

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

PUBLICATIONS OF THE
DIVISION OF WATER RESOURCES
EDWARD HYATT, State Engineer

Reports on State Water Plan Prepared Pursuant to
Chapter 832, Statutes of 1929

BULLETIN No. 25

REPORT

TO

LEGISLATURE OF 1931

ON

STATE WATER PLAN

1930

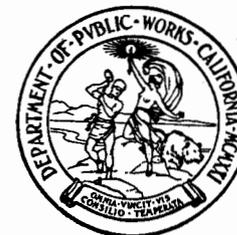


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LETTER OF TRANSMITTAL

TO THE MEMBERS OF THE LEGISLATURE,
STATE OF CALIFORNIA,
FORTY-NINTH SESSION.

I have the honor to transmit herewith a report on the State Water Plan, which has been prepared by the Division of Water Resources of this Department as directed by Chapter 832, Statutes of 1929. This report presents the results of a state-wide investigation covering a period of sixteen months.

In transmitting this report I would be unappreciative indeed if I did not bring to your attention and gratefully acknowledge the invaluable assistance rendered this investigation by the public at large. Individuals, public and private agencies, federal and state departments and other organizations have contributed data and given freely of their services.

Respectfully submitted.



Director of Public Works.

Sacramento, California,
January 1, 1931.

ACKNOWLEDGMENT

The Water Resources Investigation, as reported in this bulletin, has been assisted by so many individuals and public and private agencies that it is impracticable to express but general acknowledgment and appreciation.

Cooperating agencies of the United States have included the War Department; Bureau of Reclamation, and Water Resources and Topographic branches of the Geological Survey, Department of Interior; Division of Agricultural Engineering, National Forest Service and Weather Bureau, Department of Agriculture; Coast and Geodetic Survey, Department of Commerce; and Federal Power Commission.

Cooperating agencies of the state have included the University of California, State Highway Commission, Department of Natural Resources, Department of Public Health, and State Railroad Commission.

Stanford University, semiofficial committees, public utilities and a large number of individuals have contributed materially to the investigation. Special mention should be made of the engineers of California, many of whom have served on advisory committees, giving the Department the benefit of their wide experience and mature judgment.

The voluntary assistance of this wide group of agencies and individuals has been invaluable, and has constituted public service of the highest order.

ZATION

-----*Director of Public Works*
-----*State Engineer*

report was made under the general

prepared, and the investigation in
s outlined and executed under the

MONSTON
State Engineer

MATTHEW
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BRIDGE
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Assistants

fornia and central coast basins was

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SALINITY

G. A. ATHERTON H. L. HAEH T. H. MEANS

CHAPTER 832, STATUTES OF 1929

An act making an appropriation for work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development, and utilization of the water resources of California including the Santa Ana river, Mojave river, and all water resources of southern California.

[I object to the item of \$450,000.00 in section 1 and reduce the amount to \$390,000.00. With this reduction I approve the bill. Dated June 17, 1929. C. C. Young, Governor.]

The people of the State of California do enact as follows:

SECTION 1. Out of any money in the state treasury not otherwise appropriated, the sum of four hundred fifty thousand dollars, or so much thereof as may be necessary, is hereby appropriated to be expended by the state department of public works in accordance with law in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana river and its tributaries, the Mojave river and its tributaries, and all other water resources of southern California.

SEC. 2. The department of public works, subject to the other provisions of this act, is empowered to expend any portion of the appropriation herein provided for the purposes of this act, in cooperation with the government of the United States of America or in cooperation with political subdivisions of the State of California; and for the purpose of such cooperation is hereby authorized to draw its claim upon said appropriation in favor of the United States of America, or the appropriate agency thereof for the payment of the cost of such portion of said cooperative work as may be determined by the department of public works.

SEC. 3. Upon the sale of any bonds of this state hereafter authorized to be issued to be expended for any one or more of the purposes for which any part of the appropriation herein provided may have been expended, the amount so expended from the appropriation herein provided shall be returned into the general fund of the state treasury out of the proceeds first derived from the sale of said bonds.

FOREWORD

This report is one of a series of bulletins on the State Water Plan issued by the Division of Water Resources pursuant to Chapter 832, Statutes of 1929, directing further investigations of the water resources of California.

Prior to the studies carried out under this act, the water resources investigation had been in progress more or less continuously since 1921 under several statutory enactments. The results of the earlier work have been published as Bulletin Nos. 3, 4, 5, 6, 9, 11, 12, 13, 14, 19 and 20 of the former Division of Engineering and Irrigation, Nos. 5, 6 and 7 of the former Division of Water Rights, and Nos. 22 and 24 of the Division of Water Resources.

The full series of water resources reports prepared under Chapter 832, twelve in number, are:

Bulletin No. 25—"Report to Legislature of 1931 on State Water Plan."

Bulletin No. 26—"Sacramento River Basin."

Bulletin No. 27—"Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay."

Bulletin No. 28—"Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers."

Bulletin No. 29—"San Joaquin River Basin."

Bulletin No. 30—"Pacific Slope of Southern California."

Bulletin No. 31—"Santa Ana River Basin."

Bulletin No. 32—"South Coastal Basin."

Bulletin No. 33—"Rainfall Penetration and Consumptive Use of Water in Santa Ana River Valley and Coastal Plain."

Bulletin No. 34—"Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley."

Bulletin No. 35—"Permissible Economic Rate of Irrigation Development in California."

Bulletin No. 36—"Cost of Irrigation Water in California."

Each bulletin is printed under the caption "Reports on State Water Plan prepared pursuant to Chapter 832, Statutes of 1929." Bulletin No. 25 is the report to the Legislature presenting the accomplishments under the foregoing act. It summarizes the contents of other bulletins of the series, sets forth the progress of investigations not reported therein and covers legal, economic and other phases of certain features of the State Water Plan.

CHAPTER I

INTRODUCTION

California, embracing an area of one hundred million acres, has within its borders many million acres of agricultural lands under intensive cultivation and also extensive commercial and industrial activities contributing to the prosperity of its inhabitants, its political subdivisions, and of the United States as a whole.

During the past decade, California has increased in population at a rate greater than any other state in the Union. It now has more than 5,600,000 people living within its borders, about one-third of whom have come here from other states and foreign countries during the past ten years. With this great influx of population, the taxable wealth of the state has grown to more than ten billion dollars in 1930, 107 per cent larger than in 1920.

In order that California may be prepared to meet the continuance of this remarkable growth, it should look forward and plan for the conservation and orderly development, for all beneficial uses, of that most essential natural resource—water.

Authority for Investigation.

This investigation was authorized by Chapter 832, Statutes of 1929, appropriating \$390,000 to be expended by the Department of Public Works, "in conducting work of exploration, investigation and preliminary plans in furtherance of a coordinated plan for the conservation, development and utilization of the water resources of California including the Santa Ana river and its tributaries, the Mojave river and its tributaries, and all other water resources of southern California."

The investigation was assigned to the Division of Water Resources of the Department of Public Works and was commenced on August 14, 1929, when the funds became available.

History of Water Development in California.

The first water development of record in California goes back to the early Spanish missionaries who practiced irrigation to a small extent in the valleys of southern California in the latter part of the eighteenth century. Following the gold rush in 1849, ditches were constructed in the Sierra Nevada for placer, quartz and hydraulic mining. Some of these ditches later were utilized for irrigation and power. Dry farming was practiced, with irrigation on limited areas, until 1885 when dry farming reached its peak. Since then there has been a marked trend toward irrigation, resulting in greater production and profits.

Irrigation ditches were constructed in the valleys as early as the fifties. At first, irrigation developed gradually under private initiative and financing, using the natural stream flow on local areas. This was followed by community enterprises, irrigation districts, public utilities and municipal projects. Large modern storage and distribution works have been constructed by many of the irrigation projects so that the farmer may have an adequate and dependable water supply. Nearly three million acres are in organized irrigation districts at present, with outstanding bonds totaling \$96,000,000.

Paralleling the irrigation activities has been the development of the water resources of the state for power and municipal purposes. Since the completion in 1893 of the first polyphase hydroelectric plant in the state, there have been added 1,700,000 kilovolt amperes of installed capacity, producing in 1929, 6,400,000,000 kilowatt hours, or 18 per cent of the total hydroelectric energy produced in the United States.

The great metropolitan centers have expended large sums for works of great magnitude to bring water into their areas. The cities of Los Angeles and San Francisco, and the East Bay Municipal Utility District have gone to the Sierra Nevada for a water supply. The Metropolitan Water District of Southern California, comprising eleven cities* in southern California, now is preparing plans to import a supply from the Colorado River.

In addition to developments for water supply, extensive works have been constructed for the reclamation of swamp and overflow land and control of floods. The greater part of this has occurred in the Sacramento and San Joaquin valleys, where an area of more than 1,000,000 acres has been reclaimed with an expenditure of over \$100,000,000. The earliest works of reclamation were started in the fifties and, as in the case of the early irrigation developments, were largely the result of individual effort on a small scale. However, the magnitude of the works required for reclamation and flood control soon became so great that it became necessary to form cooperative organizations to finance and carry out construction work. These organizations took the form of swamp land and reclamation districts organized under various laws passed by the State Legislature. This method of development sufficed for the reclamation of individual tracts of land. However, the more difficult and expensive works necessary for flood control have required combined agencies of the federal and state governments and interested landowners.

The plans for and construction of flood control works in the Sacramento and San Joaquin valleys have been carried out largely by private agencies and reclamation and levee districts with supervision and financial aid in recent years by the federal and state governments acting through their respective agencies, the California Debris Commission, and the Reclamation Board, the latter acting as trustee for the interested landowners organized under the Sacramento-San Joaquin Drainage District. The total estimated cost of flood control works, to be divided equally among the federal and state governments and the landowners, will amount to about \$50,000,000. In other portions of the state extensive works for the control of floods have been constructed, notably in Los Angeles, Riverside and Imperial counties.

The first California Legislature in 1850 adopted the "Common Law of England" as the rule of decisions in the courts of the state, which adoption has been held by the courts to include the doctrine of riparian rights. This doctrine eventually came into conflict with the theory of appropriation originated by the gold miners, who "located" water for use in their mining operations in the same manner in which they acquired the mining claims. The controversy between these two opposing types of water rights has been long and bitter and is still extant. It adds to the uncertainty and cost of any water development

* On September 1, 1930.

in the state and is a serious obstacle in the way of a major State Plan of development.

In 1887, the Legislature passed the Wright Irrigation District Act, a model for all subsequent irrigation district legislation in this and other states of the arid west. After many revisions, it was definitely designated by the Legislature in 1917 as the "California Irrigation District Act." Ninety-four irrigation districts organized under this act are now in operation.

