenn, Colusa and Butte counties.

Application No. 1280 filed in the same name and the same day for power purposes. Asks for 6000 second-feet direct diversion from January 1st to December 31st and for 775,100 acre-feet to be collected between November 30th and May 1st of each season.

Prior rights. Exhibit 8 contains extracts from a paper read by Mr. Edward Hyatt, Jr., Chief of Division of Water Rights, California State Department of Public Works, before the Fifth Annual Convention of the California Section of the American Waterworks Association at Sacramento on October 24, 1924, and at a gathering of persons interested in the Iron Canyon project at Red Bluff, on October 25, 1924. It is believed that the extracts cover the subject of water rights and uses in the Sacramento Valley quite clearly and authoritatively.

Future projects in the Sacramento Valley, depending upon the natural flow of the river for their irrigation water, are infeasible. Even with provision made for storage of the winter flood waters, any study of a new project must take into consideration prior rights which may be granted through an overruling of section 11 of the Water Commission Act, and of the action which the federal government may take relative to the release of water for navigation. There is no assurance that the outcome of the situation will be favorable to new projects but there is reason to believe that the solution will be along rational lines.

In a paper read at the Sacramento-San Joaquin River Problems Conference in December, 1924, U. S. Grant 3d, Major, Corps of Engineers, U. S. Army, District Engineer, Second District, stated that measurements made during the summer of 1924 show that from 3500 to 4000 second-feet are needed in the river to maintain navigation (above Sacramento) on an economic basis.

It is imperative that navigation of the Sacramento River be maintained. If the proposed salt water barrier below the confluence of the Sacramento and San Joaquin rivers is constructed, water required for its operation will probably be much less than 3500 second-feet. There is, in the two valleys, an incentive toward conservation of water since the potential value of the lands to be deprived of irrigation water to supply the needs of navigation in the amount suggested by Major Grant will, in time, be of economic importance, and it seems possible that navigation of the river could be provided for in some other way. In any event, the Iron Canyon project would not be affected materially, unless court decisions should uphold the claim of riparian users relative to the use of flood waters, since, in a low year about 90 per cent of the seasons' supply would come from storage. If the courts hold that riparian owners can store water in reservoirs by reason of their riparian rights it will effectually destroy the value of appropriative rights. This question is now before the Supreme Court for decision in the case of *Herminghouse* vs. *Southern California Edison Co.*

The Nebraska court holds that as the right of a riparian proprietor to the use of water of a stream is an integral part of the land, it is within the constitutional guaranties of private property and can not be taken away by an act of the legislature. *Clark* vs. *Cambridge etc. Co.*, 45 Neb. 798; 64 N. W. 239. The Supreme Court of South Dakota, in a much later case, said in *St. Germain Irr. Co.* vs. *Hawthorn Ditch Company*, 32 S. Dak. 260; 143 N. W. 124:

A riparian water right can not be lost by disuse, and a statute providing that when a party entitled to the use of water fails to use all or any portion of the waters claimed by him for a period of three years, such unused waters shall revert to the public, is void as to a riparian owner as depriving him of vested rights, though valid as to one claiming only by appropriation.

Amount of water assumed to supply prior rights. On page 46 of the proceedings of the Sacramento River Problems Conference, held at Sacramento, January 25 and 26, 1924, Mr. Donald Baker of the Division of Water Rights states:

It will be seen that there are at present existing rights upon the river above the delta, which would probably be confirmed in any adjudication thereof, totaling approximately 5000 second-feet. Approval of and confirmation of beneficial use under unapproved pending applications in this section of the river would increase this to 5600 second-feet, and should the owners of unused riparian rights be allowed to exercise same in the future through an overruling of section 11 of the Water Commission Act by the Supreme Court, this might be increased to 7000–8000 second-feet, depending upon the duty allowed riparian owners.

In the table at the bottom of page 46 of the report referred to above, the flow for July, 1916, assumed to be an average year, is 6680 second-feet. Taking the average July flow for all years of record prior to 1922, however, the quantity is found to be 5790 second-feet; and if the period be extended to include July, 1924, the average will be found to be 5580 second-feet. The average flow for July, 1924, was 2870 second-feet, the minimum being 2800 second-feet. An assumed average July flow of 6000 second-feet to supply prior rights below the proposed Iron Canyon reservoir appears to be fair and on the side of safety considering availability of water for use on the Iron Canyon project.

Assuming that the monthly distribution of water to supply prior rights is identical with that shown in Table 10 for the Iron Canyon project, and further that the discharge to supply prior rights is at the rate of 6000 second-feet in July, the total seasonal allowance to supply prior rights is found to be 1,677,000 acre-feet distributed as shown in Table 11.

TABLE 11. ASSUMED MONTHLY DISTRIBUTION OF WATER TO SUPPLY PRIOR RIGHTS.

Provided that the free flow of the river above Iron Canyon dam is equal to or greater than the amounts shown.

Month	Acre-feet	Second-feet	Month	Acre-feet	Second-feet
January	0	0	July	368,940	6,000
February	0	0	August	335,400	5,455
March	16,770	273	September	201,240	3,273
April	83,850	1,364	October	67,080	1,091
May	268,320	4,364	November	0	0
June	335,400	5,455	December	0	0

Actually, there have been only six years of the 29 of record when the above supply would have been available. During 23 years there would have been shortages in August; 19 with shortages in July and August; 5 shortages in June, July and August; and in 1923–24 shortages would have occurred from May to September, inclusive. The average July flow of 5580 second-feet has been equaled, or exceeded, in 13 of the 29 years while the 6000 second-feet assumed in the studies has been equaled, or exceeded, during only 10 of the 29 years of record.

Relation of run-off and assumed irrigation requirements. The run-off of the Sacramento River at the United States Geological Survey gaging station above Red Bluff for an average year; for a low year; and for the lowest year of record is shown graphically on Plate 7. The requirements of prior rights according to the distribution shown in Table 11, and of the Iron Canyon project according to the assumptions made in the study of duty of water, distributed as shown in Table 10, are shown by hatched areas. It will be noted that in an average year the natural run-off is sufficient to supply the assumed prior rights with the exception of a small deficiency in August. Storage of winter flood water is necessary to supply the Iron Canyon project. In the season 1919–20 the run-off, without storage, would not have fully supplied prior rights from June to August, inclusive, and in the season 1923–24 the supply for prior rights, without storage, was deficient from May to September, inclusive. By comparing the run-off and total assumed demands for 1923–24, as represented by the respective areas on the diagram, it will be seen that the supply would have satisfied the assumed demands, the former being 2,972,000 acre-feet and the latter 2,477,000. However, storage would have been necessary both for the Iron Canyon project and to supply prior rights, and storage would have introduced a diminished irrigation supply by reason of evaporation losses from the reservoir. There was a shortage of irrigation water in 1920 and again in 1924. It will be recalled that in July, 1924, the discharge at Red Bluff dropped to 2800 second-feet and, according to the assumptions made in the studies of water supply, the flow to supply prior rights would not be increased through the construction of Iron Canyon reservoir, to a quantity greater than the natural flow of the river.

It is apparent that in years of low run-off the water supply for Sacramento Valley under present conditions is deficient. The situation would become more serious should section 11 of the Water Commission Act be overruled, or should the federal government insist upon the release of water for navigation. The situation would be relieved through the construction of large holdover reservoirs above Red Bluff, providing rulings regarding riparian rights did not interfere with storage in such reservoirs.

Evaporation from reservoir. The net loss of water by evaporation from the reservoir is approximately 10 per cent of the amount available for irrigation, if the lower portion of the reservoir is reserved to maintain head for power purposes. While there are many records of evaporation from pans, very little data have been gathered to determine the relation between pan measurements and the true loss from lake surfaces. On pages 61–63, Bulletin No. 9, 1920, "Water Resources of Kern River," published by the California State Department of Engineering, are given the results of measurements of pan and lake surface evaporation at Buena Vista Lake, and of lake surface evaporation at Tulare Lake. On page 79 of the report on the San Jacinto River Hydrographic Investigation, 1922, by the California State Division of Water Rights, the results of observations at Lake Elsinore are given. The results of these measurements are given in Table 12. The quantities are in feet and represent the total or gross evaporation, which, to obtain the net loss, would be reduced by the depth of rainfall. They represent the average at Tulare Lake, six-year average at Lake Elsinore, the year 1920 at Buena Vista, and a 13-year average at East Park reservoir. In the last column the gross amount that was used in the studies of the Iron Canyon water supply is shown.

TABLE 12. EVAPORATION FROM RESERVOIR.

Quantities shown represent gross evaporation in feet.

Month	Lake Elsinore	Buena Vista Lake	Tulare Lake	East Park reservoir		Used in Iron Canyon studies
				Floating pan	*80 per cent of observation pan	
October	.45	.38	.30	.37	.30	.34
November	.30	.16	.20	.20	.16	.18
December	.20	.09	.10	.13	.10	.095
January	.15	.12	.12	.09	.08	.12
February	.05	.16	.13	.14	.11	.145
March	.25	.18	.25	.23	.18	.215
April	.40	.42	.30	.40	.32	.36
May	.45	.62	.50	.61	.49	.56
June	.50	.63	.70	.69	.55	.665
July	.60	.62	.80	.88	.71	.74
August	.60	.58	.60	.82	.65	.59
September	.55	.59	.60	.61	.49	.595
Totals	4.50	4.55	4.60	5.17	4.14	4.605

*Assumed as relation between pan and open water surface.

The elevation at Iron Canyon reservoir is practically the same as at Buena Vista and Tulare lakes, and as temperature conditions, during the seven warm months when 84 per cent of the evaporation takes place, are practically the same at the three places, it is believed that the average of the gross evaporation at Buena Vista and Tulare lakes is applicable to Iron Canyon reservoir.

In the studies made, the effect of rain has been considered as reducing the evaporation shown in Table 12. The gain due to rainfall is not the total amount of rain on the reservoir surface, but is only that portion of it which has not appeared as run-off in the records of stream flow at Red Bluff. No rainfall run-off curve has been constructed for the Sacramento River, and it probably is not feasible to construct one with existing data. To determine the accretion to reservoir supply from rainfall, the curve published by C. E. Grunsky on page 85, Transactions of the A. S. C. E. for 1922, has been used. This has been redrawn on Plate 6 to show depth of monthly, instead of annual, precipitations. Results obtained from the use of this curve are approximate, but a comparatively large error in the rainfall factor would affect the final result but little.

Water to supply demands of irrigation and power development at the storage dam. The development of power has an important bearing upon the feasibility of the Iron Canyon project, since the revenue to be derived from its sale may be used in the repayment of a part of the construction costs, as will be demonstrated in the section dealing with power. The studies of water supply, therefore, take into account the amount of power possible of development at the storage dam.

Although power development is a secondary consideration, an effort was made to get as much power out of the plant as compatible with irrigation requirements.

Five studies of water supply were made on the basis of various assumptions as to irrigation and power drafts. The details of each study are shown in Tables 13* to 17,* inclusive, appearing in Appendix B.

The succession of years of low run-off since the 1920 report was prepared will materially affect the results to be obtained from any study, including the 1923-24 season. An examination of the studies made will show that the possibilities of power development at the storage dam hinge upon a season like that of 1923-24, when 90 per cent of the irrigation supply for the project must have come from storage, since no free flow in the river was available after the month of April for use on the project. Assuming that irrigation requirements are paramount, that a season like 1923-24 may occur at any time and that the operators can not foretell in October what the seasonal run-off will be, it is evident that the output of primary power during the fall and winter months is limited to the amount that can be produced by a flow that can safely be drawn from the reservoir with assurance that it would be full at the beginning of the succeeding irrigation season.

The potential primary power under Study No. 2 is greater than in Study No. 1, for the reason that in the former there would have been a holdover of 126,000 acre-feet from the previous season, while in the latter the reservoir in the previous season would have been drawn down to the minimum allowable. The 126,000 acre-feet holdover not only reduced the amount of water to be stored in 1923-24, thus allowing a larger power draft than is permissible in Study No. 1, but the extra water in the reservoir resulted in an increased head on the power plant.

Following is a summary of water and power shortages according to the studies made:

STUDY No. 1.

Irrigation draft	1,000,000 acre-feet
Maximum water surface in reservoir	El. 400
Minimum water surface in reservoir	El. 353
Storage reserved for creating power head	214,000 acre-feet
Storage available for supplying irrigation demand	747,300 acre-feet

Power draft till reservoir is full=3,600 c. f. s. x 100′ head=32,700 h.p. at 89 per cent efficiency.

Year	Month	Irrigation shortage	Per cent seasonal supply		Power shortage, horsepower	Per cent of assumed minimum
1917-18	September	11,600		1.2		
1919-20	September	108,700		10.9		
1922-23	September	34,100		3.4		
1923-24	August	83,100	8.3	20.3	5,700	17.5
1923-24	September	120,000	12.0			
1924-25	October				[1]1,500±	4.0±

[1]Table 13 is not extended to include this item.

* Tables not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

STUDY No. 2.

Irrigation draft for project .... 800,000 acre-feet
Maximum water surface in reservoir .... El. 400
Minimum water surface in reservoir .... El. 353
Storage reserved for creating power head .... 214,000 acre-feet
Storage available for supplying irrigation demand .... 747,300 acre-feet
Power draft till reservoir is full = 4,200 c. f. s. x 100′ head = 38,200 h.p. at 80 per cent efficiency.

Year	Month	Irrigation shortage	Per cent seasonal supply	Power shortage, horsepower	Per cent of assumed minimum
1923-24	September	28,200	3.5	....	....
1924-25	October	....	....	*7,000±	18±

*Table 14 is not extended to include this item.

STUDY No. 3.

Irrigation draft for project .... 800,000 acre-feet
Maximum water surface in reservoir .... El. 400
Minimum water surface in reservoir .... El. 363
Storage reserved for creating power head .... 302,000 acre-feet
Storage available for supplying irrigation demand .... 659,300 acre-feet
Power draft till reservoir is full = 4,200 c. f. s. x 110′ head = 42,000 h.p. at 80 per cent efficiency.

Year	Month	Irrigation shortage	Per cent seasonal supply	Power shortage, horsepower	Per cent of assumed minimum
1919-20	September	23,200	2.9	....	....
1923-24	July	37,200	4.6 }	....	....
1923-24	August	160,000	20.0 } 36.6	12,900	30.7
1923-24	September	96,000	12.0 }	12,500	29.8
1924-25	October	....	....	*8,000±	19. ±

*Table 15 is not extended to include this item.

STUDY No. 4.

Irrigation draft for project .... 800,000 acre-feet
Maximum water surface in reservoir .... El. 400
Minimum water surface in reservoir .... El. 373
Storage reserved for creating power head .... 425,300 acre-feet
Storage available for supplying irrigation demand .... 536,000 acre-feet
Power draft till reservoir is full = 4,200 c. f. s. x 120′ head = 45,900 h.p. at 80 per cent efficiency.

Year	Month	Irrigation shortage	Per cent seasonal supply	Power shortage, horsepower	Per cent of assumed minimum
*1899-00	September	12,300	1.5	....	....
*1900-01	September	14,800	1.9	....	....
*1902-03	September	32,200	4.0	....	....
1917-18	August	11,200	1.4 } 6.2		
1917-18	September	38,000	4.8 }	....	....
1918-19	August	1,400	0.2 } 8.2	2,900	6.3
1918-19	September	63,600	8.0 }		
1919-20	August	47,500	5.9 } 17.9	8,900	19.4
1919-20	September	96,000	12.0 }		
1920-21	October	....	....	2,300	5.0
1921-22	September	5,100	0.6	....	....
1922-23	September	86,000	10.8	6,900	15.0
1923-24	October	....	....	1,100	2.4
1923-24	November	....	....	1,800	3.9
1923-24	July	138,100	17.3 }	6,900	15.0
1923-24	August	160,000	20.0 } 49.3	14,200	30.9
1923-24	September	96,000	12.0 }	13,700	29.9
1924-25	October	....	....	**8,000±	19.4

*Shortages determined by inspection of Study No. 2 noting elevation of water surface in reservoir.
**Table 16 is not extended to include this item.

STUDY No. 5.

Irrigation draft for project .... 800,000 acre-feet
Maximum water surface in reservoir .... El. 405.5
Minimum water surface in reservoir .... El. 368.0
Storage reserved for creating power head .... 364,600 acre-feet
Storage available for supplying irrigation demand .... 757,300 acre-feet
Power draft till reservoir is full = 4,200 c. f. s. x 115′ head = 43,900 h.p. at 80 per cent efficiency.

Year	Month	Irrigation shortage	Per cent seasonal supply	Power shortage, horsepower	Per cent of assumed minimum
1923-24	September	30,600	3.8	1,700	4.0
1923-24	October	....	....	*9,400±	21. ±

*Table 17 is not extended to include this item.

Reservoir draft suggested as most practicable. The plan contemplated in Study No. 2 is apparently the better. The figures shown are modified slightly in the plan recommended for adoption, as will be shown in the discussion of power. Were it not for the uncertain status of riparian rights, a project with a draft of 1,000,000 acre-feet might be the economical choice. Because of this uncertainty, however, the project should be so lined up that the additional 200 000 acre-feet could be used on a separate unit rather than to build a main canal, with a possibility that it could not be used to full capacity. The granting, by an overruling of Section 11 of the Water Commission Act, of undeveloped riparian rights, both on the Pit and below Iron Canyon, might have a material effect on either project, but the effect would be more serious for the larger project, as it must depend to a greater extent on the free flow of the river in the earlier irrigation months to function without shortage.

Should Section 11 of the Water Commission Act be upheld, it is possible that the larger draft would be feasible, in which case there would ordinarily be 200,000 acre-feet of water available for diversion either at the diversion dam, for use on an extended project by enlarging the main canal, or for diversion at some other point, or points, along the river. The additional draft might be used to supply miscellaneous small areas along the river, for which pumps are in many cases now installed, but for which the present water supply is deficient; to supply lands on the east side of the valley lying between Tehama and Chico, either by pumping from the river near Tehama, or by siphoning across the river from the proposed west side canal; or to supply an equal area in the vicinity of Woodland by pumping from the river at Knights Landing. Surveyed canals for the accomplishment of the last two proposals are shown on the project map, Plate 2.

The allowance made for prior rights is considerably in excess of the natural average flow in the river for the month of July, at the time the irrigation demand is a maximum, and although the outcome of the water situation can not be predicted, it is not probable that a future court decree would be detrimental to the Iron Canyon project (unless the ruling should be that riparian rights apply to flood waters as well as summer flow), since the project's supply would come from storage during months when there is a shortage in the free flow to supply prior rights. The effect upon the project of a movement to increase the flow for purposes of navigation can not be foreseen.

Irrigation shortages. Study No. 2 indicates that in the 1923-24 season the project would have suffered a shortage of about 30 per cent of the September supply, or less than 4 per cent of the seasonal supply. In actual operation the shortage could have been distributed throughout the irrigation season, for it was known early that an extremely dry year was to be encountered.

Reservoir operation. Graphs of operation of the Iron Canyon reservoir are shown on Plate 8. The first column of graphs on the left represents the operation, according to Study No. 2, for an average year; a low year, such as 1919-20; and the lowest year of record, assuming an 800,000 acre-feet annual draft. In the second column, Study No. 2 is shown as modified by Study No. 5, which assumes storage in the reservoir to elevation 405.5, instead of to elevation 400. Similar graphs, representing Study No. 1 and its modification, are shown in the third and fourth columns. The suggested best plan is represented by the graphs in the second column.

Auxiliary water supply. The most important tributaries entering the Sacramento River on the west side are Thomes, Stony, Cache and Putah creeks. See Plate 2. These streams usually have large flows during the winter and spring, but the summer flow diminishes to almost nothing. They were all dry in 1924. The first two only cross the proposed project. No attempt has been made to increase the water supply for the project from these and other small water courses crossed by the main canal, as they carry little, if any, water at a time when it would be of benefit to the project. Neglecting to take account of water derived from this source is on the safe side as far as water supply is concerned.

Diversion from return flow and pumping from ground water have not been definitely disposed of, since there are so many dispositions which might be made of them. It has been thought best to leave the matter of final disposition to be worked out at the time the water available from these two sources is required for further development. This also is on the safe side as far as water supply and duty of water are concerned.

Return water. Regardless of the size, or location of the project, there, ultimately, will be a return flow that would be available for use on lands to be included in a project extension supplied with water by pumping at Knights Landing; or which could be used to supply riparian rights in the delta region below Sacramento; or, like waste water, could be used to supply lands in the San Joaquin Valley if the transfer of Sacramento River water to that valley becomes desirable.

Irrigation development in California has reached a stage where the recovery of waste, seepage and return water, has assumed a prominent position. In the Sacramento Valley a large portion of the return flow follows the troughs in the basin on either side of the river, and is carried to the river in definite channels at points fairly well down stream. Most of the return water from the proposed Iron Canyon project, if allowed to flow by gravity, will find its way into Colusa Basin, thence to the river at Knights Landing by way of Sycamore Slough or on down the Yolo By-pass.

On page 166 of the proceedings of the Second Sacramento-San Joaquin River Problems Conference, the water supervisor reports that the total return flow from Red Bluff to Sacramento, for the four months, June to September, 1924, amounted to 33 per cent of the diversions in that period on the same stretch of river. The return flow above Butte City was 11 per cent; above Colusa 18 per cent; above Knights Landing 31 per cent and above Sacramento 33 per cent.

While there might be objection upon the part of some irrigators to the use of return water, it is probable that due to the high value of water, its use will be necessary, even after storage contemplated in the plan of ultimate development of the water resources of the state has been constructed. Return water is now being used and its use will, without doubt, continue. Exhibit 9, dealing with return waters from Colusa Trough, is an extract from the Water Supervisor's Report for 1924.

POWER.

Demand for power. Plate 9 shows the demand for power by months as a percentage of the annual demand, from data furnished by the Pacific Gas and Electric Company for the Sacramento Valley, and by the San Joaquin Light and Power Corporation for the San Joaquin Valley.

Water available for power development at Iron Canyon dam. In the plan considered in the 1920 report on the Iron Canyon project, water for the project was diverted directly from the storage reservoir in a high line canal and, therefore, only water to supply prior rights was available for power development at the dam during the low water period. With the diversion works for the project located downstream from the storage dam, as contemplated in this report, all water passing the dam, including that to satisfy the demand of the proposed project as well as that to supply prior rights, becomes available for development of power at the storage dam.

Potential power at Iron Canyon dam. For any assumed irrigation draft, the potential power increases as the established normal water surface in the reservoir is raised. The rate of increase in total power is less than the rate of increase in normal water surface elevation because of the more rapid increase in storage capacity of the reservoir near its top, as shown on Plate 4. Thus, raising the normal water surface 7.5 feet (from elevation 392.5, adopted in the 1920 report, to elevation 400), results in increasing the average power head 16.3 feet (from 114.8′ to 131.1′) while an additional raise in water surface (from elevation 400 to 405.5) increases the average power head 7.9 feet (from 131.1′ to 139.0′). The gain in power head for the 7.5 feet raise is therefore at the rate of 1.52 times that for the upper 5.5 feet raise. The increase in primary power is greatly in excess of the increase in total power since the former is dependent upon minimum power head instead of the average. With the assumed irrigation draft for the Iron Canyon project the increase in the minimum power would be as follows:

Elevations			Minimum power head in feet
Normal water surface in reservoir	Minimum water surface in reservoir	Tail water	
392.5 400.0 405.5	301 353 368	253 253 253	48 100 115

As will be shown under "Analysis of Estimated Costs," economy results by raising the water surface from elevation 400 to 405.5 by reason of the increase in power. It is evident that the power gained by raising the water surface from elevation 392.5 to 400 would be more profitable.

In column 13 of tables 13* and 14* (Appendix B) is shown the amount of power available at the storage dam with an annual irrigation draft of 1,000,000 and 800,000 acre-feet respectively, upon the assumption that the storage could be increased over that considered in the 1920 report by installing movable gates in the siphon spillways, and on the crest of the emergency spillway, to raise the water surface in the reservoir from elevation 392.5 to 400. A study was made of the amount of power available with the water surface raised to elevation 405.5, the maximum assumed practicable, upon the basis of an annual irrigation draft of 800,000 acre-feet. The results of this study are shown in Table 17,* Appendix B. Any shortage which might occur, on account of the failure of the reservoir to fill, would be increased slightly with the higher working elevations because of the evaporation from a larger water surface area. However, in the study made the working storage capacity was increased by 10,000 acre-feet to allow for increased evaporation, and as the October draft in 1923 was so selected that the reservoir practically fills in the winter of 1924, the loss by the greater amount of evaporation is not appreciably felt by irrigation. It is rather a loss to power.

Power gained by passing project irrigation water through Iron Canyon power plant. The amount of power gained by passing the project irrigation water through the power plant (as modified in the following paragraph), upon the assumption that the project had been receiving a full water supply under conditions of ultimate development, is shown in Table 18,* Appendix B, to average 94,313,700 k.w.h. per year, for the past 29 years. In determining the output of power, it is assumed that the over all efficiency of the plant, measured at the switchboard, is 80 per cent.

Studies of water supply and of power development were made before the inclusion of the 7000-acre East Side unit. In the project adopted the 21,000 acre-feet of water for the East Side unit is not available for the development of power. The average annual amount of power developed by passing the 800,000 acre-feet of project irrigation water through the power plant is 94,313,700 k.w.h. The average amount of power from the 21,000 acre-feet would be 2,475,000 k.w.h., of which a considerable proportion is secondary power. The average annual out-

* Tables not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

put of power as used in this report is 584,890,000 k.w.h. The error, then, that is introduced by the inclusion of the 21,000 acre-feet of water is negligible, being .42 per cent.

Average annual power output, Iron Canyon plant. Obviously it is not practicable to install machinery up to the limit of the flood flow of the river. The average annual output of the Iron Canyon power plant, had it been in operation according to various schemes during the period 1895 to 1924, inclusive, is shown in Table 19, Appendix B, which may be summarized as follows:

Scheme	Maximum water surface in reservoir	Annual project draft, acre-feet	Installed capacity, h.p.	Average annual output, k.w.h.	Per cent primary power	Average per cent of time water available for operation at full capacity
A	400	1,000,000	100,000	530,420,000	49.9	57.5
B	400	1,000,000	105,000	548,520,000	48.2	53.5
C	400	800,000	100,000	540,990,000	55.5	56.0
D	400	800,000	105,000	558,740,000	53.9	53.0
[1]E	405.5	800,000	110,000	584,890,000	56.6	53.0

Future increase. No studies have been made of future increase in power output but it is reasonable to suppose that it would increase as the summer discharge of the river at the damsite is augmented by increase in seasonal water supply through the construction of additional reservoirs above.

Potential power on main canal at Mooney Island Slough. Construction of a diversion dam at the mouth of Red Bank Creek, as indicated on Plate 2, to raise the water surface 15 feet, combined with the drop in the river between the diversion dam and Mooney Island Slough, 4.7 miles below, results in an available static head of about 31 feet at the slough. By enlarging the main canal as far as Mooney Island, where the canal and Mooney Island Slough are a very short distance apart, to carry 3640 second-feet of the prior rights water in addition to that to supply the project irrigation demand, the 3640 second-feet become available for power development at Mooney Island. By utilizing some of the secondary power generated at Iron Canyon dam during the months May to September inclusive, an average annual output equivalent to about 10,000 h.p. of primary power can be produced through the construction of a plant at Mooney Island Slough, assuming 80 per cent efficiency at the switch board.

Average annual power output, Mooney Island plant. The capacity of the Mooney Island power plant is fixed upon the basis of the power which the available flow passing down the river will produce in October. To this quantity is applied the demand curve for the Sacramento Valley, and the required amount of power necessary to supply the demand for other months is found to be as shown in Table 20,[2] Appendix B.

[1] Recommended as best scheme.
[2] Table not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Average annual power output, Iron Canyon and Mooney Island plants combined. Plate 10 shows the possible output of power, by months, resulting from the utilization of an 800,000 acre-foot project irrigation draft according to various assumptions as to the elevation to which water may be stored in Iron Canyon reservoir, and as to the amount of generating equipment installed. It will be noted that consideration is given to seasons of average run-off, low run-off and extremely low run-off. The graphs show the output of the Iron Canyon plant alone, combined with that at the Mooney Island plant. The heavy line divides the power into primary and secondary. Primary power, lying below the line, is assumed to be the quantity which can be furnished in accordance with the demand curve for the Sacramento Valley shown on Plate 9 based upon the safe output for October. The safe output depends upon the quantity of water that can be released and still have assurance that the reservoir would fill during a season like 1923-24. Data from which the graphs were drawn appear in Tables 21,* 22, 23* and 24, Appendix B.

Attention is called to the fact that tables 13* and 14,* which are based upon storage in the reservoir to elevation 400 show an output less than 40,000 h.p. in October of most years. A study of the tables for 1923-24, however, will show that the output for October can be increased to 41,360 h.p., 40,000 h.p. primary demand plus 1360 h.p. project pumping demand, the amount indicated in Table 21.* Reducing the output for the succeeding months in accordance with the demand curve will allow the reservoir to fill. Likewise, Table 17,* based upon storage to elevation 405.5, shows an output of less than 44,000 h.p. in October but this may be boosted in a similar manner to 45,360 h.p. as indicated in Table 22. The results of combining the output from the Iron Canyon and Mooney Island plants are shown in Tables 23* and 24 and upon Plate 10.

During the time the irrigation project is developing it may be possible to so manipulate the reservoir that a greater amount of power could be developed for several years until the irrigation requirements predominate those of power.

Basis of estimated value of power. In figuring revenue from the sale of power the demand is assumed to be in accordance with the monthly distribution of power in the Sacramento Valley by the Pacific Gas and Electric Company as follows, stated in per cent of the annual:

January	6.5	July	11.4
February	6.5	August	11.3
March	6.9	September	9.7
April	6.8	October	7.4
May	8.8	November	6.9
June	10.8	December	7.0

It is assumed that power generated at the Iron Canyon and Mooney Island plants can be sold to one of the distributing companies. A main transmission line passes within five or six miles of both plants.

Both plants proposed are located where there is no possibility of trouble from ice, snow or sleet storms, and the fact that they operate

* Tables not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

directly from a large reservoir makes them especially valuable as standby plants and plants that would respond readily to the demands of a daily peak load without loss of total power available.

On Plate 10 the power developed at the Iron Canyon and Mooney Island plants and the amount used for pumping irrigation water to a part of the proposed project are shown. The graphs appearing in the fourth column from the left represent the power situation under what is believed to be the best plan of development. It will be noted that in an average year practically all (96 per cent) of the power used for project pumping falls within the area of secondary power; that in a low year approximately 69 per cent, and that even in the lowest year of record about 46 per cent of the pumping load would be supplied from secondary power. It is believed that power to be used on the project for pumping would be of practically the same value as that considered primary power, and would have the effect of raising the average value of secondary power considered as a whole.

In years of extremely low run-off conservation measures should, and probably would, be put into effect, both in the amount of water used for irrigation and in the amount of power consumed in general. This conservation would result in bringing the pumping load as represented on the graphs more nearly within the area of power developed and less auxiliary power would be required in steam or other plants than is indicated.

In estimating the value of primary power it has been assumed that 90 per cent of the power of that class as measured at the switchboard of each plant is salable. Conditions at both plants are believed to be favorable for the development of this class of power. The value of secondary power is more problematic, and in an attempt to be conservative it has been assumed that only 55 per cent is salable. From the latter part of March through April, May and early June this class of power is said to be of practically no value between 10 o'clock at night and 8 o'clock in the morning.

Information relative to the present unit value of power was sought of the Railroad Commission of the State of California. Data furnished indicates that in three comparatively recent contracts between irrigation districts and power companies, and between power companies, 4½ mills per k.w.h. is the price fixed for *all energy delivered*. The point of delivery in one case is at the selling company's switchboard, and in two cases at the purchasing company's substation.

The assumption that 90 per cent of the primary power is salable is believed to be conservative, since the output of primary power is made to correspond to the monthly demand of the Sacramento Valley. Although 90 per cent is somewhat stricter than frequently used, it is believed that daily fluctuations in demand can be completely taken care of by the plants without waste of water. The power output at the Iron Canyon plant can probably be controlled without undue fluctuations of the river discharge below the diversion dam, since the pond back of the latter comprises about 400 acres, which should produce considerable storage regulation in that it can be drawn down some at night, when the load is light, and allowed to fill during the day time. During the greater part of the irrigation season the peaks can be assumed as extending into the region of secondary power.

Average gross revenue, Iron Canyon and Mooney Island power plants. Table 25 is a summary of the average annual output of power, and the resulting gross revenue from the two proposed plants, according to the various studies made, upon the assumption that power is worth 4 mills per k.w.h. The present value of power, as near as can be determined, lies between 4 and 5 mills per k.w.h. As will appear later, estimates for the project have been prepared upon the basis of power being worth 4, 4½ and 5 mills per k.w.h. upon the assumption that money used in construction of the project would bear no interest. In addition, a study was made in which the construction cost of the reservoir and power features are amortized, assuming compound interest of 5 per cent payable semi-annually and power delivered at 4 mills per k.w.h. The studies of cost will be found at the end of the report under "Summary of Financial Considerations."

TABLE 25. POWER OUTPUT AND REVENUE IRON CANYON AND MOONEY ISLAND PLANTS.

Summary of average annual power output for years of record (1895-1924) and estimated gross revenue for various assumptions of reservoir control. Power assumed to be worth $0.001 per k.w.h. at switchboard. Assumed plant efficiency, 80 per cent.

	Project draft, 800,000 acre-feet			Project draft, 1,000,000 acre-feet		
Maximum water surface in Iron Canyon reservoir	400	405.5	405.5	400	405.5	405.5
Installation at Iron Canyon dam, (h.p.)	100,000	105,000	110,000	100,000	105,000	110,000
Installation at Mooney Island (h.p)	10,400	10,400	10,400	10,400	10,400	10,400
Iron Canyon plant:						
Primary power—						
Average horsepower, gross	46,045	50,545	50,545	40,445	44,920	44,920
Annual output, k.w.h., gross	300,720,000	330,720,000	330,720,000	264,610,000	293,500,000	293,500,000
Annual output, k.w.h., net=90 per cent of gross	270,650,000	297,650,000	297,650,000	238,150,000	264,150,000	264,150,000
Gross annual revenue	$1,082,600	$1,190,600	$1,190,600	$952,600	$1,056,600	$1,056,600
Secondary power—						
Annual output, k.w.h., gross	240,270,000	236,313,000	254,170,000	265,810,000	262,500,000	280,357,000
Annual output, k.w.h., net=55 per cent of gross	132,150,000	129,972,500	139,794,000	146,195,000	144,375,000	154,196,000
Gross annual revenue	$528,600	$519,900	$559,200	$584,800	$577,500	$616,800
Mooney Island plant:						
Primary power—						
Average horsepower, gross	9,075	9,075	9,075	9,075	9,075	9,075
Annual output, k.w.h., gross	59,333,000	59,333,000	59,333,000	59,333,000	59,333,000	59,333,000
Annual output, k.w.h., net=90 per cent of gross	53,400,000	53,400,000	53,400,000	53,400,000	53,400,000	53,400,000
Gross annual revenue	$213,600	$213,600	$213,600	$213,600	$213,600	$213,600
All sources:						
Primary and secondary power—						
Annual output, k.w.h., gross	600,323,000	626,366,000	644,223,000	589,753,000	615,333,000	633,190,000
Annual output, k.w.h., net	456,200,000	481,022,500	490,843,000	437,745,000	461,925,000	471,746,000
Gross annual revenue	$1,824,800	$1,924,100	$1,963,400	$1,751,000	$1,847,700	$1,887,000

Power used in pumping. In the 1920 report it was proposed to serve all lands within the project by means of a "High Line Gravity Canal" diverting from Iron Canyon reservoir at Bend embankment. In order to irrigate the higher lands on the west side of the river included in the former report north of Germantown (about mile 60 of the canal line shown on Plate 2) it is necessary, under the plan of diversion proposed in this report, to resort to pumping. The pumping plant to serve the higher lands north of Kirkwood would be located at the Red Bank Creek diversion dam, built integral with the headworks for the proposed "Low Line Canal." Six other plants are proposed to lift water from the main canal to various tracts, and in addition two auxiliary plants to lift water a second time, with a possibility that the number of plants in this latter class may be increased. The principal areas to be served by pumping are shown on Plate 2, the canals for that purpose being drawn in red. The area of each unit, together with the lift and power consumption, is shown in Table 26, while the average monthly distribution of the pumping load is given in Table 27.

For the plan of development considered best, there are shortages in power for pumping in years like 1919–20 and 1923–24, as indicated in the fourth column of graphs on Plate 10. It should be borne in mind, however, that when there is a shortage of irrigation water the requirements for power to pump irrigation water will be correspondingly decreased unless advantage is taken of the auxiliary water supply which may be developed by pumping from wells.

TABLE 26. PUMPING PLANT DATA AND SUMMARY OF POWER REQUIRED FOR PUMPING TO PROJECT AREAS.

Location	Acre-feet pumped	Cu. ft. per sec. maximum	Length pipe line	Size pipe line[1]	Friction head	Static head	Total head	Installed capacity		Power consumption, k.w.h.[2]
								H.P.[2]	Pumps	
Intake	[3]90,153	371	6,300′	9.0′	4.9′	50′	54.9′	3,310	3-48″	7,260,000
Thomes Creek	[4]41,550	171	6,700′	6.75′	5.0′	37.5′	42.5′	1,180	1-36″ 1-42″	2,590,000
Sta. 1175+00	31,800	130.7	1,850′	6.0′	1.5′	42′	43.5′	925	1-24″ 1-42″	2,033,000
Sta. 2271+00	[5]50,100	206.1	8,400′	7.5′	5.3′	35′	40.3′	1,350	3-36″	2,960,000
Second lift from Sta. 2271+00	12,360	50.8	5,000′	4.5′	2.8′	34′	36.8′	301	1-30″	667,000
Sta. 3260+00	8,606	35.3	1,100′	3.5′	1.0′	25′	26.0′	149	1-24″	329,000
Sta. 4307+00	2,068	8.5	700′	2.0′	0.7′	25′	25.7′	35	1-12″	78,000
Sta. 4705+00	5,489	22.6	800′	3.0′	0.7′	35′	35.7′	131	1-18″	288,000
Sta. 4976+00	41,864	172.2	1,700′	6.75′	1.3′	42′	43.3′	1,210	1-36″ 1-42″	2,660,000
Total net	230,080	....	....	....	....	....	....	8,594	....	18,865,000
Total including second pumping	283,990	....	....	....	....	....	....	....	....	....

[1] Single barrel in all cases.
[2] Efficiency of plants assumed to be 70 per cent.
[3] Includes 41,550 acre-feet pumped at second lift.
[4] Second lift to reach lands above Corning.
[5] Includes 12,360 acre-feet pumped a second time.

TABLE 27. MONTHLY DISTRIBUTION OF PUMPING LOAD.

Month	Kilowatt hours	Horsepower
October	754,600	1,360
March	188,650	340
April	943,250	1,750
May	3,018,400	5,430
June	3,773,000	7,000
July	4,150,300	7,470
August	3,773,000	6,800
September	2,263,800	4,190
Totals	18,865,000	....

FLOOD CONTROL.

Frequency and estimated volume. The curve of probable frequency of flood discharge of the Sacramento River near Red Bluff, shown on page 411 of Bulletin No. 5 published by the State Department of Public Works, Division of Engineering and Irrigation, indicates that a discharge of 300,000 second-feet may be expected once in about fifty years and that a flood of 250,000 second-feet may occur once in about twenty-five years. The maximum discharge since the gaging station near Red Bluff was established occurred on February 3, 1909, when the flow was estimated to be 278,000 second-feet.

Iron Canyon reservoir as a flood regulator. Studies made, bear out the statement in the 1920 report that "The value of the reservoir for reducing floods lies mainly in the possibility of so operating the gates of the dam as to produce the desired effect rather than in any changes in, or addition to, the design for this purpose. Without such intentional regulation the reservoir would have a comparatively small beneficial effect upon floods, while with proper regulation of the gates the flood peaks could generally be greatly reduced."

If the purpose of Iron Canyon reservoir were solely for flood control, its effect on floods and the proper method of operation could be foretold with some degree of accuracy. When this feature is combined with the twofold duties of supply for irrigation and for power, however, the problem becomes far more complex.

In the report on Iron Canyon project, published in 1914, the proposal is made that the reservoir be kept empty until the first of March, and that not to exceed 100,000 acre-feet be accumulated by March 15, and 200,000 acre-feet by March 31. If the reservoir had been operated according to this plan during the season 1920–21 it would not have filled, and there would have been an irrigation shortage of 3 per cent in September, with the 800,000 acre-foot irrigation draft project, or 13.6 per cent with the 1,000,000 acre-foot draft. In 1923–24, with the reservoir empty on March 1, keeping in mind the priority and navigation requirements, only 11,000 acre-feet would have been stored in March, and there would have been a power shortage in April, with no water available for storage, with the result that the project would have had only 11,000 acre-feet of irrigation water available for use after May 1, which would have resulted in an irrigation shortage of over 88 per cent.

It is probable that in practical operation the crest of the floods could be reduced materially for some distance below Iron Canyon dam, but it is doubtful if this reduction could be counted upon to the extent that any less precaution could be taken in maintaining works down stream from the dam for protection against floods. In this connection it should be noted that if the maximum outlet capacity at the dam for flood protection purposes is assumed to be 100,000 second-feet, it would have been necessary, during the three days, February 2, 3 and 4, 1909, to maintain a flood storage reserve of 415,000 acre-feet to reduce the flow below 100,000 second-feet; and, for the period January 15 to January 22 of the same year, the required reserve would have been 521,000 acre-feet.

It is well to keep in mind that there have been seasons of very low discharge prior to 1923–24. The seasons of 1850–51 and 1863–64 were of this type. As the latter followed, by only two years, the excessive flood season of 1861–62, it is very probable that had the reservoir been in operation the effect on irrigation would have been disastrous, owing to the overcaution bound to have been exercised if operated for flood control.

NAVIGATION.

Effect of Iron Canyon reservoir on river discharge. The average annual run-off of the Sacramento River at Sacramento is 25,200,000 acre-feet, of which approximately 15,000,000 acre-feet originate between Red Bluff and Sacramento.

Studies made of water supply and operation of Iron Canyon reservoir indicate that with an irrigation draft of 800,000 acre-feet, the minimum rate of discharge would, for the years of record, usually have been from 3000 to 3500 second-feet, or more, during the months the reservoir is filling. The discharge from the reservoir during the filling period is that required to develop the assumed primary power, the discharge decreasing as the reservoir fills.

Had the reservoir been in operation during the past 30 years the most critical month of record would have been April, 1924. During that month the discharge through the dam would have been at an average rate of about 2900 second-feet. During the month 66,500 acre-feet would have been stored and had the average rate of discharge been increased the reservoir would not have filled. The discharge for the month at the Red Bluff gaging station was 239,000 acre-feet, or at an average rate of 4000 second-feet. It appears then, that in the event a rate of discharge in the Sacramento River below the storage dam in excess of 2900 second-feet is insisted upon for the purposes of navigation during a critical period such as cited, the water supply of the Iron Canyon project might be affected seriously. However, the filling period of the proposed reservoir comes at the season of high run-off of all streams tributary to the Sacramento River and there would be little danger of navigation being interfered with through the construction of the reservoir under present conditions of storage development on tributary streams, as the flow issuing from Iron Canyon reservoir would soon be built up sufficiently to meet any reasonable requirement of navigation, even in extremely dry years. Under conditions of ultimate development of water resources, other reservoirs would be filling at the same time as Iron Canyon reservoir, but even though all tributary streams were controlled by reservoirs it is probable that power would be developed at some of them and that the power water during this period would join that from the Iron Canyon plant to create a total discharge more than sufficient to supply navigation requirements.

During periods in the irrigation season, when there is a shortage of natural flow in the river to supply prior rights, the Iron Canyon project will draw its water from storage in the reservoir and any release from the reservoir, in addition to the natural flow of the river plus water for the Iron Canyon project, would be a direct benefit to navigation. Such release is not contemplated in this report. If such release should be desired, navigation interests should bear a portion of the cost of the reservoir.

Effect of Mooney Island power plant on river discharge. The utilization of prior rights water at the proposed Mooney Island power plant on the main canal, 4.7 miles down stream from the diversion dam, involves consideration of navigation requirements between Red Bluff and Mooney Island, for the reason that the river would be diverted through the main canal between Red Bank Creek and Mooney Island, with the possible exception of a small amount necessary to supply prior rights between the latter points.

Data given in House Document No. 76, Sixty-first Congress, first session of June 28, 1909, indicate that the total tonnage of all commerce passing over any portion of the Sacramento River from Chico Landing to Red Bluff decreased from 14,586 tons in 1900 to 3280 tons in 1909. There is at present no traffic on the river north of Chico Landing, nor has there been for a number of years even during high water, according to information from the only transportation company operating in that vicinity. It therefore appears that under present conditions navigation between the diversion dam and Mooney Island power plant is not an important consideration. There is, however, a government project for maintaining navigation on the Sacramento river in this vicinity and it would be necessary to obtain the approval of the army engineers, and possibly congressional action, before navigation above Mooney Island could be abandoned definitely.

SILT.

Effect of Iron Canyon reservoir. In the plan proposed power development automatically provides storage space for the accumulation of considerable silt, since the storage reserved in Iron Canyon reservoir for creating the minimum power head amounts to 364,600 acre-feet. No studies were made to determine the silt content of the river, or the length of time the reservoir would serve as a silting basin.

SALINITY IN DELTA REGION.

Iron Canyon reservoir as a possible means of control. Sacrificing the power feature at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre-feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such use be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line.

A report upon Salinity Investigations by the Water Supervisor is contained in "Proceedings of the Second Sacramento-San Joaquin River Problems Conference of 1924." It is stated: "It will be seen that, based on the relation at the O. and A. Ferry (San Francisco and Sacramento Railroad crossing near Pittsburg) a sum of the Sacramento and Vernalis flows equal to 3500 second-feet was required (in 1924) to prevent the encroachment, or cause the recession, of salinity in the delta."

The mean discharge of the Sacramento and San Joaquin rivers in second-feet during the critical period of 116 days, between May 26, and September 20, 1924, when the combined flow was less than 3500 second-feet, is as follows:

Source of water	May 26-31	June	July	August	Sept. 1-20
Sacramento River (measured at Sacramento)	2,298	1,323	909	1,366	2,361
San Joaquin River (measured at Vernalis)	829	575	420	420	416
Combined mean discharge	3,127	1,898	1,329	1,786	2,777
Acre-feet (approximately)	37,524	113,880	79,740	107,160	111,080

Total run-off in 116 days, May 26 to September 20, inclusive	449,384 acre-feet
Total run-off in 116 days at rate of 3,500 second-feet	812,000 acre-feet
Approximate run-off in 116 days in 1924	449,400 acre-feet
Deficiency	362,600 acre-feet
Available storage, Iron Canyon reservoir	364,600 acre-feet

If Iron Canyon reservoir were to be used in the manner outlined above, the requirements of navigation would be partially satisfied although the flow in the Sacramento would not be built up to 3500 second-feet for the reason that the San Joaquin River supplies a part of the water estimated necessary to act as a natural barrier against encroachment of salt water into the lower rivers. In July, 1924, however, the average flow of the Sacramento River at Sacramento would have been built up to about 3080 second-feet in comparison with the 909 second-feet which is estimated was the approximate flow.

Other reservoirs. Assuming that other reservoirs will be constructed as time goes on it is possible that their construction, as well as that of Iron Canyon reservoir, could be so timed that the salt water menace could be kept in control through the utilization of water impounded in excess of that required during the early development of the irrigation projects for which they are built. Thus, if an artificial salt water barrier is proven to be feasible, and desirable, its construction might be deferred for several years, or until it is no longer advisable to waste the 3500 second-feet estimated to be required to act as a natural barrier.

IRON CANYON RESERVOIR, DAM AND POWER PLANT.

Iron Canyon reservoir. The location of the reservoir is indicated on Plates 1 and 2, adjacent to the project considered in this report. The dam site is located at the extreme lower end of Iron Canyon and immediately above the large irrigable area in the Sacramento Valley. Very complete data on the dam site, including topography, diamond drill records, geologists' reports and general discussions, will be found in the 1920 report.

Data relative to the reservoir now proposed are as follows:

Gross storage to elevation 405.5	1,121,900 acre-feet
Storage reserved to create a minimum power head of 115 feet	364,600 acre-feet
Gross storage available for supplying project, including allowance for evaporation losses	757,300 acre-feet
(Part of the irrigation requirements are supplied from the free flow of the river.)	
Installed power development at the storage dam	110,000 horsepower

Iron Canyon dam. The dam adopted is of the concrete gravity-section type, with vertical upstream face and 1 to 1 downstream face, the latter slope being used to reduce foundation pressures to the practicable limit. The length of the dam on top is 5175 feet. In addition to the masonry dam, the construction of the so-called Bend embankment is necessary to close a low gap in the rim of the reservoir lying 1½ miles northwest of the main dam. The location of the embankment is indicated on Plate 2 and the design, as modified for use in this report, is shown on Plate 14.

Iron Canyon power plant. Between stations 12+98 and 15+33 the section of the main dam is modified to provide for power plant installation. The revised power plant contains four 27,500 h.p. turbine driven generator units, each supplied by a 20-foot circular penstock controlled by a 20-foot by 20-foot Stoney gate and protected by trash racks as shown on Plate 15.

Flood control gates. Flood control is provided through the installation of 27 10-foot by 12-foot hydraulic operated drum gates set in the dam to discharge into the present river channel, each gate being protected by a 12-foot by 19-foot Stoney gate located at the upstream face of the dam to be operated in case the drum gates, for any reason, become inoperative.

Spillways. To pass floods beyond the capacity of the flood control gates 27 large siphons are constructed on the crest of the dam, in a position to discharge into the present river channel. The channel bottom and sides, to a point above estimated high water surface, are lined with concrete as a protection against scour of the rock formation. The crest of the siphon spillway is at elevation 392.5, which was considered the normal water surface of the reservoir in the 1920 report. In the present report consideration is given to the feasibility of increasing the head for development of electrical energy by placing movable gates on the spillways, which would be lowered if necessary to pass the larger floods. No additional right of way for the reservoir is required because the maximum elevation of water surface occasioned by an extreme flood is assumed the same as in the former report.

As brought out previously, consideration has been given to raising the normal reservoir water surface to elevation 400 and to 405.5, the latter appearing to be the better plan. That this raise in water surface might be accomplished without making radical changes in the design of the dam, the gates have been designed to operate within the throat of each siphon, as shown on Plates 11 and 12. Further consideration may indicate that a radical change in design of the spillway feature is desirable.

In the 1920 report an additional spillway, which might be considered as an emergency overflow, was provided on the west side of the river between stations 40+00 and 50+00. The crest of this overflow spillway was at elevation 397.5, the elevation at which the siphons were assumed to prime. In order to raise the water surface to elevation 400, it is proposed to place vertical steel shutters 2½ feet high on the crest, so designed that if the water in the reservoir reaches elevation 408 (6½ feet below the top of the parapets on the dam) they will go out. To raise the water surface to elevation 405.5, the design of the concrete crest is changed to provide for the installation of movable drum gates whose tops, when elevated, would be at this elevation; but when lowered, the crest would be at the originally proposed elevation of 397.5. Because of space occupied by piers between gates, the overall length of the weir would be increased to 1071 feet. Designs of gates proposed for installation on the overflow spillway under the two plans are shown on Plates 11 and 13. In a discussion appearing in the "Analysis of Costs" it is shown that it will pay to raise the water surface in the reservoir to elevation 405.5.

The designed capacity of the proposed spillways and flood control outlets in cubic feet per second is as follows:

Elevations of water surface	340	350	392.5	397.5	405.5	410.5
Siphons	....	....	....	200,000	200,000	200,000
Flood control gates	159,000	179,000	250,000	257,600	268,000	274,500
Overflow spillway	....	....	....	....	*79,200	164,000
Totals	159,000	179,000	250,000	457,600	547,200	638,500

*With the plan proposed of panels in the overflow spillway for normal water surface at elevation 400 this quantity would be about 35,000 c. f. s.

Right of way. The proposed Iron Canyon dam to store water to elevation 405.5 will back the water up the Sacramento River to a point above the town of Anderson and up Cottonwood Creek past the town of Cottonwood. The Red Bluff sheet, U. S. Geological Survey Reconnaissance Map, shows the elevation of Anderson as 432 and of Cottonwood as 429. The corresponding elevations given in Southern Pacific folders are 433 and 423. A map of the reservoir to the 400-foot contour is shown as Exhibit 6 of the 1920 report.

The proposed reservoir will submerge a portion of the Anderson-Cottonwood Irrigation District lands and according to the soil map of the district (Plate 3), on which the 400-foot contour has been superimposed, a large part of the Columbia silt loam in the bottoms will be submerged. No survey of the 405.5 contour has been made in connection with this report. However, the State Department of Public Works, Division of Engineering and Irrigation, made an estimate of the valuation of lands and improvements under the 405.5 contour in connection with other work, and this estimate, modified to include marginal areas, is included herewith as Preliminary Estimate No. 1.

Estimated cost. The estimated cost of Iron Canyon dam, Bend embankment and the power plant at the dam is shown in Preliminary Estimate No. 2, while the estimated cost of operation and maintenance of the power plant is shown in Preliminary Estimate No. 3. In Estimate No. 2 the quantities are the same as used in the 1920 report, except where changes were made necessary by change in the plan. An effort has been made to revise the unit cost in all cases in accordance with present prices and latest information as to recent costs on similar construction work.

Construction materials. In the former estimate it is stated that sand and gravel for the construction of the dam can be obtained from pits located on the railroad, three or four miles distant from the dam site.

DIVERSION WORKS.

Diversion site. The point of diversion for the proposed Iron Canyon low line gravity canal and for the Red Bank pump line is on the west bank of the Sacramento River, about 1100 feet southeast of the mouth of Red Bank Creek. By reference to Plate 17 it will be noted that the proposed diversion dam is located on the outside of a long, sweeping curve in the river and just below the bluffs on which the city of Red Bluff is situated. The bluff of indurated clay, gravel and conglomerate, forming the west bank of the Sacramento and the north bank of Red Bank Creek, resists erosion well and holds the Sacramento River in the same channel throughout the year, there being little danger of the river meandering away from the canal headworks. The topography in the immediate vicinity of the diversion dam site and a cross-section of the river channel are shown on Plate 16. The character of the site is indicated in photographs* A, B and C following the report.

The river at this point is subject to a fluctuation of from 25 to 30 feet, between low water and extreme flood stage, which requires comparatively expensive headworks and the protection of the canal against floods. The problem is complicated because of the necessity of building a dam that will divert the required amount of water into the canal, and at the same time will not materially raise the water surface elevation in the river at flood more than it rises under present conditions. The water surface in the river at low stage under present conditions is at about Elevation 235, with the extreme possibly a foot lower.

Plans considered. Estimates were prepared for a diversion dam to raise the water surface in the canal to Elevation 250, and for a low weir and intake structure that would divert at the low water elevation of 235. In the former, two plans were considered; the first to provide for the diversion of approximately 3300 second-feet of project irrigation water only, and the second to provide for diverting 3640 second-feet of water for use in the development of power at the Mooney Island power plant, in addition to the irrigation water. The larger diverting capacity is provided for simply by increasing the number of head gates in the canal intake structure and correspondingly increasing the length of the sluiceway floor. The estimates referred to appear as Preliminary Estimates No. 4, No. 6 and No. 7. As discussed under "Analysis of estimated costs," a study indicated that the revenue to be derived through the sale of power developed at the Mooney Island power plant more than offset the greater cost of building the diversion dam to raise the water surface in the canal to Elevation 250 and increasing the size of the canal to include the water for power development. Accordingly, preliminary designs were proposed only for what is considered the better plan. These are shown on Plates 17, 18, 19 and 20.

Plan proposed. The diversion works proposed are in accordance with usual practice, consisting of a dam across the river, a sluiceway at one end and a canal intake structure so arranged that the flow into the canal is at right angles to that through the sluiceway.

* Not included in printed report. Films on file in office of the Commissioner, Bureau of Reclamation, Washington, D. C.

The dam across the present main river channel is of the open weir type, utilizing roller gates similar to those on the Grand River dam in Colorado. There are fourteen of these roller gates, each 60 feet long and 15 feet 4 inches high, carried on large piers and making closure on a low concrete weir. Protection against flow through the sand, gravel and cobbles upon which the dam is founded is secured through the use of a deep concrete cut-off wall and timber sheet piles, it being assumed that a percolation factor of 6 is applicable to the foundation material. The gates are operated by electrically driven hoists located on alternate piers, there being a hoist for each gate. When the gate is raised, the elevation of the lowest portion across the waterway is 266.25, or approximately 4 feet above the elevation of highest recorded water surface. With the arrangement shown, sufficient area is provided that the water surface in the highest flood of record (estimated 278,000 second-feet at Red Bluff gaging station) would, according to calculations made, be raised only about one foot above the elevation under normal conditions. The construction of the dam is modified at the south end to make possible the utilization of the two roller gates nearest the canal intake as sluice gates. A light steel operating bridge is provided across the dam and a fishway is constructed in the wall of the east abutment.

Canal intake. The canal headworks carries ten 15-feet by 11-feet, top sealed, electrically operated, radial gates to control the flow into the canal. On account of the heavy excavation for the canal a small loss of head at the intake is desirable, and consequently the gate areas are made generous with a resulting velocity of only 4.5 feet per second through the gates. The velocity of approach across the sluiceway is about 2.5 feet per second. The bridge across the intake structure is designed to permit passage of a wagon or truck.

Pumping plant for Red Bank pump unit. The pumping plant serving the Red Bank pump unit, with a normal capacity of 371 second-feet, is built integral with the main canal headworks, the plant being placed immediately back of the west gate of the intake. A wall is built in front of the plant, with its top two feet below normal water surface in the canal, so that water passing this gate in excess of that required to supply the pumps will flow on into the canal. Provision is made for placing stop planks above the wall so that the pumping plant and canal can be operated independently.

Earth dike. On the north side of the river, east side of the valley, a dike is required across the overflow channels to high ground, 17,000 feet to the northeast, to prevent water passing around the end of the dam and undermining the abutment. The dike proposed has a top width of 10 feet; 3-to-1 upstream and 2-to-1 downstream slopes; and a maximum height of about 30 feet where it dams a slough. The top of the dike is at the elevation of the roller gate piers at the dam and rises on an even slope until it reaches the 280-foot contour. No roadway is proposed on top of the dike.

Effect on lift to Red Bank pump unit. It should be noted in passing that the construction of the diversion dam to raise the water surface 15 feet will result in a reduction by that amount in the head against which water must be pumped to the Red Bank pump unit.

Construction materials. Sand and gravel for concrete structures are available at the dam site.

MOONEY ISLAND POWER PLANT AND WASTEWAY.

Head available. As indicated on Plate 17, the Mooney Island power plant is located at a point where the West Side low line canal, in skirting the overflow bottoms, approaches very close to Mooney Island Slough, also known as Ides Creek. Between the diversion dam and Mooney Island Slough, the Sacramento River drops faster than does the canal. This difference, added to the 15-foot raise in water surface at the diversion dam, results in a head of about 31 feet available for power development at Mooney Island, as shown on Plate 22.

Power plant. The preliminary design of the proposed power plant and wasteway is shown on Plate 21. The power plant is so located that the intake is directly from the main canal, the flow to the plant being controlled by four 15-feet by 12-feet radial gates with gate sill set 6 feet above the floor of the canal. The power installation consists of two 5200 h.p. units, protected by trash racks in the forebay. Water passing through the plant will discharge directly into Mooney Island Slough. It will be necessary to do some dredging to the river, a distance of about 3500 feet, to provide sufficient capacity for the disposal of the tail water, normally 3640 second-feet.

Wasteway and check. A four-barrel siphon spillway and a three barrel sluiceway of 3750 and 1125 second-feet capacity, respectively, are proposed for the protection of the canal. These wasteways are combined with a check structure, located about 300 feet below the power house intake. In the check structure are four radial gates 11 feet wide by 12 feet high, which serve to control the head at the power plant above and the flow into the irrigation canal below. Estimates of cost appear in Preliminary Estimates Nos. 8 and 9.

Construction materials. It is assumed that sand and gravel for concrete will have to be hauled 1½ miles.

Construction program. If the project is built, consideration should be given to the construction first of the diversion dam, Mooney Island power plant and the 4.7 miles of canal between them for the purpose of generating power for use in construction of the Iron Canyon dam. The canal between the diversion dam and power plant has a surface area of approximately 100 acres and in itself will serve as a regulator of the fluctuation in discharge through the power plant.

MAIN CANAL.

(West Side Low Line Gravity Canal.)

Basis of surveys and estimates. At the time the location survey for the main canal was started it was decided to use low water level in the river at the mouth of Red Bank Creek as the elevation of water surface in the canal at diversion, no studies having been made at that time as to the relative costs with and without a diversion dam. There is a difference, therefore, of 15 feet between the elevation of the line actually surveyed and that of the probable location between the diversion dam and Mooney Island power plant. No attempt has been made to determine the economical use of this 15 feet. It might be utilized for developing secondary power at a drop near the Mooney Island power plant if the demand for this class of power should occur in the future; a part of it might be used to increase grade, thereby reducing the size of canal section; or it may be advisable to hold the canal up, making the 15 feet drop at some point as far south as Corning. This should be considered in the final designs but the accompanying estimates based upon the located line, are deemed sufficient for the purpose.

Profiles of the lines located are shown on Plate 24, accompanying the report in roll form,* a "key" to which will be found on Plate 23. Typical canal cross-sections and hydraulic properties are shown on Plate 25. The estimated cost of the main canal is given in Preliminary Estimate No. 10.

The main canal was located on relatively flat grades in order to reach the irrigable area with as short a canal as possible, since, at best, the project is very long and narrow. A grade of .00015 was adopted for the entire line, with the exception of the 4.7 miles between the diversion dam and Mooney Island power plant where the slope is .000075, for the reason that this grade appeared to meet the requirement of the studies of alternative projects in which the area included might be located farther south than in the project reported upon, more nearly than any other grade or combination of grades. Funds available for the investigation have limited this report to what seems to be the most economical project on the west side of Sacramento Valley with diversion at Red Bank Creek. However, additional studies of alternative plans should be made to determine the location of the area which could be served most economically from Iron Canyon reservoir. With this in mind the survey of the main line was extended as far as Putah Creek as explained under "Surveys."

The cost of lining the main canal with concrete is relatively high, and although the estimates were based upon a fully-lined canal below Mooney Island power plant, it has been assumed that this investment might be deferred by operating the canal unlined for several years at about two-thirds of its capacity lined. Building unlined canals to be lined at a later date works out well on the Orland project, where the force which operates the distribution system during the irrigation season is used on the concrete lining work during the winter months, thus keeping the organization intact. Ditch riders serve as foremen. Upon the assumption that lining may be deferred, the canal for the first 70 miles of its length was designed to give a velocity near the maximum safe velocity for the material in which it is to be built. The result is that the velocities for the canal when lined are rather low. Below mile 70 the sections were designed to give water depths between one-third and one-half the bottom width, resulting in unusually low velocities. A deeper section would produce higher velocities and therefore less excavation and concrete lining, but, upon the other hand, the cost of checks and turnouts would be greater. Had a project been

* Plate 24 of printed report compiled from originals (S. V. 44; 41-D-115), submitted by Walker R. Young to the Bureau of Reclamation, June, 1925, and on file in its Denver office.

adopted for study, including no pumping, or had one been adopted in which lands in the vicinity of Woodland would be supplied by a gravity canal diverting at Red Bank Creek, the water to be carried at any point along the canal would have been greater, with a resulting increase in velocity. A study of the economic balance of grade against cross-section of canal is one which must be made before final estimates are prepared. It is probable that such a study will indicate that the adoption of grades and sections other than used in the preliminary estimates would result in a small saving in the per acre cost of the project.

From Mooney Island (station 254+33) to station 4976+00, a berm is provided on the right, or upper side, with slope above at one-half to one if in cut. This berm is for construction purposes only, and is proposed for use in connection with lining of the canal. Some economical method of placing the entire lining from the left bank may be developed before or at the time of construction, which would make the berm unnecessary.

In order that maintenance of the canal might be held to a minimum, it was decided to raise the water level in the canal not more than two feet above ground surface on fairly level country and hold it at ground surface on steeply sloping or sidehill land. From near mile 35 to mile 105 the location of the proposed canal parallels the main canal of the Glenn-Colusa Irrigation District at an elevation about 40 feet higher than the constructed canal. This is considered a very good reason for placing the proposed canal well in the ground, as a break in the Iron Canyon canal would jeopardize the Glenn-Colusa canal. With a concrete lined canal the water surface in fairly flat country might, with safety, be raised to 3.0 feet above the ground level. Between stations 1175+00 and 2045+00 a comparatively deep canal section was adopted to save on excavation and concrete lining, as the location between these points is generally on steeply sloping country and as there is no gravel for concrete aggregate between stations 1626 and 2045.

Excavation. North of Stony Creek the country is rather rough topographically and the excavation will be in gravelly soil, it being very likely that occasional hard strata and cemented gravel will be encountered. Between Stony Creek crossing and mile 70 the canal is located in fairly level country where the digging should be easy. From mile 70 to about 108, where the canal skirts the foothills paralleling the Glenn-Colusa canal, the excavation will be in rolling country with some heavy cuts. South of mile 108 to the end of the canal the country is smooth and digging should be easy. No difficulties of construction are expected, but as no test pits were dug to ascertain the character of the material beyond that observed in cut banks and excavations along the line, no classification was attempted. It has been assumed in the estimates, however, that the unit cost of excavation north of Stony Creek will be materially more than south of that creek. Estimates are based upon the use of dragline excavators.

Special considerations, upper 4.7 miles of canal. The canal between the diversion dam and Mooney Island power plant will be of unusual proportions, and as the designed water depth is 16 feet the bottom of the canal will be several feet below the ground water table during times of high water in the river. The canal will be located in gravelly material, and the lower canal bank will serve as a levee, or dike, to prevent the river from breaking into the canal. Under these conditions it is doubtful if concrete lining could be sufficiently weeped to prevent displacement by external pressure. Attention is called to the section and hydraulic properties of this portion of the canal, shown on Plate 25.

By reference to Plates 2 and 17 it will be noted that above Mooney Island the canal is some distance from the river channel. The velocity of the current along the river side of the dike can never be a serious consideration on account of the heavy growth of timber and brush between it and the river. A 20-foot road is provided on the canal bank, just behind the dike, for use during construction, and for use in operating and maintaining the canal. The dike will probably be built with draglines. The 5-foot top width shown is for no purpose other than to produce a suitable thickness of bank at high water line with the slopes adopted. Under the conditions it is probable that the freeboard shown is conservative, since it results in a levee whose top is 8 feet above a flood which has occurred only once in thirty years or more.

Canal lining. Of the entire length of 120 miles of the main canal it is proposed to ultimately line with 1:2½:5 plain concrete all but the 4.7 miles between the diversion dam and Mooney Island power plant. From station 253+33 to 2878+20, where the section has a bottom width of 23 feet and water depth of 9.7 feet, to carry 1485 second-feet, the lining has been made 4 inches thick. Below Station 2878+20 the thickness is reduced to 3 inches.

It is possible that in certain areas, where the heavier clays and adobes are encountered, it will not be necessary to line the canal, as seepage may be expected to be overcome by the natural silting of the canal, and economy might result by enlarging the canal in these areas rather than to line it.

Structures. Estimates are based upon the assumption that all canal structures will be of the highest type of concrete and steel construction. Although canal structure drawings are not included in the report, preliminary designs were prepared in sketch form for use in estimating quantities.

Siphons. Siphons to carry the canal under stream beds and water courses will be an expensive item of construction, due not only to the large number required, but also to the shallowness of the channels which are proportionately wide. The preliminary estimates include the construction of 29 siphons at the following creeks:

Coyote Creek	Rice Creek	Hunters Creek
Oat Creek	Branch of Rice Creek	Funks Creek
Gerber Creek	Stony Creek	Stone Corral Creek
Elder Creek	North Fork Willow Creek	Fresh Water Creek
McClure Creek	Wilson Creek	Salt Creek
Thomes Creek	Sheep Corral Creek	Spring Creek
1st Creek South of Thomes	French Creek	Cortina Creek
2d Creek South of Thomes	Branch South Fork Willow	North Fork Sand Creek
3d Creek South of Thomes		Sand Creek
4th Creek South of Thomes	Logan Creek	Shone Creek

The typical design adopted consists of a one, two or three circular, reinforced concrete, barrel structure across the creek channel, with its top buried about 3 feet below the creek bottom. At each end the transition from the canal section to the siphon barrel is made by utilizing easy reverse curves in the form of a bell mouth, the bottom dropping as the section is narrowed. The transition from square to circular is made within the barrel. The diameter of the barrels ranges up to a maximum of 16 feet 3 inches, depending upon the location of the siphon.

The designed velocities were made comparatively low to save head, the velocities ranging between 7.1 feet per second at the upper end of the canal to 3.3 feet per second at the lower end. The capacity was calculated by Scobey's formula $Q=0.00546\ C_s d^{2.625} H^{0.5}$ given in Bulletin No. 852 published by the United States Department of Agriculture, assuming a value of $C_s = 0.345$. An allowance was made of 5 per cent over the average losses as determined from experiments, which modifies the above formula to $Q=0.0052\ C_s d^{2.625} H^{0.5}$. The head utilized at each of the siphon crossings is shown on the canal profile, Plate 24.*

Wasteways. Wasteways will also be an expensive feature of the canal on account of the scarcity of streams with deep channels. Most of the streams crossed are only flat depressions without the usual stream banks. There are no well defined channels between Willow Creek (mile 64) and Brush Creek (mile 120) which reach the Sacramento River or the main drainage canal through Colusa Basin. The present deficient channels must be opened up and in addition some provision must be made, probably in the form of siphons, for carrying waste from the proposed Iron Canyon canal under the Glenn-Colusa canal. No difficulties are encountered at the railroad or highway since the structures over wasteway channels are already of ample dimensions to pass the waste water from the canal. A redeeming feature of the wasteway problem is that a start will have been made toward solving the possible project drainage problem at the time the wasteway channels are opened up.

Following is a list of wasteways proposed, their locations are indicated on Plate 2.

Approximate mile	*Name of creek*	*Normal capacity in second-feet*
5	Mooney Island Slough	4875
14	Thomes Creek	2830
28	Rice Creek	2450
38	Stony Creek	2170
51	North Fork Willow Creek	1490
68	Logan Creek	1030
85	Stone Corral Creek	1030
94	Glenn Valley Creek	540
107	Cortina Creek	280
120	Brush Creek	65

In the typical preliminary design adopted for estimating purposes the wasteway is constructed in the lower canal bank, the discharge

* Not shown on condensed profile of this bulletin.

from the canal being controlled by electrically operated steel radial gates mounted in a reinforced concrete structure. It is assumed that the driving motors will be remote controlled from the ditch rider's quarters.

At present the Glenn-Colusa canal is carried across Stony Creek by simply constructing the lower canal bank across the creek. This bank is reconstructed each year as necessary. In order that Stony Creek may be utilized as a wasteway for the proposed Iron Canyon canal it is assumed that it would be necessary to construct a siphon to carry the Glenn-Colusa canal under the creek. Although the Glenn-Colusa expends some money in maintaining the present crossing, and would probably be willing to contribute a portion of the money required for the construction of the siphon, it has been assumed in the preliminary estimates that the entire cost would be borne by the Iron Canyon project.

Side drain intakes and culverts. Floods in the Sacramento Valley have occurred frequently in the past between Willows and Knights Landing Ridge, especially below the Willow Creek drainage area.

During a storm extending from February 28 to March 9, 1911, which caused serious flooding of areas in the vicinity of Willows it is reported that a total of 7.04 inches of rain fell, distributed as follows:

February	28	.75 inches
March	1	.90 inches
	2	.20 inches
	3	1.05 inches
	4	.50 inches
	5	.70 inches
	6	2.00 inches
	7	.90 inches
	8	.03 inches
	9	.01 inches

The maximum rainfall for any one month in this area during the period of 1878 to 1915, inclusive, was 9.39 inches. The quantity of 7.04 inches therefore is probably the maximum for any 10-day period which gave estimated run-off for the preparation of a report on Knights Landing Ridge Cut project by Haviland and Tibbetts, engineers, dated November, 1912, for streams from Willow Creek to Cortina Creek, inclusive, as follows:

Willow Creek and Walker Creek	15,000 second-feet
Logan Creek	100 second-feet
Hunters Creek	680 second-feet
Funks Creek	200 second-feet
Stone Corral Creek	1,241 second-feet
Lurline Creek	915 second-feet
Freshwater Creek	312 second-feet
Salt Creek	121 second-feet
Old Cortina Creek	29 second-feet
Cortina Creek	503 second-feet
Total	19,101 second-feet

It is probable that the canal of the proposed Iron Canyon project may be utilized to some extent in relieving this condition by taking some of the run-off near Willows and carrying it to wasteways farther down the line, thus distributing the flood over a larger area. In accordance with this plan of caring for flood waters in the minor channels, 97 overflow, or side drain intakes have been planned south of Stony Creek instead of culverts. There are only three culverts definitely planned but $100,000 has been added to the estimate, for culverts that probably would be required north of Stony Creek. Any other expenditure would be cared for under a supplemental plan, as this expenditure would be the result of conditions which might develop after the canal is constructed, including, possibly, means for taking a part of the water from some of the main channels into the canal. No attempt has been made in the preliminary estimate to determine what this expenditure might be and nothing has been allowed for it.

Checks. There are 55 checks proposed for construction in the main canal, the side slopes of the canal being warped to the vertical to accommodate radial gates. The bottom of the canal at the gates is made the width necessary to give a gate area equivalent to the water way area of the canal, with a resulting uniform flow through the checks. The gates are actuated by hand-operated worm-gear hoists mounted on an operating bridge over the check structure.

Drops. In the preliminary location survey drops in grade were made as indicated on Plates 2 and 24 as follows:

(1) Fifteen feet just below the location of Mooney Island power plant,
(2) Nine feet near mile 75, for the purpose of avoiding rough side hill construction north of the Mills Orchard tract, and to avoid cutting through the tract. If by the time a final location survey is made, these orchards have been extended to cover the preliminary location, it may be more economical to retain this nine feet of grade until Stone Corral Creek is reached.
(3) Two feet at Stone Corral Creek, to avoid expensive right of way in the Mills Orchard settlement, and to obtain a more economical cut for the canal section adopted,
(4) Two feet at Sand Creek, in order to utilize the present railroad and highway crossings just north of Arbuckle. This results in a better location, considering improvements in, and near, Arbuckle.

It is assumed that the inclined chute type of drop will be used.

In the preparation of the estimates, the two-foot drop at Sand Creek was replaced by three others aggregating two feet between miles 94 and 115 to keep the canal in economic cut. In the final location it is probable that the line would be shifted to higher ground, eliminating the three drops.

Bridges. The type of bridge adopted for carrying the highway and roads over the main canal is the single span steel truss north of mile 106 and the single span steel **I** beam type south of that point. In all cases it is assumed that the maximum load to be carried would be one 20-ton truck. The computations of the trusses were based upon the American Bridge Company's formula for one 15-ton truck, 25 per cent being added to the resulting weights of steel to allow for the increased loading. Computations of the **I** beam type bridges are based upon the formula and standard specifications for steel highway bridges adopted by the American Association of State Highway officials, approved for federal aid roads, and appearing in Bulletin No. 1259, United States Department of Agriculture.

The estimates provide for 50 truss bridges having spans from 39 to 76 feet and 5 I beam bridges with spans of 24 to 31 feet. A 16-foot roadway is provided in all cases. Concrete floors 5 inches thick are provided on three truss bridges and one I beam bridge on paved roads. All other bridges carry wooden floors made up of 3-inch decking and 2-inch flooring. Concrete abutments are estimated in all cases.

Railroad crossings. Five railroad crossings are required as follows:

Southern Pacific main line north of Tehama.
Southern Pacific main line south of Tehama.
Southern Pacific Hamilton branch east of Orland.
Southern Pacific main line north of Germantown.
Southern Pacific Fruto branch west of Willows.

The railroad to Sites has been torn up. The type of crossing adopted for purposes of the preliminary estimates is the solid reinforced concrete deck bridge carried on concrete piers and allowing for a fully ballasted road bed.

Turnouts. In the absence of a survey of the lateral system it was assumed that turnouts should be located at intervals of about one-half mile along the main canal. The amount of water to be delivered to various areas in the project is taken from column 5 of Table 8 and the average capacity of the turnouts is determined by dividing by the number in the section of canal considered. It was found that a total of 228 turnouts are required, including 2–3-foot by 3-foot boxes; 33–24-inch circular; 81–18-inch circular and 112–12-inch circular turnouts. The design contemplates steel screw lift gates installed in concrete turnout structures, the gates for the circular turnouts being set on a slope on the inside of the lower canal bank.

A box turnout with cast iron gate is assumed to be required to supply the area to the east of the canal between the diversion dam and Mooney Island Slough on account of the distance through the high water dike and the back pressure on the turnout when the river is high. Another such structure is assumed necessary to supply the area east of the railroad, and immediately south of the Glenn-Colusa Irrigation District, as the topography of that area is such that a lateral along the north side of Cortina Creek will probably be required.

Fences. The preliminary estimates are based upon the assumption that a fence will be provided on each side of the main canal for its entire length. Three barbed wires, strung on posts spaced 211 to the mile, are assumed.

Telephone system. The system assumed includes 42 telephones in booths served by 128 miles of line, utilizing 40-foot and 25-foot poles spaced 30 to the mile.

Patrolmen's quarters. It is assumed that eight patrolmen will be required to operate the main canal, with quarters located as follows:

At intake	mile 0		mile 60
Thomes Creek	mile 15		mile 75
Rice Creek	mile 30	Glen Valley Slough	mile 93
	mile 45	Cortina Creek	mile 109

In the preliminary estimate provision is made for the construction of a small cottage and garage for each patrolman.

Project headquarters. Project headquarters offices are included in a separate estimate, as this expenditure should be distributed against all features of the project.

Clearing and grubbing. There will be considerable clearing of right of way necessary on the first forty miles of canal, but very little south of there. This item will involve the removal of growths ranging from heavy timber and brush to vineyards.

Right of way. As mentioned under "Surveys," an effort was made to avoid all expensive right of way. The greatest interference was encountered at the town of Gerber, where it appears that it will be necessary to run the canal along the east townsite line, unless a material change is made in the final location. If the preliminary location were adopted it would be necessary to move a hop plant and a residence, as well as to reconstruct several blocks of street.

Construction materials. Sand and gravel for concrete in the canal lining and structures, including the lateral system, can be obtained in sufficient quantities in the creeks between the diversion dam and about mile 52 on the main canal, with an average haul of from 0.8 to 3.3 miles. Below mile 52 it is assumed that concrete aggregate will be shipped from Orland to suitable points on the Southern Pacific Railroad, from where the maximum haul would be about five miles in addition to distribution along the canal.

RED BANK PUMP CANAL.

(West Side High Line Pump Canal.)

Basis of surveys and estimates. The Red Bank pump unit includes a gross area of 39,350 acres to be watered by pumping at the project diversion dam at the mouth of Red Bank Creek. As this is the largest area proposed to be irrigated by pumping, and since it is typical of other areas to be served by pumping from the main gravity canal, a field survey and preliminary estimate were made to determine whether the pumping areas should be included within the project upon the basis of relative cost. The cost of carriage for the large pumping units of 13,500 acres and 21,300 acres adjacent to the Orland project was estimated at $10 per acre in excess of the distribution cost. For the remainder of the pumping areas no estimate was made for main canals leading from the pumps, as these were considered a part of the distribution system, with estimated cost of pumping plants added. Pumping plant data are shown in Table 26.

As indicated on Plates 2, 17, 18 and 24, it is proposed to lift 371 second-feet of water 50 feet from the main canal at its head to the Red Bank pump canal at elevation 300, which is about the highest elevation at which a canal can be constructed without getting into the rougher country farther west. Additional lifts are proposed at Thomes Creek to laterals at elevations 300 and 320, it being proposed to carry the larger canal at the lower elevation to avoid the rougher country.

The pumping plant contains three electrically driven 48-inch centrifugal pumps, delivering water into a 9-foot diameter wood stave pipe line about 1½ miles in length to the head of the high line canal. The canal is approximately 25 miles in length and wastes into the canal for the second pumping unit near Kirkwood, via Rice Creek.

Excavation, concrete lining and structures. The construction of the proposed Red Bank pump canal is similar to that of the main canal. For the upper 4.3 miles north of Elder Creek the excavation will be more difficult than to the south, and the estimated unit cost has been doubled. As indicated on Plate 26, the canal is to be lined throughout with plain concrete 3 inches thick. All structures are assumed to be built of concrete and steel.

Siphons. Ten siphons are estimated at the following places:

Coyote Creek	McClure Creek
Oat Creek	South Fork McClure Creek
South Fork Oat Creek	First creek south of Thomes Creek
Elder Creek	Second creek south of Thomes Creek
Truckee Creek	Third creek south of Thomes Creek

Wasteways. Wasteways with hand operated gates are proposed at Thomes Creek and Elder Creek.

Other structures. Other structures estimated include:

22 36-inch diameter culverts.
2 flumes.
19 checks.
14 bridges of the steel I beam type.
15 18-inch diameter turnouts.
33 12-inch diameter turnouts.
50 miles of fence.
26 miles of telephone line serving nine telephones.
3 patrolmen's quarters.

Right of way. It is estimated that 313 acres of right of way will be required.

EAST SIDE CANAL.

(To serve 7000 acres gross area east of Red Bluff.)

Basis of estimates. On Plate 2 this canal is shown diverting directly from Iron Canyon reservoir. In Exhibit 6 it is described as about 6¾ miles long, diverting at Iron Canyon dam at elevation 300 and ending at the northerly corner of lot 35, subdivision No. 9, of the Los Molinos Land Company's tracts. In the estimate prepared by the State Department of Engineering the cost of this canal is given as $63,811, including 20 per cent for contingencies and extras. In order to put this estimate upon the same basis as those prepared in connection with this report, additional items are included, and the figure for contingencies and extras was increased to include 10 per cent for engineering and administration and 15 per cent for contingencies. A summary of the revised estimate will be found in Preliminary Estimate No. 14.

In Table 8 the maximum capacity of the canal, including a 15 per cent increase for the daily peak in July, is 86.4 second-feet. The estimated cost of excavation and concrete lining for the canal of 74 second-feet capacity assumed in Exhibit 6 was increased by 10 per cent in Preliminary Estimate No. 14 to allow for the increase in capacity. The cost of items added is based upon the estimated cost of similar features on the Red Bank pump canal.

DISTRIBUTION SYSTEM.

Basis of estimate. Funds available for the investigations did not permit of a detailed survey and estimate of cost of the distribution system, nor were such surveys and estimates considered necessary at this time, since costs of similar construction on other nearby projects are indicative of what the Iron Canyon system may be expected to cost. Basing the estimate upon the cost of the distribution system of the Orland project, and the Brentwood District recently completed in the lower San Joaquin Valley, the cost of the Iron Canyon system is placed at a total of $30 per acre, assuming that water would be delivered to each 40-acre tract by a lateral system 60 per cent of which would be concrete lined. The $30 is assumed as a charge to be paid on each acre within the project against which the cost of the project is assessed (95 per cent of the gross area).

DRAINAGE SYSTEM.

Requirement. The conclusions of the 1920 Iron Canyon report regarding drainage are quite correct as far as the Orland project is concerned. It has always been maintained that with the natural surface and subdrainage conditions on the project, together with the intelligent application of a reasonable amount of irrigation water as well as maintenance of the natural water courses traversing the project area in an unobstructed state, no drainage problems would be encountered. This conclusion has been borne out by the experience of 14 years operation of the project. Where seepage or water logging has developed in the small degree that it has, it is the result of the use of an excessive amount of water and draining the surface surplus into natural water courses which have been permitted by the various landowners to become congested with vegetation and in some cases obstructed in the farm leveling operations.

Basis of estimate. Natural drainage conditions, such as exist on the Orland project, are rather the exception than the rule. A portion of the area within the proposed Iron Canyon project will be devoted to rice culture, in connection with which drainage facilities are as important as the irrigation works. Although only about one-fifth of the total area is considered suitable for rice culture, such lands are nearly all located south of Stony Creek so that the bulk of the drainage water will flow into the Colusa Basin and finally into the drains now constructed through the basin. These drains would probably have to be enlarged to care for the increased flow unless some other disposition is made of the Iron Canyon drainage water. In this enlargement consideration must be given to waste water from the project canals which in an emergency might equal in amount the carrying capacity of the main canal. Use of the drainage canal would probably be permitted by agreement with the drainage district but this agreement would undoubtedly involve reimbursement to the district for work already done in addition to the cost of enlargement.

It is not likely that extensive drainage works will be necessary north of mile 50 on the main canal, nor will drainage be required on all areas south of there, but in absence of accurate classification of areas it is estimated that a uniform total charge of $15 per acre should provide for any construction on account of the drainage problem. Cost to be levied against 95 per cent of the gross area within the project.

OPERATION AND MAINTENANCE—CANAL AND DISTRIBUTION SYSTEM.

Basis of estimate. As stated previously, it seems imperative that the rotation system of irrigation be adopted for this project on account of the long carriage system without any regulating reservoirs. Although this is not the most convenient method for the water users, it undoubtedly reduces the cost of operation to a minimum. The cost of operation of the gravity system then should compare favorably with the minimum cost on other Bureau of Reclamation projects. Since, as proposed, the canal is to be constructed with water surface near the ground level, and as a generous allowance has been made in the design of the section for growth of vegetation, the item of maintenance should also be comparatively low. The combined operation and maintenance of the system, exclusive of pumping, should therefore compare favorably with minimum costs on other Bureau of Reclamation projects, and should never be more than the average. The cost reports for 1924 indicate that during the years 1918 to 1924, inclusive, the minimum average cost per acre irrigated for all projects was $2.12 in the year 1922. The average acre cost for the Yakima-Sunnyside project during the period 1918 to 1924 was $1.47 per acre irrigated.

Operation and maintenance costs on the Orland project and Glenn-Colusa Irrigation District are of particular interest as the areas are adjacent to that of the proposed project. The costs are as follows:

Orland project operation and maintenance for 1923, which is assumed to be a typical year. Total cost $33,081.

Acres irrigable		Acres irrigated[1]		Acre-feet delivered		Acre-feet diverted	
Number	Unit cost	Number	Unit cost	Number	Unit cost	Number	Unit cost
20,174	$1.64	15,500	$2.13	46,922	$0.70	73,191	$0.45

Costs for 1924 not given as during that year the Orland project suffered the most severe water shortage in its history.

Glenn-Colusa Irrigation District operation and maintenance for 1924, which was more or less a typical year, although the amount of water diverted and the area of irrigated crops were considerably less than in 1920, 1921 and 1922. Total cost $118,718.[2]

Acres irrigable		Acre-feet diverted		Acre-feet diverted, exclusive of pumping expense	
Number	Unit cost	Number	Unit cost	Number	Unit cost
116,599	$1.02	270,000	$0.44	270,000	$0.28

[1] Average operation and maintenance per acre irrigated, 1918 to 1924, inclusive, $2.29.

[2] Includes item of $43,582 for pumping plant expense.

Cost per acre irrigated omitted for the reason that much of the area is in rice, and a considerable portion in 1924 was in pasture.

The district receives its irrigation supply by pumping from the Sacramento River through heads ordinarily varying from 6 to 8 feet during the greater part of the irrigation season.

Estimated Iron Canyon project operation and maintenance charges. As shown in Table 8 the water estimated to be required for the Iron Canyon project is 800,000 acre-feet per year. Based upon the above annual costs on other projects it appears that $0.50 per acre-foot of water diverted would be a safe estimate for application to the proposed project, exclusive of pumping. Assuming $0.50 an acre as correct, the annual operation and maintenance charge would be $400,000 or at the rate of about $1.55 per acre on the 263,055 acres against which it is assumed the charges will be assessed, which is equivalent to about $1.75 per acre on the 85 per cent of the gross area considered irrigable.

To the above must be added the cost of operating and maintaining the pumping plants shown in Preliminary Estimate No. 13 as $299,950 per year; equivalent to a charge of about $1.15 per acre distributed over the 263,055 acres against which costs are assessed. The resulting total estimated cost of operation and maintenance for the Iron Canyon project is, therefore, at the rate of **$2.70** on each acre assumed to be assessed (95 per cent of the gross area).

ANALYSIS OF ESTIMATED COSTS.

Iron Canyon reservoir. Results of studies made to determine the relative economy of raising the water surface in the reservoir to elevations 400 and 405.5 may be summarized as follows:

(a) Estimated cost including 10 per cent overhead and 15 per cent contingencies:

To raise water surface from elevation 392.5 to 405.5, Preliminary Estimate No. 17	$748,000
To raise water surface from elevation 392.5 to 400, Preliminary Estimate No. 16	183,000
To raise water surface from elevation 400 to 405.5	565,000

There would be no extra cost for right of way and little, if any, increase in operating cost. Bend embankment is not affected as freeboard provided is against floods.

(b) Estimated annual value of power gained by raising water surface from Elevation 400 to 405.5 upon the assumption that 90 per cent of the primary and 55 per cent of the secondary power is salable at the rate of 4 mills per k.w.h.:

Increase in revenue from primary power	$108,000
Increase in revenue from secondary power	30,600
Total annual increase in revenue	$138,600

Gross annual return on the investment = 138,600÷565,000 = 24.5%

No estimate was made of the increased returns that would accrue by raising the normal storage elevation from 392.5 to 400, as no power study was made for water surface at elevation 392.5, but the amount would be considerably in excess of the $138,600 shown above.

Main canal between diversion dam and Mooney Island power plant. In the study of economics of the Mooney Island power plant various estimates were prepared of the probable cost of the canal to that point. A summary of the studies will be found in Statement A under "Summary of Financial Considerations" following this analysis of estimates.

(a) **General considerations.** Maximum high water in the river reaches an elevation approximately 27 feet above low water, and since it is not practicable, on account of the topography, nor desirable considering tail water at the Iron Canyon power plant, to divert at an elevation of more than about 15 feet above low water, there would be required a high water dike for the protection of the canal, gradually decreasing in height to a point near Mooney Island Slough, where the regular bank of the canal extends above high water in the river.

Were the canal to be lined for a capacity including water for power development at Mooney Island the difference in excavation between this section and a lined section not carrying power water would be slight on account of the material required in the construction of the high water dike, and the difference in cost of a lined canal with, or without, power would consist mainly in the difference in cost of the lining. With an unlined canal carrying power water in addition to irrigation water, the excavation would be greatly increased, but even then the unlined canal would result in a material saving of cost, as will be shown.

(b) **Saving effected by building diversion dam to raise water surface 15 feet.** An unlined canal with bottom width 38 feet, water depth 16.0 feet, slopes 1½:1, grade of .0001, having a capacity of 2833 second-feet, to carry irrigation water only, and without a diversion dam other than a low weir for the control of the bed of the river at point of diversion, would require 3,164,290 cubic yards of excavation. Due to great depth of this section below the top of the high water dike, a large amount of second handling of material excavated would be required. The per cent of gravel and the chance of encountering hard strata would be greatly increased. Considering these factors it is doubtful that the unit cost would be less than $0.40 per cubic yard, making a

Total of	$1,265,716
Right of way, 115 acres at $150	17,250
	$1,282,966
Engineering and administration, 10%	128,296
	$1,411,262
Contingencies, 15%	211,688
Total canal	$1,622,950
Diversion works—Estimate No. 7	630,000
Total	$2,252,950

Considering a diversion dam constructed to raise the water surface 15 feet, but with no allowance made for power at Mooney Island, the total excavation for the unlined canal 15 feet higher amounts to 763,000 cubic yards, with 212,740 cubic yards of borrow in addition, required for completing the high water dike. There would be a very small amount of second handling of material excavated and the per cent of gravel excavation would be greatly decreased, but to cover possibility of encountering hard strata, this excavation is estimated at $0.30 per cubic yard, with $0.15 per cubic yard for borrow, making a

Total for excavation of	$260,810
Right of way, 115 acres at $150	17,250
	$278,060
Engineering and administration, 10%	27,806
	$305,866
Contingencies, 15%	45,879
	$351,745
Total canal	
Diversion works—Estimate No. 6	1,333,000
Total	$1,684,745
The saving effected by building the diversion dam to raise the water surface 15 feet is, therefore	$568,205

(c) **Reduction in cost of pumping effected by building diversion dam to raise water surface 15 feet.** In addition to the saving of $568,205 effected by the construction of the diversion dam there is a saving in the cost of power required for pumping water to the Red Bank pump canal since the construction of the diversion dam results in a reduction of 15 feet in the lift, the saving in power amounting to 1,980,000 k.w.h. per year. At $0.01 per k.w.h. the monetary saving would be at the rate of about $20,000 a year, or a total of $400,000 in the twenty-year period during which construction costs are assumed to be repaid. This is 27 per cent of the estimated cost of the diversion dam built without provision for power development at Mooney Island Slough, as shown in Preliminary Estimate No. 6. In Statement A which follows no consideration is given to the above item of economy for the reason that the saving is one which may be assumed applicable to the cost of operation rather than to cost of construction.

In all discussions of the value of power that have been presented, it has been assumed that the output would be sold, at the switchboard, to one of the distributing companies. It has also been assumed that power for pumping would be repurchased at $0.01 per k.w.h. Any other method of handling the disposition of the power will alter the estimates made.

(d) **Increased cost to build the first 4.7 miles of unlined canal to include power water.** In order to include water for development of power at Mooney Island, the capacity of the canal must be more than doubled to carry 6578 second-feet (see Plate 25). The excavation for an unlined canal would be increased to 2,012,267 cubic yards, with about 50,000 cubic yards of borrow. On account of the large amount of second handling of material, this excavation has been estimated at $0.35 per cubic yard, and $0.15 per cubic yard for borrow, making a

Total of	$711,795
Right of way, 198.4 acres at $150	29,760
	$741,555
Engineering and administration, 10%	74,155
	$815,710
Contingencies, 15%	122,345
Total canal	$938,055
Diversion works, Estimate No. 4	1,410,000
Total	$2,348,055
The increased cost of construction due to building the first 4.7 miles of unlined main canal to include power water is, therefore	$617,770

(e) **Saving effected by building the first 4.7 miles of canal, carrying irrigation and power water, unlined.** In the plan most favorably considered it is proposed to build the main canal to include irrigation and power water between the diversion dam and Mooney Island power plant unlined for the reason that there is no assurance that a lined canal could be weeped sufficiently to prevent flotation of the lining. This is particularly true of a canal diverting at river grade, in which case the bottom of the canal would be below low water level, but in either case it would be below high water in the river. If lined, reinforced concrete not less than 4 inches thick would be required. An estimate was prepared of a lined canal to Mooney Island Slough with a 47-foot bottom width and designed to carry a 16-foot depth of water, for comparison with the unlined section. Both sections are shown on Plate 25. A summary of the estimate for the lined canal is as follows:

Excavation	989,400 cubic yards at	$0.30	$296,820
Borrow	179,500 cubic yards at	0.15	26,925
Reinforced lining	33,784 cubic yards at	19.00	641,896
Right of way	170.1 acres at	150.00	25,515
			$991,156
Engineering and administration, 10%			99,115
			$1,090,271
Contingencies, 15%			163,540
Total canal			$1,253,811
Diversion works—Estimate No. 4			1,410,000
Total			$2,663,800

The money saved by building the canal with capacity to include power water as far as Mooney Island Slough, unlined, is therefore estimated to be $315,745.

Seepage loss in the 4.7 miles of unlined canal is of minor consideration since the total seepage loss, calculated upon the basis of 1.5 feet in depth over the wetted canal surface, is only about 75 second-feet, or 1.15% of the capacity of the canal.

(f) **Increased cost to build the first 4.7 miles of lined canal to include power water.** The cost of constructing a lined canal between the diversion dam built to raise the water surface 15 feet and Mooney Island power plant, but to carry irrigation water only, was estimated for comparison with the lined canal enlarged to carry power water. A canal section was considered having a bottom width of 35.0 feet, water depth 12.6 feet, side slopes 1½:1, grade of .00015, and a reinforced concrete lining 4 inches thick. The estimate is summarized as follows:

Excavation	533,000 cubic yards at	$0.30	$159,900
Borrow	437,600 cubic yards at	0.15	65,640
Lining, reinforced	24,696 cubic yards at	19.00	469,224
Right of way	115 acres at	150.00	17,250
			$712,014
Engineering and administration, 10%			71,202
			$783,216
Contingencies, 15%			117,484
Total canal			$900,700
Diversion works—Estimate No. 6			1,333,000
Total			$2,233,700

Considering lined canals, the cost of including water for power development would, according to the estimates, be $430,100. A lined canal was not adopted. The figures are given for comparison only.

Power used in pumping to project areas. Since in the present plan it is proposed to supply by pumps much of the land that under the plan proposed in the 1920 report would have been served by gravity, it is proper to compare the amount of power consumed in pumping with the power that is gained by making all the water used in the irrigation of the project available for power development at the storage dam. As shown in Table 18 the average annual gain in power would, for the years of record of river discharge, have been 94,313,700 k.w.h. Power required for pumping project water, as shown in Table 26, is 18,865,000 k.w.h. per year. The balance in favor of pumping is therefore 75,448,700 k.w.h. per year. If it is assumed that all of this balance is secondary power, 55 per cent of which might be sold at 4 mills per k.w.h., the average annual revenue gained would be approximately $166,000. In addition the Red Bank diversion makes possible the Mooney Island power plant and any profits that accrue from that source must be placed as a credit to the plan of the low line canal.

If the 15-foot drop just below Mooney Island power plant were utilized for the development of power, the results would be about as follows:

Total project water passing per year	689,000 acre-feet
Potential power at 80% efficiency	8,500,000 k.w.h.
July output, 22% of seasonal	1,870,000 k.w.h. or 2,500,000 h.p. hrs.

Equivalent to 3360 h.p. installed capacity.

This amount of power is 45 per cent of the total power required for all project pumping shown in tables 26 and 27, but it would be of no particular value until the secondary power developed at the Iron

Canyon plant had been absorbed in the market. This is shown graphically on Plate 10 on which, for the plan considered best (fourth column of graphs from the left), it is indicated that, in an average year, all of the project pumping load is supplied by secondary power, with the exception of a very small amount in the month of September. It is not probable that development of power at the drop, to supply energy for pumping in the extremely dry years, would be a paying proposition.

Other drops on the main canal might, in the final canal location, be combined in one drop and utilized in the development of additional power.

SUMMARY OF FINANCIAL CONSIDERATIONS.

A summary of the studies showing the economy of building the diversion dam to raise the surface 15 feet; constructing a power plant at Mooney Island Slough; and building the first 4.7 miles of main canal to the Mooney Island power plant unlined is shown in Statement A.

STATEMENT A.

Summary of Various Economic Studies Made of Diversion Works, Mooney Island Power Plant and Main Canal Between Them.

Diversion works—	
Water Surface Elevation 250 without power, Estimate No. 6	$1,333,000
Water Surface Elevation 235 without power, Estimate No. 7	630,000
Increased cost to raise water surface 15 feet	$703,000
Water Surface Elevation 250 with power, Estimate No. 4	$1,410,000
Water Surface Elevation 250 without power, Estimate No. 6	1,333,000
Increased cost to divert power water	$77,000
Main canal to Mooney Island power plant—	
Water Surface Elevation 235, unlined, without power	$1,622,950
Water Surface Elevation 250, unlined, without power	351,745
Saving effected by raising unlined canal 15 feet	$1,271,205
Water Surface Elevation 250, lined, without power	$900,700
Water Surface Elevation 250, unlined, without power	351,745
Saving effected by raising unlined canal 15 feet	$548,955
Water Surface Elevation 250, lined, with power	$1,253,800
Water Surface Elevation 250, unlined, with power	938,055
Saving effected by building unlined canal, with power	$315,745
Diversion works and unlined canal to Mooney Island power plant combined—	
Water Surface Elevation 235, without power	$2,252,950
Water Surface Elevation 250, without power	1,684,745
Saving effected by raising canal 15 feet	$568,205
Water Surface Elevation 250, with power	$2,348,055
Water Surface Elevation 250, without power	1,684,745
Increased cost to provide for power water	$663,310
Diversion works, unlined canal and Mooney Island power plant combined—	
Increased cost to provide for power water	$663,310
Mooney Island power plant, Estimate No. 8	928,000
Total cost chargeable to power development at Mooney Island plant	$1,591,310
Revenue from Mooney Island power plant—	
Gross annual revenue at 4 mills per k.w.h., Table 25	$213,600
Annual plant charge, Estimate No. 9, plus half of depreciation of radial gates, Estimate No. 5	47,150
Net annual revenue	$166,450
Return on investment of $1,591,310	10.5 per cent

The above comparisons show that a saving in total construction cost is effected by building the diversion dam to raise the water surface 15 feet, and that the construction of the Mooney Island power plant will result in economy.

STATEMENT B.

Summary of Estimated Cost, Power Output and Revenue.

(a) Iron Canyon reservoir and power plant.

Cost exclusive of depreciation on concrete in dam during construction repayment period.

Total cost, Iron Canyon Dam and Reservoir:

Dam and power plant, Estimate No. 2	$19,875,000
Reservoir right of way, Estimate No. 1	4,897,500
Total	$24,772,500
Annual repayments, 5%	1,238,625

Power output, see Table 25.

Average annual gross primary power, 330,720,000 k.w.h.
Average annual salable primary power, 90% of gross 297,650,000 k.w.h.
Average annual gross secondary power, 254,170,000 k.w.h.
Average annual salable secondary power, 55% of gross 139,794,000 k.w.h.

Average annual total salable power 437,444,000 k.w.h.

Estimated Annual Revenue.

Sale price per k.w.h.	$0.0035	$0.004	$0.0045	$0.005	$0.006
Gross revenue from power at indicated sale price	$1,531,054	$1,749,776	$1,968,498	$2,187,220	$2,624,664
Annual power plant charges, Estimate No. 3	265,390	265,390	265,390	265,390	265,390
Net revenue	$1,265,664	$1,484,386	$1,703,108	$1,921,830	$2,359,274
Annual repayment on construction cost of reservoir and power plant	1,238,625	1,238,625	1,238,625	1,238,625	1,238,625
Annual surplus available for payment of other project charges	$27,039	$245,761	$464,483	$683,205	$1,120,649

(b) Diversion dam, Mooney Island power plant and main canal between them to provide for power water.

Cost exclusive of depreciation on concrete (except in superstructure of powerhouse) during construction repayment period.

Total cost, diversion dam and canal to Mooney Island, chargeable to power:

Statement A	$663,310
Mooney Island power plant, Estimate No. 8	928,000
Total construction cost for Mooney Island power development	$1,591,310
Annual repayments, 5%	79,565

Power output, see Table 25.

Average annual gross power, all primary 59,333,000 k.w.h.
Average annual salable power, all primary, 90% of gross 53,400,000 k.w.h.

Estimated Annual Revenue.

Sale price per k.w.h.	$0.0035	$0.004	$0.0045	$0.005	$0.006
Gross revenue at indicated sale price	$186,900	$213,600	$240,300	$267,000	$320,400
Annual plant charges, Estimate No. 9	47,150	47,150	47,150	47,150	47,150
Net revenue	139,750	166,450	193,150	219,850	273,250
Annual construction repayments	79,565	79,565	79,565	79,565	79,565
Balance applicable to other project charges	$60,185	$86,885	$113,585	$140,285	$193,685
Repayment charges on remainder of diversion dam and canal to Mooney Island, 5 per cent of $1,684,745, Statement A.	84,237	84,237	84,237	84,237	84,237
Annual surplus from Mooney Island plant available for payment of other project charges	*$24,052	$2,648	$29,348	$56,048	$109,448

*Deficit.