In 1914, the State Water Commission, later incorporated into the State Department of Public Works, was created to administer water rights, to clarify the complex water-right situation and to safeguard the state's limited water supply as far as possible. It has functioned successfully although handicapped by constitutional and judicial limitations.

California's Water Problem.

California's water problem is two-fold, involving first the conservation and utilization of its water resources, and second, the control of floods. There are large inequalities in both the geographic and seasonal distribution of the state's water resources, as related to the demands for various purposes. The most complete conservation and utilization of the water resources, therefore, involves construction of storage reservoirs and utilization of underground basins for full development of water supplies, and also conveyance conduits to carry the supplies from areas of surplus waters to areas with insufficient local water supplies to meet their demands.

The problem of flood control is important in all portions of the state. It involves construction of various combinations of flood control works, such as detention reservoirs, levees, revetments and by-pass flood channels. Conservation and flood control works can be combined in many instances. Separate and distinct works are usually required in addition for complete solution of each phase of the problem.

The works required for solution of the state's water problem are of such great magnitude and of such far reaching scope that proper solution calls for a coordination and unification of the interests of not only the entire state, but the federal government as well, in the planning and execution of a complete program of development.

Many obstacles—financial, legal and political—lie in the path of a program of complete relief and development. Although the past development of the state's water resources for irrigation, municipal, hydroelectric power and other uses has been successfully carried out by private and public agencies under existing laws, the greater magnitude of the problems arising in the planning and execution of works for complete coordination and utilization of the state's water resources calls for an entity of wider scope and greater powers than has heretofore been necessary. The magnitude and cost of the works involved are so great that it is questionable whether local interests would have the financial capacity to carry out the development required.

Previous Investigations.

Investigation of California's water resources with the view of formulating a plan for their comprehensive development is by no means new. As early as 1873, an investigation and report, under the direction of

the War Department, were made on the water resources of the Great Central Valley. The report* outlined a plan for utilizing the water supply of the Sierra Nevada streams to greatest advantage for irrigation purposes and directed attention to the duty of government, both state and national, to lay out a "comprehensive system of irrigation" and enforce laws for proper development of the two great interior valleys.

The first effort of the state to launch a comprehensive investigation of its water resources and offer a solution of the problem concerning water utilization, was made in 1878 and resulted in "an act to provide a system of irrigation, promote rapid drainage and improve navigation on the Sacramento and San Joaquin River." Under this act, investigations were carried out by the State Engineer, William Ham. Hall. He, like the Army engineers in 1873, suggested that the water of the Great Central Valley be developed in a systematic manner. Several reports † and maps were published by the State Engineer between 1880 and 1888.

A federal investigation was made in 1900 under the auspices of the United States Department of Agriculture, Experiment Station Office. In its report ‡ there was a recommendation that the laws of the state pertaining to the appropriation and use of water be revised and that the state itself exercise full control over all streams so that irrigation development could proceed unhampered and water supplies be conserved. This was the forerunner of the movement to establish a state office for administering water rights.

In 1911 the state sponsored an investigation through a special board known as the "Conservation Commission." This commission § found that the waters of the state were the only natural resources left to the public for development, and criticized the practice then prevalent of failing to prosecute work after posting notice of appropriation.

This report was followed in 1912 by another federal investigation by the United States Department of Agriculture and a bulletin dealing with the irrigation resources of the state and their utilization** was issued.

In 1921, the studies known as "The California Water Resources Investigations" were initiated under legislative authority in Chapter 889, Statutes of 1921. Further investigations were authorized in 1925 by legislative enactment. These investigations were carried out under the direction of the State Engineer. A report †† containing a complete inventory of all water within the state's boundaries, an estimate of the gross agricultural area, and of the average amount of water that should be applied for irrigation, and a general preliminary comprehensive plan for "converting the waters of California to their greatest service in this generation and for all posterity," was filed with the

* House Executive Document, No. 290, Forty-third Congress, First Session, "Irrigation of the San Joaquin, Tulare and Sacramento Valleys, California," by B. S. Alexander, C. H. Mendell and George Davidson.

† Reports of William Ham. Hall, State Engineer, 1878-1888.

‡ Bulletin No. 100, U. S. Department of Agriculture, "Report of Irrigation Investigations in California," 1901.

§ Report of Conservation Commission of California, 1912.

** Bulletin No. 254, U. S. Department of Agriculture, Office of Experiment Station, "Irrigation Resources of California and Their Utilization."

†† Bulletin No. 4, "Water Resources of California," a report to the Legislature of 1923, also the following appendices: Bulletin No. 5, "Flow in California Streams," and Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, State Department of Public Works, 1923.

1923 Legislature. It was found in this investigation that the principal constructive features of a plan for obtaining maximum use of the state's water must revolve about its distribution for the greatly preponderant use in agriculture.

In the report* to the Legislature of 1927, a plan was advanced for importation of water to the upper San Joaquin Valley from the Sacramento River Basin to supplement the deficient water supplies in the upper San Joaquin area. Cost estimates of the major physical units were incorporated. No definite plan was included in that report for obtaining a complete supplemental supply for southern California. However, the Colorado River was suggested as a possible source as it is stated in the report,

"Although it is not apparent from what source the required large volume of new water can be obtained for the full development of the Pacific slope (southern California), nevertheless, present attention should be directed towards securing those new supplies that are available on the Colorado River and elsewhere and in coordinating their use to obtain the greatest benefit from their limited amounts."

This report, due to the lack of sufficient funds, was incomplete in certain particulars, and covered only engineering phases. The final recommendation of the report is,

"In view of the intricate nature of these problems and their momentous bearing upon the future of California, the Division and its advisors earnestly recommend that a committee representative of all those concerned in the development of the water resources of California, including national and state offices, be appointed solely for the purpose of determining first, the practicability of carrying out this plan, and second, if found to be practicable, to recommend a method of procedure."

Interest of State in Its Water Problem.

That the state is vitally concerned in the economic, systematic and equitable solution of its water problem, is evidenced by the past legislative enactments appropriating funds for flood protection and investigational work; by the recognition of the importance of the problem by the large commercial interests of Los Angeles and San Francisco in advancing \$94,125 in 1924 for the study of a particular area in distress in the upper San Joaquin Valley; by the appointment of committees from the 1927 and 1929 Legislatures to study the water problem of the state and report to the Legislature; by legislative authorization of a commission appointed by the Governor in 1929 to confer and cooperate with a federal commission and a Joint Legislative Water Committee; by formation of county committees whose function has been to assist in the solution of the problem; and by the appointment of special committees of chambers of commerce and of other organizations of the larger cities.

The state has cooperated with the federal government and the benefited landowners on the Sacramento Flood Control Project, by pledging itself to participate in the ultimate financing of the project to the extent of approximately \$17,000,000. Appropriations are being made by each Legislature to carry on the state's share of this work. In Los Angeles County it has participated financially to the extent of \$3,000,000 in the flood control work now under construction.

* Bulletin No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, 1927.

The Legislature also has been liberal in making appropriations for investigational work on water resources. The following appropriations have been made since 1921:

Chapter 889, Statutes of 1921	-----	\$200,000
Chapter 180, Statutes of 1925	-----	94,125
Chapter 476, Statutes of 1925	-----	25,000
Chapter 477, Statutes of 1925	-----	150,000
Chapter 79, Statutes of 1927	-----	15,000
Chapter 809, Statutes of 1927	-----	40,000
Chapter 78, Statutes of 1929	-----	10,000
Chapter 561, Statutes of 1929	-----	25,000
Chapter 656, Statutes of 1929	-----	15,000
Chapter 832, Statutes of 1929	-----	390,000
		\$964,125

Three legislative committees have been appointed by the State Legislature to investigate and study California's water problem. The first committee appointed by the Legislature of 1927, while in session pursuant to Assembly Concurrent Resolution No. 16, consisted of eight members, four from the Senate and four from the Assembly. It was directed, "to make a further study of the records of the State Engineer, pertaining to the subject of this resolution and to report its findings and submit its recommendations to this Legislature at the forty-seventh session thereof not later than the first week in March, 1927." This committee had available for its consideration and deliberations, the following federal and state reports pertaining to the water problem:

- House Executive Document No. 290, Forty-third Congress, First Session, "Irrigation of the San Joaquin, Tulare and Sacramento Valleys."
- Reports of William Ham. Hall, State Engineer, 1878-1888.
- Bulletin No. 100, "Report of Irrigation Investigations in California," U. S. Department of Agriculture, Office of Experiment Station, 1901.
- Report of Conservation Commission of California, 1912.
- Bulletin No. 254, "Irrigation Resources of California and Their Utilization," U. S. Department of Agriculture, 1912.
- Report, State Water Problems Conference, 1916.
- Bulletin No. 3, "Water Resources of Tulare County and Their Utilization," Division of Engineering and Irrigation, 1922.
- Bulletin No. 4, "Water Resources of California," Division of Engineering and Irrigation, 1923.
- Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923.
- Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1923.
- Bulletin No. 9, "Supplemental Report on Water Resources of California," Division of Engineering and Irrigation, 1925.
- Bulletin No. 11, "Ground Water Resources of Southern San Joaquin Valley," Divisions of Engineering and Irrigation and of Water Rights, 1927.
- Bulletin No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, 1927.
- Bulletin No. 5, "San Gabriel Investigation," 1923-1926, Division of Water Rights.

The committee reported back to the Second Session of the 1927 Legislature. The conclusions of its report were that it would take months of intensive study and public hearings before the committee would feel justified in making any recommendation upon which the Legislature could act as to the practicability of the plan contained in Bulletin No. 12, that the plan should be executed in progressive steps in harmony with existing and future local projects and that adequate legislative machinery should be provided for the execution and operation of the plan.

The committee quoted and endorsed the following recommendations from the State Engineer's report:*

"So extensive is the area, so many and varied are the interests, and so great are the expenditures involved in this plan that the usual method of procedure is impracticable. The economic, financial, legal and political problems relating to its execution are so complex and far reaching that they should be the subject of careful deliberation. The broad values and public advantages of the plan should be weighed with the costs and difficulties. Methods of execution, of operation and of financing should be considered along with the extent to which costs should be distributed."

The general conclusion of the committee was—

"that this is a matter in which, urgent as some of the needs are, the only safe policy is to make haste slowly. Any policy or plan precipitated without the most painstaking consideration is sure to result in disaster."

It recommended—

"That a legislative committee of four members of the Assembly and four members of the Senate be appointed as a permanent committee during the next two years, to continue this intensive study, to confer with the proper federal authorities, and to hold hearings of all those concerned in the development or use of the water resources of the State, with the view to making a final report to the forty-eighth session of the Legislature."