(c) Annual surplus revenue, Iron Canyon and Mooney Island power plants combined.

Sale price per k.w.h.	$0.0035	$0.004	$0.0045	$0.005	$0.006
Iron Canyon	$27,039	$245,761	$464,483	$683,205	$1,120,649
Mooney Island	*24,052	2,648	29,348	56,048	109,448
Total combined surplus available for payment of other project charges	$2,987	$248,409	$493,831	$739,253	$1,230,097

*Deficit.

Item (c) of Statement B indicates that upon the basis of twenty equal annual repayments of construction costs, without interest, the revenue derived from the sale of power generated at the two project plants would be sufficient to meet the construction cost of Iron Canyon reservoir and power plant, the diversion dam, Mooney Island power plant, and the main canal to Mooney Island power plant; and in addition would be sufficient to pay the cost of operation and maintenance of the above various features, except depreciation on concrete in the storage and diversion dams, and still leave a surplus which could be used to help meet the repayment of the construction cost of the balance of the project.

Taxes. In the following discussions, which involve the cost of operation, maintenance and the annual repayment of construction charges, no account is taken of state, county or any other taxes which might be assessed against the land.

Depreciation on concrete. In all of the cost analyses depreciation on concrete, with the exception of that in the power house superstructures, is excluded during the period of repayment of construction costs with the idea of reducing the burden on the landowners during the early years of project operation. It is believed that this point of view is justified for the reason that at the time the construction costs are fully repaid there should be a large revenue from the sale of power, more than ample to build up a sinking fund toward the replacement of concrete structures. Any departure from this viewpoint will alter practically all of the figures.

Estimated gross cost of project. Table 28 is a summary of estimated gross cost of the project based upon the assumption that power would be developed at Iron Canyon dam and at Mooney Island Slough; that the diversion dam at Red Bank Creek would be built to raise the water surface 15 feet; and that the main canal between the diversion dam and Mooney Island power plant would be built unlined with a capacity to carry both irrigation and power water.

TABLE 28. ESTIMATED GROSS COST—IRON CANYON PROJECT.

Gross area of project, 276,900 acres.

Repayment in 20 equal annual installments without interest, assessed at the same rate per acre against 95 per cent of the gross area or 263,055 acres. Costs include overhead charges and contingencies. No credits have been allowed for receipts from power sales. For net costs including credits for receipts from power sales, see Table 29.

Item	Reference	Gross cost	Gross costs per acre	
			Total	Annual
1. Iron Canyon reservoir and power plant	Estimates 1 and 2	$24,772,500	$94.17	$4.71
2. Diversion dam	Estimate 4	1,410,000	5.36	.27
3. Main canal to Mooney Island	Estimate 10	938,055	3.56	.18
4. Mooney Island power plant	Estimate 8	928,000	3.53	.17
Subtotal, items 2, 3 and 4		$3,276,055	$12.45	$0.62
Subtotal, items 1, 2, 3 and 4		28,048,555	106.62	5.33
5. Main canal below Mooney Island, exclusive of lining	Estimate 10	$5,798,255	$22.04	$1.10
6. Main canal lining	Estimate 10	7,853,545	29.85	1.49
7. Red Bank pump canal	Estimate 11	1,088,132	4.14	.21
8. Red Bank pump plants	Estimate 12	452,079	1.72	.09
9. Remainder of pump plants	Estimate 12	496,776	1.89	.09
10. Carriage for pump areas near Orland project	Page 129	348,000	1.32	.07
11. 7,000-acre East Side, unit	Estimate 14	134,000	.51	.02
Subtotal carriage system		$16,170,787	$61.47	$3.07
12. Project administration buildings	Estimate 15	$83,500	$0.32	$0.02
13. Distribution system	Page 131	7,891,650	30.00	1.50
14. Drainage system	Page 131	3,945,825	15.00	.75
Total construction items 1 to 14, inclusive		$56,140,317	$213.41	$10.67
15. Operation and maintenance canals and laterals	Page 132			$1.55
16. Operation and maintenance pumping plants	Page 133			1.15
17. Depreciation on flood control gates, Iron Canyon dam	Estimate 3	$60,735 per yr.		.23
18. Depreciation on metal work at diversion dam, except $900 charged to power	Estimate 5	$19,200 per yr.		.07
Total gross cost per acre per year				$13.67

Estimated net cost of project. In arriving at the probable net cost of the project, account should be taken of the surplus derived through the sale of power. Items 1, 2, 3 and 4 of Table 28 are not only self-supporting, but, as shown in Statement B, yield a surplus which may be used to help pay the cost of other items. Applying the surplus in this manner results in reducing the cost of the project, as shown in Table 29.

TABLE 29. ESTIMATED NET CONSTRUCTION AND OPERATION COSTS, IRON CANYON PROJECT.

Exclusive of depreciation on concrete, with exception of that in power house superstructures, as noted on page 140.

(a) Project cost.

Sale price of power per k.w.h.	$0.004	$0.0045	$0.005
Gross cost of project, Table 28	$56,140,317	$56,140,317	$56,140,317
Self-supporting features, items 1 to 4, inclusive, Table 28	28,048,555	28,048,555	28,048,555
Cost of balance of project, items 5 to 14, inclusive, Table 28	$28,091,762	$28,091,762	$28,091,762
Annual surplus accumulated for 20 years, item (e) Statement B	4,968,180	9,876,620	14,785,060
Net cost of project	$23,123,582	$18,215,142	$13,306,702

(b) Net cost per acre assumed to be assessed equally against 263,055 acres

Sale price of power	Net cost of project					
	Total net repayments	Per acre				
		Total	20 annual installments			
			Construction	Operation and maintenance	Depreciation on gates	Total
$0.004	$23,123,582	$87.90	$1.40	$2.70	$0.30	$7.40
.0045	18,215,142	69.24	3.46	2.70	.30	6.46
.005	13,306,702	50.59	2.53	2.70	.30	5.53

Comparison of cost of various units of the project. In making this comparison the cost of items 1, 2, 3 and 4, Table 28, which are self-supporting, will be omitted and for simplicity, the comparison will be made upon the basis of gross construction costs and these costs will in turn be shown in Table 30, which is a summary of the net cost of the various units including operation, maintenance, depreciation and credits from the sale of power.

The total cost of the main canal on the west side of the valley, south of Mooney Island power plant, is shared alike by gravity and pumping areas, with the exception of the Red Bank pump unit which is considered separately. The estimated cost of the main canal below Mooney Island is:

Items 5 and 6, Table 28		$13,651,800
Total project area, Plate 2	276,900 acres	
East side gravity area	7,000 acres	
West side area	269,900 acres	
Red Bank pump area	39,350 acres	
Gross area served by main canal	230,550 acres	
Area assessed, 95%		219,025 acres
Cost per acre $62.33, or 20 installments of $3.12.		

(a) **Whole project,** based upon the assumption that the total construction cost will be assessed equally against 95 per cent of the gross project area.

Construction cost, items 1 to 14, Table 28	$56,140,317
Self-supporting features, items 1 to 4, Table 28	28,048,555
Balance of project, items 5 to 14, Table 28	$28,091,762
Cost per acre, items 5 to 14, Table 28	106.79
Annual repayment per acre on basis of 263,055 acres	5.34

(b) **West side gravity lands.**

West side area served by main canal	230,550 acres
Pumping areas other than Red Bank unit, Plate 2	55,116 acres
Gross area served by gravity	175,434 acres
Gross area assessed, 95%	166,660 acres

Item	Cost per acre	20 annual installments
Construction cost of main canal as previously shown for 219,025 acres	$62.33	$3.12
Distribution system, Table 28	30.00	1.50
Drainage system, Table 28	15.00	.75
Project administration buildings, Table 28	.32	.02
Total construction cost, assessed against 166,660 acres	$107.65	$5.39

(c) **Red Bank pump unit.** The Red Bank pump unit is practically a distinct project, not depending upon the main gravity canal. While the diversion dam is utilized to effect a saving of 15 feet in the lift, this feature is not essential. It does, however, reduce the power requirements, which would be 27 per cent greater if the intake were at the present river level.

Gross area, Plate 2 ---- 39,350 acres
Gross area assessed, 95 per cent ---- 37,380 acres

Item	Total cost	Cost per acre	20 annual installments
Pump canals, item 7, Table 28	$1,088,132	$29.12	$1.46
Pumping plants, item 8, Table 28	452,079	12.10	.60
Distribution system, Table 28		30.00	1.50
Drainage system, Table 28		15.00	.75
Project administration buildings, Table 28		.32	.02
Total construction cost, assessed against 37,380 acres		$86.54	$4.33

(d) **Pump units immediately north and south of Orland project.**

Gross area, Plate 2 ---- 34,800 acres
Gross area assessed, 95% ---- 33,060 acres

Item	Total cost	Cost per acre	20 annual installments
Construction cost of main canal as under gravity lands		$62.33	$3.12
Pump canals, page 129		10.00	.50
Pumping plants, Estimate No. 12:			
Sta. 1175+Overhead and contingencies	$77,241		
Sta. 2271+Overhead and contingencies	221,045		
Second lift+Overhead and contingencies	65,224		
Total pumping plants	$363,510	11.00	.55
Distribution system, Table 28		30.00	1.50
Drainage system, Table 28		15.00	.75
Project administration buildings, Table 28		.32	.02
Total construction cost, assessed against 33,060 acres		$128.65	$6.44

(e) **Pump units south of Willows.** As stated on page 129, the canal system to serve these areas is considered a part of the distribution system with pumping plants added. The estimated cost to serve these lands is as follows:

Gross area, Plate 2 ---- 20,316 acres
Gross area assessed, 95% ---- 19,300 acres

Item	Total cost	Cost per acre	20 annual installments
Construction cost of main canal as under gravity lands		$62.33	$3.12
Pumping plants, Estimate No. 12:			
Sta. 3260+Overhead and contingencies	$19,810		
Sta. 4307+Overhead and contingencies	5,741		
Sta. 4705+Overhead and contingencies	13,371		
Sta. 4976+Overhead and contingencies	94,344		
Total, pumping plants	$133,266	6.90	.35
Distribution system, Table 28		30.00	1.50
Drainage system, Table 28		15.00	.75
Project administration buildings, Table 28		.32	.02
Total construction cost, assessed against 19,300 acres		$114.55	$5.74

(f) **East side gravity lands.**

Gross area, Plate 2 ---- 7000 acres
Gross area assessed, 95% ---- 6650 acres

Item	Total cost	Cost per acre	20 annual installments
Constructon cost of canal, Estimate No. 14	$134,000	$20.15	$1.01
Distribution system, Table 28		30.00	1.50
Drainage system, Table 28		15.00	.75
Project administration buildings, Table 28		.32	.02
Total construction cost assessed against 6,650 acres		$65.47	$3.28

TABLE 30. SUMMARY OF ESTIMATED NET COSTS WITH POWER CREDITS.

Comparison of total and per acre cost of various portions of the project exclusive of Iron Canyon reservoir and power plant, diversion dam, main canal to Mooney Island Slough and Mooney Island power plant, which are self-supporting. Areas shown are 95 per cent of the gross area against which it is assumed the cost will be assessed. Power credits distributed equally over the entire project assessed. No account taken of possible deferred charges from main canal lining or project drainage system.

Items	Whole project, 263,055 acres		West side gravity, 166,660 acres		Red Bank pump unit, 37,380 acres		Pump units near Orland, 33,060 acres		Pump units south of Willows, 19,300 acres		East Side gravity, 6,650 acres	
	Total	Annual	Total	Annual	Total	Annual	Total	Annual	Total	Annual	Total	Annual
Construction cost	$106.79	$5.34	$107.65	$5.39	$86.54	$4.33	$128.65	$6.44	$114.55	$5.74	$65.47	$3.28
Operation and maintenance, canals and laterals, Table 28		1.55		1.55		1.55		1.55		1.55		1.55
Operation and maintenance, pumping plants, Table 28 and Estimate No. 13		1.15				3.93		2.91		2.94		
Depreciation items 17 and 18, Table 28		.30		.30		.30		.30		.30		.30
Gross cost		$8.34		$7.24		$10.11		$11.20		$10.53		$5.13

Net Cost, after Crediting Surplus from Sale of Power, Item C, Statement B.

Power at 4 mills:												
Credit		$0.94		$0.94		$0.94		$0.94		$0.94		$0.94
Net cost		7.40		6.30		9.17		10.26		9.59		4.19
Power at 4½ mills:												
Credit		1.88		1.88		1.88		1.88		1.88		1.88
Net cost		6.46		5.36		8.23		9.32		8.65		3.25
Power at 5 mills:												
Credit		2.81		2.81		2.81		2.81		2.81		2.81
Net cost		5.53		4.43		7.30		8.39		7.72		2.32

Deferred charges. As previously stated, a large part, if not all, of the main canal lining, and perhaps 75 per cent of the project drainage, may be deferred until the project settlement is well advanced, thus reducing the burden during the early years of development. The possibilities along this line may be summed up as follows:

Estimated cost of concrete lining in main canal, Table 28	$7,853,545
Estimated cost of drainage system, Table 28, $3,945,825, 75% deferred	2,959,369
Total	$10,812,914
Deferred cost per acre on 263,055 acres	41.11
Deferred annual per acre cost	2.06

Possible reduction in estimated cost of pumping. As indicated in Preliminary Estimate No. 13, the cost of power at $0.01 per k.w.h. represents about 75 per cent of the estimated cost of operating the pumps serving the pumping areas. If, in the disposal of power generated at the two proposed project plants, provision is made for reserving from sale the quantity required for project pumping, it is believed that the pumping units should be charged for power at the rate at which it is sold to the distributing company. Assuming this rate to be 4 mills per k.w.h., and assuming a transformer and distribution loss of 20 per cent, the cost of power at the pumping plants would be 5 mills per k.w.h. Upon this basis the annual charge on the pumping areas shown in Table 30 would be reduced to the amounts shown below.

Pump unit	Annual cost per acre		
	Pumping charge	Gross	Net*
Red Bank pump unit	$2.48	$8.66	$7.72
Pump units near Orland	1.07	10.26	9.32
Pump units south of Willows	1.99	9.58	8.64

*Net cost = gross, less power credit at 4 mills shown in Table 30. No account taken of possible deferred charges from main canal lining or project drainage system.

Financing the project construction cost. Up to this point all discussions of cost have been based upon the assumption that the entire project would be constructed with government funds upon which no interest would be charged, and that repayment of construction costs would be made in 20 equal annual installments. To make the project feasible, it may be necessary to reduce the amount of money assumed to be furnished by the government.

The project may be divided into two distinctly separate units:

(a) Storage and power features.

(b) Canal and distribution system.

The estimated cost may be divided as follows:

Total estimated cost, Table 28		$56,140,317
Iron Canyon reservoir and power plant, item 1, Table 28	$24,772,500	
Total cost chargeable to power development at Mooney Island plant, Statement B	1,591,310	
Total storage and power features		26,363,810
Total canal and distribution system		$29,776,507

(a) **Storage and power features.** Table 31 contains a detail analysis of the amortization of costs of the storage and power features upon the assumptions that construction would cover a period of five years; that money would be available at 5 per cent interest, compounded semi-annually; and that the net revenue derived from the sale of power at 4 mills per k.w.h. would be applied in the repayment of construction costs.

Total estimated construction cost		$26,363,810
Yearly estimated construction cost		5,272,800
Annual operation and maintenance—		
Iron Canyon plant, Estimate No. 3	$56,730	
Mooney Island plant, Estimate No. 9	12,650	
Total annual operation and maintenance		69,380
Annual depreciation—		
*Iron Canyon plant, Estimate No. 3	$208,660	
Mooney Island plant, Estimate No. 9	$33,600	
**Diversion works, Estimate No. 5	900	
Total Mooney Island and diversion works	$34,500	
Total annual depreciation		243,160

The table indicates that in the 53d year after beginning of construction, the last of the construction bonds would be retired and the accumulation of a large surplus would begin.

EXPLANATION OF TABLE No. 31 AND ASSUMPTIONS USED IN ITS PREPARATION.

Column 1. The years shown in this column are based on the assumption that construction would begin at the first of the year 1928 and would be completed at the end of 1932. The operations shown on the line with any year represent the accumulations or rates of operations, during that year, or the total accumulations to the end of that year, as the case may be, with the exception of entries under column 2. The entries in column 2 are for the beginning of the year.

Column 2. Construction starts at the beginning of 1928 and extends through five years with five equal construction cost installments of $5,272,800, the amount borrowed at the beginning of each year for this purpose. With interest payable semi-annually at 5 per cent, it is necessary during the earlier years to borrow a sum in excess of construction funds sufficient to pay the second installment of interest for the previous year and also the installment that will be due July 1 next, after allowance is made for net income from plant operation. To illustrate, at the beginning of 1932, the indebtedness is found thus:

Previous indebtedness		$22,734,000	
Annual construction fund		5,272,800	
Deficit at end of 1931		452,315	
Necessary indebtedness at beginning of 1932=P=			$28,459,115
Interest on P for first six months of 1932=.025P=		$711,478	
Operating revenue for six months	$475,248		
Operation and maintenance	34,690		
Net operating revenue		440,558	
Interest that must be borrowed		$270,920	
Capitalized amount of interest to be borrowed=270,920÷.975=			277,867
Total indebtedness to be provided for			$28,736,982
Used			28,737,000

After 1934, when income begins to exceed expenses, it is assumed that the collections can be handled so as to meet interest charges whenever they fall due. Also that repayment of bonds will be made at the beginning of each year and that the smallest denomination of the bonds is $500. For these reasons it is not necessary to show a financial statement every six months.

Columns 3 and 4. It is assumed that the diversion dam, Mooney Island power plant, and the main canal to that point will be built during the first year and that the plant with its installed capacity of 10,400 h.p. (7760 k.w.) will be placed in operation at the beginning of the second year, 1929, with a sale of 90 per cent of its capacity. By the end of the fourth year construction is advanced to the point where the average output for the fifth year at the Iron Canyon plant is 30,000 h.p. (22,380 k.w.) and that 90 per cent is sold. During the construction period the

* Includes depreciation on items chargeable to power only. No depreciation allowed on concrete, except in superstructures of power plants.

** Includes depreciation on the five additional head gates at the diversion dam required for diversion of power water.

development of the use of irrigation water on the project would not be far advanced, so that most of the water in the river would be available for developing power at Mooney Island at all times, up to the capacity of the plant. During 1933, the first year after the completion of the plant, it is assumed that 90 per cent of the primary output is sold, and that beginning with 1934 the delivery reaches its maximum of 90 per cent of the primary output and 55 per cent of the secondary. See Plate 10.

Column 5. Self-explanatory.

Column 6. See preliminary estimates Nos. 3 and 9 for details. Charges are entered for every six months till end of year 1934, and thereafter for each year. Up to the end of 1931, charges are made for Mooney Island plant only, because the Iron Canyon plant is not operated till the beginning of 1932.

Column 7. See preliminary estimates Nos. 3 and 9 for details. In order that repayment of bonds may begin as soon as possible no allowance for depreciation is made during the first five years of operation. Also construction is still in progress during this time, and the machinery is new so that replacements are unlikely. However, in order that the funds may be available when needed, the annual amount set aside for replacement is increased during the years 1934 to 1947 inclusive so that by the end of 1947 the amount set aside is the same as it would have been if depreciation had been allowed as soon as equipment had gone into service. No interest is credited to this fund, although it is probable that in actual operation, enough of this fund would be on deposit to provide an income from interest payments.

Column 8. Interest at 5 per cent semi-annually.

Column 9. Sum of columns 6, 7, 8.

Column 10. Column 5 minus column 9.

Column 11. Amount applied from net earnings each year to the repayment of the bonds.

Column 12. Small working fund equal to column 10 minus column 11.

TABLE 31. EXAMPLE OF FINANCIAL OPERATION OF PROPOSED IRON CANYON PROJECT POWER DEVELOPMENT.

Estimated cost of development including overhead, $26,363,810.

Estimated rate of construction expenditure $5,272,800 per year for five years.

Ninety per cent of primary and 55 per cent of secondary power assumed sold at rate of 4 mills per k. w. h.

Interest on indebtedness assumed at 5 per cent, payable semi-annually.

1	2	3	4	5	6	7	8	9	10	11	12
					Annual expense						
Year	Indebtedness at beginning of year	Installed capacity at beginning of year, h.p.	Energy delivered, k. w. hrs.	Gross income	Operation and maintenance	Replacement fund (depreciation)	Interest on indebtedness	Total	Net income or deficit	Bond repayments	Accumulated surplus
1928	$5,408,000	0	0	0	0		$135,200	$135,200			
1928	5,408,000	0	0	0	0		135,200	135,200	(d) $135,200		
1929	10,974,500	10,400	30,590,000	$122,360	$6,325		274,363	280,688			
1929	10,974,500	10,400	30,590,000	$122,360	$6,325		274,363	280,688	(d) 158,328		
1930	16,707,500	10,400	30,590,000	122,360	6,325		417,688	424,013			
1930	16,707,500	10,400	30,590,000	122,360	6,325		417,688	424,013	(d) 301,653		
1931	22,734,000	10,400	30,590,000	122,360	6,325		568,350	574,675			
1931	22,734,000	10,400	30,590,000	122,360	6,325		568,350	574,675	(d) 452,315		
1932	28,737,000	40,400	118,812,000	475,248	34,690		718,425	753,115			
1932	28,737,000	40,400	118,812,000	475,248	34,690		718,425	753,115	(d) 277,867		
1933	29,074,500	120,400	175,525,000	702,100	34,690		726,863	761,553			
1933	29,074,500	120,400	175,525,000	702,100	34,690		726,863	761,553	(d) 59,453		
1934	29,134,000	120,100	245,422,000	981,688	34,690	133,960	728,350	897,000	84,688		
1934	29,134,000	120,400	245,422,000	981,688	34,690	133,960	728,350	897,000	84,688	$160,000	$9,376
1935	28,974,000	120,400	490,844,000	1,963,376	69,380	267,920	1,448,700	1,786,000	177,376	170,000	16,752
1936	28,804,000	120,400	490,844,000	1,963,376	69,380	267,920	1,440,200	1,777,500	185,876	185,000	17,628
1937	28,619,000	120,400	490,844,000	1,963,376	69,380	267,920	1,430,950	1,768,250	195,126	195,000	17,754
1938	28,424,000	120,400	490,844,000	1,963,376	69,380	267,920	1,421,200	1,758,500	204,876	204,000	18,630
1939	28,220,000	120,400	490,844,000	1,963,376	69,380	267,920	1,411,000	1,748,300	215,076	215,000	18,706
1940	28,005,000	120,400	490,844,000	1,963,376	69,380	267,920	1,400,250	1,737,550	225,826	225,500	19,032
1941	27,779,500	120,400	490,844,000	1,963,376	69,380	267,920	1,388,975	1,726,275	237,101	237,000	19,133
1942	27,542,500	120,400	490,844,000	1,963,376	69,380	267,920	1,377,125	1,714,425	248,951	248,500	19,584
1943	27,294,000	120,000	490,844,000	1,963,376	69,380	267,920	1,364,700	1,702,000	261,376	261,000	19,960
1944	27,033,000	120,400	490,844,000	1,963,376	69,380	267,920	1,351,650	1,688,950	274,126	274,000	20,386
1945	26,759,000	120,400	490,844,000	1,963,376	69,380	267,920	1,337,950	1,675,250	288,126	288,000	20,512
1946	26,471,000	120,400	490,844,000	1,963,376	69,380	267,920	1,323,550	1,660,850	302,526	302,500	20,538
1947	26,168,500	120,400	490,844,000	1,963,376	69,380	267,920	1,308,425	1,645,725	317,651	317,500	20,689
1948	25,851,000	120,400	490,844,000	1,963,376	69,380	243,160	1,292,550	1,605,090	358,286	358,000	20,975
1949	25,493,000	120,400	490,844,000	1,963,376	69,380	243,160	1,274,650	1,587,190	376,186	376,000	21,161
1950	25,117,000	120,400	490,844,000	1,963,376	69,380	243,160	1,255,850	1,568,390	394,986	395,000	21,147

1951	24,722,000	120,400	490,844,000	1,963,376	69,380	243,160	1,236,100	1,548,640	414,736	414,500	21,383
1952	24,307,500	120,400	490,844,000	1,963,376	69,380	243,160	1,215,375	1,527,915	435,461	435,500	21,344
1953	23,872,000	120,400	490,844,000	1,963,376	69,380	243,160	1,193,600	1,506,140	457,236	457,000	21,580
1954	23,415,000	120,400	490,844,000	1,963,376	69,380	243,160	1,170,750	1,483,290	480,086	480,000	21,666
1955	22,935,000	120,400	490,844,000	1,963,376	69,380	243,160	1,146,750	1,459,290	504,086	504,000	21,752
1956	22,431,000	120,400	490,844,000	1,963,376	69,380	243,160	1,121,550	1,434,090	529,286	529,000	22,038
1957	21,902,000	120,400	490,844,000	1,963,376	69,380	243,160	1,095,100	1,407,640	555,736	555,500	22,274
1958	21,346,500	120,400	490,844,000	1,963,376	69,380	243,160	1,067,325	1,379,865	583,511	583,500	22,285
1959	20,763,000	120,000	490,844,000	1,963,376	69,380	243,160	1,038,150	1,350,690	612,686	612,500	22,471
1960	20,150,500	120,400	490,844,000	1,963,376	69,380	243,160	1,007,525	1,320,065	643,311	643,500	22,272
1961	19,507,000	120,400	490,844,000	1,963,376	69,380	243,160	975,350	1,287,890	675,486	675,500	22,268
1962	18,831,500	120,400	490,844,000	1,963,376	69,380	243,160	941,575	1,254,115	709,261	709,500	22,029
1963	18,122,000	120,400	490,844,000	1,963,376	69,380	243,160	906,100	1,218,640	744,736	745,000	21,765
1964	17,377,000	120,400	490,844,000	1,963,376	69,380	243,160	868,850	1,181,390	781,986	782,000	21,751
1965	16,595,000	120,400	490,844,000	1,963,376	69,380	243,160	829,750	1,142,290	821,086	821,000	21,837
1966	15,774,000	89,820	490,844,000	1,963,376	69,380	243,160	788,700	1,101,240	862,136	862,000	21,973
1967	14,912,000	89,820	490,844,000	1,963,376	69,380	243,160	745,600	1,058,140	905,236	905,000	22,209
1968	14,007,000	89,820	490,844,000	1,963,376	69,380	243,160	700,350	1,012,890	950,486	950,500	22,195
1969	13,056,500	89,820	490,844,000	1,963,376	69,380	243,160	652,825	965,365	998,011	998,000	22,206
1970	12,058,500	89,820	490,844,000	1,963,376	69,380	243,160	602,925	915,465	1,047,911	1,048,000	22,117
1971	11,010,500	89,820	490,844,000	1,963,376	69,380	243,160	550,525	863,065	1,100,311	1,100,000	22,428
1972	9,910,500	89,820	490,844,000	1,963,376	69,380	243,160	495,525	808,065	1,155,311	1,155,500	22,239
1973	8,755,000	89,820	490,844,000	1,963,376	69,380	243,160	437,750	750,290	1,213,086	1,213,000	22,325
1974	7,542,000	89,820	490,844,000	1,963,376	69,380	243,160	377,100	689,640	1,273,736	1,273,500	22,561
1975	6,268,500	89,820	490,844,000	1,963,376	69,380	243,160	313,425	625,965	1,337,411	1,337,500	22,472
1976	4,931,000	89,820	490,844,000	1,963,376	69,380	243,160	246,550	559,090	1,404,286	1,404,000	22,758
1977	3,527,000	89,820	490,844,000	1,963,376	69,380	243,160	176,350	488,890	1,474,486	1,474,500	22,744
1978	2,052,500	89,820	490,844,000	1,963,376	69,380	243,160	102,625	415,165	1,548,211	1,548,000	22,955
1979	594,500	89,829	490,844,000	1,963,376	69,380	243,160	25,225	337,765	1,625,611	594,500	1,144,066
1980	0										
Totals				$93,404,152	$3,368,190	$11,532,000	$50,995,528	$65,895,718	+$30,278,066 (—)2,769,632 $27,508,434	$29,134,000	$1,144,066

(b) **Canal and distribution system.**

TABLE 32. ESTIMATED CONSTRUCTION AND OPERATION COST CANAL AND DISTRIBUTION SYSTEM.

Assumed to be built with noninterest bearing money.

Area Assessed, 95 Per Cent of Gross—263,055 Acres.

Item	Total cost	Cost per acre	
		Total	20 annual installments
Balance of diversion dam and main canal to Mooney Island not charged to power, from Statement A	$1,684,745	$6.41	
Items 5 to 11, inclusive, Table 28	16,170,787	61.47	
Subtotal, diversion dam and main canal	$17,855,532	$67.88	$3.39
Distribution system, Table 28	7,891,650	30.00	1.50
Drainage system, Table 28	3,945,825	15.00	.75
Project administration buildings, Table 28	83,500	.32	.02
Total construction cost	$29,776,507	$113.20	$5.66
Operation and maintenance, canals and laterals, Table 28			1.55
Operation and maintenance, pumping plants, Table 28			1.15
Annual depreciation, items 17 and 18, Table 28			.30
Total estimated annual payment			$8.66

The result should be compared with Table 29.

If the main canal lining and construction of 75 per cent of the drainage system are deferred, the original cost would be reduced to $72.09 per acre and the total annual charge during the first few years would be at the rate of $6.60 per acre assessed.

SUGGESTED ALTERNATIVE PROJECTS.

Area and water supply. An outstanding fact with reference to the Iron Canyon project is that the area of land available for irrigation in the Sacramento Valley, below the site of the proposed Iron Canyon reservoir, is greatly in excess of the area which can adequately be served by that reservoir. Of the 2,700,000 acres of irrigable area on the floor of the valley there are, according to census figures, only about 300,000 acres now irrigated. Other storage reservoirs on the Sacramento River above Iron Canyon are under consideration, particularly one at Kennett. Considerations involved in the Kennett reservoir are many and discussion of them is outside the province of this report. Investigation might demonstrate that the water supply for the Sacramento Valley can be augmented by bringing in water from other watersheds. A project contemplating diversion of water from the Trinity River, known as the Sampson-Hill project, has been suggested, but no consideration has been given to the proposal in this report.

Project in northern part of valley. Other things being equal, the ideal project is one including a suitable area near the source of water supply which can be served by a relatively short canal. Apparently this ideal would be approached through the inclusion of about 200,000 acres of land on the west side, north of the Glenn-Colusa county line, 7000 acres on the east side opposite Red Bluff, and approximately

64,000 acres on the east side of the valley, north of Butte Creek and lying below the low line canal surveyed by the State Department of Engineering, shown on Plate 2. If it were desirable to include a comparatively large area on the east side of the valley the 64,000 acres mentioned could replace the area south of the Glenn-Colusa county line in the project studies, thus eliminating the "shoe string" area to the south. The power features would be unchanged. The large east side area could be served either by pumping from the river or by siphoning from the west side canal.

Project in southern part of valley. The other extreme would be to construct the project in the vicinity of Arbuckle, Woodland and Dixon, where there is a large area of excellent land. In this scheme water released from Iron Canyon reservoir would be carried in the Sacramento River channel to Knights Landing, whence it would be lifted to canals extending north and south from Knights Landing Ridge. The storage dam and power plant would be the same as proposed for the project studied. As shown in Table 18, the average annual output of the Iron Canyon power plant, resulting through utilization of the 800,000 acre-foot irrigation draft for power purposes, is 94,313,700 k.w.h., assuming 80 per cent efficiency at the switchboard. Assuming transmission line and transformer efficiencies of 90 per cent and 95 per cent respectively, the average amount of power delivered at Knights Landing pumping plant annually would be about 80,600,000 k.w.h., or sufficient to lift the 800,000 acre-feet through an average static head of 62 feet, assuming 70 per cent pump efficiency and 10 per cent average loss of head in overcoming friction in the pipe line. A large part of the area west of the Yolo basin, between Arbuckle and Vacaville, not now served by an irrigation system, lies between the 25-foot and 100-foot contours. It appears that the area could be served by pumping from the river at Knights Landing with an average lift of not more than 55 or 60 feet. The loss of water in transportation in the river channel from Iron Canyon reservoir to Knights Landing should be negligible in comparison with the loss in an artificial canal of equal length.

As an alternative for pumping at Knights Landing, the same area might be served by gravity through a canal diverting at Red Bank Creek. It was with this in view that the perliminary location survey was extended to Putah Creek. It is probable that adoption of the line on the valley floor south of Dunnigan (the "Bird Creek low line" on Plates 2 and 24) would be preferable to building the canal through the hills, as the latter would require heavy construction, long flumes, etc. If this were true it would be necessary to regain the head lost at the drop by pumping up to Knights Landing Ridge at Cache Creek. At least a portion of the power required for this pumping could be developed at drops on the main canal.

Individual pumping plants along river. It might be found feasible, and desirable, to supply with water from Iron Canyon reservoir areas along the river for which pumps, in many cases, are now installed, but for which the water supply from natural flow is usually deficient.

Irrigation from Coast Range streams. An investigation covering the complete use of water entering the Sacramento Valley from the

Coast Range, in irrigation of areas on the west side of the valley, might show this plan to be feasible. There are possibilities at Red Bank, Elder, Thomes, Cache, Putah and perhaps other smaller creeks.

Combining with Glenn-Colusa Irrigation District. Several combinations with the Glenn-Colusa Irrigation District have been suggested, among them the following:

(1) Eliminate first forty miles of the main canal estimated in this report and pump water from the river to the canal at Stony Creek, combining with the district at their pumping plant.

(2) Build a diversion dam at the head of the Glenn-Colusa canal, eliminate pumping to that canal and pump through the reduced head to the Iron Canyon canal.

(3) Eliminate pumping plant at head of Glenn-Colusa canal. Enlarge the upper portion of the Iron Canyon canal and deliver Glenn-Colusa water to their canal below Stony Creek, possibly making use of the drop to generate electrical energy.

(4) Eliminate Iron Canyon main canal, build diversion dam at head of Glenn-Colusa canal, enlarge that canal and pump to areas lying above it.

(5) To serve areas south of the Glenn-Colusa project enlarge the Glenn-Colusa canal between the Glenn-Colusa county line and Cortina Creek to carry water received from the Iron Canyon canal; extend the enlarged canal to Knights Landing Ridge, approximately on the line of Bird Creek low line canal shown on Plate 2; and pump up "The Ridge," as described previously. The drop from the Iron Canyon canal to the Glenn-Colusa canal could be used to develop a part, if not all, of the power required for pumping at Knights Landing Ridge. The plan would eliminate approximately 35 miles of the "shoestring" area west of the Glenn-Colusa District.

Additional studies required. A detail study will be required to determine whether any of the alternative projects have merit. Some of them possibly could be eliminated as not fitting into the ultimate plan of irrigation development of the Great Central Valley, but in any event, careful consideration should be given to various plans in selecting the area, or areas, to be watered from Iron Canyon reservoir. Those responsible in the preparation of this report believe that a further study may indicate that a plan of development other than that selected for study will be more desirable and more economical. It is believed that the plan proposed for irrigating a large area in the southern part of the Sacramento Valley by pumping from the river at Knights Landing will prove quite attractive. It is possible that 200,000 acres in this vicinity might be included in a project in combination with about 75,000 acres in the northern end of the valley, supplied either by gravity or by pumping.

EXHIBIT 1.

November 4, 1922.

Hon. A. P. Davis,
Director, U. S. Reclamation Service,
Washington, D. C.

Dear Sir:

Referring to recent conversation relative to contemplated change of plan for the proposed Iron Canyon Project, which was outlined to you verbally during your recent visit on the ground, I submit the following:

Request is hereby made for a new survey covering a proposed change of canal system or systems, together with additional studies of other details of the project, some of which will be indicated herein.

The Sacramento Valley Development Association and the Iron Canyon Project Association are deeply appreciative of the interest shown in this great project by the U. S. Reclamation Service and particularly of the surveys and investigations made by the service by means of which the feasibility and desirability of the project have been established. Each of the reports heretofore made has indicated a wide variety of plans for distribution of the waters of the project; of these only one plan has been definitely surveyed and reported upon. After very mature deliberation we now ask that additional surveys and studies be made with a view to developing a more economical plan of distribution, also that other features of the plan heretofore considered be reviewed with a view to the adoption of the most desirable plan which can be devised for the development of the project.

As you are aware, the plan proposed in the reports above referred to involves the construction of a high line canal of expensive construction and with the added disadvantage that waters diverted through it for irrigation can not be used for the generation of power. Owing chiefly to these two factors the cost of supplying water to land through this high line canal is relatively high, and in consequence vigorous oppositon has been voiced by the owners of land comprising a very large portion of the area which would be benefited by the adoption of the high line as against a low line canal location.

It appears from an examination of all the facts available to us that a low line canal diverting from the Sacramento River at a point somewhere below the dam may prove more economical for two principal reasons:

1. Construction costs will be materially less.

2. The waters to be diverted for irrigation would be first used for power, the value of the power plant thereby materially increased and the cost of water storage for irrigation materially decreased.

We ask for a survey based upon such a change of plan of distribution and including the following:

A survey of a canal line of the highest practicable level consistent with economy and with full operation of the power plant, probably heading at or near the mouth of Red Bank Creek, a short distance below Red Bluff, and extending as far southerly on the west side of the Sacramento River as may be deemed advisable.

We ask that this canal line be definitely located, material tests made and costs carefully estimated.

We ask that surveys be made of secondary canal system or systems to cover lands in Tehama County lying above the low line canal. In this connection we have in mind a study of alternative plans, including a small canal to follow approximately the route of the high line canal proposed in the 1920 report, and a canal or canals heading south of Red Bank Creek and supplied by pumping from the proposed low line canal.

Since completion of the survey and report above referred to, a survey has been made by the State Department of Engineering of an east side canal to be supplied by pumping from the Sacramento River at a point one mile below Tehama and conveying same to land about Chico and Durham. It occurs to us that in case a diversion is made on the west side at or near Red Bank Creek, as proposed, the advisability of extending the east side canal up stream to this point should be considered and we ask that this be done.

We ask that the power feature of the project be reconsidered in the light of the proposed change, new plans and estimates made for such changes as may be advisable, including the installation of additional power units, also that the additional investment in power and prospective returns therefrom be carefully considered and reported on.

In connection with such restudy and revaluation of the power plant, we ask that consideration be given to the fact that additional storage, which will no doubt in time be developed in the watershed above Iron Canyon for distribution in the Sacramento Valley, will automatically increase the quantity of water available for power in summer and add to the value of the power plant.

It has been suggested to us by engineers of high standing in this state that the available capacity of the Iron Canyon reservoir may be materially increased by the adoption of means whereby storage would be maintained at flood level, this without any material increase in construction costs. Referring to the 1920 report (page 12), we note that the capacity of the reservoir with the water surface at 400 feet elevation, will be 961,300 acre-feet, a gain of 221,300 acre-feet, or a gain in available storage of 34.5 per cent. We suggest a very careful restudy of the spillways and means whereby they might be raised after all danger of flood is passed and the full capacity of the reservoir thereby utilized. In this connection we invite attention to the fact that the spring and early summer flow of the Sacramento River at Iron Canyon is very large, a factor which would be advantageous were such a change of plan contemplated.

We ask that a careful restudy be made of the factor which will govern the duty of water on this project. The report of 1920 assumes it will be necessary to divert 4.125 acre-feet per acre per annum at the head of the main canal. It is believed a less quantity of water will be ample and that the acreage to be watered in proportion to the quantity of water available may be materially increased, and we would like to have this matter made the subject of careful and painstaking investigation.

The foregoing are the main points which have occurred to us. No doubt other features will occur to you as warranting further study. We very respectfully ask that the project be resurveyed with a view to the development of the most economical, most practical and most desirable plan, and that report be made thereon, including plans and estimates of cost.

A copy of this letter is being forwarded to Mr. W. F. McClure, Chief, Division of Engineering and Irrigation, State Department of Public Works, with request that the division cooperate in this survey and in defraying the cost thereof.

Your favorable consideration will be cordially appreciated.

Yours very truly,

(Signed) W. A. Beard, President,

Sacramento Valley Development Association.

Vice President, Iron Canyon Project Association.

EXHIBIT 2.

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

Contract between the United States; The Department of Public Works, Division of Engineering and Irrigation, of the State of California, and the Sacramento Valley Development Association, providing for continuation of cooperative investigation of the proposed Iron Canyon Project and cooperative investigation of proposed control works on the Lower Sacramento River, Cal.

THIS AGREEMENT, Made this 26th day of January, 1924, between the UNITED STATES OF AMERICA, by HUBERT WORK, Secretary of the Interior, pursuant to the act of February 21, 1923 (42 Stat., 1281), and the act of March 4, 1923 (42 Stat., 1540), party of the first part; the DEPARTMENT OF PUBLIC WORKS, DIVISION OF ENGINEERING AND IRRIGATION, OF THE STATE OF CALIFORNIA, pursuant to Chapter 286, Session Laws of California 1923, and Chapter 121, Session Laws of California 1923, party of the second part, and the SACRAMENTO VALLEY DEVELOPMENT ASSOCIATION (a Corporation duly organized and existing under the laws of the State of California), party of the third part; Witnesseth:

2. WHEREAS, The Secretary of the Interior has allotted from the appropriation made for miscellaneous investigations of reclamation projects, available until December 31, 1924, the sum of Twenty Thousand Dollars ($20,000) to be expended in the continuation of investigations of the proposed Iron Canyon Project and in the investigation of proposed control works on the Lower Sacramento River in California, and

3. WHEREAS, The Department of Public Works, Division of Engineering and Irrigation, of the State of California, has available the sum of Ten Thousand Dollars ($10,000) to be expended in said investigations, and

4. WHEREAS, The Sacramento Valley Development Association has available the sum of Ten Thousand Dollars ($10,000) to be expended in said investigations, and

5. WHEREAS, The Commissioner of the Bureau of Reclamation has, under the authority of the Secretary of the Interior, approved for investigation and is willing to undertake and make the examinations, surveys and estimates necessary to determine the feasibility of alternate plans now suggested in connection with the proposed Iron Canyon Project in California, and also investigation of a proposed system of control works on the Lower Sacramento River in the State of California.

6. NOW, THEREFORE, in consideration of the premises and the mutual covenants and agreements herein contained, it is stipulated and agreed between the parties hereto as follows:

7. The Secretary of the Interior, upon the execution of this contract, will make available for the work proposed herein, the sum of Twenty Thousand Dollars ($20,000); the Department of Public Works, Division of Engineering and Irrigation, of the State of California, upon the execution of this contract, will make available as hereinafter provided, for the work proposed herein, the sum of Ten Thousand Dollars ($10,000) and the Sacramento Valley Development Association, upon the execution of this contract, will deposit with the Special Fiscal Agent of the Bureau of Reclamation at Denver, Colorado, for the work proposed herein, the sum of Ten Thousand Dollars ($10,000).

8. As to the said sum of Ten Thousand Dollars ($10,000) to be made available by the Department of Public Works, Division of Engineering and Irrigation, of the State of California, the Engineer in charge of the work, pursuant to paragraph 13 hereof, shall determine in his discretion the items of expenditure which shall be chargeable against said sum, and shall voucher the said items directly to the State officer designated by the Department of Public Works, Division of Engineering and Irrigation, of the State of California.

9. Each item of the work need not be paid in the proportion of the funds provided by this agreement, but the aggregate cost of the work shall be paid in said proportion, to-wit: one-half (½) by the United States, one-fourth (¼) by the Sacramento Valley Development Association and one-fourth (¼) by the Department of Public Works, Division of Engineering and Irrigation, of the State of California; *provided*, that any payments in excess of said proportion made by either party out of the funds available during the progress of the work shall be adjusted when the report contemplated by paragraph 15 hereof is made; *provided further*, that should the entire amount herein provided be not expended there shall be returned to each party any excess of the money made available by it over its proportion of the expenditure.

10. When the sums of money as specified in paragraphs 7 and 8 have been made available as therein provided, the Bureau of Reclamation of the Department of the Interior and the State Department of Public Works acting in cooperation, will, so far as the expenditure of the sum of Forty Thousand Dollars ($40,000) will permit; (a) Make such additional examinations, investigations and studies as may be determined advisable in connection with the water supply, flood control and power development at the proposed dam and reservoir site heretofore investigated at Iron Canyon, including the necessary changes in plans and estimates to provide reliable information thereon under such new conditions as may now be proposed. (b) Make examination and survey of a proposed canal (known as the Low Line Canal) diverting from the Sacramento River at or near the mouth of Red Bank Creek for the irrigation of lands on the west side of the river in the proposed Iron Canyon Project. Said investigations will include (1) classification of materials, the preparation of designs and estimates of cost of construction and the examination of irrigable lands for the purpose of determining the estimated per acre cost and the feasibility of the reclamation thereof, and (2) examination of feasibility of irrigation of lands in Tehama County, California, lying above said Low Line Canal, by pumping from said canal or otherwise. Said investigation and report are also to bring up to date the study of the water supply data for said Proposed Iron Canyon Project and the possibilities for irrigation and power development therefrom. (c) Make examination and investigation of the cost and feasibility of constructing control works on the Sacramento River so as to prevent the salt water from San Francisco Bay rendering the fresh water in the river unfit for irrigation and domestic use during periods of low river flow. Said examination and report will include investigation of surface and subsurface conditions in connection with the development of plans and estimates of cost of the proposed regulation.

Provided, that, of the total sum of $40,000 to be made available for this work the sum of $10,000 or as much thereof as may be needed shall be expended upon the surveys and investigations relating to the Iron Canyon Project which are set forth in paragraphs (a) and (b) of this section, and the sum of $30,000 together with any surplus remaining from that portion of the fund herein specified to be used upon the Iron Canyon Project surveys, shall be expended in examinations and investigations relating to the cost and feasibility of constructing control works on the lower Sacramento River, as provided in paragraph (c) of this section.

11. The Bureau of Reclamation of the Department of the Interior, the Department of Public Works, Division of Engineering and Irrigation, of the State of California, and the Sacramento Valley Development Association, agree to furnish for this investigation, as they may be called for, all records and reports and engineering data concerning the work to be performed under this contract, that they now have or that they can feasibly obtain.

Receipts shall be given for data furnished and said data will be returned to said parties at the close of these investigations.

12. All surveys and investigations contemplated hereunder shall follow a general plan of operation to be agreed upon by the Chief Engineer of the Bureau of Reclamation, the State Engineer of California, and the Sacramento Valley Development Association, through its President and General Manager. Said plan may be amended from time to time as the work progresses.

13. The work shall be performed by the Bureau of Reclamation of the Department of the Interior under the supervision of an Engineer designated by the Chief Engineer of the said Bureau. An Assistant Engineer shall be designated by the State Department of Public Works, Division of Engineering and Irrigation, to work under the direction of the said supervising engineer.

14. On completion of the surveys and investigations herein provided for, all field notes, original plans, calculations, reports and other data acquired or prepared during the investigations and surveys shall be filed with the Bureau of Reclamation of the Department of the Interior, and complete copies thereof shall be furnished the State Department of Public Works. The said original records shall be accessible at all times to the State Engineer of California, or his duly authorized representative, and to the duly authorized representative of the Sacramento Valley Development Association, upon application.

15. A report of the results of said surveys and investigations shall be promptly made by the Engineer of the Bureau of Reclamation in charge, outlining the scope of the investigations, and giving a complete record thereof with detailed estimates as contemplated by paragraph 10 hereof, with suitable explanatory maps, plans and other documents as exhibits, together with the names of the parties hereto and all

cooperating officers and a summary of expenditures incurred in the investigations, which expenditures shall include the usual overhead and general charges of the Bureau of Reclamation. The report and recommendations shall be subject to the joint approval of the Chief Engineer of the Bureau of Reclamation and the State Engineer of California. In case of their failure to agree, the Chief Engineer of the Bureau of Reclamation and the State Engineer of California shall submit separate conclusions and recommendations, both of which shall be embodied with the report.

16. This contract provides only for preliminary surveys and investigations insofar as the funds to be made available, as provided in paragraphs 7 and 8 hereof, will permit and in no way obligates the United States, the Department of Public Works, Division of Engineering and Irrigation, of the State of California, or the Sacramento Valley Development Association, as to any future action regarding the proposed projects. All work and expenditure under this contract shall cease whenever the funds to be so made available as provided in paragraphs 7 and 8 hereof shall become exhausted whether said work shall have been completed or not.

17. No member of or Delegate to Congress, or Resident Commissioner, after his election or appointment or either before or after he has qualified and during his continuance in office, and no officer, agent, or employee of the Government, shall be admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained shall be construed to extend to any incorporated company, where such contract or agreement is made for the general benefit of such incorporation or company, as provided in section 116 of the act of Congress approved March 4, 1909 (35 Stat., 1109).

IN WITNESS WHEREOF, this contract has been executed by the parties hereto the day and year first above written.

THE UNITED STATES OF AMERICA,
By HUBERT WORK, May 7, 1924,
Secretary of the Interior.

(SEAL.)

DEPARTMENT OF PUBLIC WORKS, DIVISION OF ENGINEERING AND IRRIGATION, OF THE STATE OF CALIFORNIA.
By W. F. MCCLURE, *Director of Public Works and State Engineer.*

Attest:
MYRTLE V. MURRAY, *Secretary.*

SACRAMENTO VALLEY DEVELOPMENT ASSOCIATION,
By W. A. BEARD, *President and General Manager.*

Attest:
M. A. SEXTON, *Secretary.*

EXHIBIT 3.

Berkeley, California, June 9, 1924.

Agreement covering general plan of procedure for surveys and investigations of a proposed system of control works on the lower Sacramento River and certain alternative plans for the proposed Iron Canyon project, all in the Sacramento Valley, State of California.

The undersigned at a meeting held in the office of the Bureau of Reclamation at Berkeley, California, on the day and date above written, with:

W. L. Huber	A. J. Cleary
G. A. Elliott	B. A. Etcheverry

members present of an advisory committee appointed by the California State Department of Public Works, agreed upon the following as an outline of a tentative program to be followed in the above named investigations.

Lower Sacramento River Control Works.

1. It is recognized that the primary purpose of this investigation is to determine the feasibility and probable cost of a system of control works as proposed and to this end the funds now available are to be devoted chiefly to investigation of prospective dam sites, designs and estimates of cost.

2. Sites to be considered:

Field work to be confined to Army Point. Dillon Point and San Pablo Point sites.

3. Field examinations:

One outfit operating two shifts to be placed on diamond drilling. Work to begin at Army Point site. Number of holes to be adjusted to costs as work progesses. At least two or three holes to be drilled in the sections of deepest water at the Dillon and San Pablo Point sites. Holes to be located primarily for estimating quantities of earth and rock fill and possible location of lock structures. No land holes to be drilled, surface indications being deemed sufficient for estimating purposes. It is expected that $15,000 to $20,000 will be expended in exploration work. Based upon estimates prepared by Mr. Young and informal bids received from the International Diamond Drill Contracting Co. of San Francisco it is believed that it will be more economical to do the drilling by force account. Moreover, force account work is considered advisable in this instance since it allows for a more flexible program.

4. Office studies:

(a) Effect of barrier on flood plane elevations, silting of Susuin and San Pablo Bays, tidal prism of San Francisco Bay, and navigation.

(b) Design of barrier. Principal consideration to be given to plan of constructing locks and gates to one side and making an earth and rock fill across the natural channel. Trial designs of other types of structure to be made in sketch form only.

(c) Design of required locks and gates for navigation and passage of flood water. Desirable design condition for passing floods is that an area of waterway be provided in structure equal to that of the present natural channel. Flood plane should be run through Susuin Bay joining on the Debris Commission elevations at Collinsville. Flood quantities of the Debris Commission to be used and marsh land in Susuin Bay outside of that necessary for a channel to be assumed as reclaimed.

5. Preparation of report.

Iron Canyon Project.

1. Field work:

Survey of low line canal taking out of river in the vicinity of Red Bank Creek. Survey to be adequate for making estimate of costs and areas of land above and below canal line. To be run south as far as funds will permit.

Survey of siphon across Sacramento River if funds are sufficient.

2. Office studies:

(a) Determine from maps the areas that can be served by gravity and the pumping lifts to other areas.

(b) Cost estimate of canal and structures.

(c) Revise estimates of power that can be developed at Iron Canyon dam.

(d) Consider use of gates in spillway for increasing storage behind dam.

(e) Revise cost estimates of dam.

3. Preparation of report.

DEPARTMENT OF THE INTERIOR.
BUREAU OF RECLAMATION,
By WALKER R. YOUNG, *Engineer.*

DEPARTMENT OF PUBLIC WORKS.
DIVISION OF ENGINEERING AND IRRIGATION,
By PAUL BAILEY, *Deputy Chief of Division.*

SACRAMENTO VALLEY DEVELOPMENT ASSOCIATION,
By W. A. BEARD, *President.*

EXHIBIT 4.

STATEMENT OF COST.

Iron Canyon Investigations—Sacramento Valley, California, as of October 31, 1925.

Period[1]	Engineer in charge	Cost incurred by—			
		State	Association	United States	Total
1913-1915	J. T. Whistler	....	$9,133.44	$9,600.39	$18,733.83
1919-1921	H. J. Gault	$8,670.38	[2]9,417.29	8,839.35	26,927.02
1924-1925	Walker R. Young	1,627.00	2,500.00	5,798.21	[3]9,925.21
Totals	....	$10,297.38	$21,050.73	$24,237.95	$55,586.06

[1] Early costs on the Iron Canyon project were included in Sacramento Valley accounts, 1902-1904, no detail being recorded for the various features investigated.

[2] Includes cost of printing and binding report, which expense was entirely met by the association.

[3] Costs as of October 31, 1925. At close of current investigations in the Sacramento Valley, it will be necessary to make final adjustment with the State of California as provided by existing contracts.

EXHIBIT 5.

DETAIL STATEMENT OF COST.

Total Cost of Investigation of the Iron Canyon Project, California, as of October 31, 1925, under contract dated January 26, 1924.

Location surveys	$3,475.28
Topographic surveys	43.63
Estimates	4,544.79
Consulting boards (engineering)	72.28
Engineering and inspection	83.34
Subtotal	$8,219.32
Superintendence and accounts	1,154.89
General expense (expenses of general offices)	551.00
Total actual cost	$9,925.21
Contingencies (a)	74.79
Grand total	$10,000.00
The above cost has been incurred by the various parties to contract of January 26, 1924, as follows:	
Sacramento Valley Development Association	$2,500.00
State of California	1,627.00
United States	5,798.21
Total actual cost	$9,925.21

NOTE.—(a) Estimated; to cover minor miscellaneous expenses incurred in preparation of report, etc.

EXHIBIT 6.

STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING
SACRAMENTO

REPORT ON

IRON CANYON SURVEY—EAST SIDE CANAL
APRIL, 1921

J. B. Brown, Assistant State Engineer.

H. L. McCready, Hydrographer.

11—50667

CONTENTS.

STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING

Sacramento, April 30th, 1921.

Mr. W. F. McClure,
State Engineer,
Building.

Subject: Iron Canyon Survey—East Side Canal.

Dear Mr. McClure:

There is submitted herewith a report and map of the recent reconnaissance of the Iron Canyon Survey—East Side Canal.

Two routes have been studied, a high line extending from the easterly end of the Iron Canyon dam in a general southeasterly direction, passing to the north and east of Chico and terminating at Butte Creek. The irrigable acreage under this canal is approximately 78,000 acres. Construction costs would be heavy due to the difficult country traversed.

The second study contemplates the diversion of water from the Sacramento River by means of a pumping plant located about one mile below Tehama. By utilizing the Sacramento River Channel a saving of 22 miles of main canal is made, with the further advantages of more favorable soil conditions for excavation and the development of additional power at the Iron Canyon dam by passing the water required for this canal through the turbines. A short auxiliary canal from the easterly end of the Iron Canyon dam would serve about 7,000 acres of land to the eastward of Red Bluff. The total acreage served by the two canals under the low line project is 71,000 acres.

Field work for this report was done by J. B. Brown, Assistant State Engineer, and H. L. McCready, Hydrographer, during the week of March 22d to March 26th. The estimate, report and map are the work of H. L. McCready and have been compiled during the month of April, 1921.

Very respectfully,

(Signed) J. B. Brown, Assistant State Engineer.

JBB:LAB

In the report herewith submitted an effort has been made to outline in a general way an irrigation project embracing the lands on the east side of the Sacramento River, below and adjacent to the proposed Iron Canyon project, this area to become a part of the Iron Canyon project and derive its supply from the waters impounded in the proposed Iron Canyon reservoir.

The area in question extends southward beyond the city of Chico to approximately the northern limits of the lands irrigated by the Western Canal Co. On the east it is bounded by the lower line of a type of soil described by the Bureau of Soils of the U. S. Department of Agriculture as the Tuscan stony loams. These Tuscan stony loams are classified as lands that would not be benefited by irrigation to any extent; they present a surface appearance of water-washed cobbles and have a deeper formation of cemented gravel. Where canals are located in this formation a high unit cost of construction is anticipated.

The area of irrigable land within this scope of country not now within irrigation districts is estimated at 82,000 acres.

The outlines of two plans for the main canal will be given.

First, a gravity system canal here designated as the high line canal, starting at the dam site at an elevation of 330 feet passing just above the comparatively rough hills east of the city of Los Molinos, continuing above the upper line of the irrigable lands passing to the east of the city of Chico ending at Butte Creek, elevation 200 feet, in the SE¼ of SW¼, Sec. 8, T. 21 N., R. 2 E.

There are 78,000 acres of land under this canal, 95 per cent of the irrigable land considered. Four acre-feet of water per acre will be assumed as sufficient for the season, distributed as follows:

Month	Feet per acre	Acre-feet	Per cent	Second-feet
March	0.24	18,700	6	304
April	0.40	31,200	10	524
May	0.56	43,700	14	711
June	0.76	59,300	19	996
July	0.84	65,500	21	1,066
August	0.76	59,300	19	996
September	0.28	21,800	7	363
October	0.08	6,300	2	105
November	0.08	6,200	2	103
Totals	4.00	312,000	100	....

The following are the elements of this proposed high-line canal:

Point	Acres	Miles	Distance	Depth and bottom width	Slope, feet per mile	Velocity, feet per second	Capacity, second-feet
Dam	78,000	0	6	10′ x 20′	1.06	4.50	1,066
New Creek	68,000	6	31	10′ x 18′	1.06	4.45	930
Creek	51,000	37	3	9′ x 13′	1.59	4.75	700
Rock Creek	40,000	40	4	8 5′ x 12′	1.85	4.97	550
Mud Creek	32,000	44	8	8′ x 10′	1.85	4.65	440
Chico Creek	....	52	....	....	....	....	....
Butte Creek	20,000	56	4	6.5′ x 8′	2.11	4.81	270

Side slopes of canals for estimate purposes taken as 1 to 1.

Estimated cost of high-line canal:

Yardage	1,538,000	
Cemented gravel	1,443,000 cubic yards at $1.25=	$1,800,000
Earth	95,000 cubic yards at .40=	38,000
30 creeks and arroyos requiring structures, flumes or siphons, average length 200′, cost of $200 per lineal foot		1,200,000

Concrete lining for 44 miles of canal:

1,162,000 square yards 3 inches thick at $1.10	$1,280,000
Right of way	20,000
35 bridges at an average cost of $1,200	42,000
Fencing 112 miles at $600	67,200
Telephone system	40,000
Contingencies, 10 per cent	448,720
Total	$4,935,920

Cost per acre of main canal, $63.

The second general plan of main canal here designated as the low-line canal, is to install a pumping station about one mile below the city of Tehama and pump water into a canal at elevation 210 feet. This canal would be located very nearly at the upper line of the irrigable lands and would pass to the north and west of the city of Chico, ending at the Southern Pacific Railway in NE¼, NE¼, section 24, township 21 north, range 1 east, at elevation about 170 feet. There are 64,000 acres of irrigable land under this canal in need of water in addition to 7,000 acres of land east of the city of Red Bluff which could be irrigated by a small canal extended directly from the Iron Canyon dam, making a total of 71,000 acres under this canal system or 86 per cent of the total irrigable land considered.

The duty of water and distribution for the main canal is taken the same as for the proposed high-line canal, as follows:

Month	Feet per acre	Acre-feet	Per cent	Second-feet
March	0.24	15,370	6	256
April	0.40	25,600	10	427
May	0.56	35,800	14	597
June	0.76	48,600	19	810
July	0.84	53,800	21	897
August	0.76	48,600	19	810
September	0.28	17,900	7	298
October	0.08	5,100	2	85
November	0.08	5,100	2	85
Totals	4.00	255,870	100	....

The following are the elements of the proposed low-line canal:

Point	Acres	Miles	Distance	Depth and bottom width	Slope, feet per mile	Velocity, feet per second	Capacity, second-feet
Pump station	....	0					
	64,000		15	10.5' x 16'	1.06	4.31	897
Rock Creek		15					
	47,000		5	9.5' x 13'	1.19	4.30	660
Mud Creek		20					
	37,000		2	8.5' x 12'	1.32	4.31	518
Chico Creek		22					
	29,000		5	8.0' x 11'	1.45	4.00	406
Secondary canal		27					
	24,000		3	7.5' x 10'	1.59	3.95	336
Secondary canal		30					
	16,000		2	7' x 8'	1.59	3.45	224
Secondary canal		32					
	8,000		2	6' x 6'	1.59	3.10	112
End canal		34					

Proposed canal to irrigate 7000 acres of land east of the city of Red Bluff to be constructed as part of the low-line canal system.

This canal starts at the Iron Canyon dam, elevation 300 feet, is 6¾ miles long and ends at the northerly corner of lot 35, subdivision No. 9, of the Los Molines Land Company's tracts.

The amount of water diverted per acre per annum for this canal is estimated at three acre-feet instead of four acre-feet as used on the lower main canal because of the great difference in length; this canal beng only 6 miles long.

The following distribution and amounts of water are estimated to be required:

Month	Feet per acre	Acre-feet	Per cent	Second-feet
March	0.18	1,260	6	21
April	0.30	2,100	10	35
May	0.42	2,940	14	49
June	0.57	3,990	19	67
July	0.63	4,410	21	74
August	0.57	3,990	19	67
September	0.21	1,470	7	25
October	0.06	420	2	7
November	0.06	420	2	7
Totals	3.00	21,000	100	....

Elements of the secondary canal of the proposed low-line canal system.

Elements of Proposed Secondary Canal.

Point	Acres	Miles	Distance, miles	Depth and bottom width	Slope, feet per mile	Velocity, feet per second	Capacity, second-feet
Dam at elevation 300 feet	7,000	0	2	4' x 4'	5.28	4.56	74
Distributing canal	6,000	2	1¼	4' x 3.5'	5.12	4.20	63
Salt Creek	2,000	3¼	3½	3' x 3'	.0035	3.00	21
End	....	6¾	....	....	....	....	....

Estimated cost:

3,500 cubic yards cemented gravel at $1.25	$4,375.00
17,000 cubic yards earth at 60 cents	10,200.00
5 bridges at $800	4,000.00
Concrete lining for 3¼ miles, 28,800 square yards at $1.20	34,600.00
Contingencies and extras, 20 per cent	10,636.00
Total	$63,811.00

Cost of canal per acre of ground, $9.

Estimated Cost of Low-Line Canal Pumping Station.

Maximum quantity of water to be pumped, 897 cubic feet per second, 400,000 gallons per minute. This quantity of water is to be passed through the turbines at the Iron Canyon dam generating a certain amount of electrical energy, the water will flow on down the Sacramento River to the proposed pumping station where it will be lifted into the low-line canal; the relative generation and use of power is given in the following table:

Month	Head, feet	Second-feet	Foot pounds	Efficiency factor	Horse-power	Kilowatts
March	130	256	2,080,000	.61	1,875	1,400
April	130	427	3,460,000	.61	3,120	2,330
May	130	597	4,850,000	.61	4,370	3,260
June	130	810	6,580,000	.61	5,920	4,410
July	130	897	7,280,000	.61	6,560	4,890
August	112	810	5,670,000	.61	5,110	3,810
September	98	238	1,825,000	.61	1,644	1,230
October	91	85	483,000	.61	435	320
November	88	85	467,000	.61	421	310

Power Used in Pumping.

Month	Lift	Second-feet	Foot pounds	Efficiency factor	Horse-power	Kilowatts	Excess kilowatts generated
March	20	256	319,000	.61	950	710	690
April	21	427	559,000	.61	1,670	1,250	1,080
May	24	597	893,000	.61	2,630	1,960	1,300
June	24	810	1,212,000	.61	3,610	2,700	1,710
July	25	897	1,398,000	.61	4,170	3,110	1,780
August	26	810	1,314,000	.61	3,910	2,920	890
September	25	238	400,000	.61	1,130	830	340
October	25	85	132,600	.61	400	300	20
November	24	85	127,200	.61	380	280	30

The excess electrical energy generated would have a certain value and reduce the cost of operating and maintaining the pumping station.

Cost of Pumping Station.

Three pumps: 45-inch, 70-inch and 92-inch	$60,000.00
Three motors: 630, 1310 and 2260 horsepower	33,000.00
Three hydraulic gate valves	5,000.00
Pipe and flanges (3 pumps)	12,000.00
Transformers, switchboards, transmission, etc.	25,000.00
Building, sump	75,000.00
Freight, cartage and installation	20,000.00
Priming and pressure system	6,000.00
Contingencies and extras, 10 per cent	23,600.00
Total	$259,600.00

Cost of Low-Line Canal.

Excavation:		
160,625 cubic yards cemented gravel at $1.25		$200,780.00
633,125 cubic yards earth at 40 cents		253,250.00
Sixteen creeks and arroyos requiring concrete structures, flumes or siphons, average length, 200 feet:		
Estimated cost at $200 per lineal foot		640,000.00
Concrete lining for 34 miles of canal, 774,800 square yards 3-inch lining at $1.10		852,000.00
Right of way— 44 acres at $20	$880.00	
82 acres at 150	12,300.00	
100 acres at 50	5,000.00	
58 acres at 400	23,200.00	
Total for right of way		41,380.00
Twenty bridges, average cost $1,200		24,000.00
Fencing, 68 miles at $600		40,800.00
Telephone system		25,000.00
Pumping plant		259,600.00
Contingencies, 10 per cent		233,100.00
Total		$2,560,990.00

Cost per acre for 64,000 acres, $40.

EXHIBIT 7.

UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE

University Farm, Davis, California,
March 30, 1925.

Mr. Walker R. Young,
Engineer, Bureau of Reclamation,
110 Agriculture Hall,
Berkeley, California.

Dear Mr. Young:

Answer to your inquiry of November 4th last, relating to probable duty of water and percentages of land that should be considered suitable for orchard and rice under the revised plans for the proposed Iron Canyon project, has been delayed by numerous causes, chiefly my desire to await completion of computations on our 1924 water duty studies in Sacramento Valley and my desire to spend a few days in field with your questions before me.

The questions you raise would obviously deserve much more study if the final design and the construction of the project were to be based on the answers given. For purposes of present planning, however, the answers given below are believed to be safe; *i. e.*, generous enough to cover all reasonable net requirements on the land, but sufficiently low to force good preparation of the land and such careful and efficient methods of irrigation as shall reasonably restrict use, first, to the amounts of moisture the soil will retain, and, as the season advances, to replenishing the moisture the crop utilizes or that is lost by causes it would be unreasonable to expect the farmers to eliminate.

With the above explanation, our answers to your questions are as follows:

1. What is the probable net duty for rice on clay and adobe soils?

Answer: 5 acre-feet per acre. We believe that land requiring more water than this will not long remain in rice. With the exception of work on six fields in 1924, all of our rice duty studies have been carried out under the irrigation practice first used almost universally but now generally followed on first and second year land only, viz: to keep the fields moist from seeding to about 30 days after emergence of the plants and then submerge with increasing depths up to about 6 inches. Present practice is to substitute all-season submergence; *i. e.*, from seeding to draining for harvest. Until we have more information on duty under all-season submergence we can only assume that duty under the old method will apply.

2. What is the probable net duty for orchards?

Answer: From 1.00 to 1.50 acre-feet per acre, averaging (after "weighting" according to soil types and areas) 1.37 acre-feet per acre; or, for general present purpose, 1.50 acre-feet per acre.

Our basis for arriving at the above has been to take a duty of 1.00 acre-feet per acre for loam soils 6 to 10 feet deep with ground water below 10 feet, 1.50 acre-feet per acre for shallow loams with tight sub-soil free from ground water, for gravelly soils, and for clays. With a ground water higher than 10 feet we assume a use of 0.80 acre-feet per acre, but have not included any such areas. More is required on shallow and tight soils, not because the soil will hold more, but because of the larger number of irrigations required and the consequent greater surface losses.

3. What is the probable net duty for general crops?

Answer: 1 to 1.50 acre-feet per acre; or, generally, 1.50 acre-feet per acre, the same as for orchards.

In this answer, please note that we do not include alfalfa in "general crops." For alfalfa we use 2.50 acre-feet per acre for loams, 2.00 acre-feet per acre for clays, and 4.00 acre-feet per acre for gravelly soils, or a weighted average of 2.75 acre-feet per acre.

4. What percentage of the area above the proposed low-line canal should be considered orchard land?

Answer: 50 per cent. This is based on our judgment of soil, drainage, topography, and good balance combined.

NOTE.—Furthermore, we make field crops (not counting alfalfa) interchangeable with orchards in this percentage. The percentage we assume for alfalfa is 40.

5. What percentage of the area below the proposed low-line canal should be considered orchard land?

Answer: Again including field crops (exclusive of alfalfa) interchangeably, 25 per cent, and alfalfa 45 per cent.

We have classed as orchard land all of the Columbia, Elder, and Altamont series and the Willows loams, but all of these soils are excellent for alfalfa and might be so classed, except for their general value for orchards.

6. What percentage of the area above the proposed low-line canal should be considered rice land?

Answer: 10 per cent. Includes Kirkwood clays, Willows clay adobes, and Tehama clays (one-half only).

7. What percentage of the area below the proposed low-line canal should be considered rice land?

Answer: 30 per cent. Includes Kirkwood clays, Willows clay adobes, Willows clays (in part only), Tehama clays, Sacramento clays, and Capay clays.

Yours truly,

FRANK ADAMS,

Professor of Irrigation Investigations and Practice.

EXHIBIT 8.

EXTRACTS

From paper read before the Fifth Annual Convention of the California Section of the American Waterworks Association at Sacramento on October 24, 1924.

CONTROL OF APPROPRIATIONS OF WATER BY THE STATE DIVISION OF WATER RIGHTS

by

EDWARD HYATT, JR.,
CHIEF OF DIVISION OF WATER RIGHTS
STATE DEPARTMENT OF PUBLIC WORKS

* * * California in her constitution had inherited the riparian right doctrine from the common law of England and almost from the first the difficulty, or rather impossibility, of reconciling the two theories was apparent (Riparian and Appropriation Doctrine).

The riparian principle is that the right to the water in a stream is vested entirely in the abutting landowners; that the right is not created by use and does not cease with disuse. It originated in England, a land of humid climate where irrigation was unknown, where there were no rights in a stream or use of its waters other than by the landowners along the banks. It is practically universally admitted that the theory of riparian rights is entirely unsuited to an arid region or one where the lands require irrigation. Thus it is seen that the two classes of water rights trace their origin to entirely different sources and are absolutely conflicting both in theory and practice. After a great deal of litigation the issue between them was squarely joined in the famous case of *Lux* vs. *Haggin*, which was decided in 1886, in which decision by a four to three majority the riparian right was held to be a right of property protected under constitutional principles and superior to appropriative claims. By this decision riparian rights were definitely recognized and the riparian doctrine definitely fastened upon the state. * * *

* * * Without doubt, California, where irrigation was so important, had the poorest water laws of any state in the Union. Many other irrigation states refused from the beginning to recognize riparian rights, probably as a direct result of California's troubles, and in the nonirrigating states the appropriation doctrine was unnecessary. * * *

* * * In California there was determined opposition to any change, however, by the holders of vested water rights, particularly by riparian owners, and the movement for a water code was unsuccessful until 1913, when due to the efforts of several earlier boards and commissions the present Water Commission Act was passed.

The act provided a code for the orderly administration by the state of its remaining water resources, for ajudication of rights already in existence, for the distribution of water by water master to water right owners, and for stream system investigations. Due to the conditions described the statute was necessarily long and complicated. The basic principles as established by court decisions through sixty years could not be more than modified, established rights could not be endangered, and unused riparian rights being more or less property rights were a doubtful subject of legislation. The Water Commission Act probably went as far as possible by legislation to establish a complete and efficient code; *however, the simple fact was that a direct and efficacious solution was not possible at this late date in California as it has been earlier in other western states.* * * *

* * * The increasing prosperity of the state, coupled with the fact that further agricultural and power development is limited by the water available, has tremendously accelerated the demand. The operation of the Water Commission Act, which provides that riparian rights not used by 1924 will lapse, has also had its effect. * * *

* * * As already explained, since the Water Commission Act went into effect in 1914, appropriative water rights can be acquired only under its provisions, and, since that time, all such rights are clearly defined.

However, most of the present irrigated acreage in the state acquired its rights prior to the Water Commission Act, and the loose methods of filing then existing and the lack of supervision to determine whether all or any part of such rights have become vested by use has resulted in the existence of a vast number of rights undefined and in a great many cases even unrecorded. * * *

* * * It will therefore be seen that California's water code is complete as to appropriative water rights. Procedure for the initiation of new rights, for the adjudication of old rights, and for the distribution of water to all existing rights is complete, and the problems created before the adoption of the Water Commission Act could be gradually and surely worked out were it not for the riparian right situation. Returning to this for a moment, section 11 of the Water Commission Act provides that riparian rights not exercised for a period of ten years after the final passage of the act in 1914 will lapse. This law will very shortly become effective. If we were able to say definitely that it will be upheld by the courts the solution of our worst water troubles would be in sight. However, legal opinion is divided as to whether or not this law will be upheld. Some of the best qualified attorneys in the state say the United States Supreme Court will in no case allow such a law, even if the State Supreme Court should, others that the United States court will uphold the state court in whatever it decides in this case. All we can do in this matter is to wait and hope for the best. * * *

* * * By the United States census figures there were 10,900 acres irrigated from the Sacramento River direct in 1902 above Sacramento, and 194,000 acres in 1919; that is, about 18 times as much land was irrigated in 1919 as in 1902 from the Sacramento River direct.

The majority of the development in the valley has come about since 1910, and mainly since the Water Commission Act became effective, so that nearly all of the larger water rights from the river have been secured through permit from the State Water Commission or Division of Water Rights, making our records unusually complete as regards the Sacramento Valley.

* * * The irrigable area in the floor of the Sacramento Valley is 2,700,000 acres besides the foothill lands, which will some day need water. Considering that by the census there are only about 300,000 acres irrigated at the present time, it is seen that irrigation development will not be stopped by lack of suitable agricultural lands in the Sacramento Valley. * * *

* * * The normal low flow of the Sacramento River during irrigation months is about 4500 second-feet measured at Red Bluff, which is the accepted point of measurement in this connection. In 1924 the lowest flow at this point was 2800 second-feet, which constitutes the irrigation supply for the valley and the delta regions below, since in a dry year the tributaries contribute practically no water at the critical seasons. While the Feather, Yuba and American rivers are first magnitude streams with large annual run-offs, they are not spring-fed, such as the upper Sacramento, and their low flow amounts to only a few hundred second-feet, which is entirely diverted in critical seasons by agricultural interests along those streams.

With the figures in mind that the normal low flow of the Sacramento is 4500 second-feet and the extreme low flow 2800, the existing rights to divert from the river below Red Bluff and above Sacramento are somewhat as follows:

The Division of Water Rights has issued permits for about 4800 second-feet. Unapproved applications are approximately 2000 second-feet more. These figures do not indicate the actual amount of water which will be diverted, since each permit includes some unirrigable land or some portion of its land must lie fallow each year, or perhaps some portion of the right will be forfeited through nonuse. From the records of use of water on these projects at present on file at the division an estimate is made that the applications and permits now before the office will ultimately be issued licenses or final water rights, to about 3600 second-feet.

From records of water pumped and such other information as is available, it is estimated that about 2000 second-feet should be allowed for the total of other used rights, both appropriative and riparian, on the river, making a total of about 5600 second-feet of actual existing rights by use, or which may be secured under applications now pending.

There are in addition large areas of riparian land along the river which have not as yet used water and if section 11 of the Water Commission Act regarding riparian rights is overruled by the courts, possibly 2000 second-feet more would be ultimately demanded by these lands, making a total of around 7500 second-feet. Adding up the total claims on the river, without reducing them in accordance with actual use, brings up the total to over 10,000 second-feet.

Assuming the rights by use to be about 5600 second-feet, and with only 2800 second-feet available at Red Bluff this year, the natural question is, how do these lands get sufficient water? The answer is that not all holders of water rights exercise them, there is a very considerable return flow, and very strict conservation measures were adopted, as it was apparent as early as January, 1924, that the situation was very serious and a water conference was held at that time. As a result of this the Division of Water Rights was asked to appoint a water supervisor for the season of 1924 and as I will explain further on, this work has had a high degree of success.

Summarizing the figures quoted you will note that there are rights by use to the waters of the river to an estimated figure of 5600 second-feet, which is just double the 1924 low flow of 2800 second-feet; therefore, considering only irrigation above Sacramento, it would seem the supply is fully appropriated and that new projects will be forced to store winter waters.

However, irrigation in the Sacramento Valley above Sacramento is only one angle and these irrigation projects only one of the interests having a claim upon the river. An equally important claim comes from the delta region below Sacramento. This area is little known in spite of its vast importance to the State of California. The Sacramento-San Joaquin delta contains 390,000 acres of highly productive lands requiring irrigation, and is estimated to produce annually crops valued at between $50,000,000 and $70,000,000. The delta farmers secure their water supply from either the Sacramento or the San Joaquin River or from the many sloughs which traverse the region and connect the two rivers.

During the irrigation season their supply mainly comes from the Sacramento and penetrates through the sloughs into the San Joaquin delta as well, since the low flow of the San Joaquin River is comparatively small, around 400 second-feet. The elevation of the delta lands is just about sea level and the water channels are, of course, many feet below sea level; therefore they may be considered arms of San Francisco Bay and the only reason why the salt water does not come up into the delta is that the fresh water from the two rivers keeps it out. As the fresh water supply diminishes in the summer the salt water creeps farther and farther into the delta region. This situation has been getting worse year by year, due to a variety of causes, but principally due to the depletion of the summer flow of the Sacramento River by irrigation diversions. The delta landowners claim water rights both by riparian rights and appropriation and also claim the right to have enough water in the river to keep the salinity condition below the danger point, and have stated that for this purpose it is necessary that 3500 second-feet be allowed to pass Sacramento. You will note that this is considerably more water than there was available in the river above diversions during the past summer.

The salinity situation is alarming and of the greatest importance. Residents of Sacramento are probably not aware that salinity to the extent of 25 parts per 100,000 appeared at Freeport, 10 miles below Sacramento, and that if no conservation measures had been taken this year it is probable that the Sacramento domestic supply would have been contaminated by salt from the ocean.

A number of solutions have been suggested for the salinity problem. At the present time investigation is under way to determine whether or not a dam across the bay itself at Carquinez Straits or at some other point is feasible. Very large storage of winter waters in order to supply this necessary water to the delta region is also under consideration.

A third important interest on the river is the navigation interests represented by the United States Government through the Army Engineer's office. Navigation on the river below Sacramento is at the present time of great importance and is of some importance above Sacramento, although in low seasons like 1920 and 1924 navigation has been abandoned above this city. However, it is admitted that the United States Government has the paramount right in the waters of a stream in the interests of navigation and could force, if it so chose, upper diverters to release enough water for the purposes of navigation. Major U. S. Grant, the engineer officer in charge of this district, has stated that from 3000 to 3500 second-feet in the river above Sacramento would satisfy navigation requirements.

Thus we have three interests, each of which apparently needs all the water in the Sacramento River in the summer time during a low season. The interests of the delta region and navigation would seem to be somewhat the same; that is, if the United States Government should require 3000 or 3500 second-feet for navigation purposes this would supply the delta with all the water which they state they need. * * *

EXHIBIT 9.

EXTRACTS FROM BULLETIN NO. 4.

PROCEEDINGS OF THE SECOND SACRAMENTO-SAN JOAQUIN RIVER PROBLEMS CONFERENCE AND WATER SUPERVISOR'S REPORT, 1924.

Colusa trough return waters.

As a result of the maintenance of the gaging station on the Colusa trough at the Colusa-Williams highway, some interesting information on return water and its relation to diversion was obtained for an area of about 66,000 acres irrigated on the west side of the Sacramento River between Hamilton City and Colusa. The irrigation in this area was divided nearly equally between rice and general crops or pasture. The Colusa trough at the point of measurement is the main drain of Reclamation District 2047 and as such carries practically the entire drainage from the Glenn-Colusa, Jacinto-Provident, Princeton-Codora-Glenn, Compton-Delevan and Maxwell irrigation districts. Also at the point of measurement there is very little drainage, other than that from these districts, flowing. Table 27 gives the data obtained. It shows the diversions and return water for each month, June to October, inclusive, and for the entire period, the percentage which the return bears to the diversions, and the acreages irrigated. It is to be noted that the Compton-Delevan and Maxwell irrigation districts have pumping plants on the trough which pick up this return water and again use it for irrigation. The drainage from this latter irrigation returns to the trough above the point of measurement. For this reason, in computing the return flow in per cent of diversions, it is necessary to add the trough diversions to the measured return at the Colusa-Williams highway. As shown in the table, the return flow for the period June to October was 30 per cent of the diversions.

TABLE 27. RELATION BETWEEN THE RETURN WATER IN COLUSA TROUGH AT COLUSA-WILLIAMS HIGHWAY AND THE DIVERSIONS FROM WHICH THE RETURN WATER IS DERIVED.

	June		July		August		September		October		June to October, inclusive		Acreage irrigated	
	Acre-feet	c. f. s.	Acre-feet	c. f. s.	Acre-feet	c. f. s.	Acre-feet	c. f. s.	Acre-feet	c. f. s.	Acre-feet	c. f. s.	General	Rice
Diversions.														
Glenn-Colusa and Jacinto irrigation districts	54,000	907	53,500	870	43,300	704	25,600	430	5,200	84	181,600	598	25,302	17,594
Provident Irrigation District	19,600	329	20,200	328	18,200	296	10,700	180	784	13	69,484	229	3,925	7,031
Princeton-Codora-Glenn Irrigation District	7,220	121	7,780	127	5,650	92	3,940	66	846	14	25,436	84	3,785	864
Compton-Delevan Irrigation District—river	277	5	310	5	400	6	157	3	6	0	1,150	4	100	4,000
Compton-Delevan Irrigation District—trough	6,590	111	6,020	98	5,090	83	2,510	42	0	0	20,210	66		
Maxwell Irrigation District—river	2,970	50	1,910	31	1,470	24	1,770	30	1,270	21	9,390	31	1,820	1,466
Maxwell Irrigation District—trough[1]	1,050	18	1,280	21	1,620	26	655	11	803	13	5,408	18		
Total diversions	91,707	1,541	91,000	1,480	75,730	1,231	45,332	762	8.909	145	312,678	1,030	34,932	30,955
Return.														
Colusa trough measured at Colusa-Williams highway[2]	17,900	300	12,600	205	14,200	231	14,600	245	7,580	123	66,880	220	....	....
Trough diversions	7,640	128	7,300	119	6,710	109	3,165	53	803	13	25,618	84	....	....
Total return	25,540	428	19,900	324	20,910	340	17,765	298	8,383	136	92,498	304	....	....
Return in per cent of diversions	28%		22%		28%		39%		94%		30%			

[1] Includes diversions by pumps used for gun clubs.
[2] This includes the flow for the first twelve days of June, before gage was established, which has been estimated on a basis of the mean flow of 300 second-feet as measured for June 13 to 30.

Quality of return water—tests.

Discussion has been had relative to the fitness for irrigation of some return waters, especially those from the rice fields located in more or less alkali area. In order to obtain some idea, therefore, of the difference in salts and alkali content between the Sacramento River water and that in the Colusa trough, a few samples of water were taken and tested during the 1924 season. The testing was done by the chemical laboratory of the State Highway Commission.

On July 30th a sample was taken of the Colusa trough water at the Maxwell road, and at the same time one was taken from the adjacent Maxwell Irrigation District canal carrying water diverted from the Sacramento River at the pumping plant, about seven miles distant. The results of the tests of these two samples are given in Table 28.

TABLE 28. TESTS OF WATER SAMPLE FROM THE COLUSA TROUGH AND FROM CANAL WATER DIVERTED FROM THE SACRAMENTO RIVER.

Tests	Parts per million	
	Return water in Colusa trough	Canal water from Sacramento River
Alkalinity bicarbonates	207.00	121.00
Alkalinity carbonates	000.00	000.00
Total hardness	164.00	156.00
Sulphates as SO^4	0.50	1.50
Chlorides as Cl	65.00	65.00
Alkali as Na	49.00	19.00
Alkali coefficient*	24.00	107.00
Alkali rating	good	good

*Alkali coefficient is the depth in inches of water which on evaporation would yield sufficient alkali to render a four-foot depth of soil injurious to the most sensitive crops.

NOTE.—Samples taken on July 30, 1924, at the Colusa trough and Maxwell Irrigation District canal crossing of the Maxwell road.

It will be noted that, although the trough water had an alkali coefficient about four and a half times lower (see definition for this coefficient at bottom of Table 28) than the canal water from the river, both samples were given an alkali rating as "Good."

Early in the fall the rice fields are drained of all of the water which has been ponded during the summer, and at this time, therefore, there is a considerable increase in the return to the Sacramento River of such water. To show the difference in the alkali content of the river water before and at the peak of this fall drainage samples were taken from the river at Elkhorn Ferry, about 12 miles above Sacramento, one on August 18th and the other on September 12th. On September 12th, also, a sample was taken from the back borrow-pit of District 787, just above its junction with the river. The borrow-pit was carrying all of the drainage from Colusa Basin. The results of the tests of these three samples are given in Table 29.

TABLE 29. TESTS OF SACRAMENTO RIVER WATER BEFORE AND AT THE PEAK OF THE RICE FIELD DRAINAGE AND OF COLUSA BASIN DRAINAGE AT THE PEAK.

Tests	Parts per million		
	River water at Elkhorn ferry on August 18	River water at Elkhorn ferry on September 12	Colusa basin drainage at Knights Landing on September 12
Total solids	333	316	582
Suspended solids	10	37	73
Dissolved solids	323	297	509
Bicarbonates	158	134	260
Total hardness	210	198	213
Temporary hardness	130	117	85
Permanent hardness	80	81	298
Chlorine as Cl	64	60	82
Sulphates as SO^4	47	27	95
Alkali coefficient	32	34	24
Alkali rating	good	good	good

NOTE.—Elkhorn ferry is located about 12 miles above Sacramento. The sample of Colusa basin drainage water was taken from the back borrow-pit of District 787 just above its junction with the Sacramento River at Knights Landing, which is located about 34 miles above Sacramento.

Of the flow at Elkhorn Ferry on August 18, the return from District 70 drain. District 108 drain, Colusa Basin and Sacramento Slough amounted to 44 per cent. On September 12 the return from these same channels, although greater, was only 24 per cent of the flow at Elkhorn Ferry, because of the increased river flow due to decreased draft.

Unfortunately for the value of the comparison, the return from District 70 drain, District 108 drain, Colusa Basin and Sacramento Slough (representing practically the total of return water similar to Colusa Basin water) on August 18th amounted to 44 per, cent of the river flow at Elkhorn Ferry, whereas on September 12th the return from these same channels, although greater in amount, was only 24 per cent of the Elkhorn Ferry flow because of the increased river flow due to reduction in diversions. This may account for the fact that the September 12th test appears to differ very little from the August 18th test, although a large quantity of return water of considerable hardness and low alkali coefficient, as shown by the September 12th Colusa Basin drainage test, was entering the river.

No comprehensive conclusions can be drawn from the few tests that have been made, but it was desired to record the little information that has been obtained in this connection.

IRON CANYON PROJECT—CALIFORNIA.

PRELIMINARY ESTIMATES.

1. Iron Canyon Reservoir Right of Way.
2. Iron Canyon Dam, Bend Embankment and Power Plant—Construction.
3. Iron Canyon Dam and Power Plant—Operation and Maintenance.
4. Diversion Works—Construction.
5. Diversion Works—Operation and Maintenance.
6. Diversion Works—Construction—Alternative Plan.
7. Diversion Works—Construction—Alternative Plan.
8. Mooney Island Power Plant—Construction.
9. Mooney Island Power Plant—Operation and Maintenance.
10. Main Canal—Construction.
11. Red Bank Pump Canal—Construction.
12. Pumping Plants—Construction.
13. Pumping Plants—Operation and Maintenance.
14. East Side Canal—Construction.
15. Project Headquarters—Construction.
16. Iron Canyon Dam—Construction—Increased cost to raise water surface from elevation 392.5 to 400.
17. Iron Canyon Dam—Construction—Increased cost to raise water surface from elevation 392.5 to 405.5.

PRELIMINARY ESTIMATE No. 1.

Iron Canyon Project—California.

IRON CANYON RESERVOIR RIGHT OF WAY.

Estimated valuation of lands and improvements.

Flow line at elevation 405.5.

Estimate by California State Department of Public Works, Division of Engineering and Irrigation, except as noted.

			Summary
Lands.			
Irrigated and cultivated, 14,100 acres at $196 per acre		$2,763,600	
Grazing, 17,500 acres at $25 per acre		437,500	
Marginal between Elevation 405.5-410.5, added to estimate, 4400 acres at $25 per acre		110,000	$3,311,100
Anderson-Cottonwood Irrigation District. (Bond issue $1,255,000 less $15,000 paid in 1925.)			
One-third of irrigable area submerged and this proportion of bonded indebtedness charged against Iron Canyon project		$413,333	
Capitalization of increased maintenance costs		375,000	788,333
Railroads.			
Anderson-Belle Vista Railroad relocation—			
10 miles at $15,000 per mile	$150,000		
Sacramento River bridge	50,000		
Churn Creek bridge	30,000	$230,000	
Southern Pacific Railroad—			
Present location not changed.			
Fill at Cottonwood Creek to be increased and bridge raised and extended	$75,000	75,000	305,000
Roads.			
State highway—			
Relocation of two miles at $23,000 per mile	$46,000		
Cottonwood Creek bridge	50,000	$96,000	
Balls Ferry steel bridge		50,000	146,000
Transmission and telephone lines.			
Pacific Gas and Electric Company power lines—Relocation 17 miles at $20,000 a mile		$340,000	
Telephone lines—Relocate 7 miles at $1,000 a mile		7,000	347,000
Total estimated cost			$4,897,433
Roughly			4,897,500

PRELIMINARY ESTIMATE No. 2.

Iron Canyon Project—California.

IRON CANYON DAM, BEND EMBANKMENT AND POWER PLANT.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Cofferdams	$530,000	$670,450
Gravity section of dam	3,191,678	4,037,473
Power house section	5,586,305	7,066,675
Flood control section	4,180,780	5,288,687
Ogee spillway section	713,595	902,698
Earth blanket	85,500	108,157
Foundation grouting and drainage	37,500	47,437
Lighting	6,000	7,590
Bend embankment	810,920	1,025,814
Construction railroad and equipment	195,000	246,675
Constrution camp	250,000	316,250
Pernanent camp	64,000	80,960
Finishing and cleaning up	60,000	75,900
Total exclusive of right of way	$15,711,278	$19,874,766
Roughly		$19,875,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 3.

Iron Canyon Project—California.

IRON CANYON DAM AND POWER PLANT.

OPERATION AND MAINTENANCE.

Rating, 110,000 h.p. .... 100,000 k.v.a.

Four turbine driven generator units.

Turbines, 30,000 h.p. .... Generators .... 25,000 k.v.a

Item	Quantity	Unit cost	Total cost	Summary
Storage Dam.				
Operation and maintenance:				
It is assumed that the dam will be operated and maintained by the force that operates the power plant, and all charges for this purpose are included below under that feature.				
Depreciation:				
Flood control gates and hand rail (including engineering and administration, 10%; and contingencies, 15%)	$1,518,380	4%	$60,735	
Total depreciation on gates and hand rail				$60,735
Remainder of dam not already depreciated under power house and flood control gates (including engineering and administration, 10%; and contingencies, 15%)	13,248,300	1%	132,483	
Total depreciation on remainder of dam				132,483
The last item is based on the assumption that the dam and reservoir will be useless after 100 years for reasons that can not be foreseen. The charge is not assumed assessed against the project during the repayment period as explained in the text.				
Power Plant.				
Operation and maintenance:				
Engineering and administration			$6,000	
Operation:				
Superintendent, 44% of time	1	$3,600	$1,584	
Operators	3	2,100	6,300	
Assistant operators	3	1,800	5,400	
Supplies, 25% of labor			3,321	
Total operation			$16,605	
Maintenance:				
Superintendent, 44% of time	1	$3,600	$1,584	
Electrician	1	2,400	2,400	
Helper	1	1,800	1,800	
Machinist	1	2,400	2,400	
Helper	1	1,800	1,800	
Laborers	3	1,500	4,500	
Supplies			14,484	
Total maintenance			$28,968	
General expense	10%		5,157	
Total operation and maintenance				$56,730
Depreciation:				
Power house and equipment (including engineering and administration, 10%; and contingencies, 15%)	$4,934,765	4%	$197,330	
Gates (including engineering and administration, 10%; and contingencies, 15%)	106,260	6½%	6,900	
Trash rack (including engineering and administration, 10%; and contingencies, 15%)	67,298	6½%	4,370	
Total depreciation				208,660
Total annual plant charge				$265,390

PRELIMINARY ESTIMATE No. 4.

Iron Canyon Project—California.

DIVERSION WORKS.

Raise in water surface 15 feet. Power developed at Mooney Island Slough.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Coffer dams	$25,000	$31,625
Dam across river channel	655,460	829,157
Sluiceway	190,202	240,605
Canal intake	79,999	101,199
Earth dike	86,500	109,422
Railroad spur	25,000	31,625
Construction camp	25,000	31,625
Permanent improvements	12,500	15,813
Finishing and cleaning up	5,000	6,325
Right of way	8,000	10,120
Totals	$1,112,661	$1,407,516
Roughly		$1,410,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 5.

Iron Canyon Project—California.

DIVERSION WORKS.

OPERATION AND MAINTENANCE.

Elevation of water surface in canal .... 250 feet

Diversion, including irrigation water for project and water for development of power at Mooney Island power plant, approximately .... 6,500 second-feet

Item	Quantity	Unit cost	Total cost	Summary
Operation and maintenance:				
Included as a part of the project operation and maintenance charge. No charge made against power as there are no additional expenses at the diversion dam as a result of power development at Mooney Island power plant.				
Depreciation—metal work:				
Charged against power since the cost of the diversion dam is assumed to be paid through sale of power.				
Roller crest gates and hoists (including engineering and administration, 10%; and contingencies, 15%)	$429,291	4%	$17,172	
Foot bridge (including engineering and administration, 10%; and contingencies, 15%)	26,565	4%	1,063	
Radial gates and hoists (including engineering and administration, 10%; and contingencies, 15%)	27,704	6⅔%	1,847	
Total annual depreciation on metal work			$20,082	$20,100
Charge to Mooney Island power plant one-half of depreciation on radial gates				900
Net annual depreciation on metal work chargeable to diversion dam				$19,200
Depreciation—concrete:				
No depreciation charged against concrete work during the period of repayment of construction cost.				
*Total cost of diversion works less metal work, earth dike and right of way	$806,898	2%	$16,138	$16,100
Total depreciation on concrete in diversion dam				$16,100

*Cost of cofferdams, excavation, sheet piling, rip-rap, etc., assumed to be distributed against concrete.

PRELIMINARY ESTIMATE No. 6.

Iron Canyon Project—California.

DIVERSION WORKS.

Raise in water surface, 15 feet.

No power development at Mooney Island Slough.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Cofferdams	$25,000	$31,625
Dam across river channel	655,460	829,157
Sluiceway	175,381	221,857
Canal intake	44,062	55,738
Earth dike	86,500	109,422
Railroad spur	25,000	31,625
Construction camp	25,000	31,625
Permanent improvements	4,500	5,692
Finishing and cleaning up	5,000	6,325
Right of way	8,000	10,120
Totals	$1,053,903	$1,333,186
Roughly		$1,333,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 7.

Iron Canyon Project—California.

DIVERSION WORKS.

No raise in water surface.

No power development at Mooney Island Slough.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Cofferdams	$25,000	$31,625
Low weir across river channel	199,008	251,746
Sluiceway	132,807	168,002
Canal intake	100,000	126,500
Railroad siding	5,000	6,325
Construction camp	25,000	31,625
Permanent improvements	4,500	5,692
Finishing and cleaning up	5,000	6,325
Right of way	2,000	2,530
Totals	$498,315	$630,370
Roughly		$630,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 8.

Iron Canyon Project—California.

MOONEY ISLAND POWER PLANT.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Forebay and tailrace	$90,800	$114,862
Power house and equipment	624,000	789,360
Construction camp	2,500	3,162
Permanent improvements	12,500	15,813
Finishing and cleaning up	1,000	1,265
Right of way	3,000	3,795
Totals	$733,800	$928,257
Roughly		$928,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 9.

Iron Canyon Project—California.

MOONEY ISLAND POWER PLANT.

OPERATION AND MAINTENANCE.

Installed capacity, 10,400 h.p.

Item	Quantity	Unit cost	Total cost	Summary
Operation and maintenance:				
Operation—				
Labor—Superintendent	1 (6% time)	$3,600	$216	
Operators	3	2,100	6,300	
Supplies	25% of labor		1,629	
Total operation			$8,145	
Maintenance—				
Labor—Superintendent	1 (6% time)	$3,600	$216	
Laborer	1	1,500	1,500	
Total labor			$1,716	
Supplies	100% labor		1,716	
Total maintenance			$3,432	
Total estimated field cost			$11,577	$11,500
General expense	10%			1,150
Total annual operation and maintenance				$12,650
Depreciation:				
Concrete and paving (including engineering and administration, 10%; and contingencies, 15%)	$29,750	2%	$595	
Structural steel (including engineering and administration, 10%; and contingencies, 15%)	21,632	6⅔%	1,442	
Power house and equipment (including engineering and administration, 10%; and contingencies, 15%)	789,360	4%	31,574	
Total annual depreciation				33,600
Total annual plant charge				$46,250
Assumed depreciation on radial gates and hoists at diversion works (one-half that shown in Estimate No. 5)				900
Total annual plant charge assumed to be carried by power				$47,150

PRELIMINARY ESTIMATE No. 10.

Iron Canyon Project—California.

MAIN CANAL.

SUMMARY OF CONSTRUCTION COSTS.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Excavation and borrow	$2,986,521	$3,777,950
Concrete lining	6,208,336	7,853,545
Siphons	917,299	1,160,383
Wasteways	335,882	424,891
Side drain intakes	16,609	21,010
Culverts	104,502	132,195
Checks	250,317	316,651
Bridges	259,356	328,085
Railroad crossings	48,873	61,824
Turnouts	39,222	49,616
Fence	33,600	42,504
Telephone system	30,720	38,861
Patrolmen's quarters	28,000	35,420
Clearing and grubbing	13,370	16,913
Right of way	260,875	330,007
Totals	$11,533,482	$14,589,855

Roughly $14,590,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 11.

Iron Canyon Project—California.

RED BANK PUMP CANAL.

SUMMARY OF CONSTRUCTION COST.

Details of estimate not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

Item	Estimated cost	
	Field	Total
Excavation	$83,846	$106,065
Concrete lining	534,377	675,987
Siphons	81,288	102,829
Wasteways	5,841	7,389
Culverts	13,030	16,483
Flumes	29,700	37,570
Checks	20,667	26,144
Bridges	15,409	19,492
Turnouts	4,861	6,149
Fence	7,000	8,855
Telephone system	6,240	7,894
Patrolmen's quarters	10,500	13,283
Clearing and grubbing	2,500	3,162
Right of way	44,925	56,830
Totals	$860,184	$1,088,132

Roughly $1,088,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 12.

Iron Canyon Project—California.

PUMPING PLANTS.

CONSTRUCTION.

Basic data: 70%
Plant efficiency assumed..........
Discharge pipe lines—
Wood stave pipe assumed. 50%
Allowance for water hammer..........
Single barrel assumed in all cases.
Costs shown in the estimate are based upon pipe in place including grading, cradles and fencing.
The linear foot cost is based upon the following unit costs:
Lumber, measured in the rough— .... $45.00 per M B. M.
Staves, delivered.......... 20.00 per M B. M.
Treatment.......... 12.00 per M B. M.
Assembling.......... 1.00 per M B. M.
Dowels..........
.... $78.00 per M B. M.
Total lumber..........
Metal work— .... $0.04 per lb.
Bands and shoes.......... .01 per lb.
Installation and painting..........
.... $0.05 per lb.
Total metal work..........

PRLIMINARY ESTIMATE No. 12—Continued.

Item	Quantity	Unit cost	Total cost	Summary
Intake plant, head 50 feet:				
Pumping plant	371 c. f. s.	$315.00	$116,865	
Pipe line, 9.0 feet diameter	6,300 ft.	17.00	107,100	
Total, intake plant				$223,965
Thomes Creek plant, head 37.5 feet:				
Pumping plant	171 c. f. s.	$310.00	$53,010	
Pipe line, 6.75 feet diameter	6,700 ft.	12.00	80,400	
Total, Thomes Creek plant				133,410
Plant at Station 1175+00, head 42 feet:				
Pumping plant	131 c. f. s.	$315.00	$41,265	
Pipe line 6.0 feet diameter	1,850 ft.	10.70	19,795	
Total, plant at Station 1175+00				61,060
Plant at station 2271+00, head 35 feet:				
Pumping plant	206 c. f. s.	$310.00	$63,860	
Pipe line 7.5 feet diameter	8,400 ft.	13.20	110,880	
Total, plant at Station 2271+00				174,740
Second lift, Station 2271, head 34 feet:				
Pumping plant	51 c. f. s.	310.00	$15,810	
Pipe line 4.5 feet diameter	5,000 ft.	7.15	35,750	
Total, second lift				51,560
Plant at Station 3260, head 25 feet:				
Pumping plant	35 c. f. s.	$295.00	$10,325	
Pipe line, 3.5 feet diameter	1,100 ft.	4.85	5,335	
Total, plant at Station 3260				15,660
Plant at Station 4307, head 25 feet:				
Pumping plant	8.5 c. f. s.	$295.00	$2,508	
Pipe line, 2.0 feet	700 ft.	2.90	2,030	
Total, plant at station 4307				4,538
Plant at Station 4705, head 35 feet:				
Pumping plant	23 c. f. s.	$310.00	$7,130	
Pipe line, 3 feet diameter	800 feet	4.30	3,440	
Total, plant at Station 4705				10,570
Plant at Station 4976, head 42 feet:				
Pumping plant	172 c. f. s.	$315.00	$54,180	
Pipe line 6.75 feet diameter	1,700 feet	12.00	20,400	
Total, plant at Station 4976				74,580
Total estimated field cost				$750,083
Engineering and administration	10%			75,008
				$825,091
Contingencies	15%			123,764
Total estimated cost, pumping plants				$948,855
Roughly				$949,000

Does not include interest during construction.

NOTE.—The first two pumping plants listed are chargeable to the Red Bank pump canal.

PRELIMINARY ESTIMATE No. 13.

Iron Canyon Project—California.

PUMPING PLANTS.

OPERATION AND MAINTENANCE.