Following out the recommendation of the legislative committee, another committee, composed of four members each from the Senate and Assembly, was appointed to make a further investigation of the entire matter and report back to the forty-eighth session of the Legislature in 1929. The personnel of this committee was:

Senate Members

Ralph E. Swing, Vice Chairman, San Bernardino
 Edwin A. Mueller, El Cajon
 H. C. Nelson, Eureka
 Will R. Sharkey, Martinez

Assembly Members

B. S. Crittenden, Chairman, Tracy
 E. G. Adams, Secretary, Livingston
 Van Bernard, Butte City
 F. W. Mixter, Exeter

This committee, under the leadership of B. S. Crittenden, pursued the subject vigorously from July, 1927, to December, 1928. More than twenty public hearings were held in all parts of the state.

Additional reports on specific features were furnished the committee for its consideration. A legal advisory board of nine eminent attorneys, particularly well versed in water law, prepared an excellent report. The Industrial Water Users Association of Contra Costa County submitted a report in connection with a salt water barrier below the confluence of the Sacramento and San Joaquin rivers. The State Engineer had prepared a special report of financing by electric power revenue which might be anticipated in connection with the Kennett reservoir on the Sacramento River. The committee presented a preliminary report to the 1929 Legislature in January of that year, and a final report in the following April. The reports dealt with the subject in a

* Bulletin No. 12, "Summary Report on the Water Resources of California and a Coordinated Plan for their Development," Division of Engineering and Irrigation, 1927.

comprehensive manner and while the conclusions are too extensive to reprint in this volume, the final report recommended submission to the electorate of a bond issue to construct units of the plan totaling \$109,000,000.

In addition to the legislative committee's report, the Legislature of 1929 had available for consideration the following additional reports prepared by the Division of Engineering and Irrigation and Division of Water Rights:

Reports of Division of Engineering and Irrigation:

- Bulletin No. 13, "The Development of the Upper Sacramento River," containing cooperative report on Iron Canyon Project by U. S. Bureau of Reclamation, 1928.
- Bulletin No. 14, "The Control of Floods by Reservoirs," 1928.
- Bulletin No. 19, "Santa Ana Investigation, Flood Control and Conservation," 1928.
- Bulletin No. 20, "Kennett Reservoir Development, an Analysis of Methods and Extent of Financing by Electric Power Revenue," 1929.
- Bulletin No. 22, "Report on Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," 1929.

Reports of the Division of Water Rights:

- Bulletin No. 6, "San Gabriel Investigation," 1926-1928.
- Bulletin No. 7, "San Gabriel Investigation—Analysis and Conclusions," 1929.

After receipt by the Legislature of the report of the Joint Legislative Committee, two constitutional amendments were introduced, one providing for construction of units of the plan totaling \$109,000,000, amended to \$124,000,000, and the other construction of units totaling \$30,000,000. Both measures, after lengthy discussion and consideration, failed of adoption by the Legislature. It was apparent that it would be inadvisable to enter upon such a large program without complete data on all phases of the subject—engineering, economic, financial and legal. Three laws were enacted by that Legislature, providing for further studies and a report to the forty-ninth session. The first provided for a continuation of the studies by a legislative committee, the second for appointment of a commission by the Governor to cooperate and confer with a similar commission to be appointed by the President of the United States and to cooperate and confer with the Joint Legislative Committee, and the third for a further appropriation to the Department of Public Works. These acts were signed by the Governor and became effective August 14, 1929.

The following members of the Legislature were appointed to serve on the Joint Legislative Committee, with one exception the same as for the 1927 committee:

Senate Members

Ralph E. Swing, Vice Chairman, San Bernardino
 Edwin A. Mueller, El Cajon
 H. C. Nelson, Eureka
 Will R. Sharkey, Martinez

Assembly Members

B. S. Crittenden, Chairman, Tracy
 Van Bernard, Butte City
 Robert P. Easley, Antioch
 F. W. Mixter, Exeter

This committee was directed by the Legislature to make an investigation of the water problem of the state (a) including the desirability for, and location of, a salt water barrier at or near Carquinez Strait; (b) the water problem of those counties not included in the Big Basin (Great Central Valley of California); and (c) to recommend to the Legislature at the forty-ninth session a state-wide policy for the conservation and use of the waters of the state.

The precedent for the state's participation in a program for the complete development and utilization of its water resources has already been established by its active participation with the federal government and other agencies in planning and financing certain works for the control of floods. The complete development and utilization of the state's water resources involve not only flood control, but also storage and distribution of available supplies for agricultural, municipal, hydroelectric, industrial, navigation and other uses. The extension of the scope of participation and activities of the state to include both phases of the state's water problem appears to be a logical step from the precedent established in dealing with a part of the problem.

Interest of Federal Government in California's Water Problem.

The interest of the federal government in California's water problem is evidenced by its past and present activities in studying several phases thereof. Investigations, as heretofore stated, began as early as 1873, followed by other investigations in 1900 and 1912. Further investigations now are in progress by the War Department, the Departments of the Interior and Agriculture, and by the Federal Power Commission. The study being made by the Department of the Interior, through the Bureau of Reclamation, is in cooperation with the state.

The federal government also has participated in the solution of the flood problems. In the Sacramento Flood Control Project it has pledged itself to contribute up to a maximum of \$17,600,000. It has financed the Boulder Canyon Project in the amount of \$165,000,000. Upon completion, this latter project will solve the flood control problem of Imperial Valley and also make available a water supply for the irrigation of additional lands in the area tributary to the Colorado River and for importation to southern California for domestic purposes. In addition to these activities the federal government has been making contributions toward the collection of stream flow data on California streams since 1895.

The precedent established by the above described activities and participation of the federal government in the state's water problem, together with established policies relating to navigation, flood control and reclamation, would appear to offer a logical basis for extension of federal participation in construction of works required for conservation and utilization of the state's water resources.

Joint Interest of Federal and State Governments.

The combined interest of federal and state governments in the water problem of California is manifested by creation in 1929 of the Federal-State Water Resources Commission to investigate and report on the problem. Under authority of Chapter 561, Statutes of 1929, the Governor appointed a commission of seven members which conferred with

one composed of three members appointed by the President. The membership of the commission was:

United States Members

- Elwood Mead, Commissioner, U. S. Bureau of Reclamation, Department of the Interior
 Thomas M. Robins, Lieutenant Colonel, Corps of Engineers, U. S. Army
 Frank E. Bonner, Executive Secretary, Federal Power Commission.

California Members

- George C. Pardee, Chairman, Oakland.
 William Durbrow, Grass Valley.
 B. A. Etcheverry, Berkeley.
 Alfred Harrell, Bakersfield.
 W. B. Mathews, Los Angeles.
 Warren Olney, Jr., San Francisco.
 Frank E. Weymouth, Los Angeles.

The following sat with the commission as representatives of the state in their official capacities:

- B. B. Meek, Director of Public Works.
 W. J. Carr, member of the State Railroad Commission.

Matt I. Sullivan sat with the commission, at its request, in the later meetings as the representative of Governor-elect Rolph.

Edward Hyatt, State Engineer, acted as secretary of the commission.

The first meeting of the commission was held on January 13, 1930. In all, sixteen meetings were held. Most of these meetings were joint sessions with the Legislative Water Committee, five of which were devoted to public hearings. A report was rendered to the President of the United States and to the Governor of California on December 27, 1930.

Urgency of Solution of California's Water Problem.

While many sections of the state have water problems, there are three large and important areas where the problem of water shortage has become acute and requires immediate action for its solution. These are upper San Francisco Bay, Sacramento-San Joaquin Delta and Sacramento Valley; upper San Joaquin Valley;* and Pacific slope of southern California.

In the delta of the Sacramento and San Joaquin rivers and upper San Francisco Bay area, the water supplies of agriculture and industry are menaced by the invasion of saline water. This salinity condition has become aggravated during the last few years of subnormal run-off. In the delta is an area of more than 400,000 acres of the richest agricultural lands in the state, of which about 350,000 acres are now under cultivation. The taxable wealth of this area is approximately \$45,000,000 and the value of its agricultural products in 1929 was about \$30,000,000. The industries located along the shores of Suisun Bay

*That portion of the San Joaquin Valley extending southerly from Chowchilla River.

are an important part of the industrial structure in California. The capital investment of these industries is approximately \$43,000,000, their taxable wealth approximately \$15,000,000, their annual payrolls approximately \$13,000,000, and the annual value of their products approximately \$112,000,000. Accompanying this situation in the delta and upper San Francisco Bay area there have been irrigation and navigation problems in the Sacramento River above the delta. Continued irrigation diversions, particularly in the summer months in years of subnormal run-off, have reduced the stream flow of the river to the extent that navigation has been greatly impaired. This condition has resulted in warnings being sent out by the federal government to irrigators to curtail their diversions and during several of the subnormal run-off years, such as 1920 and 1924, the lands served from the Sacramento River have been furnished with a deficient irrigation supply. Pumping costs in supplying these lands also were increased during these years due to the lower water levels in the stream. All of the foregoing problems resulting from deficient stream flow are closely interrelated and remedial measures for their solution are urgent.

In the upper San Joaquin Valley, due to an overdraft on its mean annual water supply, a gross area of some 400,000 acres of developed land is in need of a supplemental supply. The average annual value of its agricultural products is over \$30,000,000. If retrogression is allowed to proceed on these farmed lands its effect will be felt in the urban areas in the immediate vicinity and also to some extent in the large metropolitan areas—Los Angeles and San Francisco.

In the Santa Ana River Basin of southern California, 60 per cent of the land under irrigation is overdrawing its available local water supply. While salvage of present local wastes will take care of a part of this overdraft, there is urgent need for an imported supply to care for the remainder and for increasing development. In some other parts of the South Coastal Basin, there also is an overdraft on local water supplies. The city of Los Angeles has voted a bond issue to bring in an additional supply from Mono Basin and the Metropolitan Water District of Southern California, consisting of eleven cities,* including Los Angeles, is taking steps to bring in water from the Colorado River. In San Diego County the city of San Diego likewise is planning to bring a supply from the Colorado River. The water problem in all of these areas is acute and immediate consideration must be given to its early solution.

Scope of Report.

This report sets forth for the main hydrographic divisions of the state, the available water supply, the water requirements for all purposes, the major units of an engineering plan for the ultimate development of the water resources in the principal areas of the state, the units of the plan which should be built first to relieve stress in the highly-developed areas deficient in local supplies, investigations in progress in minor but important areas, legal problems that confront the execution of the State Plan together with suggestions for remedial measures, and economic and financial aspects of initial units of the plan that

*On September 1, 1930.

would aid in the solution of California's water problem. These subjects are summarized in Chapter II of this report and are dealt with in greater detail in succeeding chapters.

There have been certain limitations in evolving a plan for the entire state. Funds and time have given opportunity for presenting only the major units of a plan for the principal hydrographic divisions. Other minor units not presented are important and necessary and ultimately will have to be built to give complete service. There are other important areas for which studies are now in progress.

In this report, the engineering, economic and legal aspects of the plan are discussed. Conclusions are reached as to the engineering feasibility of certain units and the extent to which revenues from the sale of water and power could carry the costs, but no evaluation is made of benefits which would accrue to certain interests indirectly and which would play an important part in determining the economic soundness of any project. Conclusions are given as to the units which should be constructed first to afford relief to the regions of water shortage, but no recommendations are made relative to methods of financing.

Basic Principles of a State Water Plan.

In the formulation of the engineering plan, as set forth in this report, the following economic principles are recognized as fundamental:

1. It should be formulated with a long time viewpoint.
2. It should be a progressive development with the various units constructed only as necessity demands.
3. It should be in consonance with present rights and interests as far as practicable so as to result in the least possible interference with existing agencies and their operations.
4. The water requirements of all interests must be given consideration.
5. Accruing benefits must far outweigh the damages which might result from the execution of the plan.
6. The fullest practicable utilization of both local and imported waters should be made, particularly in areas of deficient water supply.
7. The initial units constructed for the rehabilitation of agriculture should now be extended only to developed areas of deficient local water supply.
8. Units of initial development should be so planned that they can be enlarged and extended at the minimum expense to allow for expansion as economics dictate and that they are in accord with an ultimate plan of development.
9. The plan should be so formulated and carried out that the greatest benefit will be obtained at the least cost.

CHAPTER II

SUMMARY AND CONCLUSIONS

The investigation of the water resources of the state in evolving the State Water Plan has required many detailed studies, a full understanding of which makes necessary, even in this summary report, a presentation of considerable length and detail. The purpose of this chapter is to present, in a concise form, the results and conclusions of the investigation and primary features of the plan. These, together with the bases of the studies, are set forth in more detail in the succeeding chapters.

Water Resources.

The water supply of the state, by basins, is set forth in the following tabulation. These figures do not include contributions to the surface run-off and ground water replenishment from rainfall on valley floors. In some localities this may constitute a considerable portion of the available water supply. Because of the lack of definite information on this subject, the supply from this source has not been included in the following estimates, which contain only the run-off from the mountain and foothill areas:

Water Supply

Basin ¹	Area of drainage basin in square miles	Seasonal run-off in acre-feet (Season, October 1 to September 30)			
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929
North Pacific Coast.....	16,543	26,797,000	23,659,000	21,906,000	25,034,000
Sacramento River.....	21,369	24,801,000	20,593,000	17,920,000	19,027,000
San Joaquin River.....	18,178	11,980,000	10,160,000	8,547,000	8,137,000
San Francisco Bay.....	2,219	824,000	634,000	526,000	600,000
Central Pacific Coast.....	9,488	2,248,000	1,927,000	1,228,000	1,166,000
South Pacific Coast.....	6,079	1,114,000	1,146,000	894,000	709,000
Great Basin.....	8,876	3,624,000	2,956,000	2,463,000	2,395,000
Total.....	82,752	71,388,000	61,075,000	53,484,000	57,068,000

¹ See Plate III, following page 62, for location of basins.

The run-off from the North Pacific Coast and Central Pacific Coast basins is largely physically unavailable for use in the state as a whole and a portion of the run-off from the Great Basin now is used outside of the state.

In addition to the run-off from streams within the state, water will be available for southern California from the Colorado River in accordance with the terms of the Boulder Canyon Project Act, passed by Congress on December 21, 1928, and later approved by the President.

Water Requirements.

The water requirements in the seven basins are based on the aggregate needs for domestic, municipal, irrigation, industrial, salinity control and navigation purposes. In each basin there will be a need for water for one or more, or even all, of these uses. In some basins,

one use predominates and controls the requirements. In the Sacramento River, San Joaquin River, North Pacific Coast, Central Pacific Coast and Great Basins, irrigation use is the controlling factor. In the San Francisco Bay and South Pacific Coast basins, domestic, municipal and industrial uses play an important part in determining the water requirements. In these two latter areas, water, in addition to that required for irrigation of lands in the same basin, is needed to meet the larger demands of industry and densely populated centers. The following table gives, by basins, gross and net water service areas which ultimately will require a water supply, if they are developed.

Water Service Areas

Basin	Gross area in acres	Net area in acres
North Pacific.....	421,000	337,000
Sacramento River (including Sacramento-San Joaquin Delta).....	6,435,000	4,266,000
San Joaquin River.....	3,219,000	5,704,000
San Francisco Bay.....	998,000	870,000
Central Pacific Coast.....	770,000	616,000
South Pacific Coast.....	2,400,000	2,000,000
Great Basin.....	3,600,000	2,880,000
Total for state.....	22,843,000	16,673,000

Water requirements, for any particular area, vary not only in amount with the use to which the water is put, and in monthly demand, but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area and the opportunity afforded for reuse of water, which is controlled by topographic, geographic and geologic conditions, are factors that have an important bearing on water requirements. For these reasons, variations in treatment of the problems for the different areas necessitated the use of different terms of use as follows:

“Gross allowance” designates the amount of water diverted at source of supply.

“Net allowance” designates the amount of water actually delivered to the area served.

“Consumptive use” designates the amount of water actually consumed through evaporation, transpiration by plant growth and other processes.

“Net use” designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

In the North Pacific Coast Basin, the water requirements are based on gross allowance for irrigation of 80 per cent of the gross agricultural area. Additional water would be required for other purposes, but the amount would be relatively small. For the Sacramento Valley, lower San Joaquin Valley, foothill areas of the Sacramento and San Joaquin river basins, Central Pacific Coast and the Great Basin, the requirements are estimated on the basis of gross irrigation allowance on net irrigable areas. A substantial part of this water in some of these basins would be available for reuse. The requirements for the Sacramento-San Joaquin Delta are based on consumptive use for irrigation and

unavoidable evaporation and transpiration losses on the entire area. In the upper San Joaquin Valley, the total water requirements are estimated on the basis of net use on net irrigable areas. For the San Francisco Bay Basin, both gross and net allowance are used in estimating the requirements for the various areas within the region for municipal, industrial and agricultural purposes. In the South Pacific Coast Basin, the requirements are estimated on the basis of gross allowance for irrigation on net irrigable areas and for municipal use in urban areas. In addition to the foregoing uses, water would be required for navigation on the Sacramento River and for controlling salinity in the Sacramento-San Joaquin Delta and upper San Francisco Bay region.

On the foregoing basis, the ultimate gross annual water requirements, by basins, are as follows:

Water Requirements

Basin	Gross annual water requirements in acre-feet ¹
North Pacific Coast.....	1,011,000
Sacramento River (including Sacramento-San Joaquin Delta).....	15,864,000
San Joaquin River.....	13,326,000
San Francisco Bay.....	1,735,000
Central Pacific Coast.....	1,540,000
South Pacific Coast.....	3,340,000
Great Basin.....	10,000,000
Total for state.....	46,816,000

¹ Actual use is much less than gross allowance. A considerable portion would be available for reuse in some basins.

² Includes requirements for salinity control (see pages 79 and 80).

Ultimate Major Units of State Water Plan.

A comparison of water supply and requirements indicates a large excess of water over the needs in the North Pacific Coast Basin, some excess in the Sacramento River Basin and a deficiency in supply in the other basins if each is considered as a unit. To provide an adequate and dependable supply for these areas, a plan must be formulated not only to overcome the unequal geographic distribution with respect to the needs, but also to regulate the seasonal distribution so that the availability of supply will be in consonance with the demand. Such a plan has been formulated for the larger and more important divisions of the state. Under this plan, the basins favored with water in excess of their needs would be furnished a regulated supply in accordance with the requirements of their ultimate development. Waters in excess of these requirements would be conveyed to areas of deficiency and there used to supplement local waters and afford those areas supplies adequate to meet their future ultimate requirements. The primary physical features of this plan are storage reservoirs, both surface and underground, which would be used for regulating the available run-off, and conduits for conveying the supply from points of origin to areas of use. In conjunction with the surface reservoirs, hydroelectric power plants would be utilized in some cases to generate electric energy incidental to the primary use of the reservoir. In some instances the reservoirs also would be utilized to reduce flood flows,

improve navigation and control salinity. The plan* set forth in this report includes only the major units for the principal geographic divisions of the state. Other storage and conveyance units, both constructed and to be constructed, are necessary and essential parts of any comprehensive plan for the development of the state's waters. Additional reservoir sites exist, which if developed would increase the degree of control and perfect utilization of these waters. Many distributory conduits and other accessory works not shown in this report also will be necessary. A plan has not been presented for the entire state. However, the one that is presented provides a system of physical works which would make available a water supply for the benefit of 75 per cent of the agricultural area, 90 per cent of the taxable wealth and 90 per cent of the population of the state. Certain portions of the area affected by this plan and other areas of the state still are under investigation.

Great Central Valley—Sacramento and San Joaquin River Basins—
The plan for the development of the Great Central Valley comprises surface storage reservoirs and conveyance systems, operated in conjunction with underground reservoirs. In the Sacramento Valley, only major surface storage reservoirs are included in the plan, it being considered that the distribution system is a feature for local development. In the lower San Joaquin Valley†, major surface reservoirs also are proposed for the storage and regulation of excess run-off. For the development of the upper San Joaquin Valley‡, both surface reservoirs and underground storage are considered part of the plan. In the lower San Joaquin and Sacramento valleys, however, the underground storage capacity is not utilized, although in the future it may play an important part in the ultimate utilization of the water resources. Major conveyance units also are included for the transportation of supplemental supplies. The plan for conveying supplemental supplies to the upper San Joaquin Valley involves the pumping of water from the Sacramento-San Joaquin Delta up the San Joaquin River and exchanging it at Mendota for San Joaquin River water, which would be diverted at Friant reservoir, for a supplemental supply for the eastern side of the upper San Joaquin Valley. For the western side of the upper San Joaquin Valley, the full supply would be pumped to the area. Most of the latter supply also would come from the Sacramento-San Joaquin Delta.

The available and utilizable underground storage capacity in the upper San Joaquin Valley would be operated to obtain the fullest practicable beneficial use of the local and imported supplies. The operation of the underground reservoirs in a specified manner similar to that of a surface reservoir would be required to accomplish the desired results.

The plan of diverting water from the delta for exportation to the San Joaquin Valley would have the great advantage of interfering least with present rights and interests, and of being capable of utilizing the

* See Plate IV, following page 90.

† "Lower San Joaquin Valley" is defined as that portion of the valley extending northerly from the Chowchilla River and a line from Mendota westerly to Oro Loma, and the "upper San Joaquin Valley" as that portion extending southerly from these lines.

waters derived from the entire catchment area after they have flowed past all upstream users and after all upstream requirements have been met.