Item	Quantity	Unit cost	Total cost	Summary
Operation and maintenance (except electric energy):				
Labor, materials and supplies (3 times Minidoka S. Side for 1923)	11,792,400 ac.-ft.	$0.0042	$49,528	
General expense, 10%			4,953	
Total, operation and maintenance				$54,481
Depreciation	$948,855	4%	$37,954	$37,954
Total annual plant charge (exclusive of electric energy)				$92,435

Gross pumping area, Plate 2	94,466 acres
Area assessed, 95 per cent	89,740 acres
Annual plant charge per acre (exclusive of electric energy)	$1.03
Red Bank pump unit:	
Gross area, Plate 2	39,350 acres
Area assessed, 95 per cent	37,380 acres
Electric energy, 9,850,000 k.w.h. at $0.01	$98,500.00
General expense, 10 per cent	9,850.00
Total	$108,350.00
Annual charge for electric energy per acre	$2.90
Annual plant charge per acre	1.03
Total annual pumping charge per acre	$3.93
Pump units near Orland:	
Gross area, Plate 2	34,800 acres
Area assessed, 95 per cent	33,060 acres
Electric energy, 5,660,000 k.w.h. at $0.01	$56,600.00
General expense, 10 per cent	5,660.00
Total for electric energy	$62,260.00
Annual charge for electric energy per acre	$1.88
Annual plant charge per acre	1.03
Total annual pumping charge per acre	$2.91
Pump units south of Willows:	
Gross area, Plate 2	20,316 acres
Area assessed, 95 per cent	19,300 acres
Electric energy, 3,355,000 k.w.h. at $0.01	$33,550.00
General expense, 10 per cent	3,355.00
Total for electric energy	$36,905.00
Annual charge for electric energy per acre	$1.91
Annual plant charge per acre	1.03
Total annual pumping charge per acre	$2.94

PRELIMINARY ESTIMATE No. 14.

Iron Canyon Project—California.

EAST SIDE CANAL.

Diverting at Iron Canyon Dam to supply 7000 acres east of Red Bluff.

SUMMARY OF CONSTRUCTION COSTS.

Capacity of canal at its head, 86 second-feet.

Item	Estimated cost	
	Field	Total
Head works and tunnel at Iron Canyon dam	$10,000	$12,650
*Excavation (state's estimate+10%)	16,000	20,240
*Concrete lining (state's estimate+10%)	38,100	48,197
Siphons and flumes	15,000	18,975
Culverts	3,000	3,795
Checks	1,000	1,265
*Bridges (state's estimate)	4,000	5,060
Turnouts	1,500	1,897
Fence	4,000	5,060
Telephone system	1,000	1,265
Patrolmen's quarters	3,500	4,428
Clearing and grubbing	500	632
Right of way	8,000	10,120
Totals	$105,600	$133,584

Roughly $134,000

Does not include interest during construction.

*Items estimated by California State Department of Engineering. (See Exhibit 6.) Excavation and concrete lining are increased by 10 per cent in consideration of the increase in canal capacity from 74 to 86 second-feet.

All other items are approximated upon the basis of similar construction on the Red Bank pump canal, Preliminary Estimate No. 11.

PRELIMINARY ESTIMATE No. 15.

Iron Canyon Project—California.

PROJECT HEADQUARTERS.

CONSTRUCTION.

Item	Quantity	Unit cost	Total cost	Summary
Improvements:				
Office buildings			$50,000	
Warehouses			10,000	
Garage and equipment			5,000	
Grounds			1,000	
Total estimated field cost				$66,000
Engineering and administration	10%			6,600
Totals				$72,600
Contingencies	15%			10,890
Total estimated cost of project headquarters				$83,490

Roughly $83,500

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 16.

Iron Canyon Project—California.

IRON CANYON DAM.

CONSTRUCTION.

Estimated cost to raise water surface in reservoir from elevation 392.5 to 400 by installing movable gates in the siphon spillways and auxiliary crests on the ogee spillway. See Plate 11.

Storage between elevation 392.5 and 400 .... 186,200 acre-feet
Gross reservoir storage .... 961,300 acre-feet

Item	Quantity	Unit cost	Total cost	Summary
Flood control section:				
Station 15+33 to 21+00. Slide gates, 15′ x 7.5′:				
Structural steel	117,000 lbs.	$0.08	$9,360	
Cast iron—				
Gates	133,000 lbs.	.15	19,950	
Gate guides	142,000 lbs.	.15	21,300	
Stem guides	5,400 lbs.	.25	1,350	
Stuffing boxes	4,300 lbs.	.35	1,505	
Rolled steel stems	49,100 lbs.	.25	12,275	
Steel bolts	13,000 lbs.	.10	1,300	
Bronze—				
Gate seats	25,200 lbs.	.75	18,900	
Screws	270 lbs.	.75	202	
Hoists, 54-20⅔: 1 geared; 27 sets of 2	45,200 lbs.	.35	15,820	
Freight	534,470 lbs.	.01	5,345	
Installation and painting	534,470 lbs.	.05	26,724	
			$134,031	
Total, slide gates in place	27	5,000.00	135,000	
Total increased cost, flood control section	....	....	....	$135,000
Ogee spillway section:				
Station 40+00 to 50+00. Auxiliary crests, 2′ 6″ x 10′ 1″ panels:				
Structural steel	53,900 lbs.	$0.08	$4,312	
Cast steel posts, 100	7,000 lbs.	.25	1,750	
Cast iron sockets, 100	3,000 lbs.	.15	450	
6″ rubber belt seals, 4 ply	1,490 l. f.	.70	1,043	
Freight	65,000 lbs.	.01	650	
Installation and painting	65,000 lbs.	.02	1,300	
			$9,505	
Total, auxiliary crests in place	99 panels	96.00	9,504	
Total increased cost, ogee spillway section	....	....	....	9,504
Total estimated increased field cost	....	....	....	$144,504
Engineering and administration	10%	....	....	14,450
				$158,954
Contingencies	15%	....	....	23,843
Total increased cost	....	....	....	$182,797

Roughly $183,000

Does not include interest during construction.

PRELIMINARY ESTIMATE No. 17.

Iron Canyon Project—California.

IRON CANYON DAM.

CONSTRUCTION.

Estimated cost to raise water surface in reservoir from Elevation 392.5 to 405.5 by installing movable gates in the siphon spillways and on the ogee spillway. See Plates 12 and 13.

Storage between Elevation 392.5 and 405.5 .... 346,800 acre-feet

Gross reservoir storage .... 1,121,900 acre-feet

Item	Quantity	Unit cost	Total cost	Summary
Flood control section:				
Station 15+33 to 21+00:				
Additional concrete in siphon spillway to accomodate gates	1,460 cy.	$9.00	$13,140	
Slide gates, 15' x 13':				
Structural steel	166,000 lbs.	.08	13,280	
Cast iron—				
Gates	138,000 lbs.	.15	20,700	
Gate guides	188,000 lbs.	.15	28,200	
Stem guides	8,100 lbs.	.25	2,050	
Stuffing boxes	6,700 lbs.	.35	2,345	
Rolled steel stems	96,100 lbs.	.25	24,050	
Steel bolts	17,500 lbs.	.10	1,750	
Bronze—				
Gate seats	37,300 lbs.	.75	27,975	
Screws	340 lbs.	.75	255	
Hoists, 54-60: 1 geared; 27 sets of 2	89,600 lbs.	.35	31,360	
Freight	747,640 lbs.	.01	7,476	
Installation and painting	747,640 lbs.	.05	37,382	
			$196,823	
Total, slide gates in place	27	7,300.00	197,100	
Total increased cost, flood control section				$210,240
Ogee spillway section:				
Station 39+29 to 50+00:				
Excavation—				
Class II, base of dam and discharge channel	46,800 cy.	$1.50	$70,200	
Class II, deep cutoff	8.530 cy.	7.50	63,975	
Total excavation	55,330 cy.		$134,175	
Concrete—				
Crest and piers, 1:2½:5	18,300 cy.	$14.00	$256,200	
Downstream cutoff, 1:3:6	950 cy.	7.75	7,362	
Deep cutoff, 1:3:6	8,530	7.75	66,108	
Total concrete in place	27,780 cy.		$329,670	
Movable crest gates, 65' x 8' hydraulic operated drum gates—				
Gates, seat castings hinges	1,350,000 lbs.	$0.06	$81,000	
Pier plates and operating mechanism	225,000 lbs.	.15	33,750	
Freight	1,575,000 lbs.	.015	23,625	
Installation and painting	1,575,000 lbs.	.07	110,250	
			$248,625	
Movable crest gates in place	15	16,650.00	249,750	
Total ogee spillway section				713,595
Total gross				$923,835
Credit—elimination of gravity section from Station 39+29 to 40+00:				
Excavation—				
Class II, deep cutoff	530 cy.	$7.50	$3,975	
Concrete—				
Dam, 1:3:6	1,500 cy.	7.50	11,250	
Deep cutoff, 1:3:6	530 cy.	7.75	4,108	
Total concrete in place	2,030 cy.		$15,358	
Parapets	142 l. f.	10.00	1,420	
Credit for gravity section				$20,753
Credit—elimination of original ogee spillway				
Sta. 40+00 to 50+00:				
Excavation—				
Class II, base of dam and discharge channel	43,500 cy.	$1.50	$65,250	
Class II, deep cutoff	8,000 cy.	7.50	60,000	
Total excavation	51,500 cy.		$125,250	

PRELIMINARY ESTIMATE No. 17—Continued.

Item	Quantity	Unit cost	Total cost	Summary
Concrete—				
Crest, 1:3:6	16,600 cy.	$7.50	$124,500	
Deep cutoff, 1:3:6	8,000 cy.	7.75	62,000	
Total concrete in place	24,600 cy.		$186,500	
Credit for ogee spillway				$311,750
Total credits				$332,503
Total estimated increased field cost=cost less credits				$591,332
Engineering and administration	10%			59,133
				$650,465
Contingencies	15%			97,570
Total estimated increased cost				$748,035

Roughly $748,000

Does not include interest during construction.

WATER SUPPLY AND POWER STUDIES.

*Details not printed to save space. These are on file at office of Division of Engineering and Irrigation and may be consulted there.

TABLE 19. OUTPUT OF POWER AT IRON CANYON IN THOUSANDS OF KILOWATT HOURS, BY YEARS.

Year	Maximum water surface elevation 400. 1,000,000 acre-feet project. Maximum installation.		Maximum water surface elevation 400. 800,000 acre-feet project. Maximum installation.		Maximum water surface, 405.5. 800,000 acre-feet project. Maximum installation.
	100,000 h.p. *57.5%	105,000 h.p. *53.5%	100,000 h.p. *56%	105,000 h.p. *53%	110,000 h.p. *53%
1895-96	527,720	549,520	534,530	554,130	584,950
1896-97	586,980	609,030	596,990	621,490	652,550
1897-98	518,970	528,070	497,940	508,840	565,200
1898-99	507,020	517,540	512,660	523,560	550,450
1899-00	568,870	587,930	581,430	602,230	632,900
1900-01	548,350	568,900	551,200	570,400	600,500
1901-02	543,030	559,380	548,570	567,770	596,450
1902-03	581,560	603,900	580,480	602,280	633,720
1903-04	599,280	620,530	600,500	626,650	659,350
1904-05	621,140	645,640	625,730	652,980	685,800
1905-06	526,480	548,280	534,030	554,380	581,500
1906-07	574,210	598,710	586,040	608,840	606,650
1907-08	566,700	588,500	579,130	600,930	620,100
1908-09	526,230	548,030	537,370	556,470	582,800
1909-10	586,540	610,040	588,440	610,690	642,050
1910-11	540,000	560,800	557,220	576,320	603,950
1911-12	528,380	547,440	598,870	617,970	584,300
1912-13	562,710	584,510	577,480	599,280	628,950
1913-14	561,680	585,080	564,980	586,780	616,300
1914-15	556,300	578,000	566,180	587,330	616,520
1915-16	558,020	579,820	560,980	582,780	612,050
1916-17	530,960	549,100	546,710	562,120	588,750
1917-18	454,230	462,560	465,980	474,150	497,700
1918-19	503,810	520,170	508,160	522,710	551,000
1919-20	365,200	367,920	385,160	387,880	410,200
1920-21	581,680	602,680	583,530	605,330	637,150
1921-22	489,120	502,740	504,150	517,750	544,300
1922-23	476,380	485,580	500,490	507,580	531,700
1923-24	290,570	290,570	313,700	313,700	334,970
Average annual	530,420	548,520	540,990	558,740	584,890

*Average percentage of time during which water is available to operate plant to full capacity.

TABLE 22. IRON CANYON PROJECT.

Irrigation draft 800,000 acre-feet. Maximum reservoir elevation 405.5. Maximum installation 105,000 horsepower and 110,000 horsepower. Primary power output in October 44,000 horsepower.

Iron Canyon Only—Quantities in Horsepower.

Month	1915-1916			1919-1920			1923-1924		
	Potential output*	Primary demand	Primary demand + pumping load	Potential output	Primary demand	Primary demand + pumping load	Potential output	Primary demand	Primary demand + pumping load
October	45,360	44,000	45,360	45,360	44,000	45,360	45,360	44,000	45,360
November	41,000	41,000	41,000	41,000	41,000	41,000	41,000	41,000	41,000
December	202,000	41,600	41,600	41,600	41,600	41,600	41,600	41,000	41,600
January	352,000	38,600	38,600	38,600	38,600	38,600	38,600	38,600	38,600
February	515,000	38,600	38,600	38,600	38,600	38,600	38,600	38,600	38,600
March	382,000	41,000	41,340	50,000	41,000	41,340	41,340	41,000	41,340
April	224,000	40,400	42,150	153,000	40,400	42,250	42,150	40,400	42,150
May	147,000	52,300	57,730	88,200	52,300	57,730	72,400	52,300	57,730
June	115,000	64,300	71,300	91,200	64,300	71,300	73,700	64,300	71,300
July	118,000	67,800	75,270	81,600	67,800	75,270	70,700	67,800	75,270
August	98,400	67,300	74,100	70,600	67,300	74,100	62,800	67,300	74,100
September	62,700	57,600	61,790	56,000	57,600	61,790	43,300	57,600	61,790
Average	....	49,500	....	....	49,500	....	....	49,500	....

*On the graphs prepared from the above tables the maximum output for water surface at elevation 400 is shown as 100,000 horsepower and for water surface at elevation 405.5 the maximum output is shown as 105,000 and 110,000 horsepower.

TABLE 24. IRON CANYON PROJECT.

Irrigation draft 800,000 acre-feet. Maximum reservoir elevation 405.5. Maximum installation 105,000 horsepower, and 110,000 horsepower at Iron Canyon, and 10,400 horsepower at Mooney Island, total 115,400 and 120,400 horsepower. Primary power based on 44,000 horsepower at Iron Canyon in October and 9000 at Mooney Island. October output= 53,000 horsepower + 1360 horsepower pumping load.

Iron Canyon and Mooney Island Combined—Quantities in Horsepower.

Month	1915-1916			1919-1920			1923-1924		
	Potential output*	Primary demand	Primary demand + pumping load	Potential output	Primary demand	Primary demand + pumping load	Potential output	Primary demand	Primary demand + pumping load
October	54,360	53,000	54,360	54,360	53,000	54,360	54,360	53,000	54,360
November	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400
December	210,500	50,100	50,100	50,100	50,100	50,100	50,100	50,100	50,100
January	359,900	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500
February	522,900	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500
March	390,400	49,400	49,740	58,400	49,400	49,740	49,740	49,400	49,740
April	232,250	48,650	50,400	161,250	48,650	50,400	50,350	48,650	50,400
May	157,260	63,000	68,430	98,460	63,000	68,430	82,660	63,000	68,430
June	125,260	77,400	84,400	101,460	77,400	84,400	83,960	77,400	84,400
July	128,260	81,600	89,070	91,860	81,600	89,070	80,960	81,600	89,070
August	108,660	81,000	87,800	80,860	81,000	87,800	73,060	81,000	87,800
September	72,250	69,400	73,590	65,550	69,400	73,590	52,850	69,400	73,590
Averages	....	59,620	....	....	59,620	....	....	59,620	....

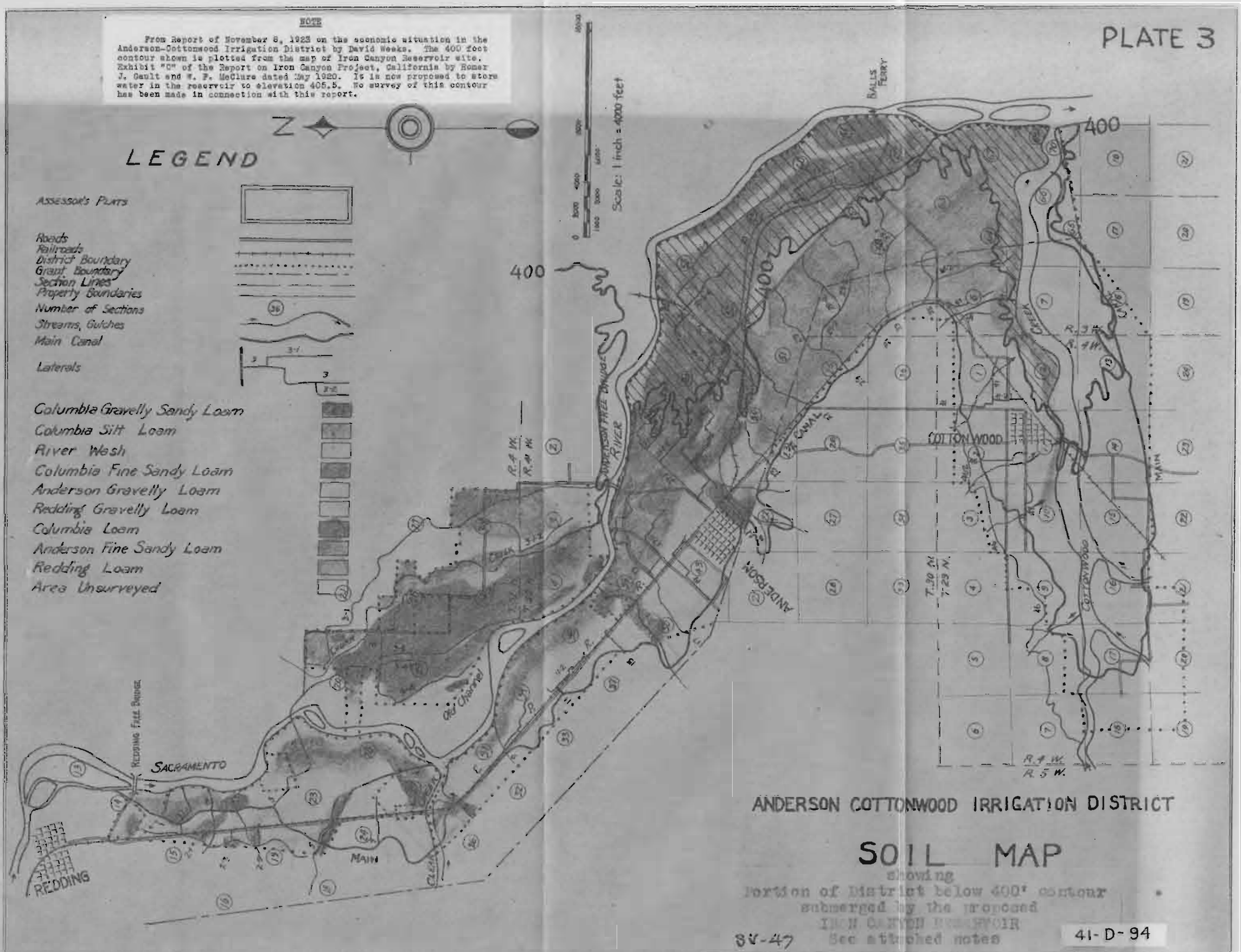
*On the graphs prepared from the above table, the maximum output for water surface at elevation 400 is shown as 110,400 horsepower, and for maximum water surface at elevation 405.5 the maximum output is shown as 115,400 and 120,400 horsepower.

Iron Canyon Project—California.

PHOTOGRAPHS.*

Numbers at the side of the sheet are those by which the films on file in the Commissioner's office, Bureau of Reclamation, Washington, D. C., are known. If additional prints are desired, order should be by number, thus: Iron Canyon 10.

*Not included in printed report.


NOTE
From Report of November 8, 1923 on the economic situation in the Anderson-Cottonwood Irrigation District by David Weeks. The 400 foot contour shown is plotted from the map of Iron Canyon Reservoir site, Exhibit "C" of the Report on Iron Canyon Project, California by Homer J. Gault and W. F. McClure dated May 1920. It is now proposed to store water in the reservoir to elevation 405.5. No survey of this contour has been made in connection with this report.
PLATE 3
LEGEND
Assessor's Plats
Roads
Railroads
District Boundary
Grant Boundary
Section Lines
Property Boundaries
Number of Sections
Streams, Gulches
Main Canal
Laterals
Columbia Gravelly Sandy Loam
Columbia Silt Loam
River Wash
Columbia Fine Sandy Loam
Anderson Gravelly Loam
Redding Gravelly Loam
Columbia Loam
Anderson Fine Sandy Loam
Redding Loam
Area Unsurveyed
Scale: 1 inch = 4000 feet
400
BALLS FERRY
SACRAMENTO
REDDING FREE BRIDGE
ANDERSON FREE BRIDGE
RIVER
ANDERSON
COTTONWOOD
COTTONWOOD
CREEK
MAIN
Old Channel
REDDING
R.4 W.
R.5 W.
R.3 W.
R.4 W.
T.30 N.
T.29 N.
ANDERSON COTTONWOOD IRRIGATION DISTRICT
SOIL MAP
showing
Portion of District below 400' contour
submerged by the proposed
IRON CANYON RESERVOIR
See attached notes
SV-47
41-D-94

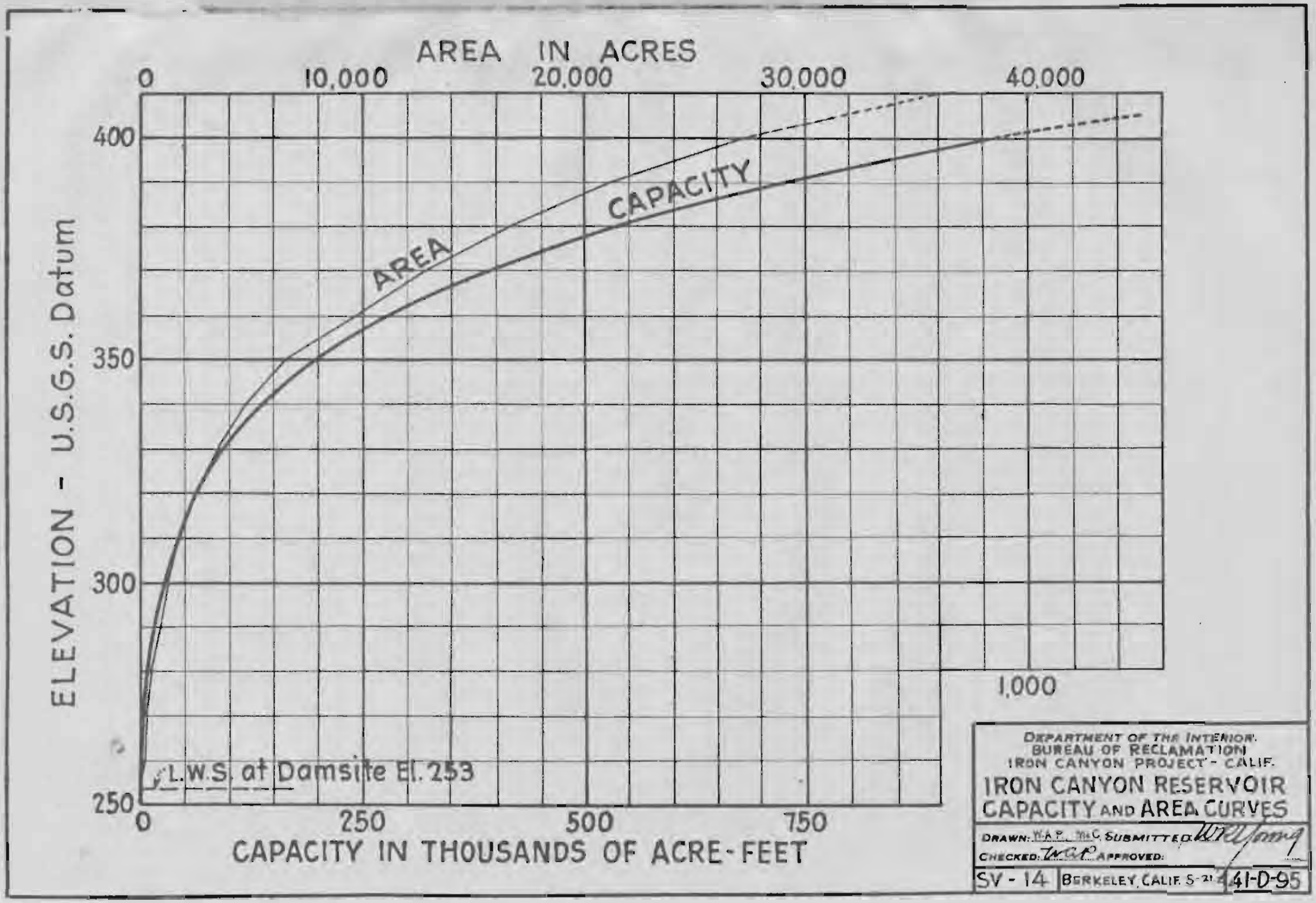

AREA IN ACRES
0
10,000
20,000
30,000
40,000
1,000
ELEVATION - U.S.G.S. Datum
400
350
300
250
AREA
CAPACITY
L.W.S. at Damsite El. 253
0
250
500
750
CAPACITY IN THOUSANDS OF ACRE-FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF.
IRON CANYON RESERVOIR
CAPACITY AND AREA CURVES
DRAWN: W.A.P. W.L.C. SUBMITTED:
CHECKED: W.A.P. APPROVED:
SV - 14
BERKELEY, CALIF.
41-D-95

PLATE 4

PLATE 5

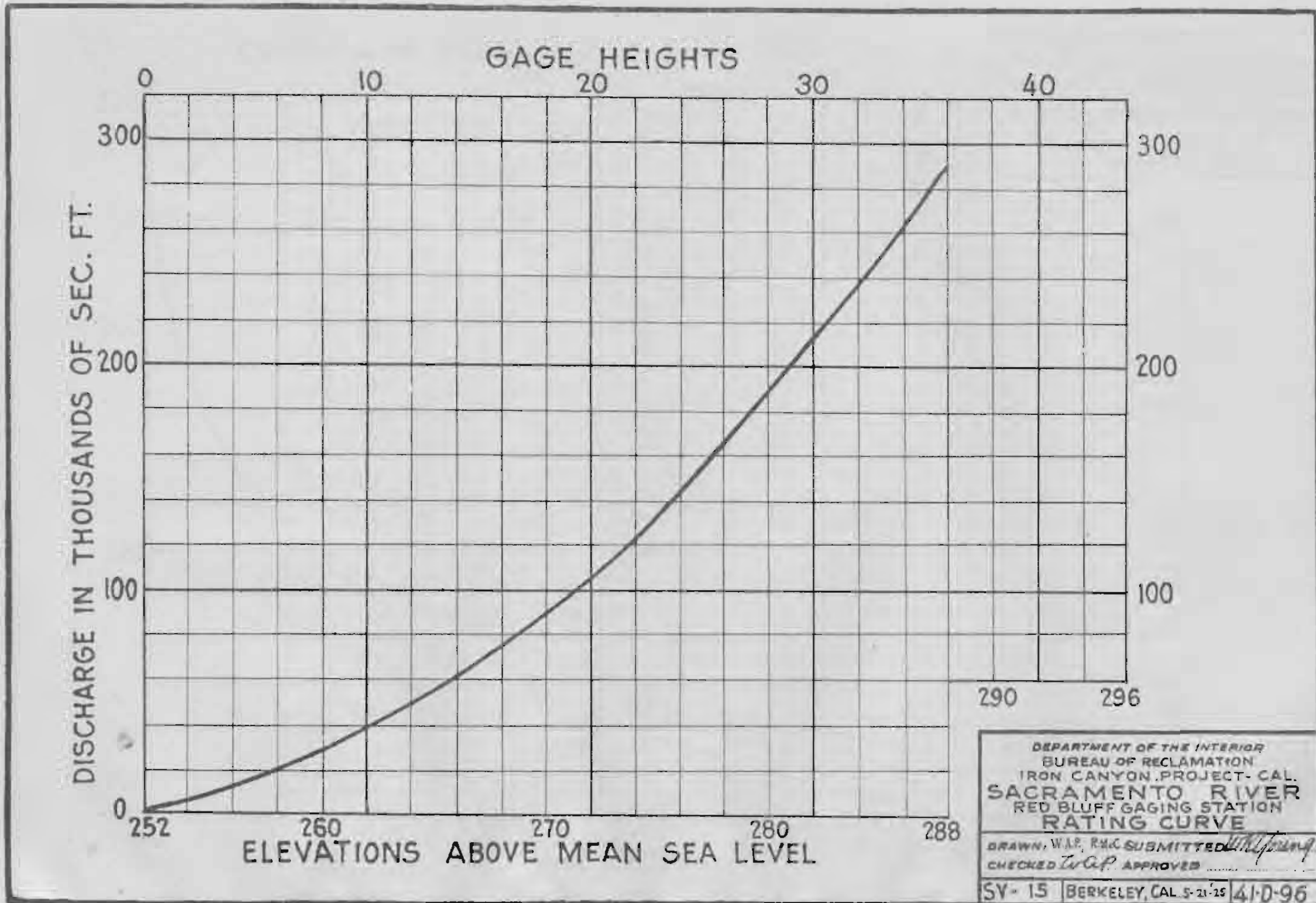
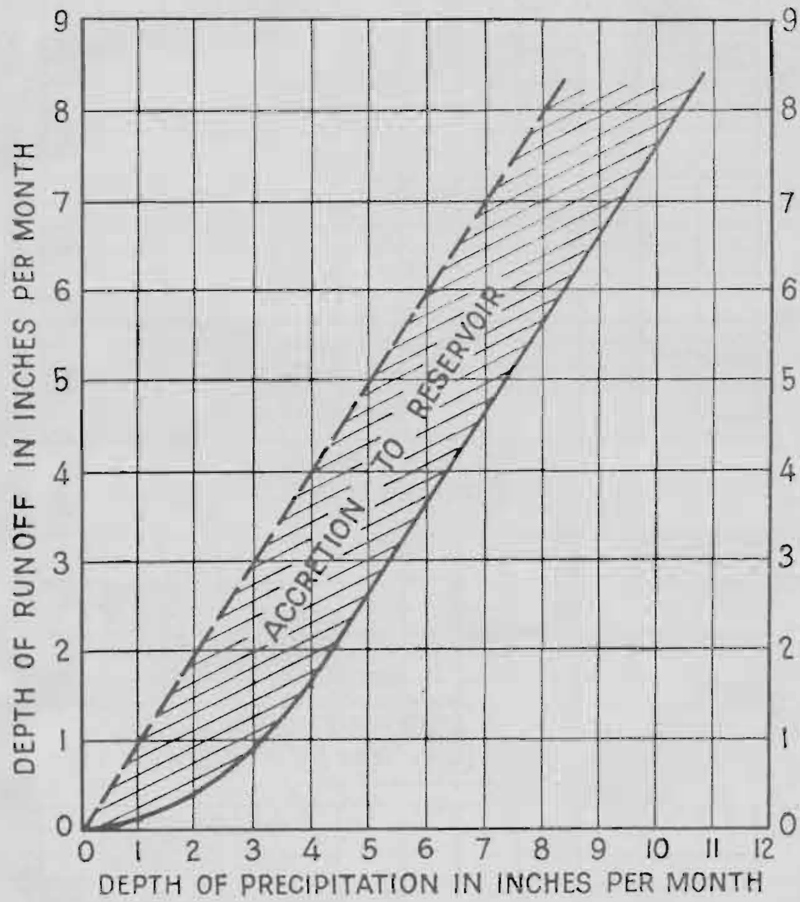

GAGE HEIGHTS
0
10
20
30
40
300
200
100
0
DISCHARGE IN THOUSANDS OF SEC. FT.
252
260
270
280
288
290
296
ELEVATIONS ABOVE MEAN SEA LEVEL
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CAL.
SACRAMENTO RIVER
RED BLUFF GAGING STATION
RATING CURVE
DRAWN: W.A.P. R.M.C. SUBMITTED
CHECKED APPROVED
SV-15
BERKELEY, CAL. 5-21-25
41-D-96

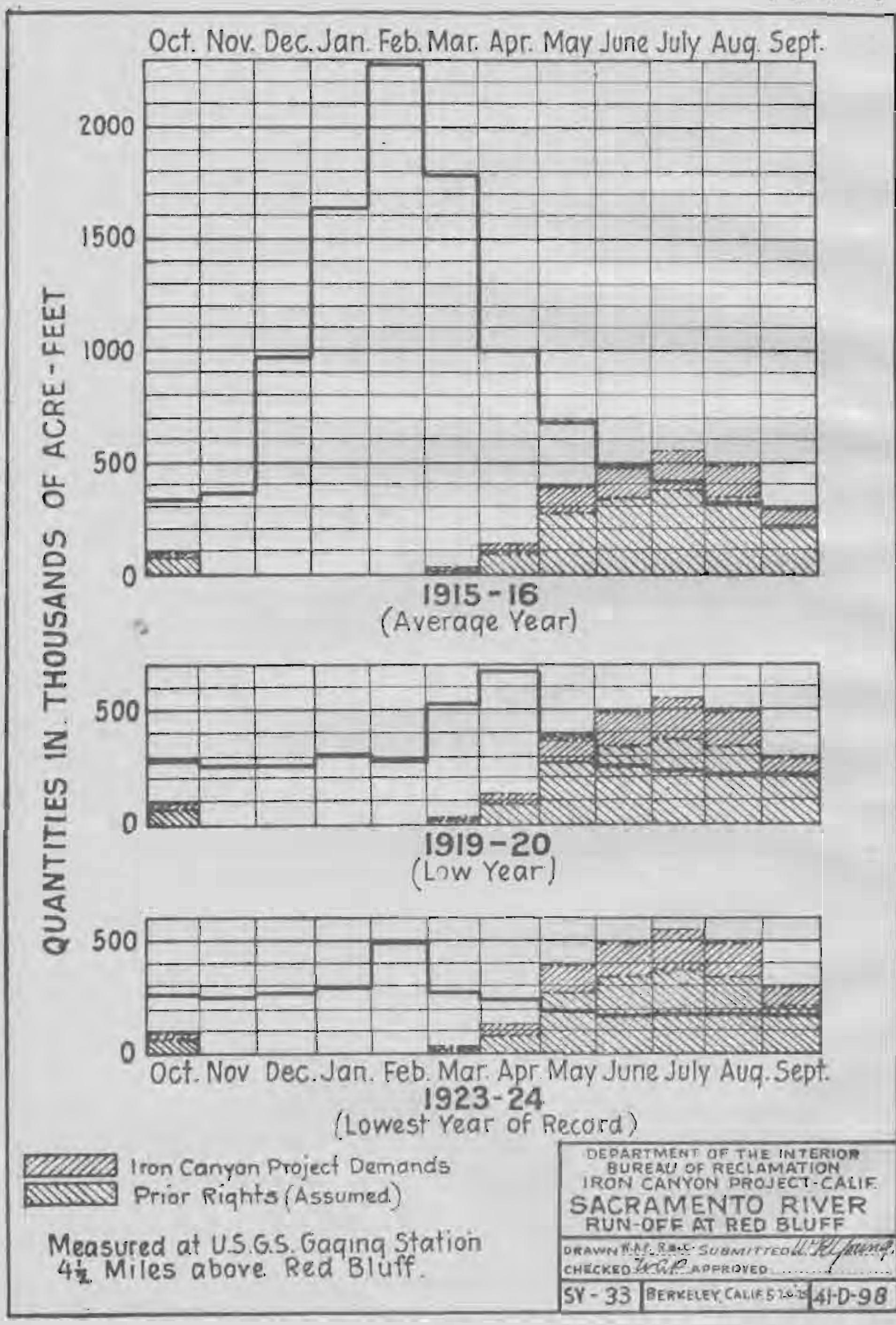
PLATE 6

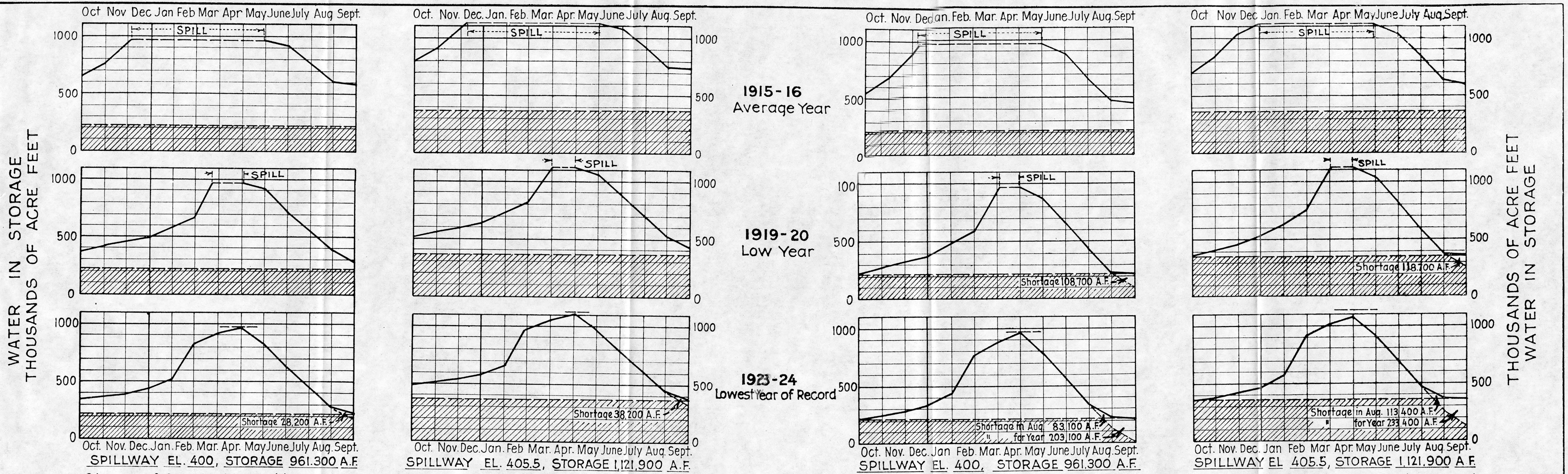


FROM RAINFALL-RUNOFF CURVE BY C.E.GRUNSKY. SEE PAGE 85, VOLUME LXXXV, TRANSACTIONS A.S.C.E. FOR 1922. ORIGINAL CURVE HAS BEEN CONVERTED TO RAINFALL AND RUNOFF BY MONTHS.

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT CALIFORNIA
IRON CANYON RESERVOIR
RAINFALL-RUNOFF CURVE
DRAWN W.A.P. R.M.C. SUBMITTED
CHECKED APPROVED
SV-40 | BERKELEY, CALIF. 6-19-'25 | 41-D-97

PLATE 7


Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept.
QUANTITIES IN THOUSANDS OF ACRE-FEET
2000
1500
1000
500
0
1915-16
(Average Year)
500
0
1919-20
(Low Year)
500
0
Oct. Nov Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept.
1923-24
(Lowest Year of Record)
Iron Canyon Project Demands
Prior Rights (Assumed)
Measured at U.S.G.S. Gaging Station
4½ Miles above Red Bluff.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIF.
SACRAMENTO RIVER
RUN-OFF AT RED BLUFF
DRAWN
SUBMITTED
CHECKED
APPROVED
SY-33
BERKELEY, CALIF.
41-D-98



SPILLWAY EL. 400, STORAGE 961,300 A.F.

Storage of 214,000 Acre-Feet below El. 353 is reserved to create minimum power head of 100 ft.

SPILLWAY EL. 405.5, STORAGE 1,121,900 A.F.

Storage of 364,600 Acre-Feet below El. 368 is reserved to create minimum power head of 115 ft.

SPILLWAY EL. 400, STORAGE 961,300 A.F.

Storage of 214,000 Acre-Feet below El. 353 is reserved to create minimum power head of 100 ft.

SPILLWAY EL 405.5, STORAGE 1,121,900 A.F.

Storage of 364,600 Acre-Feet below El 368 is reserved to create minimum power head of 115 ft

To produce a uniform output of power and to supply water required for navigation and prior rights, the discharge, till reservoir is filled, is assumed equivalent to 4200 c.f.s. times the indicated minimum heads $Q = \frac{4200 \times 100 \text{ or } 115}{\text{Available Head}}$

$Q = \frac{3600 \times 100 \text{ or } 115}{\text{Available Head}}$ To produce a uniform output of power and to supply water required for navigation and prior rights, the discharge, till reservoir is filled, is assumed equivalent to 3600 c.f.s. times the indicated minimum heads

GROSS ANNUAL PROJECT DEMAND - 800,000 ACRE-FEET

GROSS ANNUAL PROJECT DEMAND - 1,000,000 ACRE-FEET

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF.
IRON CANYON RESERVOIR
GRAPHS OF OPERATION
DRAWN SUBMITTED
CHECKED APPROVED
SV-11 BERKELEY, CAL 5-23-25 41-D-99

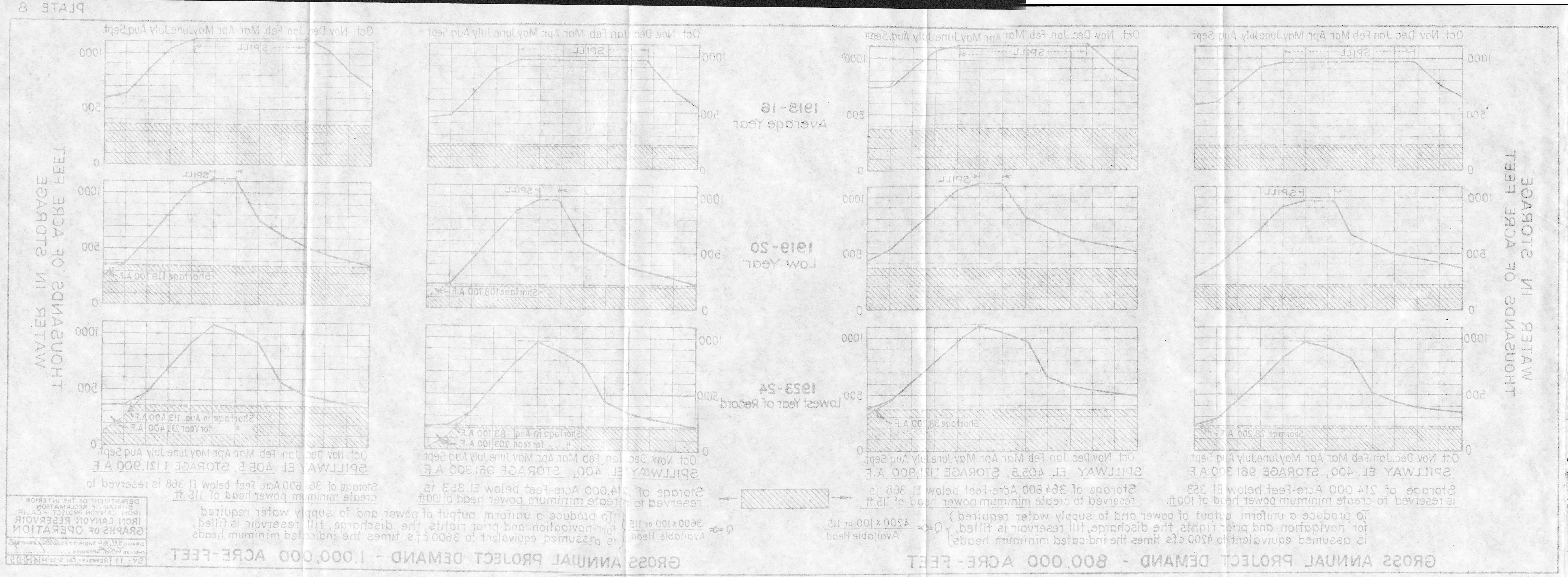
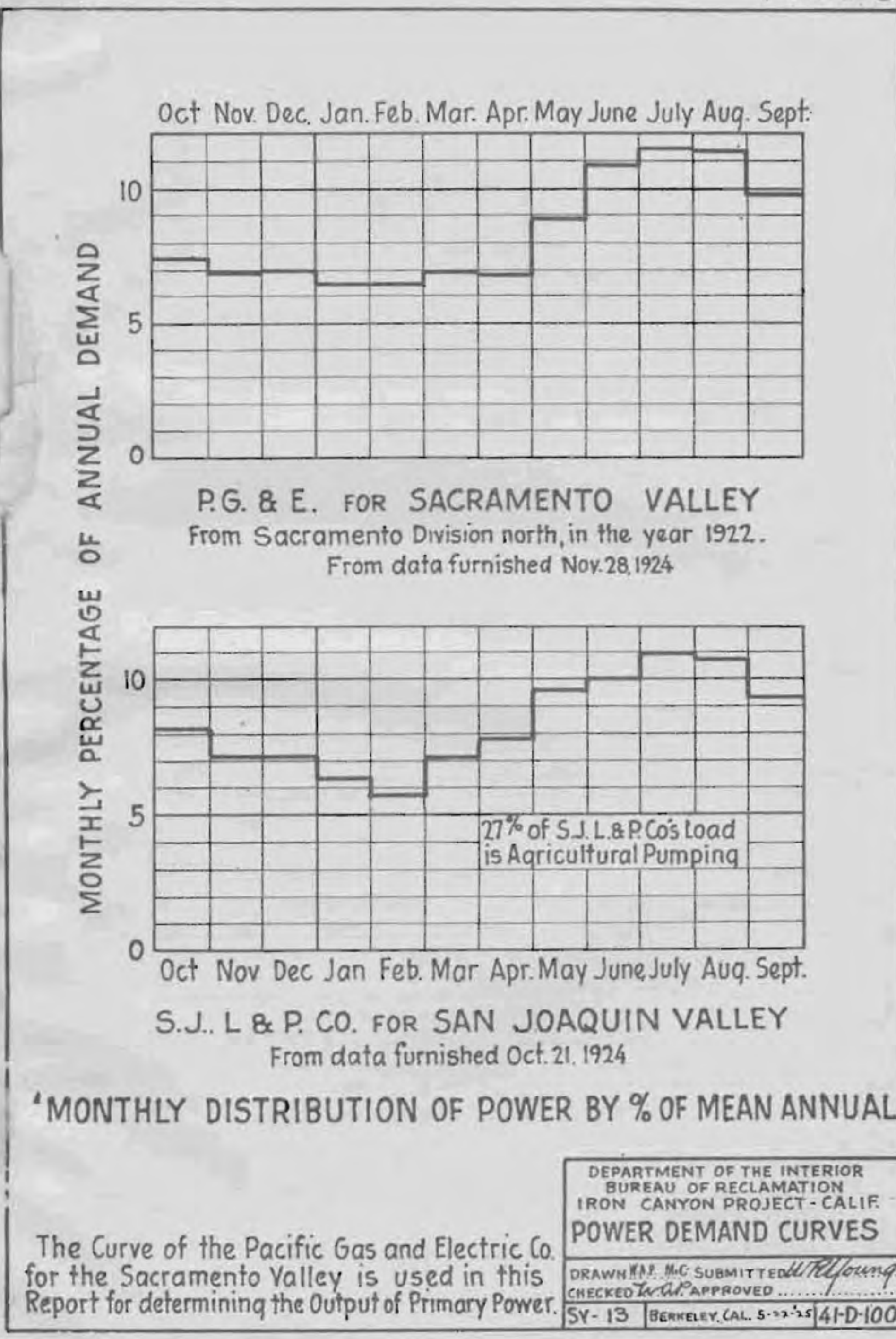
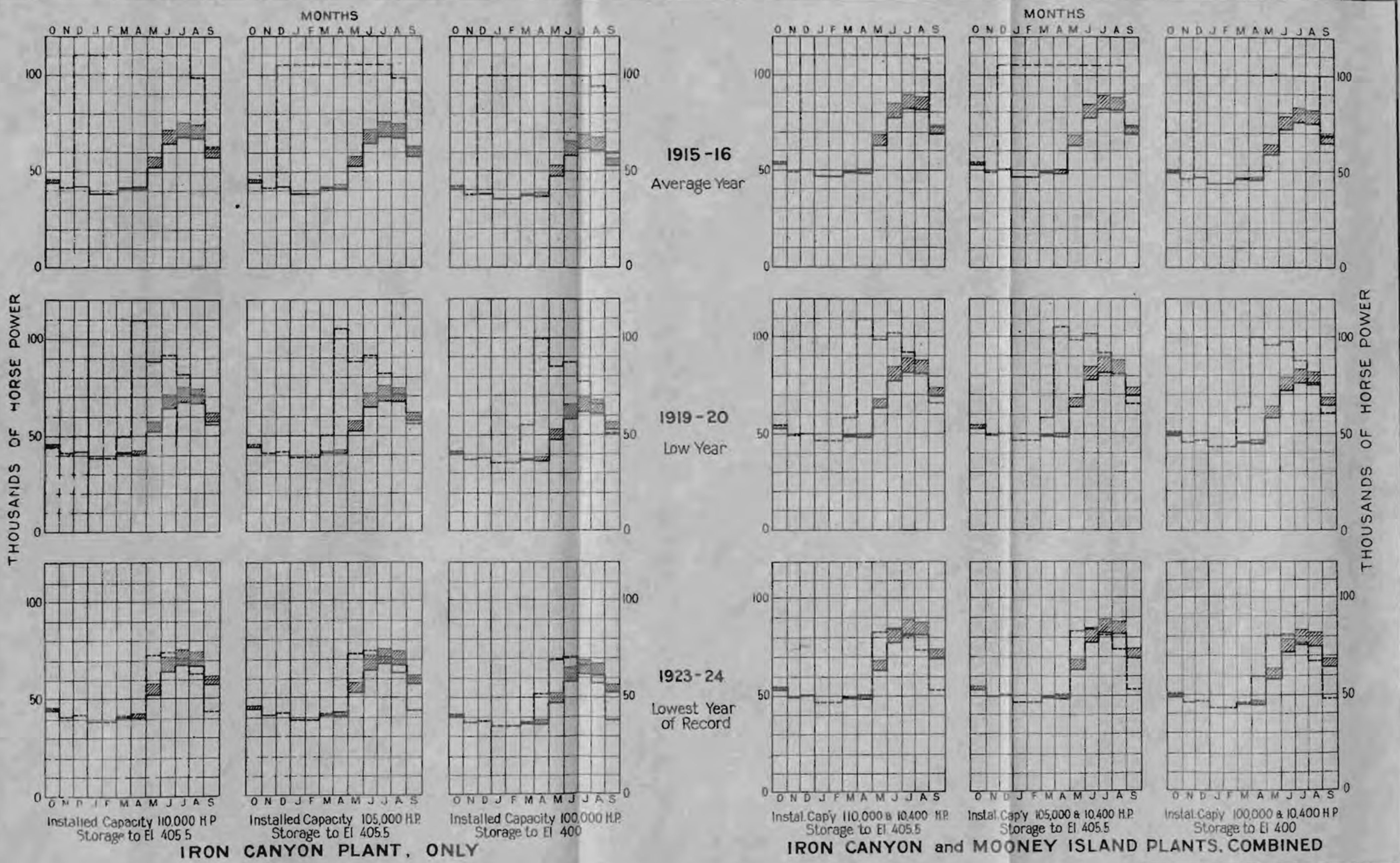


PLATE 8
WATER IN STORAGE
THOUSANDS OF ACRE FEET
Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept.
1000
500
0
SPILL
1915-16
Average Year
1919-20
Low Year
1923-24
Lowest Year of Record
Shortage 28,200 A.F.
Shortage 38,100 A.F.
Shortage 108,100 A.F.
Shortage 118,100 A.F.
Shortage in Aug. 83,100 A.F.
for Year 203,100 A.F.
Shortage in Aug. 113,400 A.F.
for Year 233,400 A.F.
SPILLWAY EL. 400, STORAGE 961,300 A.F.
SPILLWAY EL. 405.5, STORAGE 1,121,900 A.F.
Storage of 214,000 Acre-Feet below El. 353 is reserved to create minimum power head of 100 ft.
Storage of 364,600 Acre-Feet below El. 368 is reserved to create minimum power head of 115 ft.
To produce a uniform output of power and to supply water required for navigation and prior rights, the discharge, fill reservoir is filled, is assumed equivalent to 4200 c.f.s. times the indicated minimum heads
$Q = \frac{4200 \times 100 \text{ or } 115}{\text{Available Head}}$
To produce a uniform output of power and to supply water required for navigation and prior rights, the discharge, fill reservoir is filled, is assumed equivalent to 3600 c.f.s. times the indicated minimum heads
$Q = \frac{3600 \times 100 \text{ or } 115}{\text{Available Head}}$
GROSS ANNUAL PROJECT DEMAND - 800,000 ACRE-FEET
GROSS ANNUAL PROJECT DEMAND - 1,000,000 ACRE-FEET
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF.
IRON CANYON RESERVOIR
GRAPHS OF OPERATION

PLATE 9


Oct Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sept.
MONTHLY PERCENTAGE OF ANNUAL DEMAND
10
5
0
P.G. & E. FOR SACRAMENTO VALLEY
From Sacramento Division north, in the year 1922.
From data furnished Nov. 28, 1924
10
5
0
27% of S.J. L.& P. Co's Load is Agricultural Pumping
Oct Nov Dec Jan Feb. Mar Apr. May June July Aug. Sept.
S.J. L & P. CO. FOR SAN JOAQUIN VALLEY
From data furnished Oct. 21. 1924
MONTHLY DISTRIBUTION OF POWER BY % OF MEAN ANNUAL
The Curve of the Pacific Gas and Electric Co. for the Sacramento Valley is used in this Report for determining the Output of Primary Power.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF.
POWER DEMAND CURVES
SY-13
BERKELEY, CAL. 5-22-25
41-D-100



LEGEND

——— Primary Power, based on demand curve of Pacific Gas and Electric Co. for Sacramento Valley is limited to the maximum output that can be secured in a season like 1923-24 with the assurance that the reservoir will fill

– – – Estimated Output Iron Canyon Project Power Plants.

▨ Estimated Pumping Load for Iron Canyon Project

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT CALIFORNIA

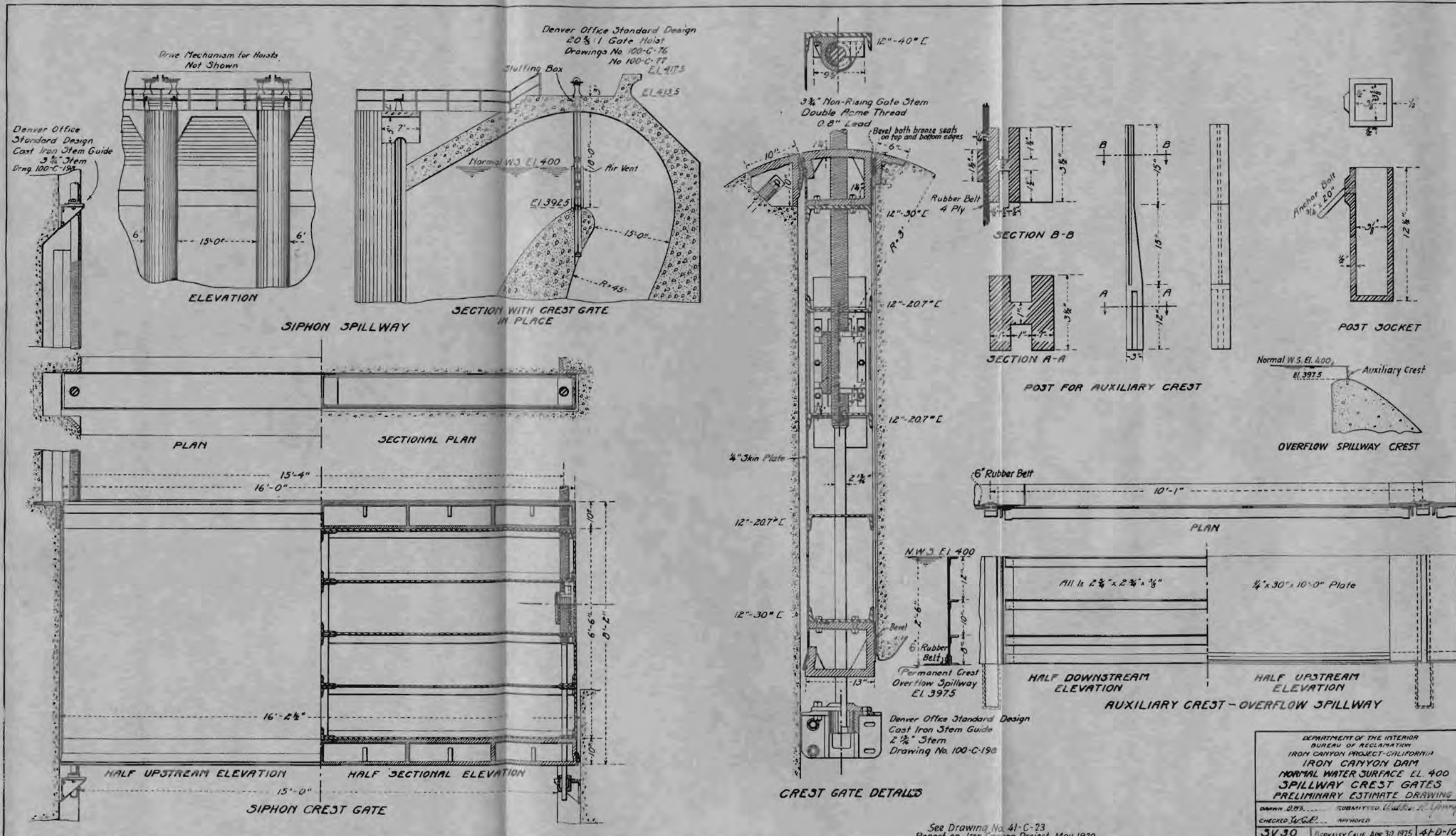
POWER CURVES

IRRIGATION DRAFT 800,000 AC.FT.

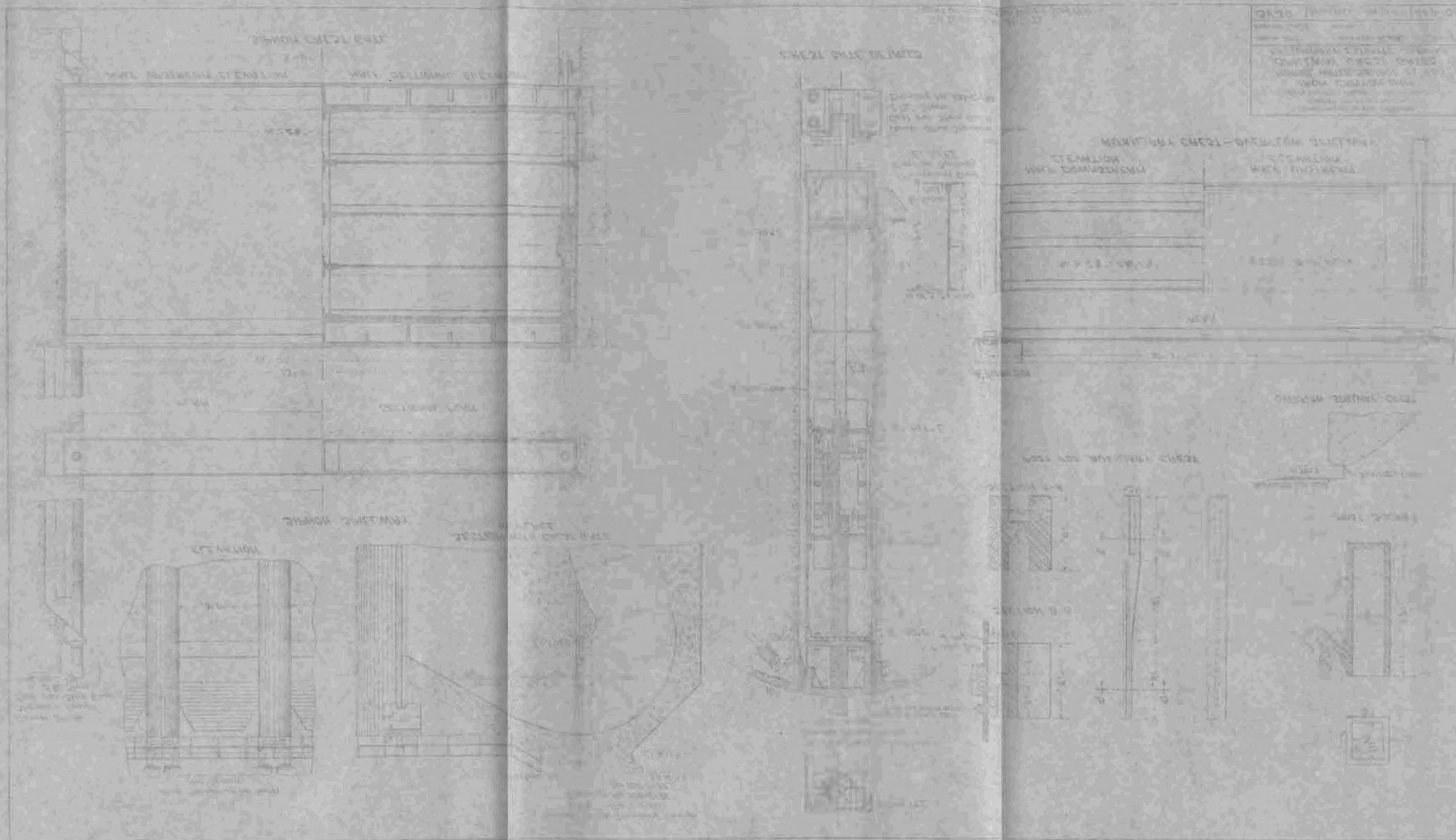
DRAWN W.A.R. R.McC. SUBMITTED Walker R. Young
CHECKED C.G.P. APPROVED

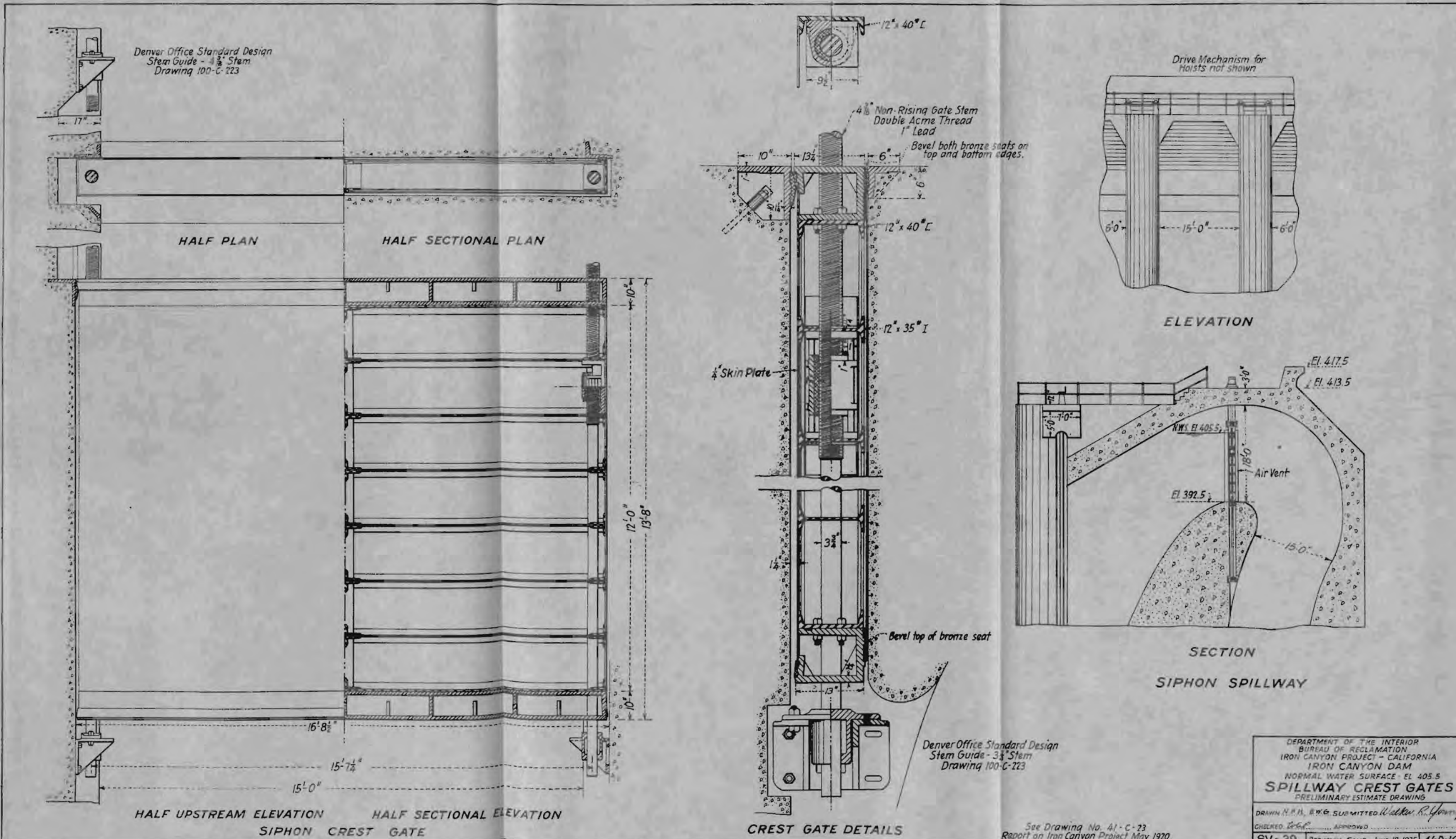
SV - 12	Berkeley, Calif., June 16, 1925	41-D-101

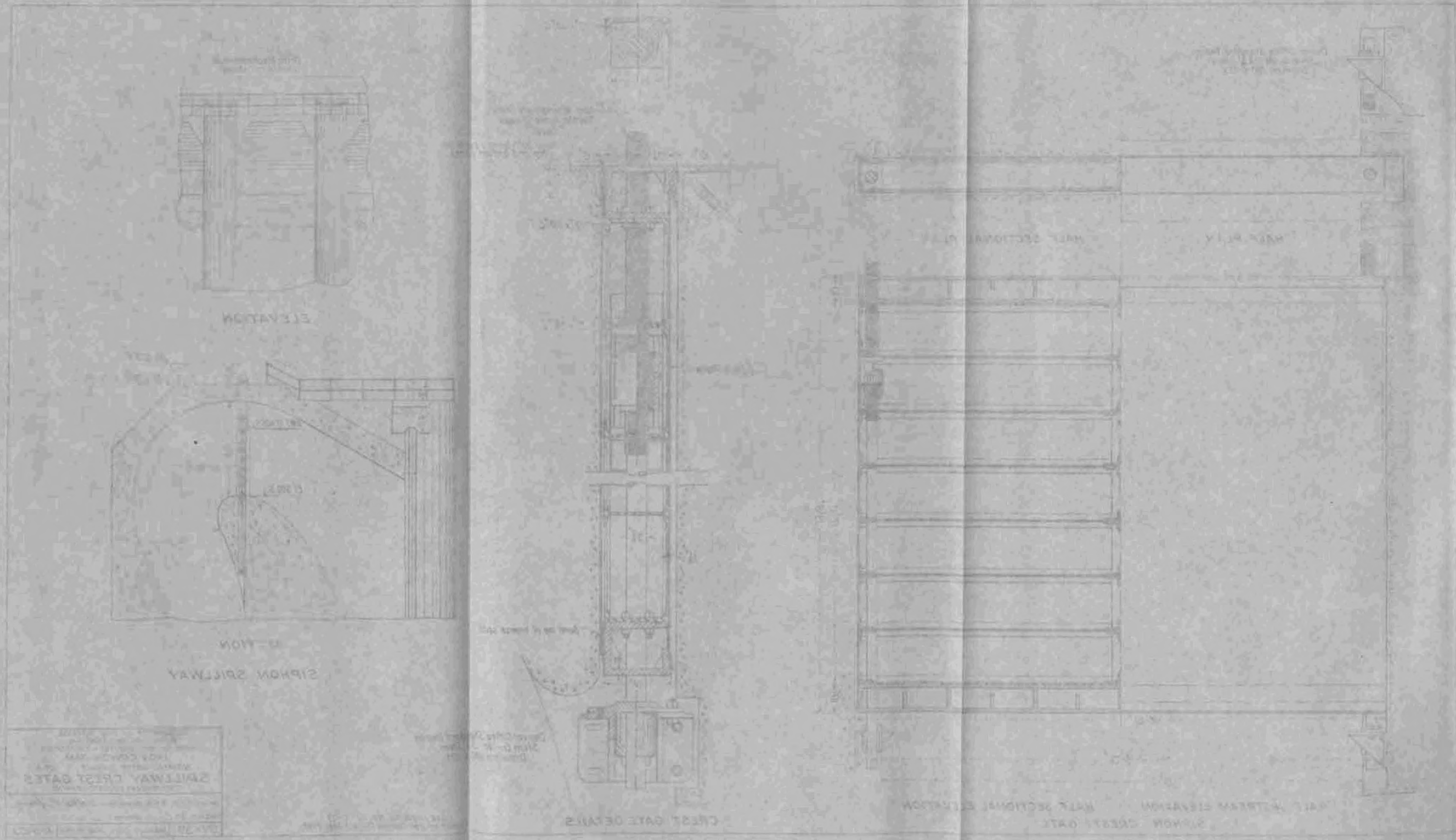
PLATE II

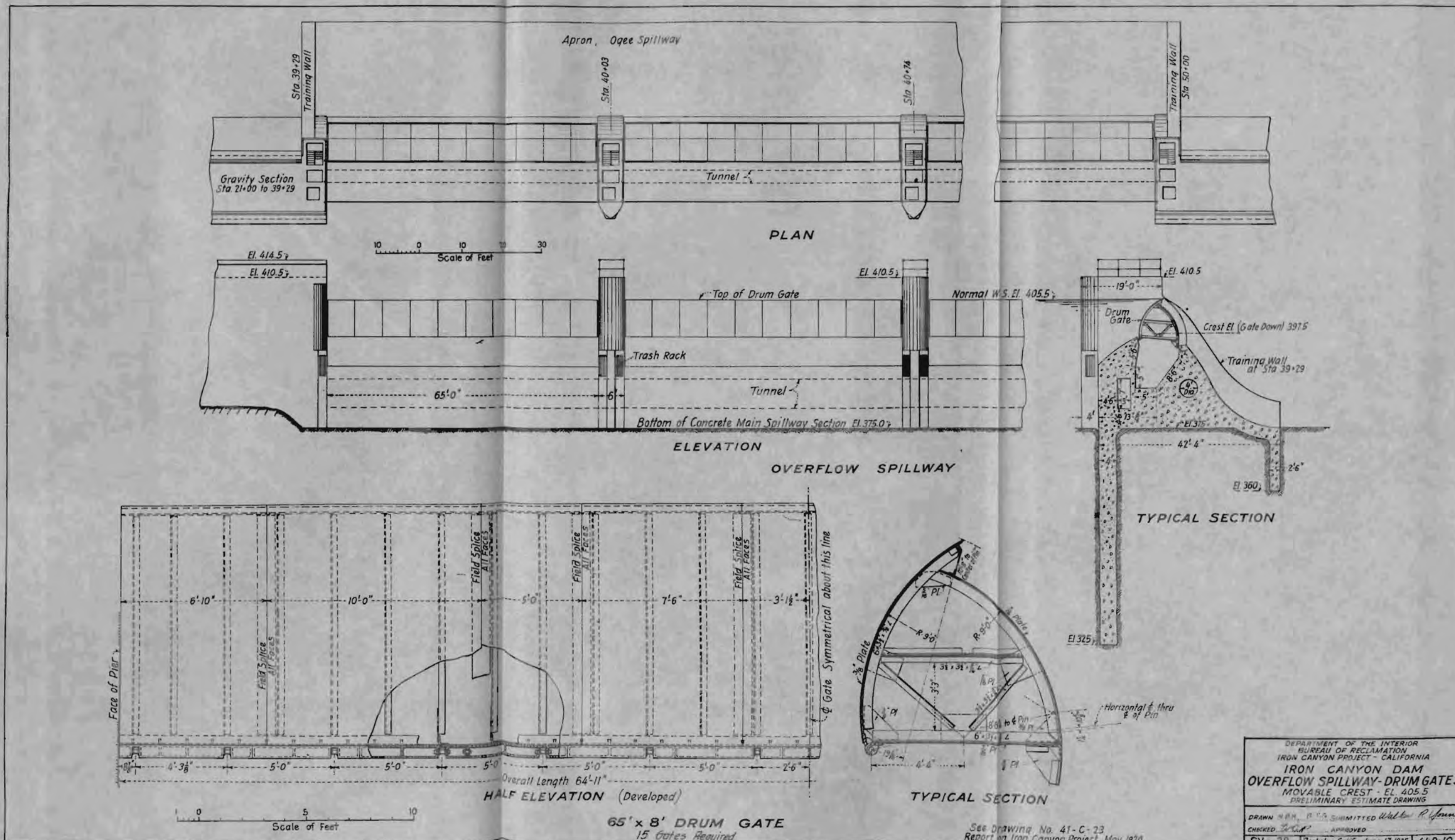


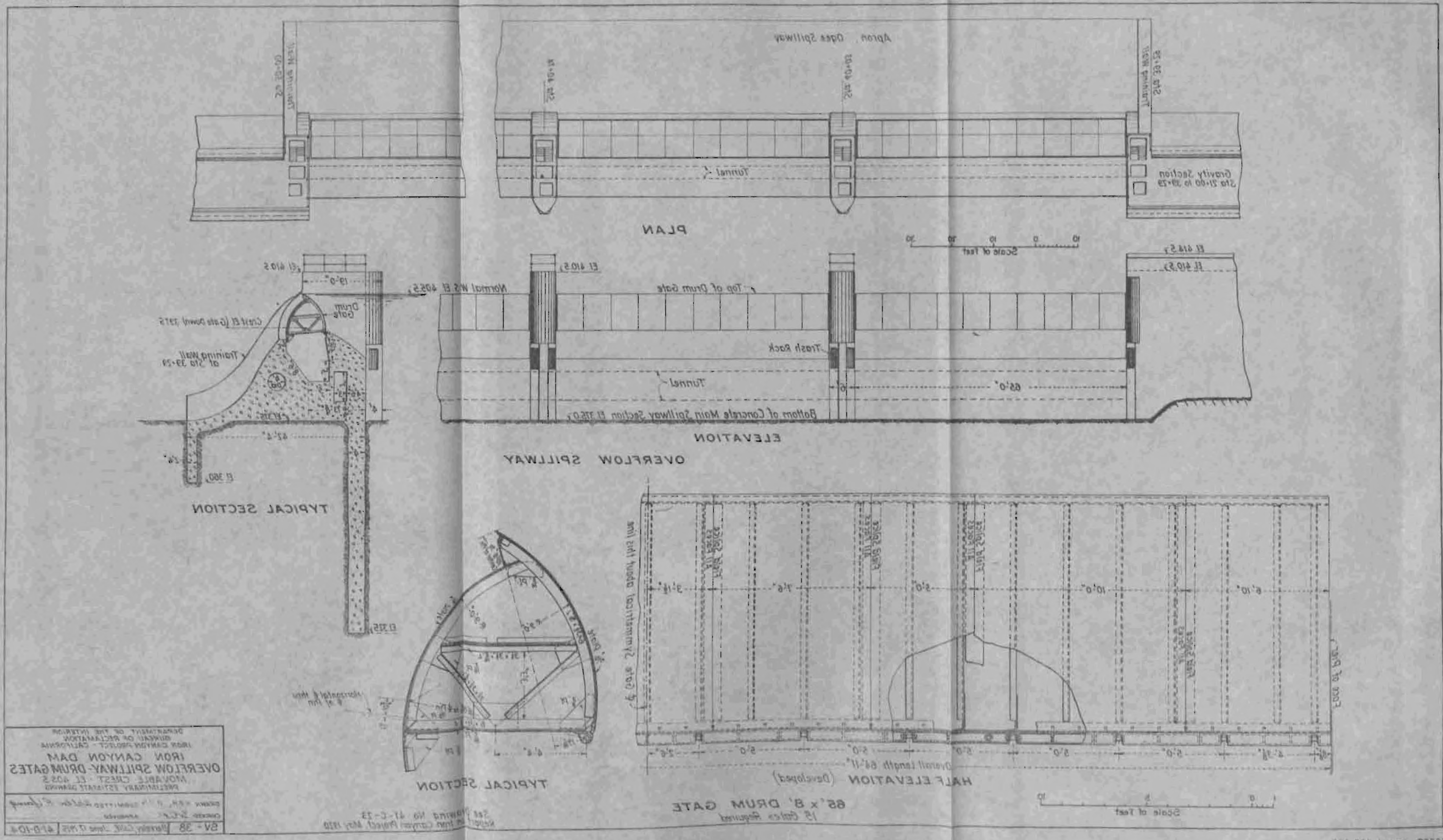
Drive Mechanism for Hoists Not Shown
Denver Office Standard Design 20⅝:1 Gate Hoist Drawings No. 100-C-76 No 100-C-77
Stuffing Box
El. 417.5
El. 413.5
Denver Office Standard Design Cast Iron Stem Guide 3¾" Stem Drng. 100-C-198
Normal W.S. El. 400
Air Vent
El. 392.5
15'-0"
R=45'
10'-0"
ELEVATION
SECTION WITH CREST GATE IN PLACE
SIPHON SPILLWAY
PLAN
SECTIONAL PLAN
15'-4"
16'-0"
16'-2½"
15'-0"
HALF UPSTREAM ELEVATION
HALF SECTIONAL ELEVATION
SIPHON CREST GATE
12"-40# C
3¾" Non-Rising Gate Stem Double Acme Thread 0.8" Lead
Bevel both bronze seats on top and bottom edges
12"-30# C
12"-20.7# C
¼" Skin Plate
R=3'
Bevel
6" Rubber Belt
N.W.S. El. 400
Permanent Crest Overflow Spillway El. 397.5
Denver Office Standard Design Cast Iron Stem Guide 2¾" Stem Drawing No. 100-C-198
CREST GATE DETAILS
Rubber Belt 4 Ply
SECTION B-B
SECTION A-A
POST FOR AUXILIARY CREST
Anchor Bolt ¾" x 20"
POST SOCKET
Normal W.S. El. 400
El. 397.5
Auxiliary Crest
OVERFLOW SPILLWAY CREST
6" Rubber Belt
10'-1"
PLAN
All Ls 2¾" x 2¾" x ⅜"
¼" x 30" x 10'-0" Plate
HALF DOWNSTREAM ELEVATION
HALF UPSTREAM ELEVATION
AUXILIARY CREST – OVERFLOW SPILLWAY
See Drawing No. 41-C-23 Report on Iron Canyon Project, May 1920.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
IRON CANYON DAM
NORMAL WATER SURFACE EL. 400
SPILLWAY CREST GATES
PRELIMINARY ESTIMATE DRAWING
DRAWN D.B.S.
SUBMITTED
CHECKED
APPROVED
3V30
BERKELEY, CALIF. APR 30, 1925
41-D-102

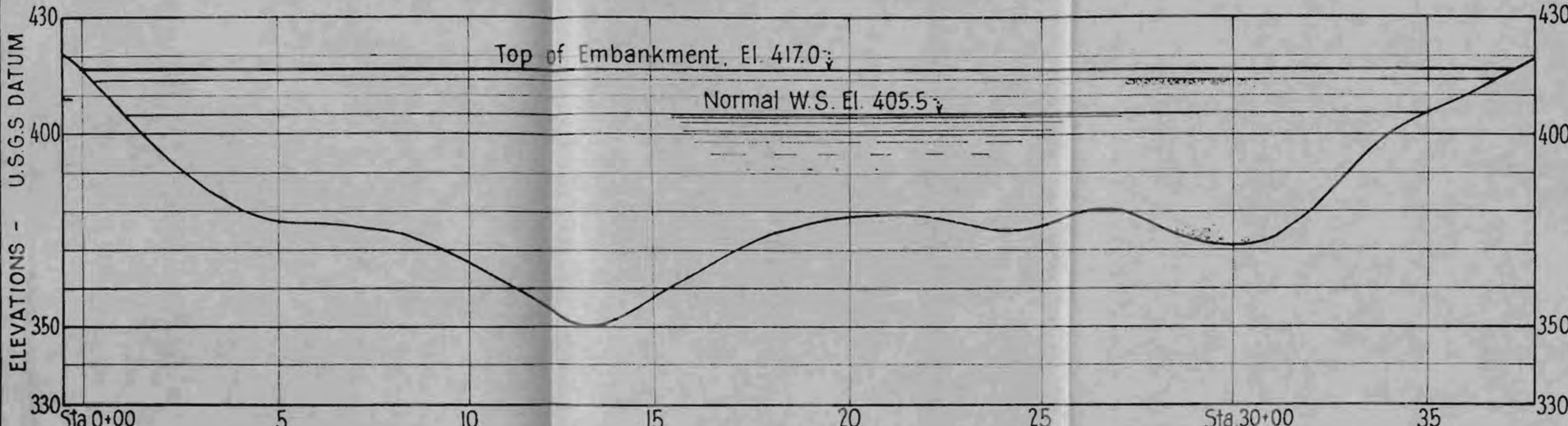



Denver Office Standard Design
Stem Guide - 4 3/4" Stem
Drawing 100-C-223
HALF PLAN
HALF SECTIONAL PLAN
HALF UPSTREAM ELEVATION
HALF SECTIONAL ELEVATION
SIPHON CREST GATE
12" x 40# C
4 3/4" Non-Rising Gate Stem
Double Acme Thread
1" Lead
Bevel both bronze seats on top and bottom edges.
12" x 40# C
12" x 35# I
1/4" Skin Plate
Bevel top of bronze seat
Denver Office Standard Design
Stem Guide - 3 3/4" Stem
Drawing 100-C-223
CREST GATE DETAILS
Drive Mechanism for Hoists not shown
ELEVATION
El. 417.5
El. 413.5
N.W.S. El. 405.5
Air Vent
El. 392.5
SECTION
SIPHON SPILLWAY
See Drawing No. 41-C-23
Report on Iron Canyon Project, May 1920
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
IRON CANYON DAM
NORMAL WATER SURFACE - EL 405.5
SPILLWAY CREST GATES
PRELIMINARY ESTIMATE DRAWING
SV-39
BERKELEY, CALIF. JUNE 18 1925
41-D-103

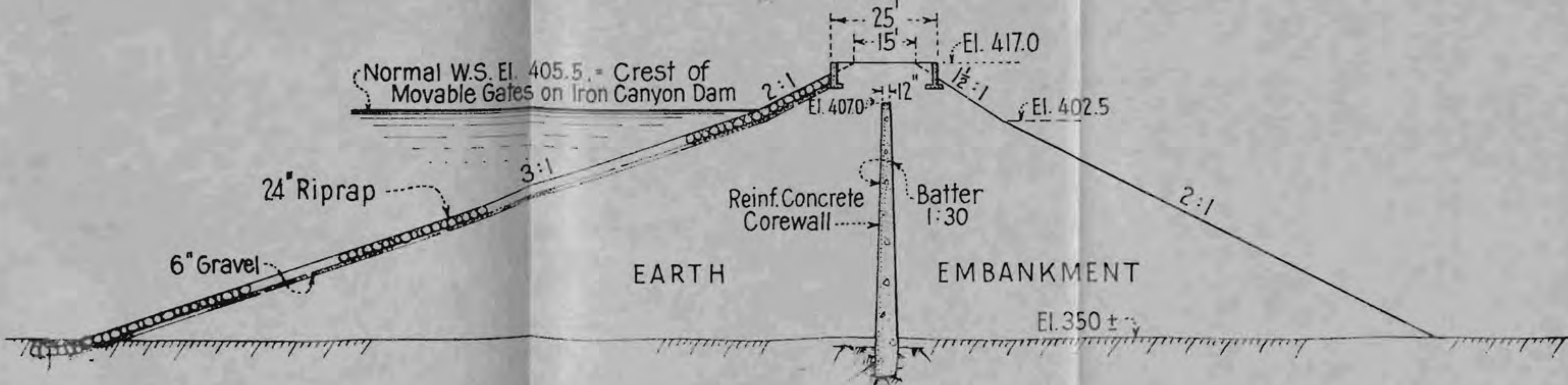



Apron, Ogee Spillway
Sta. 39+29 Training Wall
Sta. 40+03
Sta. 40+74
Training Wall Sta. 50+00
Gravity Section Sta. 21+00 to 39+29
Tunnel
PLAN
Scale of Feet
El. 414.5
El. 410.5
Top of Drum Gate
Normal W.S. El. 405.5
Trash Rack
65'-0"
Tunnel
Bottom of Concrete Main Spillway Section El. 375.0
ELEVATION
OVERFLOW SPILLWAY
El. 410.5
19'-0"
Drum Gate
Crest El. (Gate Down) 397.5
Training Wall at Sta 39+29
42'-4"
El. 360
El. 325
TYPICAL SECTION
Face of Pier
Field Splice All Faces
6'-10"
10'-0"
5'-0"
7'-6"
3'-1½"
℄ Gate Symmetrical about this line
5'-0"
2'-6"
Overall Length 64'-11"
HALF ELEVATION (Developed)
Scale of Feet
65' x 8' DRUM GATE
15 Gates Required
⅜" Plate
R.9'-0"
Horizontal ℄ thru ℄ of Pin
4'-4"
TYPICAL SECTION
See Drawing No. 41-C-23
Report on Iron Canyon Project, May 1920
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
IRON CANYON DAM
OVERFLOW SPILLWAY-DRUM GATES
MOVABLE CREST - EL. 405.5
PRELIMINARY ESTIMATE DRAWING
SUBMITTED Walter R. Young
SV-38
Berkeley, Calif. June 17 1925
41-D-104


PLAN
Apron, Ogee Spillway
Tunnel
Gravity Section Sta 21+00 to 39+29
Scale of Feet
Normal W.S. El. 405.5
Top of Drum Gate
Trash Rack
Tunnel
Bottom of Concrete Main Spillway Section El. 375.0
ELEVATION
OVERFLOW SPILLWAY
Drum Gate
Training Wall at Sta 39+29
TYPICAL SECTION
TYPICAL SECTION
HALF ELEVATION (Developed)
Overall length 64'-11"
65' x 8' DRUM GATE
15 Gates Required
Scale of Feet
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
IRON CANYON DAM
OVERFLOW SPILLWAY-DRUM GATES
MOVABLE CREST - EL 405.5
PRELIMINARY ESTIMATE DRAWING
See Drawing No. 41-C-23
Report on Iron Canyon Project May 1920



ELEVATION



ASSUMED MAXIMUM SECTION

NOTE

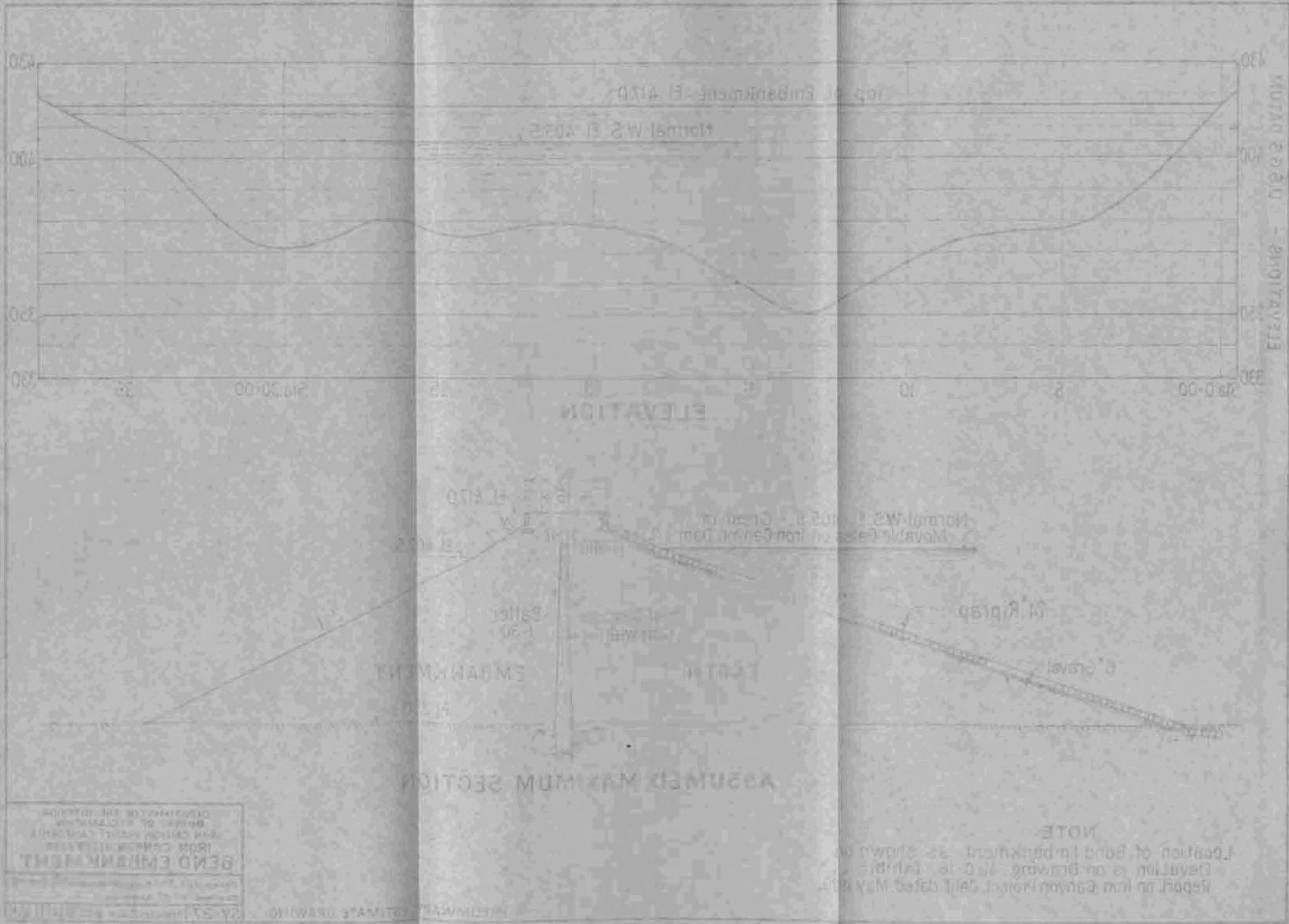
Location of Bend Embankment as shown on Elevation is on Drawing 41-C-16, Exhibit E. Report on Iron Canyon Project, Calif. dated May 1920.

PRELIMINARY ESTIMATE DRAWING

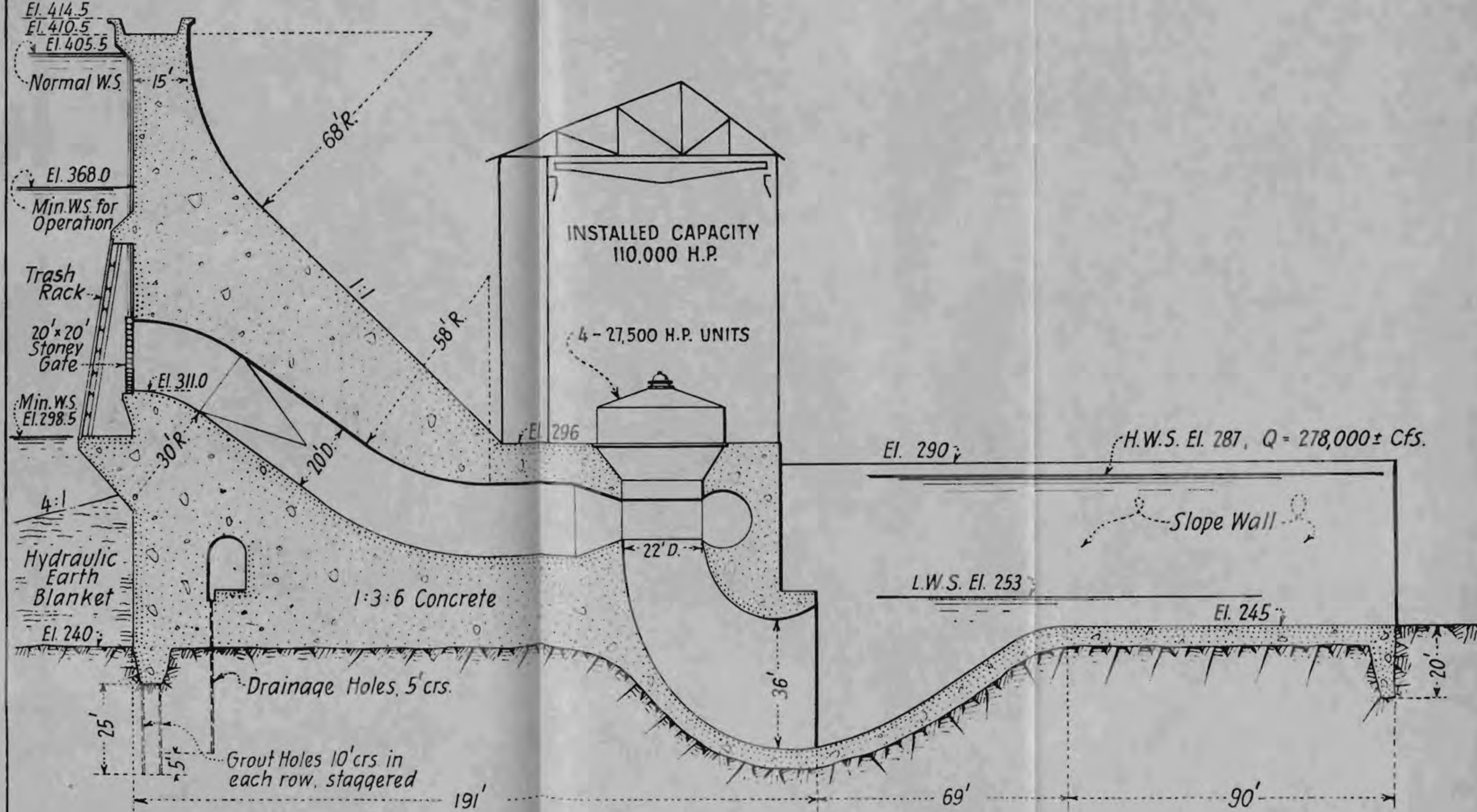
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
IRON CANYON RESERVOIR
BEND EMBANKMENT

DRAWN: N.B.H., R.M.C. SUBMITTED: W.R. Young
CHECKED: ... APPROVED: ...

SV-37 BERKELEY, CALIF., 6-22-25 41-D-105



NOTE
Location of Bend Embankment is shown on ... Elevation is on Drawing ... Exhibit ... Report on Iron Canyon Project, dated May 19..



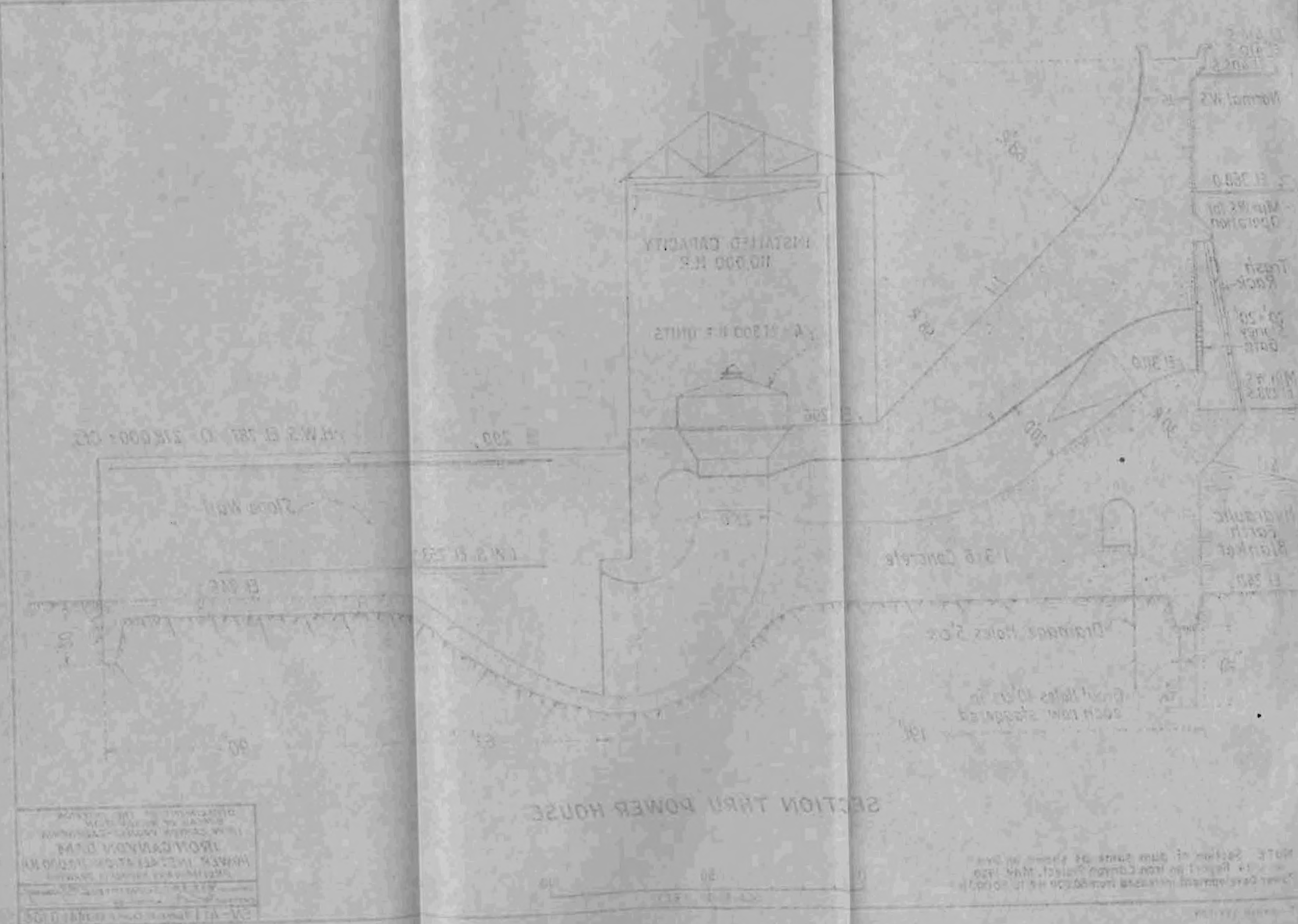
SECTION THRU POWER HOUSE

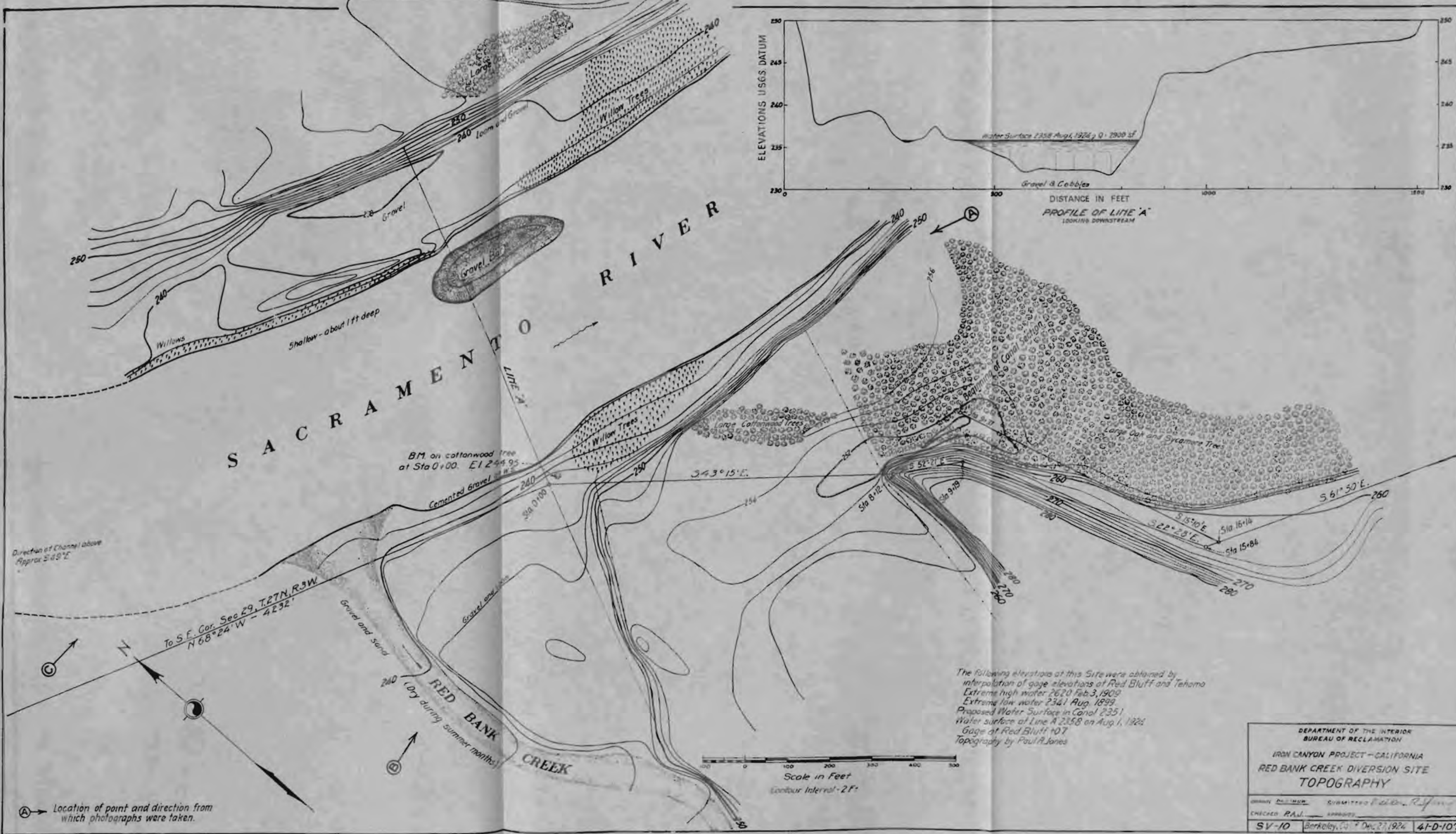
NOTE: Section of dam same as shown on Dwg. 41-C-24 Report on Iron Canyon Project, May, 1920. Power Development increased from 60,000 H.P. to 110,000 H.P.