A summary of the major features and costs of the plan in the Great Central Valley (including Trinity River diversion) is as follows:

Surface storage units—

Number of reservoirs.....	24 (two constructed)
Number of reservoirs with power features....	13 (two constructed)
Aggregate storage capacity.....	17,817,000 acre-feet

Capital cost (exclusive of two constructed)—

Excluding power plants.....	\$492,200,000
Including power plants.....	595,900,000

Conveyance units in San Joaquin Valley—

Number.....	6
Capital cost	\$88,000,000

An analysis of the major units, both storage and conveyance, in conjunction with the underground reservoirs in the upper San Joaquin Valley, operated for the several purposes, through the eleven-year period 1918–1929, shows that a water supply could have been made available for all ultimate uses in the Great Central Valley. This period is one of subnormal run-off and includes the season 1923–24, the driest of record. The method of operation and the accomplishments are as follows:

1. The amount of water utilizable for storage and regulation in the major reservoir units was obtained by deducting from the full natural run-off of the streams entering the Great Central Valley, the net use of 2,283,000 acre-feet per season for an adequate and dependable irrigation supply for 1,439,000 acres, being the net irrigable mountain valley and foothill lands lying at elevations too high to be irrigated by gravity from the major reservoir units, thus providing for the ultimate needs of these areas, and also deducting from the flow of the Tuolumne River 448,000 acre-feet per year for the water supply of the city of San Francisco. An additional amount of 224,000 acre-feet per year also was furnished the San Francisco Bay Basin from Pardee Reservoir on the Mokelumne River.
2. Space in the principal reservoirs would have been reserved for flood control. This space, operated in a specified manner, would materially reduce flood flows on the major streams, resulting in an increased degree of protection to areas subject to overflow in both the Sacramento and San Joaquin valleys and a decrease in potential annual flood damages in these areas. The sizes of floods which probably would be exceeded on the average of once in 100 years

(except as noted), without and with the space reserved, at several of the principal points in the Sacramento and San Joaquin valleys are as follows:

Location	Flood flow in second-feet exceeded once in 100 years on the average	
	Without reservoir control	With reservoir control
Sacramento River at Red Bluff.....	1303,000	1187,000
Sacramento River at Red Bluff (flow exceeded once in 14 years on the average).....	218,000	125,000
Sacramento River at Colusa.....	370,000	250,000
Sacramento River at Colusa (flow exceeded once in 14 years on the average).....	254,000	170,000
Sacramento River below city of Sacramento.....	670,000	535,000
Feather River below confluence with Yuba River.....	400,000	201,000
Feather River below confluence with Bear River.....	430,000	226,000
San Joaquin River below confluence with Merced River.....	70,000	50,000
San Joaquin River below confluence with Tuolumne River.....	103,000	64,000
San Joaquin River below confluence with Stanislaus River.....	133,000	82,000
Sacramento and San Joaquin rivers at confluence.....	780,000	596,000

¹ Mean daily flow on day of crest of flood.

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

3. Stored water would have been released from the major reservoir units in a manner so as to supplement unregulated flows and return waters to make water supplies available for the following purposes:

- A supply of 9,033,000 acre-feet per season, gross allowance, without deficiency, available in the principal streams for the irrigation of all of the net area of irrigable lands of all classes—2,640,000 acres—on the Sacramento Valley floor.
- A supply of 1,200,000 acre-feet per season, without deficiency, for the irrigation of all the net area of 392,000 acres of irrigable lands, and for unavoidable losses in the Sacramento-San Joaquin Delta.
- A flow maintained in the Sacramento River sufficient to provide required depths for navigation as far upstream as Chico Landing, with improvement in present depths upstream to Red Bluff.
- A fresh water flow of not less than 3300 second-feet past Antioch into Suisun Bay, which would have controlled salinity to the lower end of the Sacramento-San Joaquin Delta.
- A surface supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent, for the irrigation of all the net area of 1,810,000 acres of irrigable land of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills below the major reservoirs on the eastern side of the valley. The deficiency could have been reduced by the utilization of the available underground storage capacity.
- A supply of 4,700,000 acre-feet per season, without deficiency, for the irrigation of a net area of 2,350,000 acres of class 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley. This would have been accomplished by utilization of underground storage capacity in conjunction with the major reservoir and conveyance units proposed.

- A supply of 1,570,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent, for the irrigation of all the net irrigable area of 785,000 acres of class 1 and 2 lands on the western slope of the upper San Joaquin Valley.
- A water supply and channel depth in the San Joaquin River sufficient to provide a navigable depth of six feet as far upstream as Salt Slough, nine miles above the Merced River.
- A supply of 403,000 acre-feet per season, with a maximum seasonal deficiency of 35 per cent in that portion of this supply—323,000 acre-feet—for irrigated lands only, in 1924, available in the Sacramento-San Joaquin Delta for use in the San Francisco Bay Basin. This amount, together with full practical development of local resources and annual importations of 224,000 acre-feet from the Mokelumne River and 448,000 acre-feet from the Tuolumne River and an importation from the Eel River, would have given an adequate and dependable supply for the ultimate development of this basin.
- The generation of more than five billion kilowatt hours of electric energy annually, on the average.

With all of the Great Central Valley units operated for the foregoing purposes, substantial amounts of water over and above the requirements would have wasted into Suisun Bay during the eleven-year period 1918-1929, as follows:

Year	Amount in acre-feet	Year	Amount in acre-feet
1918.....	3,885,000	1924.....	1,002,000
1919.....	4,112,000	1925.....	2,860,000
1920.....	2,288,000	1926.....	2,925,000
1921.....	8,071,000	1927.....	9,469,000
1922.....	8,434,000	1928.....	7,498,000
1923.....	2,934,000		
		Average.....	4,862,000

Although there would have been a large surplus in each year, most of it would have occurred in the winter months from unregulated run-off. During the summer months, water would have been released from the reservoirs sufficient only to care for all needs. The average monthly distribution of waste water for the period 1918-1929 would have been as follows:

Month	Amount in acre-feet
January.....	722,000
February.....	1,320,000
March.....	1,486,000
April.....	187,000
May.....	219,000
June.....	113,000
July.....	0
August.....	0
September.....	0
October.....	33,000
November.....	323,000
December.....	474,000
Total.....	4,862,000

Surplus Waters in Sacramento River Basin—The same analysis from which the foregoing results were obtained shows that by the utilization of the physical works proposed herein for the Sacramento River Basin, including the Trinity River diversion, regulated supplies, without deficiency in amount and dependable in time, could have been made available in the principal streams to irrigate all of the net irrigable

lands—2,640,000 acres—in the Sacramento Valley, after allowing a gross diversion of 3,241,000 acre-feet, with a net use of 1,945,000 acre-feet per year, for the irrigation of a net irrigable area of 1,234,000 acres of foothill and mountain valley lands in the Sacramento River Basin. The analysis also shows that there would have been a large surplus of water in every year, over and above these needs, in the basin above the Sacramento-San Joaquin Delta. Some of this surplus water would have been contributed directly by releases and spill from the reservoirs and the remainder would have been that returning to the streams from water applied for irrigation on the valley floor, or foothills at elevations higher than the reservoirs but draining directly to the valley floor. The portion of this surplus water not used in or diverted from the Sacramento-San Joaquin Delta would have wasted into the ocean. A large part of this surplus, however, could have been put to beneficial use in all years, except in winter months when a portion would have wasted. The following tabulation gives the amounts of water contributed by the reservoirs and the surplus available in the delta for the maximum and minimum years and the average annual for the eleven-year period 1918-1929.

Surplus Water in Sacramento River Basin

	Amount of water in acre-feet		
	Maximum year, 1927	Minimum year, 1924	Average annual for period 1918-1929
Releases and spill from major reservoir units.....	19,837,000	10,608,000	15,141,000
Gross requirements for lands on Sacramento Valley floor.....	9,033,000	9,033,000	9,033,000
Surplus from releases and spill.....	10,804,000	1,575,000	6,108,000
Return water—from valley floor.....	3,843,000	3,843,000	3,843,000
Return water—from foothills above reservoirs.....	341,000	341,000	341,000
Total surplus available in delta.....	14,988,000	5,759,000	10,292,000

The ultimate average annual requirements for the Sacramento-San Joaquin Delta and salinity control would amount to 3,590,000 acre-feet. A portion of this would be contributed by water from the San Joaquin Valley streams, but if the entire amount had been obtained from Sacramento Valley waters during the eleven-year period 1918-1929, there still would have been surpluses in the maximum and minimum years of 11,399,000 and 2,164,000 acre-feet respectively, and an average annual surplus for the period of 6,702,000 acre-feet.

In the accomplishments with the foregoing method of operation, the Sacramento Valley would have received an irrigation supply without deficiency. Another study was made for the same eleven-year period with a method of operation which would be the same as the foregoing, except that an additional supply of 1,500,000 acre-feet annually would be made available in the Sacramento-San Joaquin Delta in accord with a uniform demand. This additional supply would have resulted, however, in some additional deficiencies and less wasted surplus and would have been 35 per cent deficient itself in 1924. It would have been obtained with a maximum deficiency of 22 per cent in the supply

to the Sacramento Valley and with the same maximum deficiencies in the supplies for the areas in the San Joaquin Valley and San Francisco Bay Basin.

Navigation—Navigation would be improved and extended on the Sacramento and San Joaquin rivers by the operation of the major reservoir units. In the low water season, navigation is greatly impaired above the city of Sacramento. With the reservoirs of the plan, particularly Kennett, in operation, a satisfactory navigable depth of five to six feet could be maintained from Sacramento to Chico Landing, 138 miles, and the river depth could be improved from the latter point to Red Bluff, an additional distance of 52 miles. On the San Joaquin River above Stockton, navigation has been practically abandoned. It could be restored to a navigable depth of six feet from the Stockton Ship Canal to Salt Slough, nine miles above the Merced River, a total distance of 95 miles, by the utilization of the ponds which would be formed by dams of the San Joaquin River pumping system. To do this would require the installation of a lock at each dam. If it should be desirable to extend navigation from Salt Slough to Mendota, the benefits that would accrue from such extension might justify altering the location of the proposed pumping system for irrigation by following the river to the latter point.