0 50 100
SCALE OF FEET

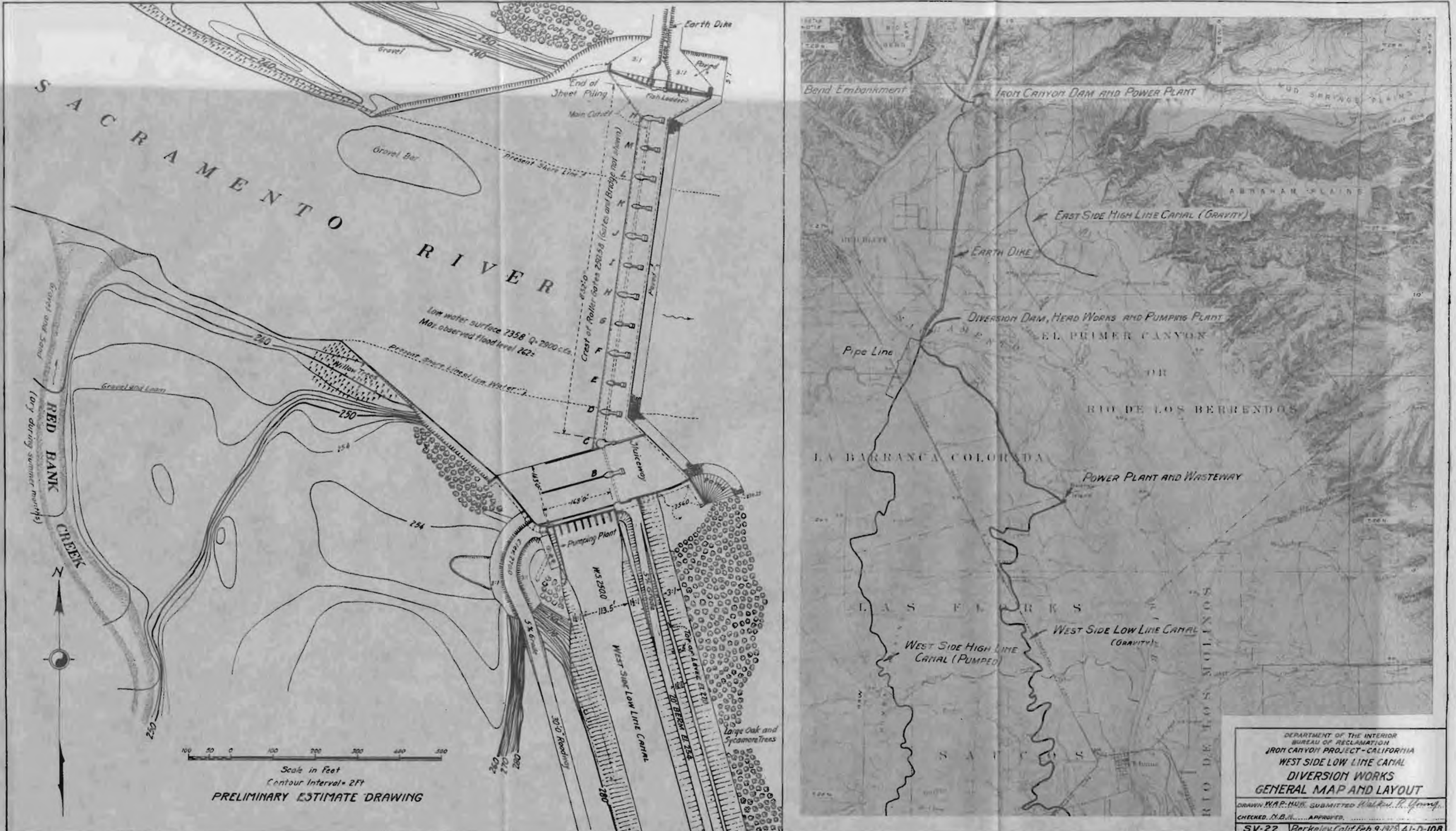
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
IRON CANYON DAM
POWER INSTALLATION-110,000 H.P.
PRELIMINARY ESTIMATE DRAWING
DRAWN W.A.P. R.McC. SUBMITTED W.K. Young
CHECKED W.C.P. APPROVED
SV-41 | BERKELEY, CALIF. 7-27-25 | 41-D-106

PLATE 15


Normal W.S.
El 360.0
Min W.S. for Operation
Trash Rack
20'x20' Coaster Gate
El 310
INSTALLED CAPACITY
110,000 H.P.
4 - 27500 H.P. units
H.W.S. El 287 Q=218,000 c.f.s.
Stone Wall
L.W.S. El 253
El 246
1:3:6 Concrete
Hydraulic Earth Blanket
El 282
Drainage Holes 5' o.c.
Grout Holes 10' o.c. in each row staggered
SECTION THRU POWER HOUSE
IRON CANYON DAM
POWER INSTALLATION

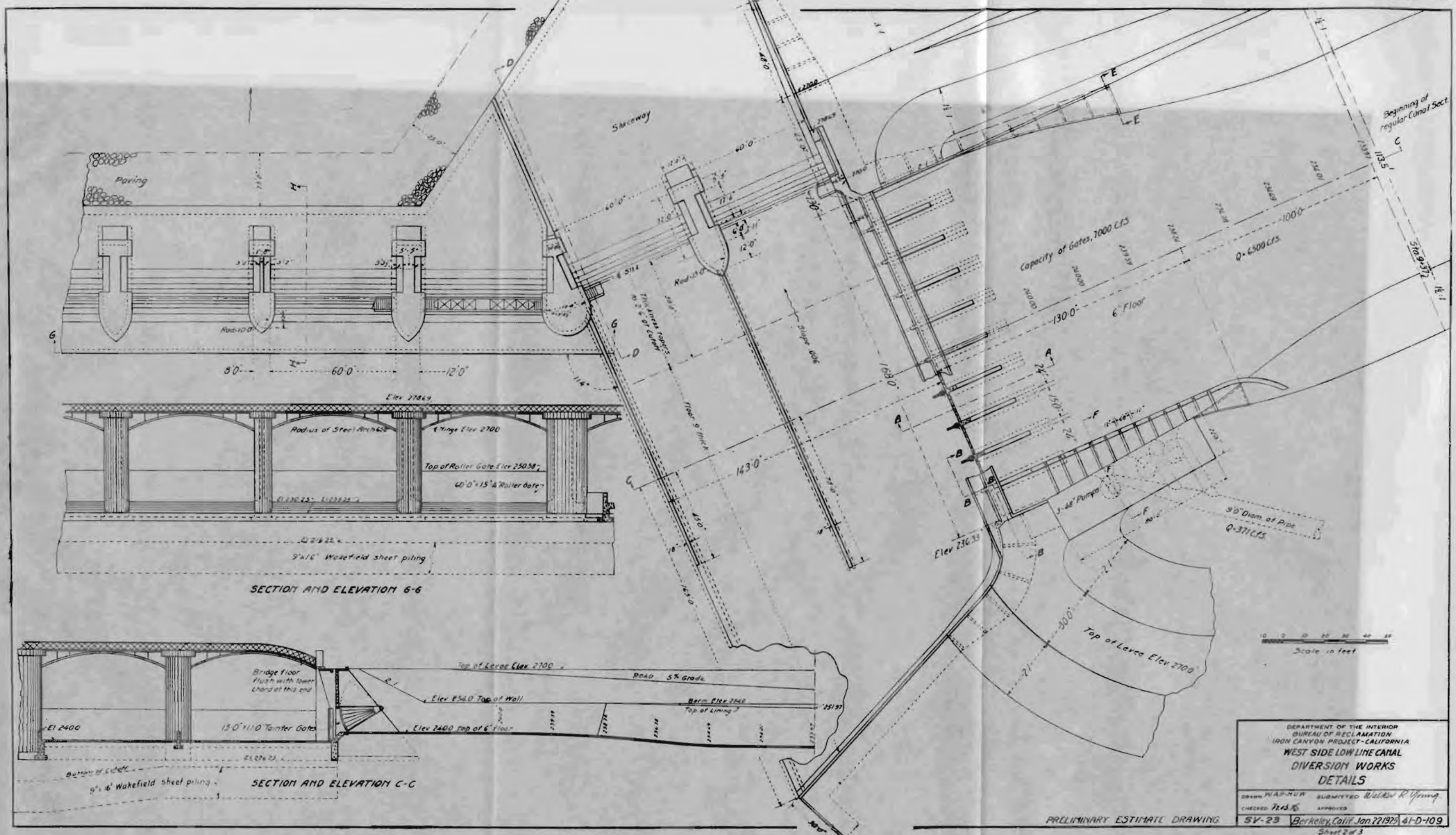


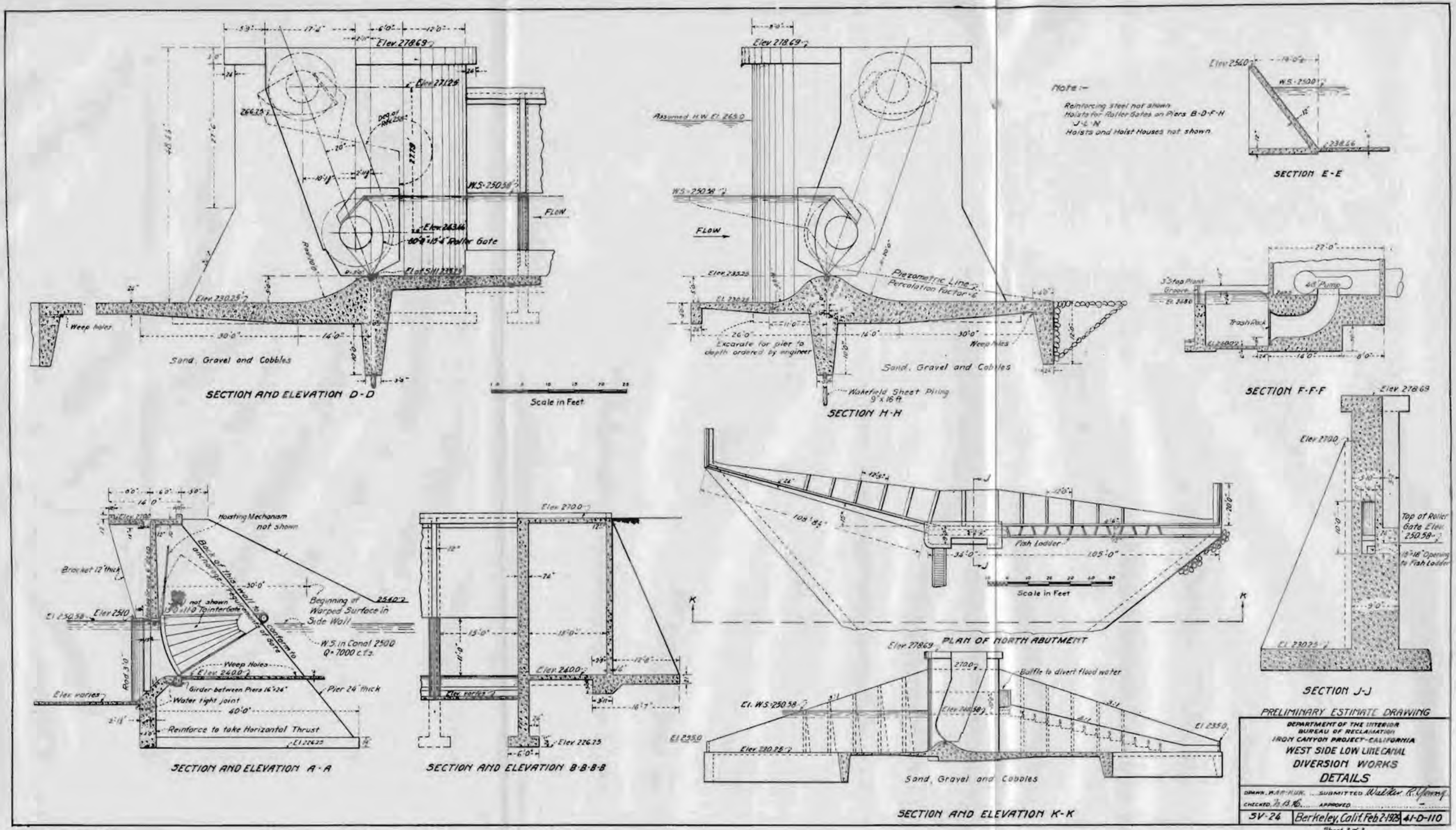
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT – CALIFORNIA
RED BANK CREEK DIVERSION SITE
TOPOGRAPHY
SV-10
Berkeley, Cal. Dec 27, 1924
41-D-107
PROFILE OF LINE "A"
LOOKING DOWNSTREAM
ELEVATIONS U.S.G.S. DATUM
DISTANCE IN FEET
Water Surface 235.8 Aug 1, 1924 @ Q = 2900 s.f.
Gravel & Cobbles
SACRAMENTO RIVER
RED BANK CREEK
(Dry during summer months)
Large Oak Trees
Willow Trees
Loam and Gravel
Gravel
Gravel Bar
Willows
Shallow – about 1 ft deep
LINE "A"
Large Cottonwood Trees
Beginning of Canal Section
Large Oak and Sycamore Trees
B.M. on cottonwood tree at Sta 0+00. El 244.95
Cemented Gravel
S 43° 15' E.
S 61° 30' E.
S 22° 28' E.
Sta 0+00
Sta 8+12
Sta 16+14
Sta 15+84
Direction of Channel above Approx S 89° E
To S.E. Cor. Sec 29, T.27N, R.3W.
N 68° 24' W – 4232'
Gravel and Sand
Gravel and Loam
The following elevations at this Site were obtained by interpolation of gage elevations at Red Bluff and Tehama
Extreme high water 262.0 Feb. 3, 1909
Extreme low water 234.1 Aug. 1899
Proposed Water Surface in Canal 235.1
Water surface of Line A 235.8 on Aug 1, 1924
Gage at Red Bluff +0.7
Topography by Paul A. Jones
Scale in Feet
Contour Interval – 2 Ft
Location of point and direction from which photographs were taken.


SACRAMENTO RIVER
Earth Dike
Large Oak Trees
Gravel
Paved
End of Sheet Piling
Fish Ladder
Main Cutoff
Gravel Bar
Present Shore Line
Crest of Roller Gates 250.58 (Gates and Bridge not shown)
Low water surface 235.8 Q=2900 c.f.s.
Max. observed flood level 262±
Present Shore Line at Low Water
Willow Trees
Gravel and Sand
Gravel and Loam
RED BANK CREEK
(dry during summer months)
Sluiceway
Pumping Plant
West Side Low Line Canal
30'0" Roadway
Top of Levee
Large Oak and Sycamore Trees
Scale in Feet
Contour Interval = 2Ft
PRELIMINARY ESTIMATE DRAWING
Bend Embankment
IRON CANYON DAM AND POWER PLANT
EAST SIDE HIGH LINE CANAL (GRAVITY)
EARTH DIKE
DIVERSION DAM, HEAD WORKS AND PUMPING PLANT
Pipe Line
EL PRIMER CANYON
OR
RIO DE LOS BERRENDOS
LA BARRANCA COLORADA
POWER PLANT AND WASTEWAY
LAS FLORES
WEST SIDE HIGH LINE CANAL (PUMPED)
WEST SIDE LOW LINE CANAL (GRAVITY)
RIO DE LOS MOLINOS
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
WEST SIDE LOW LINE CANAL
DIVERSION WORKS
GENERAL MAP AND LAYOUT
DRAWN W.A.P.-H.O.K. SUBMITTED Walker R. Young
CHECKED N.B.H. APPROVED
SV-22 Berkeley, Calif. Feb. 9-1925 41-D-108


PRELIMINARY ESTIMATE DRAWING
SACRAMENTO RIVER
RED BANK CREEK
SV-22
GENERAL MAP AND LAYOUT
DIVERSION WORKS
WEST SIDE LOW LINE CANAL
IRON CANYON PROJECT—CALIFORNIA

PLATE 17


Sluiceway
Paving
Beginning of regular Canal Sect.
Capacity of Gates, 7000 C.F.S.
Q = 6500 C.F.S.
6" Floor
Floor 9' thick
Slope .006
3-48" Pumps
9'0" Diam. of Pipe
Q = 371 C.F.S.
Top of Levee Elev 2700
Scale in feet
Elev 2786.9
Radius of Steel Arch 65'
Top of Roller Gate Elev 2503.8
60'0" x 15'6" Roller Gate
9"x16" Wakefield sheet piling
SECTION AND ELEVATION G-G
Top of Levee Elev 2700
ROAD 5% Grade
Elev 2540 Top of Wall
Berm Elev 2540
Top of Lining
Bridge floor flush with lower chord at this end
El 2400
15'0" x 11'0" Tainter Gate
Elev 2400 top of 6" floor
9"x16" Wakefield sheet piling
SECTION AND ELEVATION C-C
PRELIMINARY ESTIMATE DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
WEST SIDE LOW LINE CANAL
DIVERSION WORKS
DETAILS
SV-23
Berkeley, Calif. Jan. 22 1925
41-D-109
Sheet 2 of 3


SECTION AND ELEVATION D-D
Elev. 278.69
Elev. 271.25
W.S. 250.58
Elev. 263.46
60'0" x 15'4" Roller Gate
FLOW
Elev. 230.25
Weep holes
Sand, Gravel and Cobbles
Scale in Feet
SECTION H-H
Assumed H.W. El. 265.0
Piezometric Line
Percolation Factor 6
Excavate for pier to depth ordered by engineer
Wakefield Sheet Piling 9" x 16 ft.
Note:-
Reinforcing steel not shown
Hoists for Roller Gates on Piers B-D-F-H J-L-N
Hoists and Hoist Houses not shown
SECTION E-E
SECTION F-F-F
3' Stop Plank Groove
48" Pump
Trash Rack
SECTION J-J
Top of Roller Gate Elev. 250.58
15" x 18" Opening to Fish Ladder
SECTION AND ELEVATION A-A
Hoisting Mechanism not shown
Bracket 12" thick
Back of this wall to conform to arc along requirement of gate
Beginning of Warped Surface in Side Wall
W.S. in Canal 250.0
Q = 7000 c.f.s.
Weep Holes
Girder between Piers 16" x 24"
Water tight joint
Pier 24" thick
Reinforce to take Horizontal Thrust
SECTION AND ELEVATION B-B-B-B
Elev. 270.0
Elev. 240.0
Elev. 226.25
PLAN OF NORTH ABUTMENT
Fish Ladder
SECTION AND ELEVATION K-K
Baffle to divert flood water
El. W.S. 250.58
Sand, Gravel and Cobbles
PRELIMINARY ESTIMATE DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
WEST SIDE LOW LINE CANAL
DIVERSION WORKS
DETAILS
SV-24
Berkeley, Calif. Feb 2-1915
41-D-110
Sheet 3 of 3

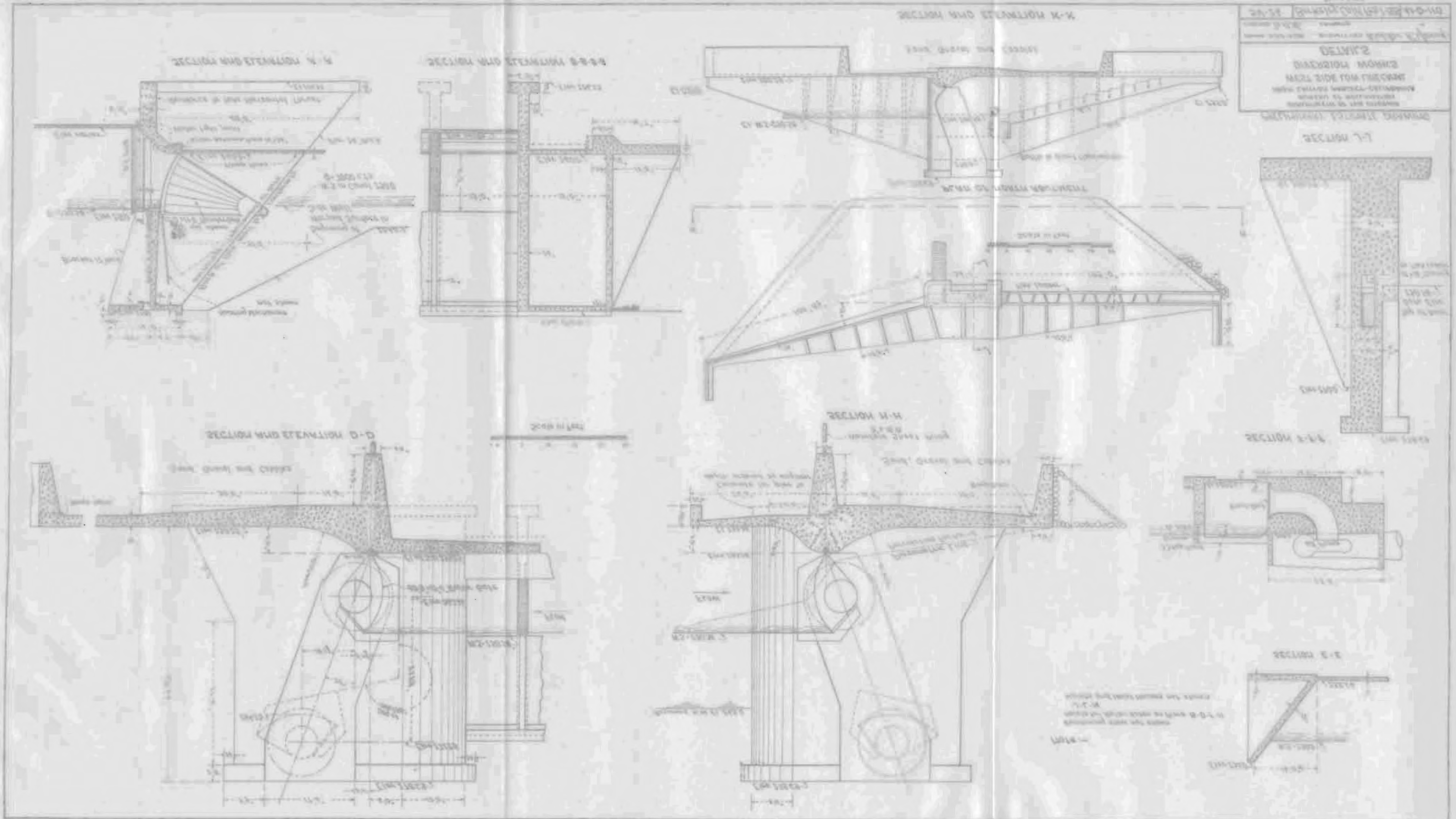
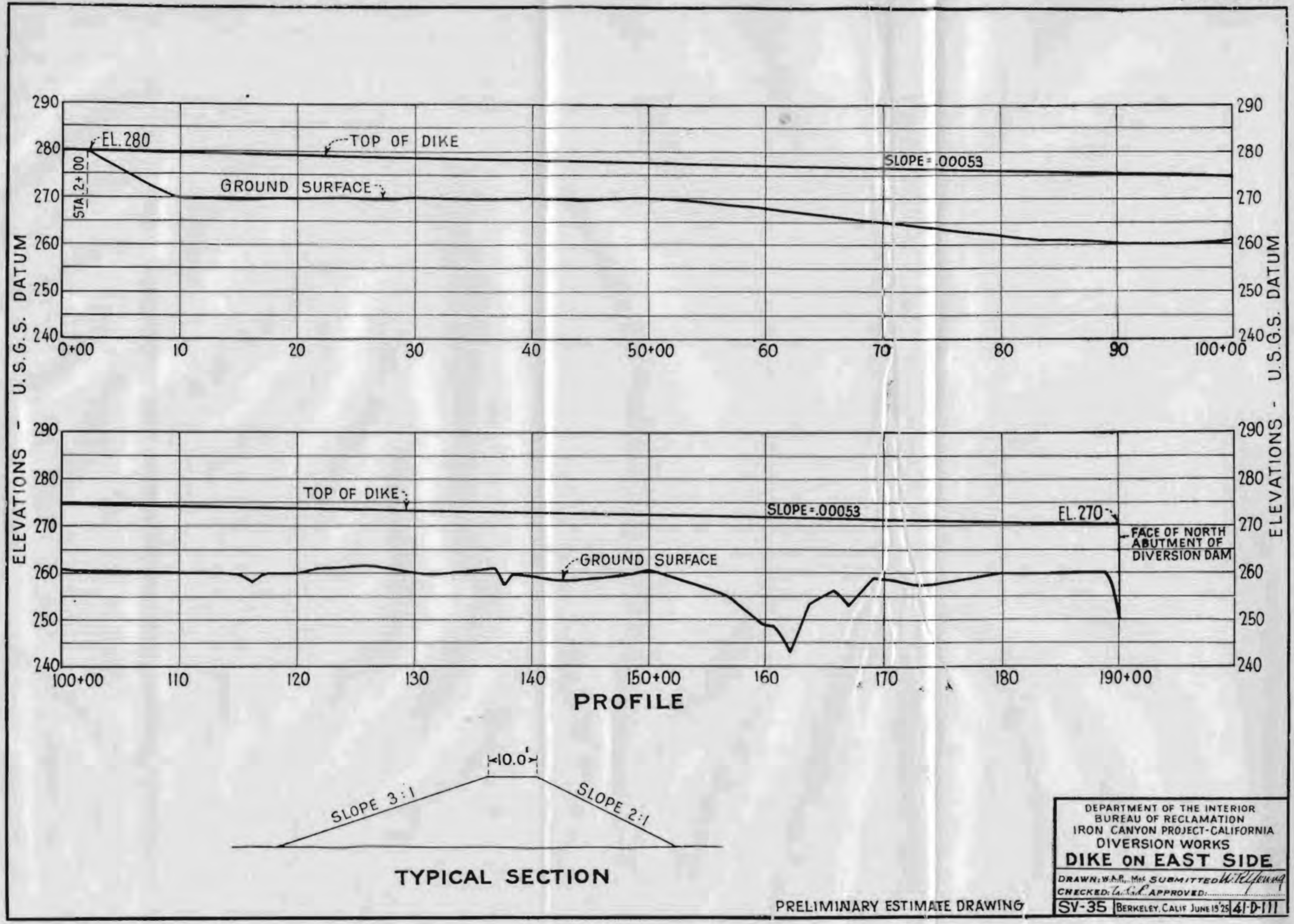


PLATE 19


EL. 280
TOP OF DIKE
SLOPE = .00053
STA. 2+00
GROUND SURFACE
ELEVATIONS - U.S.G.S. DATUM
0+00
10
20
30
40
50+00
60
70
80
90
100+00
TOP OF DIKE
SLOPE = .00053
EL. 270
FACE OF NORTH ABUTMENT OF DIVERSION DAM
GROUND SURFACE
100+00
110
120
130
140
150+00
160
170
180
190+00
PROFILE
10.0'
SLOPE 3:1
SLOPE 2:1
TYPICAL SECTION
PRELIMINARY ESTIMATE DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
DIVERSION WORKS
DIKE ON EAST SIDE
DRAWN: W.A.P., Mc SUBMITTED W.R. Young
CHECKED: APPROVED:
SV-35
BERKELEY, CALIF. JUNE 15 '25
41-D-111

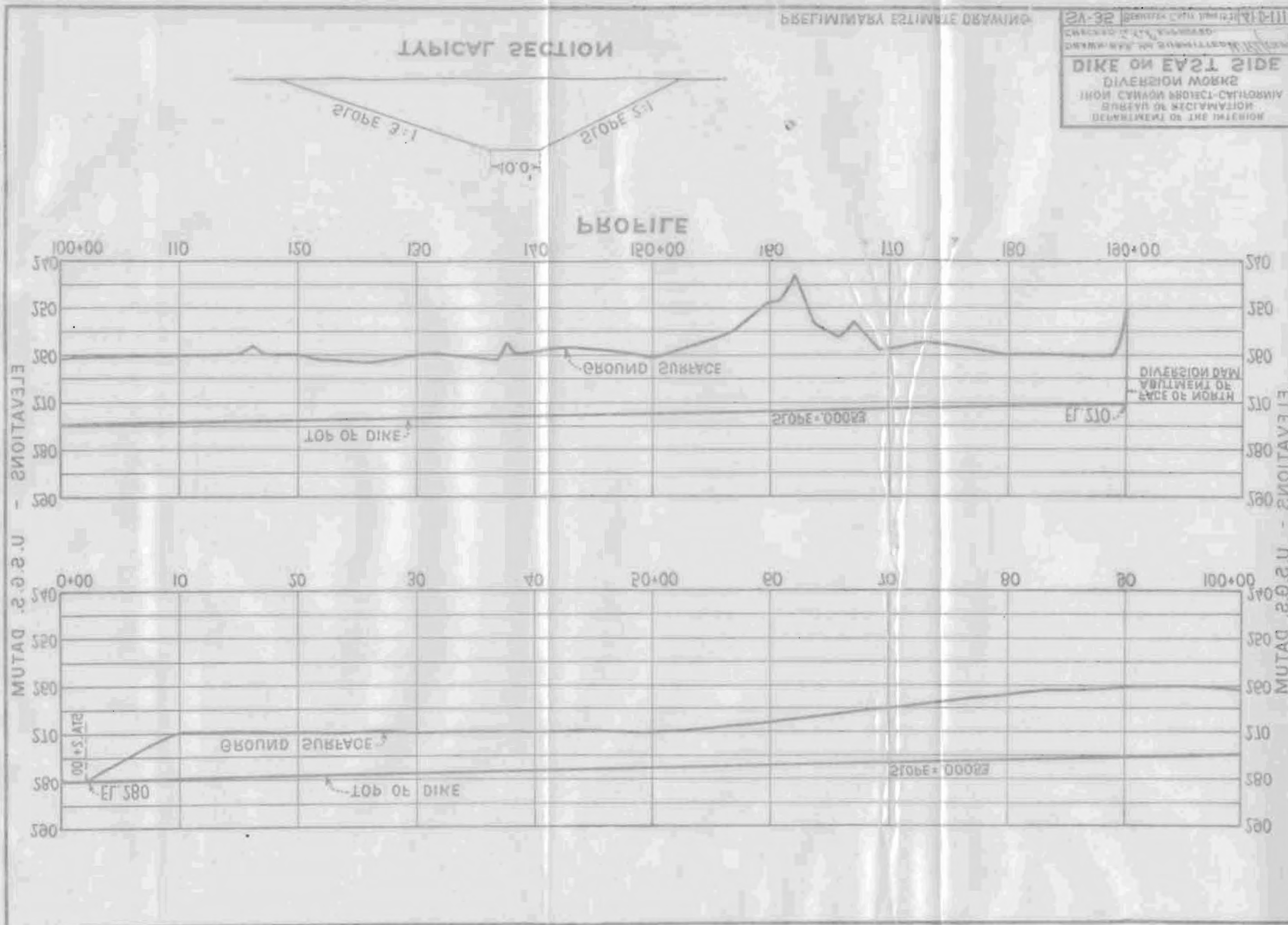
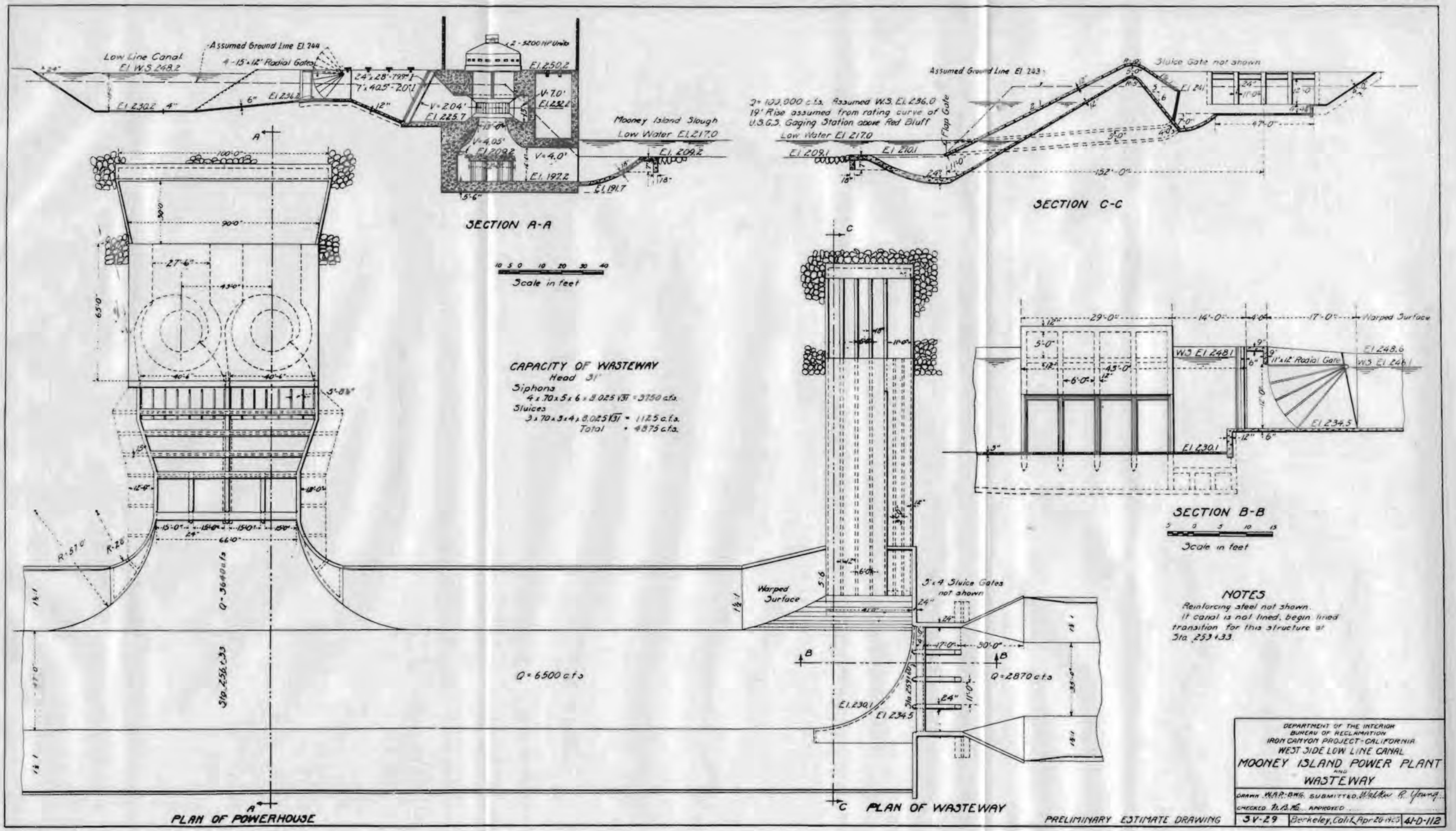
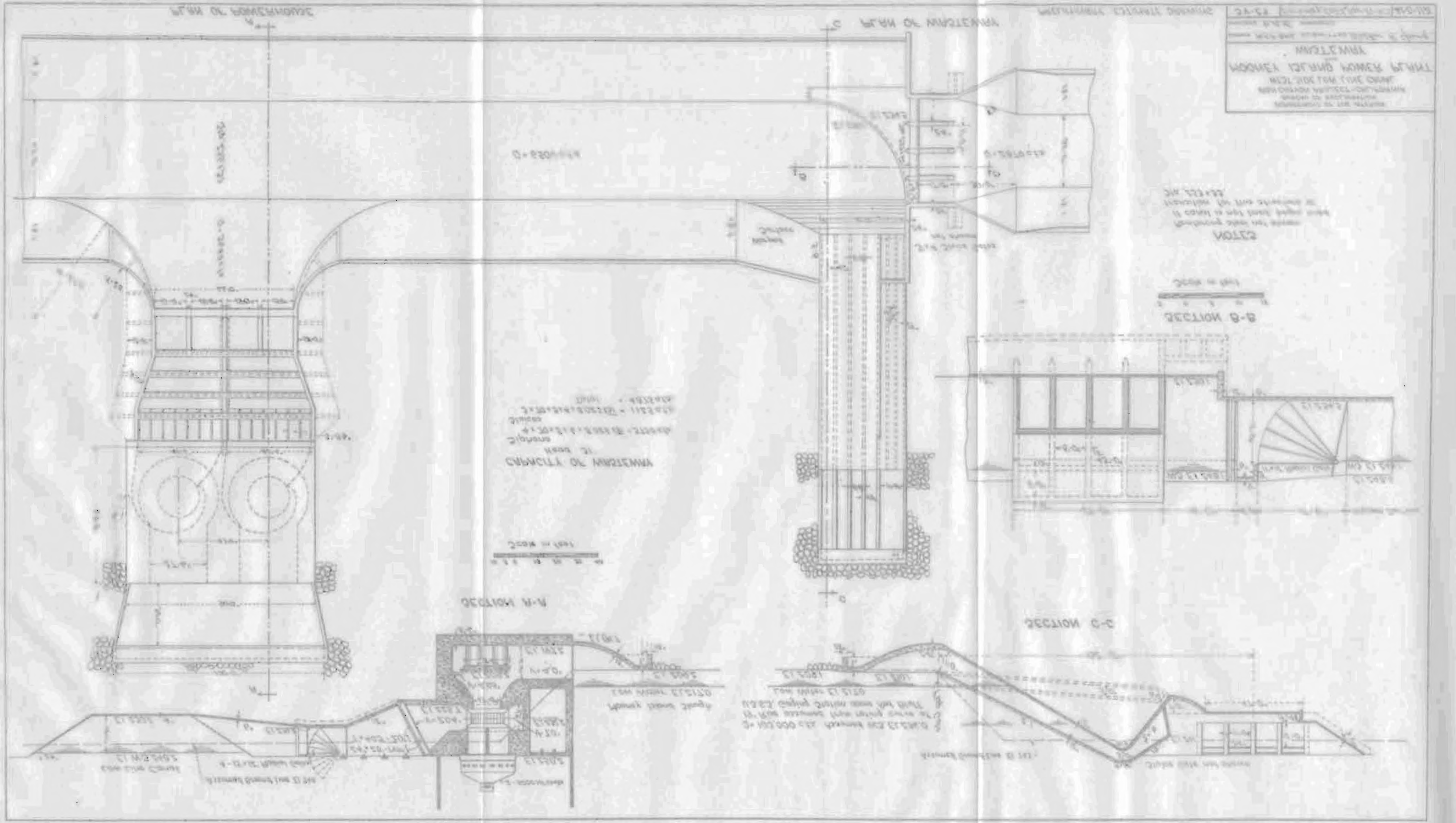
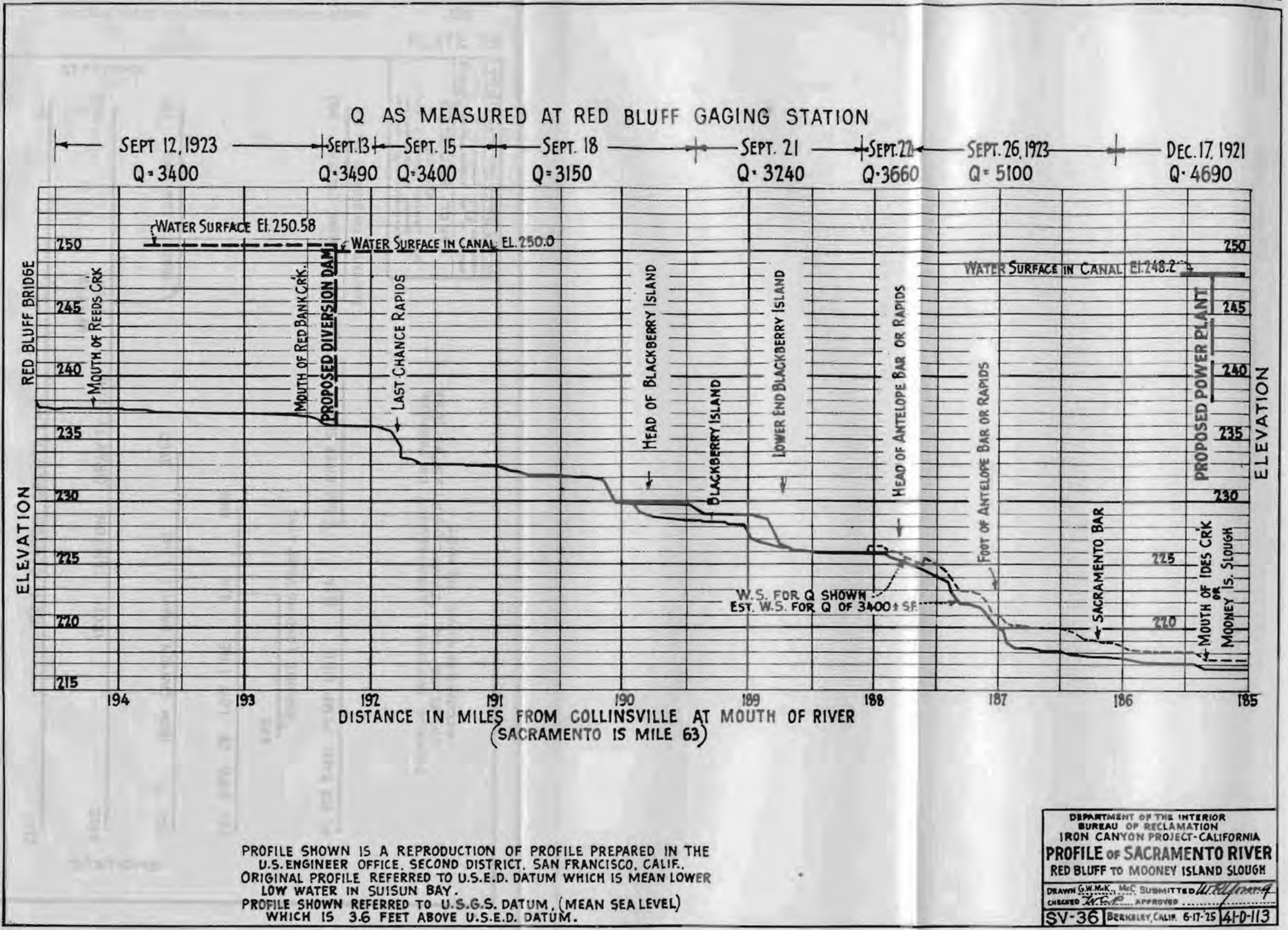

PRELIMINARY ESTIMATE DRAWING
SV-35
DIKE ON EAST SIDE
DIVERSION WORKS
IRON CANYON PROJECT-CALIFORNIA
BUREAU OF RECLAMATION
DEPARTMENT OF THE INTERIOR
TYPICAL SECTION
SLOPE 3:1
SLOPE 2:1
10.0'
PROFILE
ELEVATIONS - U.S.G.S. DATUM
GROUND SURFACE
TOP OF DIKE
SLOPE=.00053
EL. 270
FACE OF NORTH ABUTMENT OF DIVERSION DAM
EL. 280
STA. 2+00
100+00
150+00
190+00
0+00
50+00

PLATE 20


SECTION A-A
SECTION C-C
SECTION B-B
PLAN OF POWERHOUSE
PLAN OF WASTEWAY
Low Line Canal
El. W.S. 248.2
Assumed Ground Line El. 244
4 - 15' x 12' Radial Gates
2 - 5200 HP Units
Mooney Island Slough
Low Water El. 217.0
Assumed Ground Line El. 243
Sluice Gate not shown
Q = 100,000 c.f.s. Assumed W.S. El. 236.0
19' Rise assumed from rating curve of
U.S.G.S. Gaging Station above Red Bluff
Low Water El. 217.0
Flap Gate
Scale in feet
CAPACITY OF WASTEWAY
Head 31'
Siphons
4 x 7.0 x 5 x 6 x 8.025 √31 = 3750 c.f.s.
Sluices
3 x 7.0 x 5 x 4 x 8.025 √31 = 1125 c.f.s.
Total = 4875 c.f.s.
Warped Surface
11' x 12' Radial Gate
5' x 4 Sluice Gates not shown
Q = 3640 c.f.s.
Q = 6500 c.f.s.
Q = 2870 c.f.s.
Sta. 256+33
NOTES
Reinforcing steel not shown.
If canal is not lined, begin lined transition for this structure at Sta. 253+33.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
WEST SIDE LOW LINE CANAL
MOONEY ISLAND POWER PLANT AND WASTEWAY
DRAWN W.A.P., B.M.G. SUBMITTED Walker R. Young
CHECKED
PRELIMINARY ESTIMATE DRAWING
3V-29 Berkeley, Calif. Apr. 26, 1920 41-D-112




Q AS MEASURED AT RED BLUFF GAGING STATION
SEPT 12, 1923 Q=3400
SEPT. 13 Q=3490
SEPT. 15 Q=3400
SEPT. 18 Q=3150
SEPT. 21 Q=3240
SEPT. 22 Q=3660
SEPT. 26, 1923 Q=5100
DEC. 17, 1921 Q=4690
WATER SURFACE El. 250.58
WATER SURFACE IN CANAL EL. 250.0
WATER SURFACE IN CANAL El. 248.2
RED BLUFF BRIDGE
MOUTH OF REEDS CRK
MOUTH OF RED BANK CRK.
PROPOSED DIVERSION DAM
LAST CHANCE RAPIDS
HEAD OF BLACKBERRY ISLAND
BLACKBERRY ISLAND
LOWER END BLACKBERRY ISLAND
HEAD OF ANTELOPE BAR OR RAPIDS
FOOT OF ANTELOPE BAR OR RAPIDS
SACRAMENTO BAR
MOUTH OF IDES CRK OR MOONEY IS. SLOUGH
PROPOSED POWER PLANT
W.S. FOR Q SHOWN
EST. W.S. FOR Q OF 3400± S.F.
ELEVATION
250
245
240
235
230
225
220
215
194
193
192
191
190
189
188
187
186
185
DISTANCE IN MILES FROM COLLINSVILLE AT MOUTH OF RIVER
(SACRAMENTO IS MILE 63)
PROFILE SHOWN IS A REPRODUCTION OF PROFILE PREPARED IN THE U.S. ENGINEER OFFICE, SECOND DISTRICT, SAN FRANCISCO, CALIF.
ORIGINAL PROFILE REFERRED TO U.S.E.D. DATUM WHICH IS MEAN LOWER LOW WATER IN SUISUN BAY.
PROFILE SHOWN REFERRED TO U.S.G.S. DATUM, (MEAN SEA LEVEL) WHICH IS 3.6 FEET ABOVE U.S.E.D. DATUM.
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
PROFILE OF SACRAMENTO RIVER
RED BLUFF TO MOONEY ISLAND SLOUGH
DRAWN G.W.McK., McC SUBMITTED
CHECKED
APPROVED
SV-36
BERKELEY, CALIF. 6-17-25
41-D-113

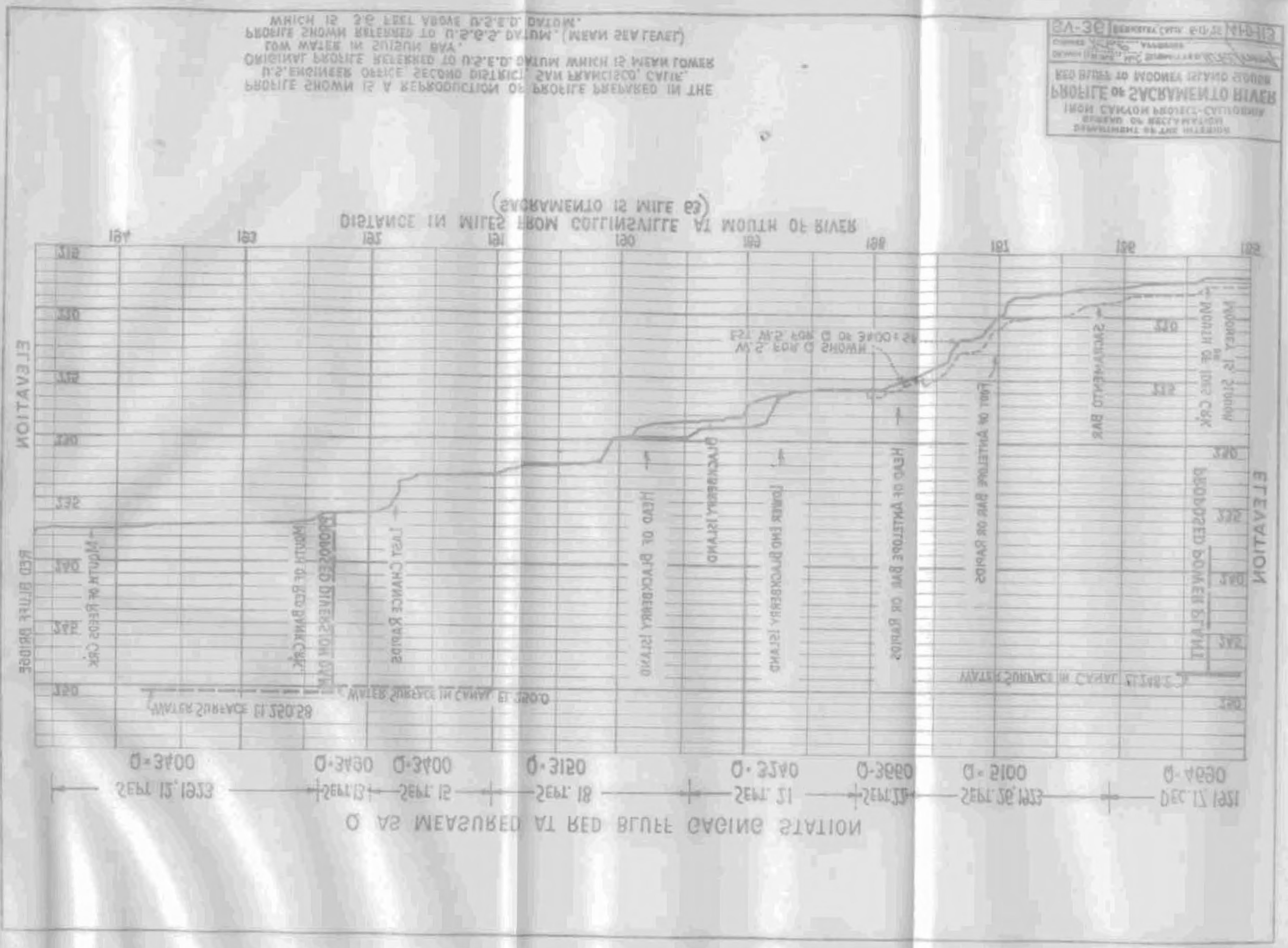
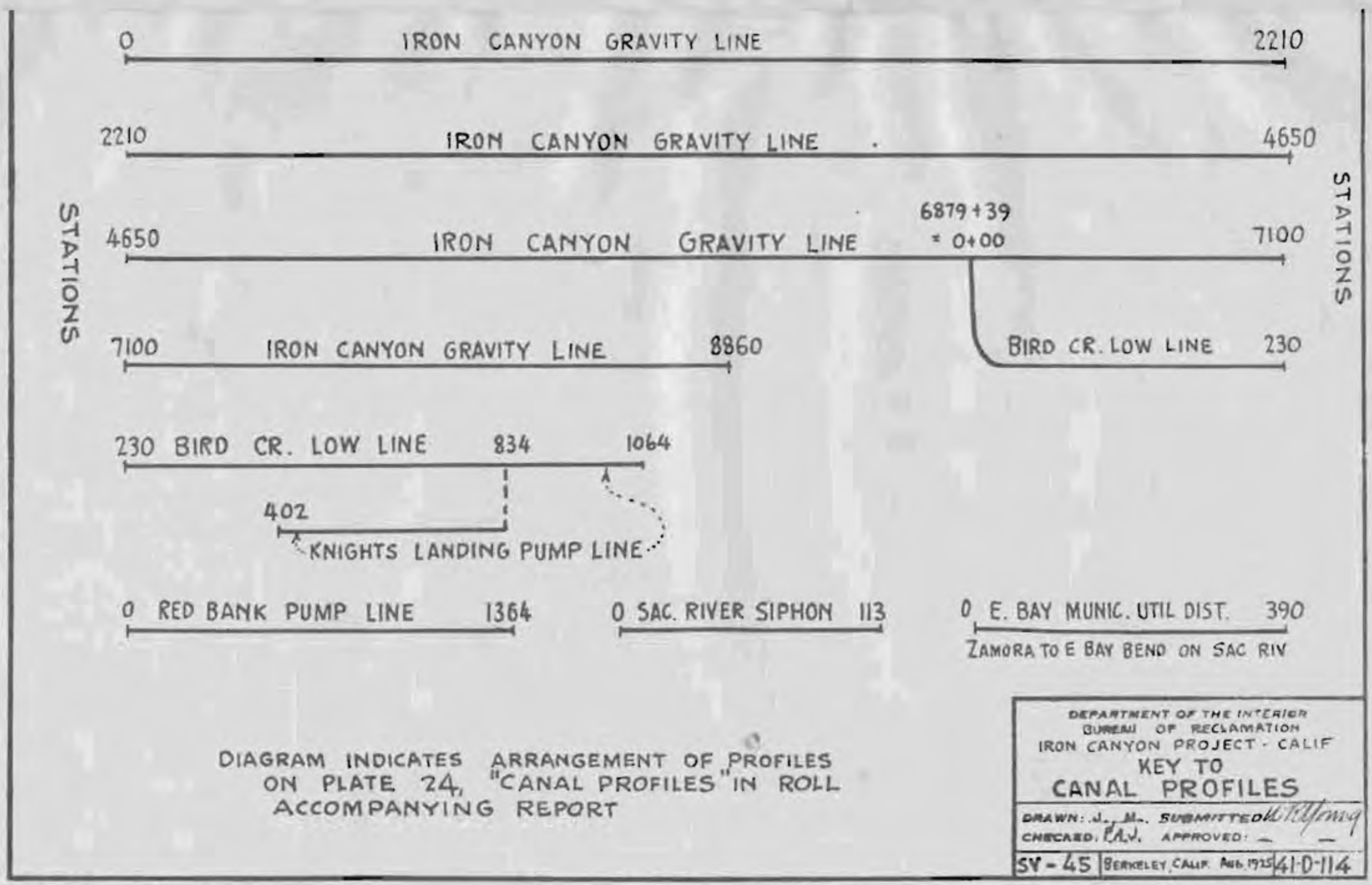

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT-CALIFORNIA
PROFILE of SACRAMENTO RIVER
RED BLUFF to MOONEY ISLAND SLOUGH
SV-36
PROFILE SHOWN IS A REPRODUCTION OF PROFILE PREPARED IN THE U.S. ENGINEER OFFICE, SECOND DISTRICT, SAN FRANCISCO, CALIF.
ORIGINAL PROFILE REFERRED TO U.S.E.D. DATUM WHICH IS MEAN LOWER LOW WATER IN SUISUN BAY.
PROFILE SHOWN REFERRED TO U.S.G.S. DATUM. (MEAN SEA LEVEL) WHICH IS 3.6 FEET ABOVE U.S.E.D. DATUM.
DISTANCE IN MILES FROM COLLINSVILLE AT MOUTH OF RIVER
(SACRAMENTO IS MILE 63)
ELEVATION
RED BLUFF BRIDGE
MOUTH OF REEDS CR'K
MOUTH OF RED BANK CR'K
PROPOSED DIVERSION DAM
LAST CHANCE RAPIDS
HEAD OF BLACKBERRY ISLAND
BLACKBERRY ISLAND
LOWER END BLACKBERRY ISLAND
HEAD OF ANTELOPE BAR OR RAPIDS
FOOT OF ANTELOPE BAR OR RAPIDS
SACRAMENTO BAR
MOUTH OF IDES CR'K
MOONEY IS. SLOUGH
PROPOSED POWER PLANT
EST. W.S. FOR Q OF 3400 c.s.
W.S. FOR Q SHOWN
WATER SURFACE EL. 250.58
WATER SURFACE IN CANAL EL. 250.0
WATER SURFACE IN CANAL EL. 248.2
Q = 3400
Q = 3430
Q = 3400
Q = 3150
Q = 3240
Q = 3660
Q = 5100
Q = 4690
SEPT. 12, 1923
SEPT. 13
SEPT. 15
SEPT. 18
SEPT. 21
SEPT. 24
SEPT. 26, 1923
DEC. 17, 1921
Q AS MEASURED AT RED BLUFF GAGING STATION

PLATE 22

PLATE 23


STATIONS
STATIONS
0 IRON CANYON GRAVITY LINE 2210
2210 IRON CANYON GRAVITY LINE 4650
4650 IRON CANYON GRAVITY LINE 7100
6879+39
= 0+00
7100 IRON CANYON GRAVITY LINE 8860
BIRD CR. LOW LINE 230
230 BIRD CR. LOW LINE 834 1064
402
KNIGHTS LANDING PUMP LINE
0 RED BANK PUMP LINE 1364
0 SAC. RIVER SIPHON 113
0 E. BAY MUNIC. UTIL DIST. 390
ZAMORA TO E BAY BEND ON SAC RIV
DIAGRAM INDICATES ARRANGEMENT OF PROFILES
ON PLATE 24, "CANAL PROFILES" IN ROLL
ACCOMPANYING REPORT
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF
KEY TO
CANAL PROFILES
DRAWN: J. M. SUBMITTED:
CHECKED: F.A.J. APPROVED:
SY-45
BERKELEY, CALIF. AUG. 1925
41-D-114

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROPOSED IRON CANYON PROJECT-CALIF.