San Francisco Bay Basin—The principal unit located in the San Francisco Bay Basin, and included in previous reports to the Legislature in the plan for the maximum utilization and conservation of the state's water, is a salt water barrier below the confluence of the Sacramento and San Joaquin rivers. The desired primary functions of a barrier would be to prevent the invasion of saline water into upper San Francisco Bay and the Sacramento-San Joaquin Delta, act as a diversion dam for the exportation of water to the upper San Joaquin Valley and, by the creation of a fresh water lake, provide a means of diversion of fresh water supplies for the industrial, metropolitan and agricultural areas of the upper San Francisco Bay region. A study has been made of alternate plans of controlling the invasion of saline water and making available an adequate and dependable source of water supply for the upper bay and delta area. One plan would utilize a physical barrier below the confluence of the Sacramento and San Joaquin rivers and the other would utilize fresh water releases from storage in mountain reservoirs, without a barrier. The conclusions of the study are as follows:

It would be physically feasible to construct a barrier at sites in Carquinez Strait and at Point San Pablo at a capital cost of \$50,000,000 and \$75,000,000, and an annual cost of \$3,900,000 and \$5,600,000, respectively. Foundation conditions are not so favorable at Chipps Island site. The estimated capital and annual costs of a barrier at that site, based upon preliminary designs and estimates, are \$40,000,000 and \$3,300,000, respectively. The combination of a highway crossing with a barrier is not economically warranted. The furnishing of an adequate and dependable cheap fresh water supply for industrial use would no doubt prove an attraction to heavy users of industrial water and probably would stimulate industrial growth in the upper bay area. If this were accomplished by the assistance of a barrier with a fresh water lake maintained by adequate water supplies furnished from mountain

storage reservoirs, the attraction might be still further enhanced. However, the large expenditures required for a barrier might result in these benefits being entirely offset by the burden in additional taxes that the local industrial area might have to assume as its share of a barrier cost. Moreover, other competing industrial areas naturally would offer counter attractions, such as comparable water rates, and hence it can not be expected that there would be any rapid influx of industries to locate on a barrier lake. Therefore, in so far as fresh water supply is a factor in industrial development, the essential requirement would be the furnishing of adequate fresh water supplies by the consummation of the most practicable plan which can be devised. Control of salinity and a dependable supply of fresh water for the upper bay area could be provided with equal certainty without a barrier by releasing water from mountain storage reservoirs. The cost of water that might be saved as a maximum in any year in controlling salinity with a barrier would considerably exceed the cost of development of an equal amount in mountain storage reservoirs.

With salinity controlled by fresh water releases without a barrier, a dependable fresh water supply could be made available in the Sacramento-San Joaquin Delta, from which supply the bay area could be feasibly and satisfactorily served by conduits. A barrier is not essential for the exportation of water to the San Joaquin Valley or for the reclamation of marsh lands adjoining Suisun and San Pablo bays. A plan of development with salinity control without a barrier, providing conduits from the delta to serve the bay area, additional works of channel enlargement between the Sacramento River and the San Joaquin Delta and works for the reclamation of bay marsh lands, could be consummated at a capital and annual cost of less than half that required for a development with a barrier.

It is finally concluded that a salt water barrier is not necessary or economically justified as a unit in the State Water Plan.

South Pacific Coast Basin—The plan of obtaining additional water supplies for this basin, as presented in this report, is the conservation of as large a part as possible of the supplies originating within the basin and the importation of water from the Colorado River and other outside sources such as Mono Basin. For ultimate development, the deficiency in local supplies after deduction of the estimated utilizable yield from local resources is 1,800,000 acre-feet per year. At present, a part of this deficiency is made up by an average annual importation of 160,000 acre-feet from Owens River by the city of Los Angeles and by the utilization of return water in the form of sewage from several urban areas in the South Coastal Basin. Added supplies amounting to an average of 240,000 acre-feet annually probably can be obtained from Owens River and Mono Basin, requiring the enlargement of the present Los Angeles aqueduct. Also, a considerable portion of the return sewage water from urban areas wasted into the ocean might be reclaimed for reuse, thereby reducing the importation requirements to that extent.

The Colorado River aqueduct, as planned by the Metropolitan Water District of Southern California, would deliver, according to the estimates of that district, about 990,000 acre-feet per year into terminal storage on the Pacific slope after deducting aqueduct losses and approximately 900,000 acre-feet net delivery from terminal storage. The capital cost of the complete aqueduct to deliver this amount of water is estimated by the Engineering Board of Review for the Metropolitan Water District to be \$199,618,000. This estimated cost does not include interest during construction, nor the cost of terminal storage reservoirs and distributary conduits.

Ultimate development of the 2,000,000 acres of net habitable area in the South Pacific Coast Basin would require distributary conduits to San Diego and Orange counties and to the heads of the San Gabriel and San Bernardino basins and possibly into Ventura County if the deficiencies in local supplies for ultimate development were to be met by supplies from the Colorado River aqueduct. Routes for these conduits have been reconnoitered, but cost estimates have not been prepared.

North Pacific Coast, Central Pacific Coast and Great Basins—No units of a State Plan are presented herein for the development of the water resources of these basins. Investigations in progress in these basins are described in Chapter IX.

Initial Units of State Water Plan.

Three important regions in the state have water problems which have become acute and which require immediate attention. These are the upper San Francisco Bay, Sacramento-San Joaquin Delta and Sacramento Valley; upper San Joaquin Valley; and Pacific slope of southern California. In the first area, the water shortage exists in the summer and fall months of nearly every year, with a large surplus naturally tributary and available to the affected area in other months. To correct this condition, the only requirement is proper control, regulation and distribution of the tributary water. In the upper San Joaquin Valley and in southern California, there are highly developed areas overdrawing the average water supplies naturally and legally available to them. There are no nearby sources which can be developed to obtain a sufficient yield. The only relief is to obtain supplies from outside sources. Plans are presented for meeting the immediate future needs in these areas.

Sacramento River and San Francisco Bay Basins—The water problem in the Sacramento River Basin is that of invasion of saline water into the upper San Francisco Bay and delta region. Attendant with this situation, the flow in the river during the summer months of sub-normal years has been so low that navigation has been greatly hampered and distance of navigability has been much reduced. During several of the past dry years, particularly in 1920 and 1924, the irrigators drawing their supply from the Sacramento River were forced to accept a deficient supply. Increased pumping costs also resulted from the low discharge in the stream. All of these problems—salinity in the delta and upper San Francisco Bay region, navigation and deficiency in irrigation supply along the Sacramento River—are closely allied.

The plan proposed for the immediate relief of these areas is the construction of the Kennett reservoir and Contra Costa County conduit. The dam for the Kennett reservoir would be 420 feet high, creating a reservoir of 2,940,000 acre-feet capacity. The estimated cost, including an afterbay and power plants, is \$84,000,000. This is the most favorable and economic initial unit of the State Water Plan in the Sacramento River Basin adjudged feasible of construction when consideration is given to the extent of the benefits that would result from its operation.

The reservoir could be operated to attain the following accomplishments:

1. Control floods in Sacramento River to 125,000 second-feet mean daily flow on day of flood crest, measured at Red Bluff, exceeded once in fourteen years on the average. The controlled flow exceeded once in 100 years on the average would be 187,000 second-feet, due to the uncontrolled run-off between Kennett reservoir and Red Bluff. Flood flows in excess of 125,000 second-feet would be of short duration.
2. Maintain a navigable depth in the Sacramento River of five to six feet from the city of Sacramento to Chico Landing, with a substantial increase in depth from the latter point to Red Bluff.
3. Furnish in the Sacramento River an irrigation supply for the lands above Sacramento, without deficiency, up to 6000 second-feet in July, thus furnishing a supply in all years to all lands under irrigation along the Sacramento River above the delta. There would have been over 700,000 acre-feet more water available for these lands in 1924.
4. Furnish an irrigation supply, without deficiency, for the present requirements of the Sacramento-San Joaquin Delta.
5. Control salinity to the lower end of the Sacramento-San Joaquin Delta by release of water to maintain a fresh water flow past Antioch into Suisun Bay of not less than 3300 second-feet.
6. Make available in the delta a water supply, without deficiency, for the developed industrial and agricultural area along the south shore of Suisun Bay in Contra Costa County.
7. Make available an irrigation supply, without deficiency, in the delta sufficient in amount to fully supply the "crop lands" now being served from the San Joaquin River above the mouth of the Merced River. This would be conveyed to these lands by the San Joaquin River pumping system and would make possible the exportation of all the available supply in the San Joaquin River at Friant. This is not believed essential as an immediate step.
8. Generate 1,581,100,000 kilowatt hours of hydroelectric energy per year on the average incidental to other uses, the sale of which would help defray the cost of the unit.

The Contra Costa County conduit would serve the industrial and agricultural areas along the south shore of Suisun Bay. It would have a point of diversion near Knightsen, at the westerly end of Rock Slough in the San Joaquin Delta, and, with a succession of pumping plants, would extend westerly above all the existing industries into Clayton

and Ygnacio valleys, a total length of 50 miles. The conduit would have a capacity of 120 second-feet at the head and decrease in successive steps to a minimum capacity of 20 second-feet at the lower end. A feeder pipe line with a capacity of five second-feet would serve the industries in Martinez and vicinity. These conduits would be capable of furnishing the industries a fresh water supply of 22 million gallons per day and an adequate supplemental supply to the developed agricultural areas. The estimated cost is \$2,500,000.

Upper San Joaquin Valley—The upper San Joaquin Valley is that part of the valley extending southerly from the Chowchilla River and a line extending from Mendota to Oro Loma. On the eastern side of the valley there are about 400,000 acres of highly developed lands deficient in water supply available from combined surface and underground sources to meet their immediate needs. The deficiency in water supply for the period 1921-1929 averaged about 387,000 acre-feet annually. In addition to these lands, there are irrigated areas lying north of the lower Kings River and westward of the trough of the valley that are in need of a supplemental fresh water supply to blend with the ground water supply, which has a considerable mineral content.

The water supply considered available for an initial step is that which could be developed by utilization of surplus water of the San Joaquin River and that available by purchase under rights devoted to inferior use on "grass lands" for pasture, now being served by diversions from this river above the mouth of the Merced River. It is proposed to acquire these waters with due consideration for all existing rights that may be invaded in the process. Sufficient water to meet the present deficiency could be obtained from these sources at a cost less than that from any other source. Until this water supply is completely used and additional water is required for new lands, construction of the San Joaquin River pumping system, to import water from the Sacramento River Basin, could be deferred, unless there should be a series of years with smaller stream flows than have been experienced in the past.

In the operation of the physical works, an adequate water supply would be allowed to pass the Friant dam to meet the demands of the "crop lands" (lands devoted to growing of crops now served from the San Joaquin River above the mouth of the Merced River).

The physical works proposed for furnishing a supplemental water supply to these areas are:

1. Friant reservoir with a gross capacity of 400,000 acre-feet and a usable capacity of 270,000 acre-feet above elevation 467 feet, diversion elevation of San Joaquin River-Kern County canal.
2. San Joaquin River-Kern County canal to Kern River with a maximum diversion capacity of 3000 second-feet.
3. Madera canal with a maximum capacity of 1500 second-feet.
4. Magunden-Edison pumping system with a capacity of 20 second-feet.
5. San Joaquin River pumping system, maximum capacity 3000 second-feet (construction deferred).
6. Sacramento-San Joaquin Delta cross channel (construction deferred).

The amounts of water that could have been obtained from the foregoing sources, with the above described works (items 1 to 4, inclusive) during the forty-year period 1889-1929, including an allowance for the Madera area of 180,000 acre-feet annually, on the average, through this period, are as follows:

Period	Average annual amount in acre-feet
1889-1929	1,032,000
1909-1929	833,000
1917-1929	602,000
1919-1929	593,000
1921-1929	601,000
1924-1929	500,000

Taking into consideration all factors—extent of irrigation development, water supply, present and probable future condition of the underground reservoirs and irrigation methods now practiced in these areas—it is believed the supply which could be obtained from the surplus waters and "grass land" rights in the San Joaquin River above the mouth of the Merced River, based upon the modified stream flow records for the period 1921-1929, would be adequate to fully supplement the deficiencies in the available local supplies for maintaining present development and to a certain extent replenish the underground reservoirs.

It further is believed that an equitable distribution of these waters among the counties in which the developed areas of deficient supply are located would be as follows:

County	Average exportable water supply at Friant reservoir, 1921-1929, in acre-feet
Madera	108,000
Fresno	50,000
Tulare	318,000
Kern	125,000
Total	601,000

If it should prove desirable and necessary to furnish a direct surface supply from imported water from the San Joaquin River to lands lying in and east of Tulare Lake in Kings County, now used chiefly for the growing of annual crops and now having a variable water supply, water would be available for this purpose, however, with a reduction of supply to the other counties. It is estimated that 90,000 acre-feet seasonally would be adequate for the irrigation of the lands now cropped.

The capital cost of the physical works of the initial plan for the upper San Joaquin Valley, exclusive of the cost of water rights and general expense, are:

Friant dam, reservoir and power plant	\$15,500,000
San Joaquin River-Kern County canal	27,300,000
Madera canal	2,500,000
Magunden-Edison pumping system	100,000
San Joaquin River pumping system (construction deferred)	15,000,000
Sacramento-San Joaquin Delta cross channel (construction deferred)	4,000,000
Total	\$64,400,000

The cost of the Friant reservoir unit includes \$1,500,000 for a 30,000 kilovolt ampere power plant at the dam. This plant would be operated with waters allowed to pass the dam to meet the "crop land" rights. It is assumed that at the end of a ten-year period these waters would

be diverted for use in the upper San Joaquin Valley and therefore be unavailable for the generation of power in the plant. The cost of this plant would therefore be amortized in this period and a new plant of 10,000 kilovolt ampere capacity would be constructed on the Madera canal, at a cost of \$500,000, to utilize the power drop at the dam into that canal.

South Pacific Coast Basin—The immediate problem on the Pacific slope of southern California is to obtain additional supplies from local resources by greater conservation efforts and from sources outside of the basin so that the deficiency now being supplied by overdraft on certain of the underground reservoirs may be met. The units for initial development are the Colorado River aqueduct and the Santa Ana River flood control and conservation works.

The initial development of the Colorado River aqueduct, as recommended by the Engineering Board of Review of the Metropolitan Water District of Southern California, would have a delivery capacity of 800 second-feet, or about 580,000 acre-feet per year. The tunnels and surface conduits would be constructed to the full capacity of 1500 second-feet, but pressure siphons and pumping plants would be constructed for only 800 second-feet. The Parker dam and its appurtenances would be deferred. Clarification works, however, would be installed at the intake on the Colorado River in lieu of the Parker reservoir. Provision would be made for terminal storage near the lower end of the aqueduct on the Pacific slope in the amount of 100,000 acre-feet. Suitable locations for reservoirs to provide this capacity are available along the aqueduct line in the Cajalco Canyon and Puente Hills district. The total cost for the initial development, including terminal storage, is estimated by the Engineering Board of Review to be \$198,572,000. This does not include interest during construction.

Since as much of the supply from local sources as can be practicably conserved will be necessary, in addition to imported water, and since several years will be required to secure an additional supply from Mono Basin and the Colorado River, attention must be given to the conservation of these local supplies. This can be accomplished in part by the regulation of floods so that these waters may be sunk into the underground basins by the employment of flood control and spreading works. The plan for the Santa Ana River Basin comprehends construction of works on the main stream and on its principal tributaries. In the upper Santa Ana Valley, the works would consist of improvement of flood channels, construction of debris dams and spreading works on the main stream and tributaries and utilization of mountain gravel storage. In the lower Santa Ana River Basin, the plans include a large reservoir in the lower Santa Ana Canyon, improvement and acquisition of the channel on the Santa Ana River below the reservoir, and reservoirs on Santiago Creek. The estimated cost of these works is \$16,200,000. It is believed construction and operation of these physical works in the Santa Ana River Basin would save about 90 per cent of the flood waters of this basin now wasting into the ocean and would control larger floods on the main stream and its tributaries than any yet recorded.

Summary of Costs for Initial Units of State Water Plan—The estimated costs of the units for initial development are as follows:

Item	Cost
Great Central Valley—	
Kennett reservoir.....	\$84,000,000
Sacramento-San Joaquin Delta cross channel (construction deferred).....	4,000,000
San Joaquin River pumping system (construction deferred).....	15,000,000
Friant reservoir.....	15,500,000
Upper San Joaquin Valley conduits.....	29,900,000
Rights of way, water rights and general expense.....	8,000,000
Subtotal, Great Central Valley.....	\$156,400,000
San Francisco Bay Basin—	
Contra Costa County conduit.....	2,500,000
South Pacific Coast Basin—	
Colorado River aqueduct.....	198,800,000
Santa Ana River Basin flood control and conservation works.....	16,200,000
Subtotal, South Pacific Coast Basin.....	214,800,000
Total.....	\$373,700,000

¹ Estimate of Engineering Board of Review for Metropolitan Water District. Does not include interest during construction. Estimate rounded to nearest \$100,000.

² Estimate rounded to nearest \$100,000.

Economic Aspects of Initial Units of State Water Plan.

A fundamental prerequisite to the execution of a plan for any unit of the State Water Plan must be a consideration of its economic soundness. This involves a comparison of annual costs of units and derived benefit values, comprising revenues from sale of water and power and other benefits, which would be gained by federal, state, county and city governments, public and privately owned utilities, industrial and commercial interests and individuals. The annual costs for all the units for initial development and the anticipated revenues from the sale of water and electric energy only for the units of the Great Central Valley and San Francisco Bay Basin are presented herein. No attempt is made to evaluate the other benefits.

The capital and gross annual costs of the units for both immediate and complete initial development in the Great Central Valley and the upper San Francisco Bay region are presented in the following tabulations. The annual costs include operation and maintenance charges, interest at 4½ per cent per annum, amortization on a forty-year sinking fund basis at four per cent, and depreciation on a four per cent sinking fund basis with different lengths of service for the various elements of the unit. The annual revenues are based upon the sale of water for industrial and agricultural use in Contra Costa County and for agricultural use in the upper San Joaquin Valley, and electric energy generated at the power plants at Kennett and Friant reservoirs. These revenues, especially from the sale of water for irrigation and industrial uses, are estimated as the total amounts which would be realized when the supplies provided are fully utilized and sold at the unit prices indicated. There may be a considerable period of time after completion of any unit before the water supplies provided are fully utilized. However, it is anticipated that the revenues from sale of electric energy probably would be realized within a relatively short period. Any excess deficiency arising as between revenues and annual cost during the period of development would have to be provided by some other means.

The following tabulations summarize the estimated capital and annual costs and anticipated revenues for the immediate and complete initial developments for the Great Central Valley and upper San Francisco Bay region:

Item	Immediate Initial Development	
	Capital cost	Gross annual cost
CAPITAL AND ANNUAL COST—		
Kennett reservoir.....	\$84,000,000	\$5,297,000
Contra Costa County conduit.....	2,500,000	300,000
Friant reservoir.....	15,500,000	1,062,000
Madera canal.....	2,500,000	213,000
San Joaquin River-Kern County canal.....	27,300,000	2,225,000
Magunden-Edison pumping system.....	100,000	18,000
Rights of way, water rights and general expense.....	7,000,000	389,000
Total.....	\$138,900,000	\$9,504,000
ANNUAL REVENUES—		
Electric energy sales:		
1,591,800,000 kilowatt hours at \$0.00265.....	\$4,218,000	
105,000,000 kilowatt hours at \$0.0035.....	367,000	
Total electric energy sales.....	\$4,585,000	
Water sales:		
600,000 acre-feet for upper San Joaquin Valley, based on average for twelve-year period 1917-1929, at \$3 per acre-foot.....	\$1,800,000	
43,500 acre-feet for Contra Costa County conduit at \$6.90 per acre-foot.....	300,000	
Total water sales.....	\$2,100,000	
Total revenues, electric energy and water.....	\$6,685,000	\$6,685,000
NET ANNUAL COST IN EXCESS OF REVENUES.....		\$2,819,000

¹ Includes \$1,500,000 for cost of 30,000 kilovolt ampere power plant, the amortization of which, in a ten-year period, is included in the annual cost.

Item	Complete Initial Development	
	Capital cost	Gross annual cost
CAPITAL AND ANNUAL COST—		
Kennett reservoir.....	\$84,000,000	\$5,297,000
Sacramento-San Joaquin Delta cross channel.....	4,000,000	300,000
Contra Costa County conduit.....	2,500,000	300,000
San Joaquin River pumping system.....	15,000,000	2,500,000
Friant reservoir.....	14,500,000	885,000
Madera canal.....	2,500,000	213,000
San Joaquin River-Kern County canal.....	27,300,000	2,225,000
Magunden-Edison pumping system.....	100,000	18,000
Rights of way, water rights and general expense.....	8,000,000	444,000
Total.....	\$157,800,000	\$12,182,000
ANNUAL REVENUES—		
Electric energy sales:		
1,581,100,000 kilowatt hours at \$0.00242.....	\$3,826,000	
23,000,000 kilowatt hours at \$0.0035.....	80,000	
Total electric energy sales.....	\$3,906,000	
Water sales:		
1,720,000 acre-feet for upper San Joaquin Valley, based on average for forty-year period 1889-1929, at \$3 per acre-foot.....	\$5,160,000	
43,500 acre-feet for Contra Costa County conduit at \$6.90 per acre-foot.....	300,000	
Total water sales.....	\$5,460,000	
Total revenues, electric energy and water.....	\$9,366,000	\$9,366,000
NET ANNUAL COST IN EXCESS OF REVENUES.....		\$2,816,000

¹ Does not include the cost of the 30,000 kilovolt ampere power plant of the immediate initial development, which would not be operated under the complete initial development, but does include a new 10,000 kilovolt ampere plant costing \$500,000 on the Madera canal, the amortization of which in a forty-year period is included in the annual cost.

The foregoing estimates are based on financing the development at an interest rate of four and one-half per cent per annum and on an amortization period of forty years. To illustrate the added cost for both capital and annual costs with a higher rate of interest and the decreased cost with a lower rate of interest and for a fifty-year period of amortization, the tables on pages 51 and 52 are presented. The rates of interest vary from six per cent to interest free money. For all annual costs with interest, amortization is estimated on a four per cent sinking fund basis. With interest free money, it is estimated on a straight line basis for a forty-year period.