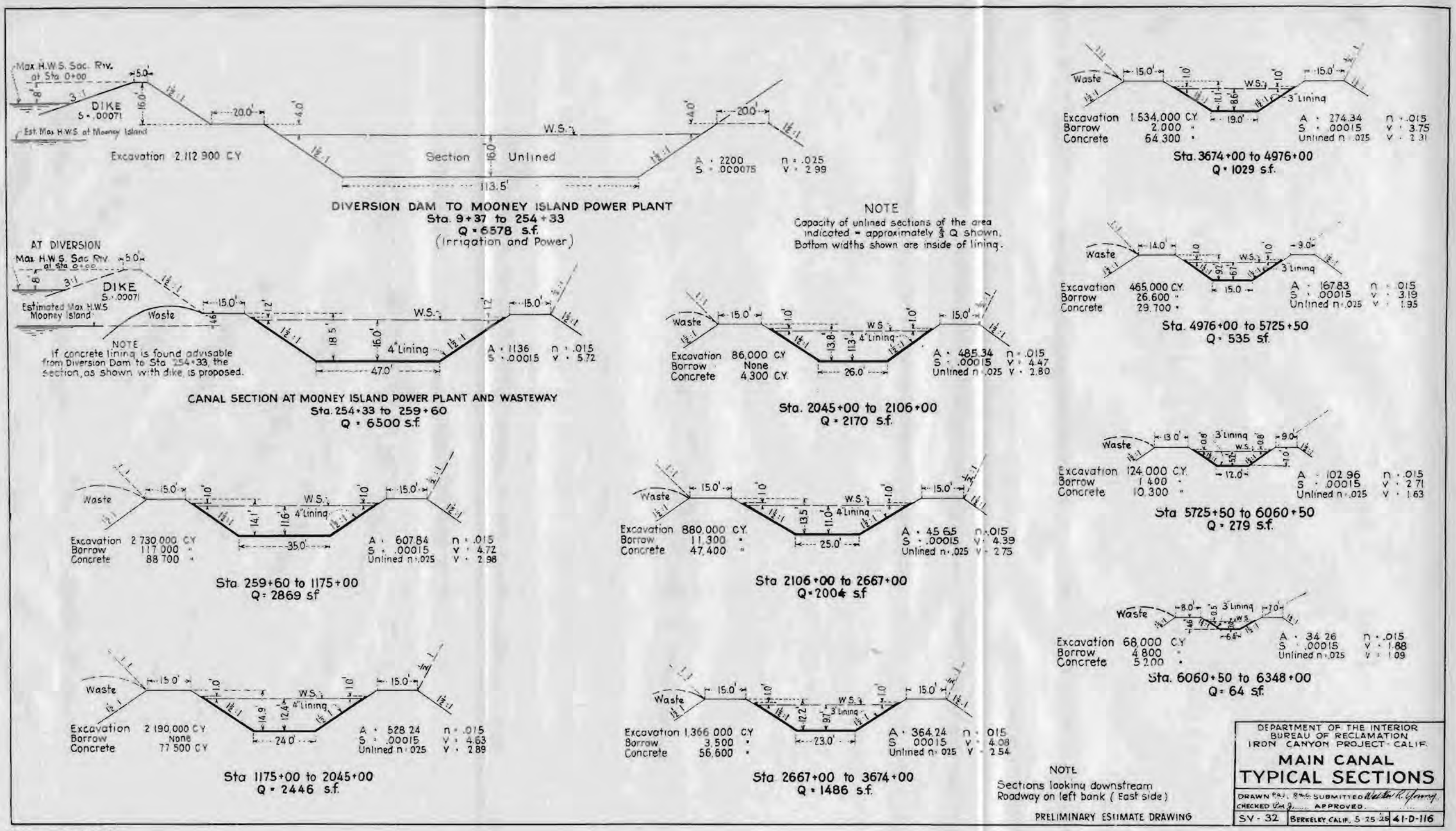
CANAL PROFILES

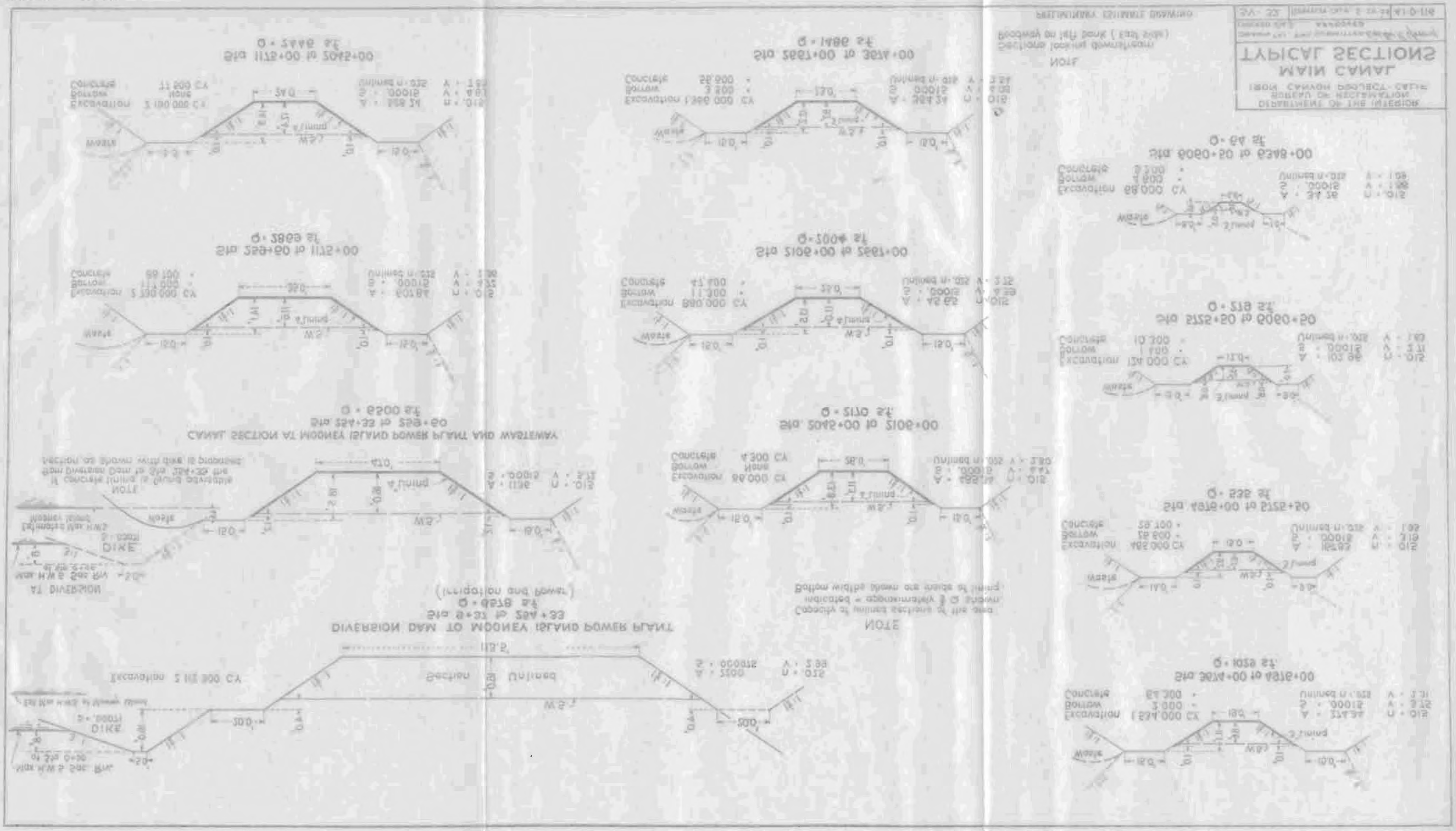
PRELIMINARY LOCATION

JUNE 1925.

THESE CONDENSED PROFILES WERE COMPILED FROM ORIGINALS (S.V.44; 41-D-115) SUBMITTED BY WALKER R YOUNG TO THE BUREAU OF RECLAMATION JUNE 1925, AND ON FILE AT ITS DENVER OFFICE.
THE SCALES OF THE ORIGINAL PROFILES ARE: HORIZONTAL, 1 INCH=400 FEET; VERTICAL, 1 INCH=20 FEET
LINEAL DISTANCES ON THESE PROFILES ARE EXPRESSED IN STATIONS OF 100 FEET.
COMPILED BY DIV. OF ENG. AND IRRIG. STATE DEPT. OF PUBLIC WORKS, CALIF.

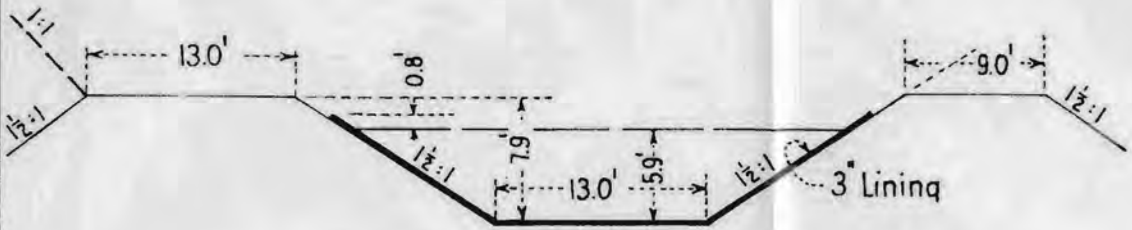

PLATE 34
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROPOSED IRON CANYON PROJECT—CALIF.
CANAL PROFILES
PRELIMINARY LOCATION
JUNE 1915
IRON CANYON GRAVITY CANAL
IRON CANYON GRAVITY CANAL
IRON CANYON GRAVITY CANAL
IRON CANYON GRAVITY CANAL
RED BANK PUMP LINE
BIRD CREEK CANAL
KNIGHTS LANDING PUMP LINE
RED BANK PUMP LINE
Elevation in feet


Max. H.W.S. Sac. Riv. at Sta 0+00
DIKE
S = .00071
Est. Max. H.W.S. at Mooney Island
Excavation 2,112,900 C.Y.
Section Unlined
W.S.
113.5'
A = 2200 n = .025
S = .000075 V = 2.99
DIVERSION DAM TO MOONEY ISLAND POWER PLANT
Sta. 9+37 to 254+33
Q = 6578 s.f.
(Irrigation and Power)
AT DIVERSION
Max. H.W.S. Sac. Riv. at Sta. 0+00
DIKE
S = .00071
Estimated Max. H.W.S. Mooney Island
Waste
NOTE
If concrete lining is found advisable from Diversion Dam to Sta. 254+33, the section, as shown with dike, is proposed.
4" Lining
47.0'
A = 1136 n = .015
S = .00015 V = 5.72
CANAL SECTION AT MOONEY ISLAND POWER PLANT AND WASTEWAY
Sta. 254+33 to 259+60
Q = 6500 s.f.
NOTE
Capacity of unlined sections of the area indicated = approximately 2/3 Q shown. Bottom widths shown are inside of lining.
Excavation 2,730,000 C.Y.
Borrow 117,000
Concrete 88,700
A = 607.84 n = .015
S = .00015 V = 4.72
Unlined n = .025 V = 2.98
Sta 259+60 to 1175+00
Q = 2869 s.f.
Excavation 2,190,000 C.Y.
Borrow None
Concrete 77,500 C.Y.
A = 528.24 n = .015
S = .00015 V = 4.63
Unlined n = .025 V = 2.89
Sta 1175+00 to 2045+00
Q = 2446 s.f.
Excavation 86,000 C.Y.
Borrow None
Concrete 4,300 C.Y.
A = 485.34 n = .015
S = .00015 V = 4.47
Unlined n = .025 V = 2.80
Sta. 2045+00 to 2106+00
Q = 2170 s.f.
Excavation 880,000 C.Y.
Borrow 11,300
Concrete 47,400
A = 456.5 n = .015
S = .00015 V = 4.39
Unlined n = .025 V = 2.75
Sta 2106+00 to 2667+00
Q = 2004 s.f.
Excavation 1,366,000 C.Y.
Borrow 3,500
Concrete 56,600
A = 364.24 n = .015
S = .00015 V = 4.08
Unlined n = .025 V = 2.54
Sta 2667+00 to 3674+00
Q = 1486 s.f.
Excavation 1,534,000 C.Y.
Borrow 2,000
Concrete 64,300
A = 274.34 n = .015
S = .00015 V = 3.75
Unlined n = .025 V = 2.31
Sta. 3674+00 to 4976+00
Q = 1029 s.f.
Excavation 465,000 C.Y.
Borrow 26,600
Concrete 29,700
A = 167.83 n = .015
S = .00015 V = 3.19
Unlined n = .025 V = 1.95
Sta. 4976+00 to 5725+50
Q = 535 s.f.
Excavation 124,000 C.Y.
Borrow 1,400
Concrete 10,300
A = 102.96 n = .015
S = .00015 V = 2.71
Unlined n = .025 V = 1.63
Sta 5725+50 to 6060+50
Q = 279 s.f.
Excavation 68,000 C.Y.
Borrow 4,800
Concrete 5,200
A = 34.26 n = .015
S = .00015 V = 1.88
Unlined n = .025 V = 1.09
Sta. 6060+50 to 6348+00
Q = 64 s.f.
NOTE
Sections looking downstream
Roadway on left bank (East side)
PRELIMINARY ESTIMATE DRAWING
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIF.
MAIN CANAL
TYPICAL SECTIONS
DRAWN SUBMITTED
CHECKED APPROVED
SV-32 BERKELEY, CALIF. 5-25-38 41-D-116



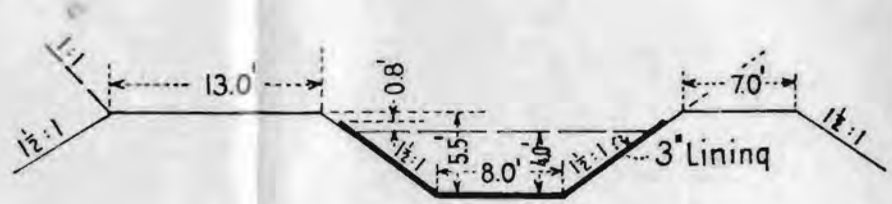
TYPICAL SECTIONS
MAIN CANAL
IRON CANYON PROJECT - CALIF.
BUREAU OF RECLAMATION
DEPARTMENT OF THE INTERIOR
PRELIMINARY ESTIMATE DRAWING
NOTE
Sections looking downstream
Roadway on left bank (East side)
Sta 1175+00 to 2045+00
Q = 2446 s.f.
Sta 2667+00 to 3674+00
Q = 1486 s.f.
Sta 6060+50 to 6348+00
Q = 64 s.f.
Sta 259+60 to 1175+00
Q = 2869 s.f.
Sta 2106+00 to 2667+00
Q = 2004 s.f.
Sta 5725+50 to 6060+50
Q = 279 s.f.
CANAL SECTION AT MOONEY ISLAND POWER PLANT AND WASTEWAY
Sta 254+33 to 259+60
Q = 6500 s.f.
Sta. 2045+00 to 2106+00
Q = 2170 s.f.
Sta 4976+00 to 5725+50
Q = 536 s.f.
DIVERSION DAM TO MOONEY ISLAND POWER PLANT
Sta 9+37 to 254+33
Q = 6578 s.f.
(Irrigation and Power)
NOTE
Capacity of unlined sections of the area indicated = approximately ⅔ Q shown
Bottom widths shown are inside of lining
Sta 3674+00 to 4976+00
Q = 1029 s.f.
NOTE
If concrete lining is found advisable from Diversion Dam to Sta. 254+33, the section as shown with dike is proposed.
AT DIVERSION
DIKE
Waste
W.S.
4" Lining
3" Lining
Section Unlined
Excavation 2 112 300 C.Y
A = 2200 n = .015
S = .000075 V = 2.99

PLATE 25



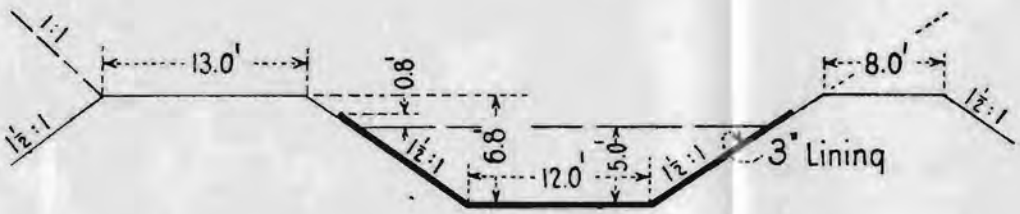
END OF PIPE LINE TO ELDER CREEK
STA. 81+75 TO 557+20
Q = 378 S.F.

EXCAVATION	208,000 C.Y.	A = 128.92	n = .015
CONCRETE	16,200 C.Y.	S = .00015	V = 2.93



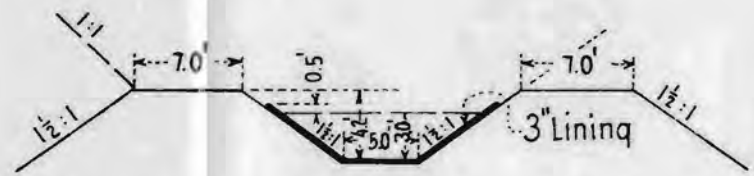
THOMES CREEK TO E. & W. CTR LINE, T. 4 N.
STA. 1003+26 TO 1214+34
Q = 125 S.F.

EXCAVATION	54,000 C.Y.	A = 56.0	n = .015
CONCRETE	5,000 C.Y.	S = .00015	V = 2.23



ELDER CREEK TO THOMES CREEK
STA. 568+15 TO 980+24
Q = 259 S.F.

EXCAVATION	181,000 C.Y.	A = 97.5	n = .015
CONCRETE	12,600 C.Y.	S = .00015	V = 2.66



E. & W. CTR LINE, T.4N. TO N. BR. OF N. FORK OF RICE CR.
STA. 1214+34 TO 1364+53
Q = 51 S.F.

EXCAVATION	18,500 C.Y.	A = 28.5	n = .015
CONCRETE	2,400 C.Y.	S = .00015	V = 1.78

PRELIMINARY ESTIMATE DRAWING

DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
RED BANK PUMP CANAL
TYPICAL SECTIONS
DRAWN P.A.J., R.McC. SUBMITTED W.R. Young
CHECKED P.A.J. .... APPROVED
SV-42 BERKELEY, CALIF. 41-D-117

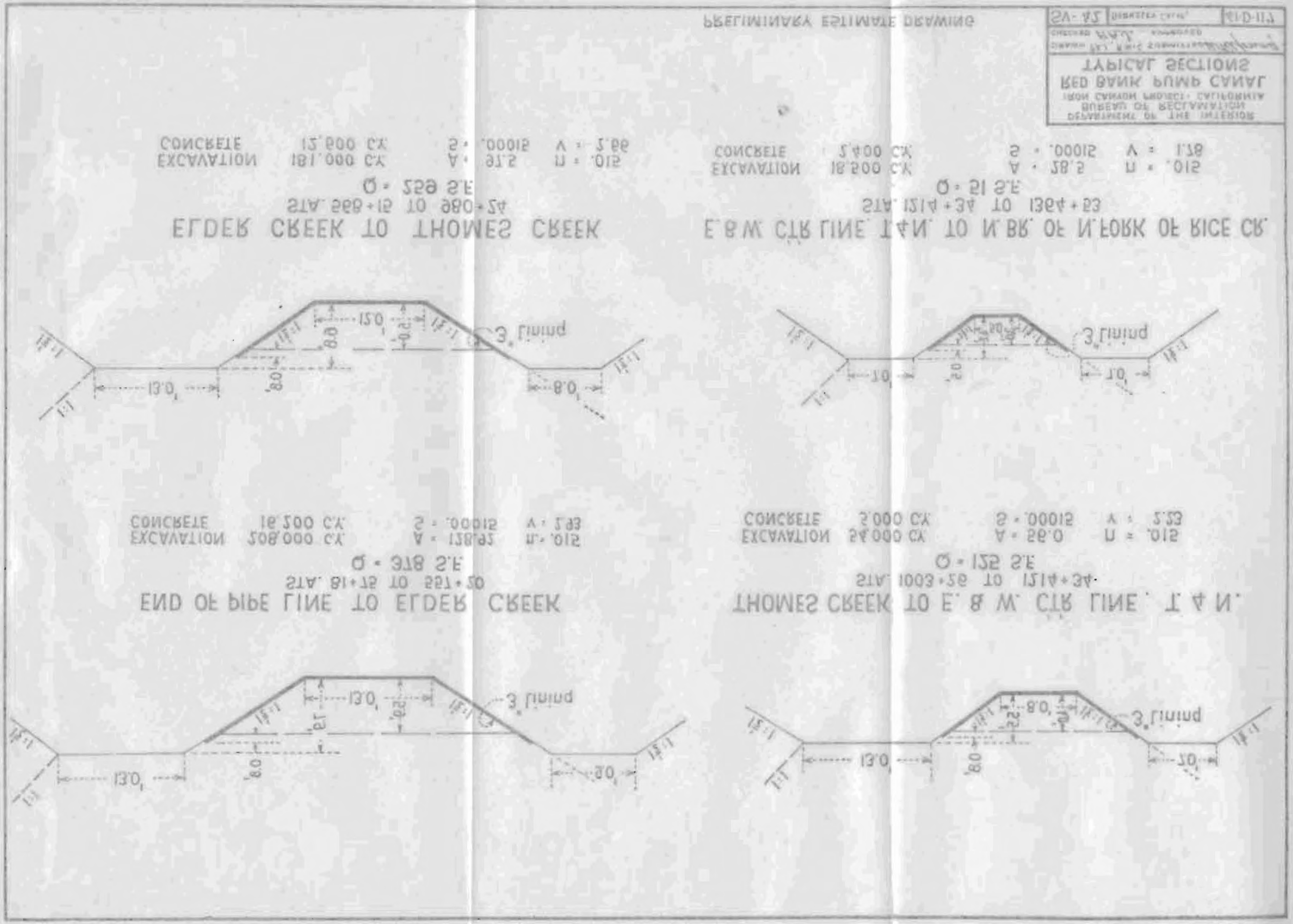

PRELIMINARY ESTIMATE DRAWING
SV-A2 GIBRALTER CALIF. 41-D-117
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
IRON CANYON PROJECT - CALIFORNIA
RED BANK PUMP CANAL
TYPICAL SECTIONS
ELDER CREEK TO THOMES CREEK
STA. 568+15 TO 980+24
Q = 259 S.F.
EXCAVATION 181,000 C.Y. A = 97.5 n = .015
CONCRETE 12,600 C.Y. S = .00015 V = 2.66
E. & W. CTR LINE. T.4N. TO N. BR. OF N. FORK OF RICE CR.
STA. 1214+34 TO 1364+53
Q = 51 S.F.
EXCAVATION 18,500 C.Y. A = 28.5 n = .015
CONCRETE 2,400 C.Y. S = .00015 V = 1.78
END OF PIPE LINE TO ELDER CREEK
STA. 81+75 TO 557+20
Q = 378 S.F.
EXCAVATION 208,000 C.Y. A = 128.92 n = .015
CONCRETE 16,200 C.Y. S = .00015 V = 2.93
THOMES CREEK TO E. & W. CTR LINE. T. 4 N.
STA. 1003+26 TO 1214+34
Q = 125 S.F.
EXCAVATION 54,000 C.Y. A = 56.0 n = .015
CONCRETE 5,000 C.Y. S = .00015 V = 2.23
3" Lining
13.0'
8.0'
12.0'
7.0'
9.0'

PLATE 26

CHAPTER VI.

REPORT OF THE BOARD OF ENGINEERS ON IRON CANYON PROJECT.

To the United States Reclamation Service, the California State Department of Engineering, and the Iron Canyon Project Association.

GENTLEMEN: This board has convened at Red Bluff, California, in accordance with the request of April 19, 1920, of the chief engineer of the United States Reclamation Service, copy of which precedes this report.

Various plans of an Iron Canyon dam were discussed in the printed report of October, 1914. These plans were all based on Location I, as shown on general location map, Exhibit B, following page 76[1]. Subsequent boring investigations, carried out in accordance with recommendations made in 1914, revealed less favorable foundation conditions than had been assumed and further borings and drift work were deemed advisable to ascertain whether other dam sites in the canyon might be found where conditions are more satisfactory.

In accordance with suggestions made in reports of Mr. Hamlin,[2] a member of this board, and Prof. A. C. Lawson,[3] of the University of California, two lower dam sites have now been examined, marked Location II and Location III on Exhibit B, which have made possible an intelligent comparison and which have resulted in the selection of a dam site at Location III, about 3 miles below the original Location I. The geological conditions and the reasons for preferring Location III are explained in the following paragraphs.

The dam site at Location I is that proposed in the cooperative report. The one favorable feature of this site is the considerable amount of Agglomerate No. 1 in the abutments of the dam. This material, however, has a thickness of only 35 feet across the valley and in the river channel it has been entirely cut through into the soft sands and tuffs below, as shown on Exhibit D.[4] At this site the agglomerate is harder than at any other point in Iron Canyon.

The unfavorable conditions are:

(a) Agglomerate No. 1 and the soft sands and tuffs below dip upstream, an attitude which favors percolation outward from beneath Agglomerate No. 1.

(b) The soft sands and tuffs beneath Agglomerate No. 1 are pervious, as shown by the fact that nearly all drill holes in this vicinity yielded artesian water.

(c) The narrow gorge cut through Agglomerate No. 1 extends some distance upstream from the dam site. Leakage will occur from the bottom of this gorge unless it is filled with impervious material, which

[1] Page 205 of this bulletin.
[2] Appendix 1, page 41, "Report on Iron Canyon Project, 1920," by United States Reclamation Service.
[3] Appendix 3, page 71, "Report on Iron Canyon Project, 1920," by United States Reclamation Service.
[4] Exhibit A, lower figure, of this bulletin; see page 203.

may prove to be an expensive and uncertain operation. Regarding this matter Prof. A. C. Lawson states: "Water entering these sands of the river trench under the head established by the reservoir would partly pass out under the surrounding country and escape at distant points, but would tend chiefly to escape by the shortest outlet, which would be at the downstream toe of the dam. Judging by the incoherence of the sands, their coarse texture, their caving in the drill holes, the artesian flow from some of them and the strong undercutting of the river banks below low water, it seems probable that this escaping water at the lower toe of the dam, under high pressure, would acquire sufficient velocity to scour the sand at the points of escape. If this were so then a process making for the undermining of the dam and its ultimate failure would be inaugurated, since scouring would retreat upstream below the dam."

(d) Paynes Creek basalt is a very pervious formation, and is in general underlaid by a thin bed of porous stream gravel. To make this formation water-tight a cut-off wall must be built, extending well down into Agglomerate No. 1, along the axis of the proposed spillway structure. In addition the spillway structure must be built on this pervious formation.

(e) Extensive erosion will occur in Paynes Creek Canyon if the spillway is built as located. Agglomerate No. 1 has been deeply trenched by Paynes Creek and nearly cut through in places. Below are the soft sands and tuffs some 100 feet in thickness, before any hard beds are reached. The overflow from the spillway, falling over the west wall of Paynes Creek Canyon, will soon cut through Agglomerate No. 1 and undermine it and the basalt above.

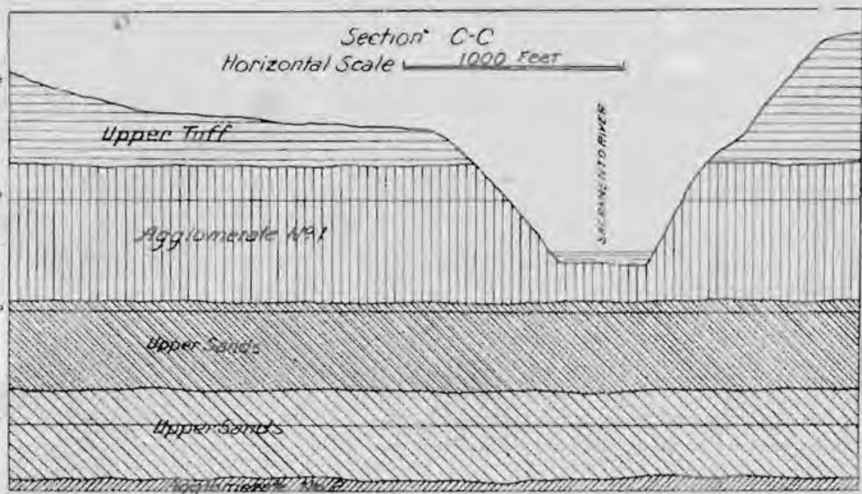
When all the adverse conditions at this site are considered it is not believed that a dam such as proposed is practicable. Obviously an earth or masonry dam would also be impracticable.

Prof. Lawson recommended tests at a dam site here designated Location II, at a point where the hard Agglomerate No. 2 crosses Sacramento River, forming a riffle or small rapids. Here drill holes show Agglomerate No. 2 to be from 9 to 28 feet thick and that it rests upon pervious sands and tuffs of unknown thickness, but at least 100 feet thick. The pervious sands and tuffs which rise from beneath Agglomerate No. 1 at Location I would here form the abutments of the proposed dam. It is believed that Agglomerate No. 2 is not thick enough for the foundations of a masonry dam and that the sands and tuffs both beneath and above Agglomerate No. 2 are pervious. This dam site can not be recommended.

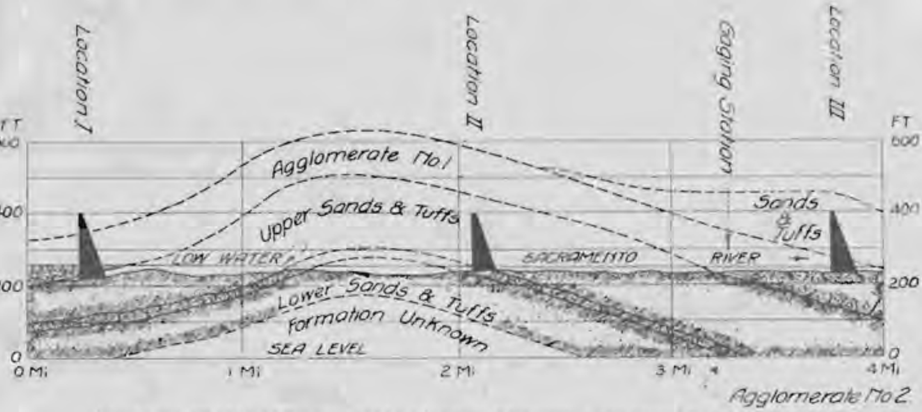
At Location III Agglomerate No. 1 is about 140 feet thick. The river canyon has been cut down into it some 30 feet, leaving about 110 feet in thickness above the pervious sands and tuffs on which it rests. This is a sufficient thickness to withstand the upward hydraulic pressure from a full reservoir, as planned.

Here Agglomerate No. 1 is not as hard as at Location I, but its bearing power is sufficient to withstand the pressures from a properly designed masonry dam. The dip of Agglomerate No. 1 and the formations both above and below it is downstream, hence the removal of material from beneath Agglomerate No. 1 by percolating water is not possible.

EXHIBIT A.



Geologic Section of Sacramento Canyon One-third Mile Upstream from Location III.



Geologic Profile of Sacramento Canyon Through Locations I, II and III.

If cut-off walls in the sands and tuffs which rest upon Agglomerate No. 1 are found necessary, they can be constructed in the dry above high-water level in the river. Here the canyon is wide enough to permit the construction of flood-control gates, siphon spillways, and supplementary overflow spillways.

In anticipation of the selection of Location III the Denver office of the United States Reclamation Service has made tentative plans and estimates of two types of dam, viz, gravity-section concrete and a combination of solid masonry for the high portion of the dam with buttress and slab construction for the sides. In addition for comparative purposes the previous estimate of a rock-fill earth-faced type of dam at Location I with masonry spillway and power-plant features has been revised by adding a deep cut-off wall in porous lava under the spillway and by increasing unit prices to correspond with present market conditions. The comparison stands as follows:

Location	Type	Date	Available reservoir capacity, acre-feet	Estimated cost, including right of way and Bend embankment	Cost per acre-foot
I	Earth faced rock fill	1914	603,000	$10,385,250	$17.20
I	Earth faced rock fill	1920	603,000	16,080,000	26.70
III	Gravity concrete	1920	640,000	17,977,000	28.10
III	Combination reinforced and gravity concrete	1920	640,000	17,385,000	27.20

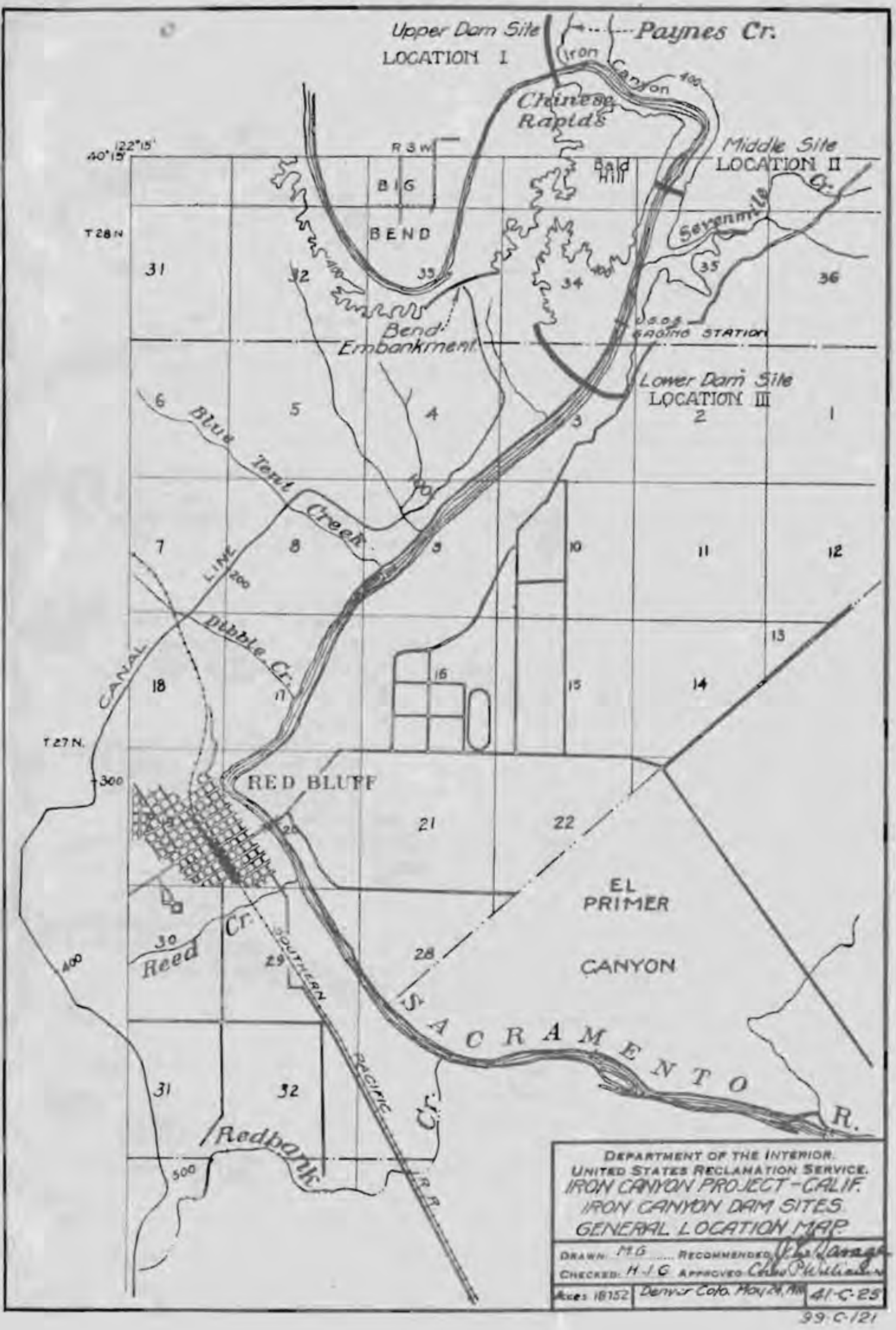
The above estimates are not strictly comparable even on the basis of acre-foot cost. The designs for Location I provide for only 190,000 second-feet spillway capacity at assumed high water, the remainder of the flood peak being figured as absorbed in surplus reservoir capacity over that required for irrigation. This entire surplus capacity and even more is now needed for irrigation alone by reason of irrigation rights on the river initiated and largely matured since 1914. This would necessitate at Location I a greatly increased expenditure for spillway.

On the other hand, the first two estimates include the cost of a 70,000-horsepower installation, while the last two make provision for only 60,000-horsepower. The reduction in cost occasioned by this last difference is, however, likely to be smaller than the addition which would have to be made for spillway purposes, so that it is likely that no great difference would exist in the acre-foot cost at either location and that this cost will be close to $28, barring in either case entirely unforeseen foundation and flood contingencies.

In regard to the amount of storage required, it should be stated that a revised study has been made by Mr. Gault, who bases his study on a net duty on the land of 2.75 feet, a total canal loss of one-third with a consequent diversion duty of 4.125 feet, as compared with 3 feet, which was used in the 1914 report. Mr. Gault further deviates from the older report in considering it necessary to pass the entire flow through the reservoir when the flow is 6000 second-feet or less, during May to August, inclusive; 5000 second-feet or less in April and September; and 4000 second-feet or less in the remainder of the year, the limit in the 1914 report being 4750 second-feet. The reason for this deviation is the large expansion of pumping irrigation in the Sacramento Valley since 1914, which has practically absorbed the entire normal low-water flow above the mouth of the Feather River, the rights so far matured aggregating between 5500 and 6000 second-feet. This leaves little, if any, water for navigation or for claims of riparian owners. On the other hand, the project itself may produce some return flow.

On the above basis Mr. Gault figures that with a reservoir all devoted to irrigation and holding 640,000 acre-feet, shortages would have been as per the following table:

EXHIBIT B.



99-C-121

Per Cent of Deficiency.

1898	7.9
1899	3.4
1900	1.1
1901	.6
1918	13.0
1919	1.1
1920 (up to Oct. 1)	16.4

In the above, no consideration was had of the Anderson-Cottonwood District appropriation just above the reservoir of 400 second-feet, which is in process of maturing, except that since 1918 a small portion of the above was actually diverted. The ultimate appropriation may be cut down to about 300 second-feet if the Iron Canyon project should acquire with the district lands necessary for the reservoir the water appurtenant thereto. This diversion will slightly increase the above shortages, possibly about 2 per cent.

This board has taken cognizance of the above facts merely to consider the general correctness of the size of reservoir to be provided. Further study might suggest a change; but, if so, it is not likely to be of sufficient importance to affect the main object of this report.

Location III, being geologically shown to be the most desirable one, and similarity of tentative estimates indicating no great superiority as to cost of the rejected upper Location I, has been made the basis for further study of dam design. The longitudinal section along the dam center line, together with the plan of the dam, is shown in Exhibit L,* following page 76.*

The first question which arises is the character of material available for construction. Local material consists of agglomerate, soft sandstone, tuff, and cemented gravel. At about four miles distance excellent concrete aggregate may be had in large quantities. Hard riprapping rock is not available short of Paynes Creek, about three miles upstream, or may be had from quarries on the main Southern Pacific Railway, 40 miles or more north of Red Bluff.

The entire length of the dam is about one mile, all but 1700 feet being 70 feet or less in height. The channel section would have a length of 800 feet and have a height of 170 feet, and 900 feet length of dam located on the canyon slopes would have a height ranging from 170 to 70 feet.

The spillway flow to be provided for is estimated at 350,000 second-feet. It is possible to release this flow over a long spillway on the west shoulder of the canyon at some distance from the channel section. The down flow of this mass of water on its return to the river would take place through existing gulches and channels which might be enlarged for the purpose, but which by reason of their length to the river and the friability of the local formation would be extremely expensive to protect from erosion. We believe that only an emergency spillway of relatively small capacity is permissible on the west shoulder of the river canyon.

A spillway channel on either one or both of the canyon sides, with short return channel to the river, would involve very difficult and expensive construction features. The discharge would have to be

* Exhibit L not included in this bulletin. Page reference is to "Report on Iron Canyon Project, 1920," by United States Reclamation Service.

turned at right angles toward the channel under high velocity and the sandstone and tuff formation through which this channel would have to be largely constructed would require extraordinary protection against erosion.

The problem of spillway discharge becomes relatively simple through a solid concrete channel section of the dam and similarly such section would afford the most economical means of power water discharge. Such section would also inspire the greatest confidence in view of the presence of a large population in the valley below the dam.

The principal reason for the selection of Location III was explained in previous paragraphs to be the existence of a mass of agglomerate 110 feet in thickness below the river channel at the dam site. This material where exposed at the surface is a natural concrete which is probably water-tight and has considerable hardness and great bearing power, in every way satisfactory as a foundation for a high concrete dam. The records of borings, however, are not nearly so favorable. The fine binding material in the interior of the mass is rather soft, so that but a small percentage of core was produced. In a drift in the east abutment of the dam also the material becomes rather soft away from air exposure.

A bearing test was made by Mr. Gault indicating for the softest part of the material that no yielding resulted under a pressure of approximately 40 tons per square foot, the test surfaces being 1 square foot and the material being dry. To what extent in such test the side support of the material under stress aided in supporting the load is uncertain as is also the softening effect which water might produce. We believe, however, that this agglomerate will furnish a safe foundation provided the maximum pressures do not exceed 10 tons, which is close to the limiting stress in the Denver design, of which the maximum section is shown in Exhibit M.*

In this section the back slope has been taken as 1:1, or flatter than an ordinary gravity section as a result of gate and siphon spillway design. The section is large enough to provide against one-third full pressure uplift near the heel, diminishing to zero near the toe.

The general agglomerate mass is probably reasonably water-tight even where it may lack hardness. Nevertheless, a cut-off trench of 40 or 50 feet into this material at the heel may be regarded as necessary. The material seems to be remarkably free from seams, but grouting below the plane of cut-off is desirable as a precautionary measure, together with providing drains back of the cut-off, these drains to be confined in depth to the agglomerate and on no account to penetrate to the underlying sandstone and tuff.

With such provisions it is not likely that any material uplift under the foundation will develop, and the provision to the extent explained above seems entirely sufficient. There is, however, some doubt as to whether the base of the dam should not be spread in an upstream direction with steel reinforcement reaching into the main base of the dam to take up shear and tension, to lessen the abruptness of the change from no load to full load, and to keep the maximum load within the 10-ton limit.

* Exhibit M not included in this bulletin.

The material in the hillsides continues to be agglomerate for a height of about 30 feet, above which level occur tuffs and sandstones, which in large part seem less desirable as a foundation for a masonry dam. The estimates prepared in Denver assume concrete masonry construction from end to end. It seems to us desirable that designs be also made on the basis of earth-dam construction, such construction to commence at points on either side of the masonry section, where an abutment wall could be feasibly founded on agglomerate by deep excavation, but where the height of the dam above the surface has become diminished to from 80 to 70 feet. This is suggested largely by foundation conditions, although it may also lead to lesser cost.

In regard to spillway and power outlets, the solution offered by the Denver office can not at present be improved upon in the limited time available to this board. It should be stated, however, that we believe the apron protection below the dam may have to be extended to insure the standing wave occurring on the apron. Possibly an increase in height of upstep may be required to minimize the distance from dam to wave. It may also be wise to consider a concrete upstream apron under the earth blanket, reaching possibly 100 feet upstream on bottom and canyon sides to insure against water passing down between earth apron and dam face.

The safety of the dam as designed, or as it may be redesigned, depends not only on the immediate foundation but also on the conditions of underflow in the sandstone and tuff beds below the agglomerate. To satisfy ourselves as to this crucial feature we have studied boring records and examined these beds where they rise in the exposed canyon sides upstream from the dam site, as shown on Exhibit D.*

The artesian flow from various bore holes indicates that the sandstone will permit slow flow of water. The most dangerous places in such cases are usually the planes of contact between different beds. Contact wherever examined seems to be perfect. The flow proceeds probably from the coarser layers which may not be extensive although pockets may occur with great frequency.

We believe that danger from a rapid flow establishing itself along certain lines under the dam, such as might begin carrying material and ultimately leading to the undermining of the dam, would be very serious to the extent of causing condemnation of the dam site if it were not for the fact that these sandstone layers below the dam are overlaid by a heavy capping of reasonably dense agglomerate dipping in a downstream direction. This agglomerate layer, 140 feet thick where not eroded by the river and with a minimum thickness next the dam of 110 feet, is so far as known remarkably free of seams. No springs have been discovered on the surface of this layer. The weight of this mass is sufficient, as previously stated, even where not overlaid, as in the sides of higher strata, to resist the full upward pressure which might be caused by underflow. Should any seam exist and water rise through it, it is not readily conceivable that any sand would be discharged through it, and if any sand movement from below should gain headway, it seems certain that the seam would become promptly clogged and choke any further upward movement of sand.

* Exhibit A, lower figure, of this bulletin; see page 203.

The possible occurrence of seams in this material has been especially a subject of study on the part of Mr. Hamlin, who holds that no fear in that regard need be entertained.

We conclude, therefore, that while conditions for a dam at the best site available are far from ideal, a safe dam can be constructed at this point, Location III, but it must be admitted that the item of contingencies to guard against all dangers which may become apparent upon opening up the foundation may be greater than usual and that the total for this dam, including also overhead expenses, estimated at 25 per cent, may be exceeded.

Your instructions did not require us to extend this study to the problem of project feasibility. We have, nevertheless, given some thought to this matter in connection with further action contemplated by the Iron Canyon Project Association.

So far as the dam and reservoir are concerned the present estimate stands about as follows:

Total cost, including 60,000 horsepower development	$17,977,000 00
Credit to irrigation on account of power	7,500,000 00
Net charge for reservoir to irrigation	$10,477,000 00
Available capacity, 640,000 acre-feet, net cost per acre-foot available	$16 40
Irrigable area, 225,000 acres, net cost per acre	46 60

As to the total acre cost we have used certain revised estimates made by Mr. Gault of the main canal and distribution features, indicating that the former may cost about $50 per acre and the latter $37, resulting in a total cost exceeding $130 per acre. It is possible that a greater credit may be secured for power, against which there is also the possibility that requirements as to unquestioned safety of the dam may compel large additional expenditures over those estimated.

The project is one which can become possible only through full support of the great majority of landowners, and it is well that they have a general knowledge of possible cost to guide them in their further efforts, for which purpose such figures as are now in our possession are above presented in this report.

Comparing this cost with the cost of plan A-4 in the 1914 report, with smaller total storage, if the cost of that plan had been reduced by probable power value only and had not received credit for flood control, for which under the changed water-right conditions the reservoir contains no reservation, the acre cost as then estimated would have been $65. Additional diversion as now figured, together with a practically doubled cost of labor and materials, would, roughly, result in about the same acre cost as is now figured in connection with a changed dam location.

D. C. Henny.
A. J. Wiley.
Homer Hamlin.
W. F. McClure.
J. L. Savage.
H. J. Gault.

Red Bluff, California, May 7, 1920.

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PUBLICATIONS OF THE DEPARTMENT OF PUBILC WORKS.

DIVISION OF ENGINEERING AND IRRIGATION.

Bulletin No. 1—California Irrigation District Laws, 1921 (Obsolete).
*Bulletin No. 2—Formation of Irrigation Districts, Issuance of Bonds by Irrigation Districts, Expenditure of Construction Funds, etc.
Bulletin No. 3—Water Resources of Tulare County and their Utilization, 1922.
Bulletin No. 4—Water Resources of California.
Bulletin No. 5—Flow in California Streams.
Bulletin No. 6—Irrigation Requirements of California Lands.
Bulletin No. 7—California Irrrigation District Laws, 1923 (Obsolete).
*Bulletin No. 8—Cost of water to Irrigators in California.
Bulletin No. 9—Supplemental Report on Water Resources of California.
Bulletin No. 10—California Irrigation District Laws, 1925 (Obsolete).
Bulletin No. 10a–Sacramento Flood Control Project, 1925 (with packet of maps).
Bulletin No. 11—Ground Water Resources of the Southern San Joaquin Valley.
Bulletin No. 12—Summary Report on the Water Resources of California and a Coordinated Plan for Their Development.
Bulletin No. 13—The Development of the Upper Sacramento River.
Bulletin No. 18—California Irrigation District Laws, 1927.
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