The Engineering Board of Review for the Metropolitan Water District of Southern California has prepared an estimate of the annual cost of the complete aqueduct, which follows:

Interest at 4½ per cent on \$200,000,000-----	\$9,500,000
Taxes and insurance-----	250,000
Electric energy for pumping-----	3,367,000
Operation, maintenance, repairs and renewals-----	2,217,000
Storage in Boulder Canyon reservoir-----	272,000
Total annual charges-----	\$15,606,000

This annual cost is based on a diversion of 1500 second-feet, which would amount to some 1,086,000 acre-feet per year, or, according to the estimates of the Metropolitan Water District, about 990,000 acre-feet per year delivered into terminal storage on the Pacific slope after deducting aqueduct losses, and 900,000 acre-feet net delivery from terminal storage. The foregoing estimate of annual cost does not include bond redemption.

The estimated capital cost of the physical works for the Santa Ana River project, designed both for the salvage of flood wastes and flood protection, is shown in the second table on page 52 for several rates of interest during the period of construction. Annual costs, including interest, depreciation, amortization, operation and maintenance, also are shown. These costs are shown with amortization on both a forty-year and fifty-year, four per cent, sinking fund basis, with interest at the same rates as those used for the construction period. The annual cost also is shown for the project constructed without interest. This cost includes depreciation, operation and maintenance, and amortization on a forty-year straight line basis, but no interest on bonds.

Many interests, other than those actually receiving water in the upper San Joaquin Valley, would be greatly benefited. In the Sacramento Valley there would be many beneficiaries. The reduction of floods on the Sacramento River would furnish an additional degree of protection to the overflow lands in the Sacramento Flood Control Project, resulting in a reduction of potential annual flood damages. The federal and state governments, the various districts and individual landowners would be interested in this feature. The improvement of navigation on the Sacramento River for 190 miles above the city of Sacramento is a feature in which the federal government would be interested and is a basis upon which it might be expected to participate

CAPITAL AND ANNUAL COSTS OF INITIAL DEVELOPMENTS—GREAT CENTRAL VALLEY

Immediate Initial Development

Item	Interest rate in per cent					
	6	5	4½	4	3½	3
Capital cost.....	\$143,500,000	\$140,400,000	\$138,900,000	\$137,400,000	\$136,000,000	\$134,500,000
Gross annual cost (40-year, 4 per cent sinking fund amortization).....	11,047,000	10,308,000	9,504,000	8,716,000	7,951,000	7,192,000
Total revenue, electric energy and water.....	6,885,000	6,885,000	6,885,000	6,885,000	6,885,000	6,885,000
Net annual cost in excess of revenues.....	5,262,000	3,621,000	2,819,000	2,031,000	1,266,000	507,000
Gross annual cost (50-year, 4 per cent sinking fund amortization).....	11,385,000	9,757,000	8,980,000	8,170,000	7,418,000	6,687,000
Total revenue, electric energy and water.....	6,885,000	6,885,000	6,885,000	6,885,000	6,885,000	6,885,000
Net annual cost in excess of revenues.....	4,700,000	3,072,000	2,275,000	1,494,000	733,000	*18,000
Gross annual cost (amortization on a 40-year straight line basis).....						
Total revenue, electric energy and water.....						
Net annual revenue in excess of cost.....						4,787,000
						6,685,000
						1,918,000

*Revenue in excess of annual cost.

CAPITAL AND ANNUAL COSTS OF INITIAL DEVELOPMENTS—GREAT CENTRAL VALLEY

Complete Initial Development

Item	Interest rate in per cent					
	6	5	4½	4	3½	3
Capital cost.....	\$162,900,000	\$159,800,000	\$157,900,000	\$156,200,000	\$154,700,000	\$152,900,000
Gross annual cost (40-year, 4 per cent sinking fund amortisation).....	15,008,000	13,112,000	12,182,000	11,266,000	10,391,000	9,502,000
Total revenue, electric energy and water.....	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000
Net annual cost in excess of revenues.....	6,642,000	3,746,000	2,816,000	1,900,000	1,025,000	136,000
Gross annual cost (50-year, 4 per cent sinking fund amortisation).....	14,364,000	12,466,000	11,556,000	10,646,000	9,778,000	8,898,000
Total revenue, electric energy and water.....	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000
Net annual cost in excess of revenues.....	4,998,000	3,100,000	2,190,000	1,283,000	412,000	*468,000
Gross annual cost (amortisation on a 40-year straight line basis).....						6,673,000
Total revenue, electric energy and water.....						9,366,000
Net annual revenue in excess of cost.....						2,693,000

*Revenue in excess of annual cost.

CAPITAL AND ANNUAL COSTS OF SANTA ANA RIVER BASIN PROJECT

Item	Interest rate in per cent					
	6	5	4½	4	3½	3
Capital cost.....	\$16,200,000	\$16,000,000	\$15,900,000	\$15,800,000	\$15,700,000	\$15,600,000
Gross annual cost— Amortisation on 40-year, 4 per cent sinking fund basis.....	1,468,000	1,288,000	1,200,000	1,114,000	1,028,000	944,000
Amortisation on 50-year, 4 per cent sinking fund basis.....	1,402,000	1,225,000	1,168,000	1,051,000	960,000	882,000
Net annual cost in excess of revenues.....						675,000

financially. The furnishing of a full supply to the lands under irrigation along the Sacramento River and in the Sacramento-San Joaquin Delta would be of great benefit to the lands above the city of Sacramento in their being assured an adequate supply in all years without being curtailed in their diversions because of navigation requirements or the possibility of being enjoined by the water users below the city of Sacramento. Some of the lands above Sacramento also would be benefited in all years, and particularly in dry years, by decreased pumping charges due to higher water levels in the Sacramento River channel. This would be a substantial sum in dry years. The city of Sacramento would be benefited as to the quality of its water supply which it obtains from the Sacramento River. In all years, a flow of not less than 5000 second-feet would be passing the intake of its pumping plant. In 1920, the mean flow during one 24-hour period in July was as low as 440 second-feet. On this day there was a reversal of flow upstream amounting to a maximum of 2300 second-feet.

Control of salinity to the lower end of the Sacramento-San Joaquin Delta would relieve the salt water menace in that area and would furnish the irrigated lands a fresh water supply at all times. The furnishing of an adequate and suitable water supply to the industrial and agricultural areas along Suisun Bay not only would benefit the immediate area, but also the metropolitan areas of Oakland and San Francisco.

The relief afforded the upper San Joaquin Valley by the consummation of this plan would prevent the retrogression of a large area of agricultural land. The maintenance of these lands in production would prevent a loss of taxable wealth in the southern valley counties, help to restore agricultural credit, maintain and increase business in communities of the affected areas and between these areas and the large metropolitan centers, and assist in the protection of public utility and banking investments in these areas.

Water Right Problems.

A plan for the utilization of the water resources of the state, through their conservation and conveyance from areas of surplus to those of deficient supplies, would disturb the regimen of many of the streams, necessitating adjustments with existing water rights. The major problems and proposed remedial measures are briefly outlined as follows:

The storages, equalizations of flow, exportations, importations, and exchanges of water involved would effect changes in existing conditions under which the riparian owner has the right of maintenance as against nonriparian usage.

Stream flow regulation by storage and exportations from points above riparian ownership in themselves are violative of the riparian right, but not of the appropriative right of nonriparian landowners within the watershed. Exchanges of water are probably permissible, even against riparian objection. Riparian rights may be purchased and the vendors thereby eliminated as objectors and the place of use of appropriative rights held by such vendors may be changed, sub-

ject to no injury to others. Water may be stored underground and later pumped for exportation from the basin wherein it was stored.

Dependence upon eminent domain offers the only certain expedient in dealing with the riparian objector. Dependence upon the police power of the state is inadvisable in view of existing decisions; the doctrine exempting flood and freshet water from riparian ownership is very limited in its applicability; dedication to public use and prescription are ineffectual against timely objection; and the extent of state authority over navigable waters is uncertain.

Under existing procedure a project might be long delayed pending injunction suits by many claimants in many courts and condemnation suits in many courts before many juries. Excessive awards might make such a project exceedingly expensive.

A constitutional amendment providing a revised law of eminent domain relative to water projects administered by a properly constituted and empowered agency having state-wide jurisdiction, should afford fair compensation to the riparian owner without undue delay or expense in the prosecution of a plan.

Such an amendment should vest jurisdiction over suits to enjoin a plan and for damages in the eminent domain agency; provide for a conversion of such suits into condemnation proceedings and unite actions pertaining to interrelated rights; provide for condemnation of all or a portion of a right; provide for conclusive findings as to damages, offsetting benefits and compensation; provide for awards either in money or substituted benefits or physical adjustments; provide for the offset of any benefits reasonably certain to accrue, such as flood protection, salinity control, navigation, irrigation, ground water, and higher stream levels and reduced pumping costs; provide for compensation by a guarantee of specified conditions which would make offsetting benefits certain; and also provide for a taking upon security given without compensation first paid.

Investigations in Progress.

Investigations now are in progress in several areas of the state in which there are insufficient data available thus far to carry out final studies of water requirements and supplies and formulate final plans for development and operation to serve the ultimate needs. For the most part, these involve the more or less isolated valleys in the northern and southern part of the state and along the Central Coastal region, and which lie outside of the Great Central and South Pacific Coast basins. However, important additional studies in the South Pacific Coast Basin also are involved.

In Siskiyou, Modoc, Shasta and Lassen counties, investigations are under way to determine water requirements, to adjudicate and distribute available water supplies and also to determine the amount and source of supplemental water supplies necessary for the ultimate needs. Considerable progress has been made in the adjudication and distribution of available local supplies, and this has generally resulted in increasing extent and efficiency of utilization. Detail studies with the cooperation of local interests have been under way in the upper Pit River Basin since 1928, and substantial progress has been made in assembly of data.

In the San Francisco Bay and Central Pacific Coast basins, investigations are in progress in Napa, Santa Clara, Salinas and Santa Maria valleys and in Ventura County. The basic data required involve the measurement of flow of streams and the observation of ground water levels. Studies will be made to determine the available supply, present use, ultimate requirements, and surplus or deficiency in water supply. Except for Ventura County, where work was started in 1927, these investigations were begun in 1929. Considerable progress has been made in establishing stream gaging stations and measurements of well levels, but additional gaging stations must be established and more extensive observations of ground water made in order to furnish the basic data required for carrying out final studies.

Investigations in the desert region of southern California are under way in Antelope Valley and Mojave River Basin. In the former area, gaging stations have been established, but additional work is required on observation of ground water levels to determine the amount of available local water supply. In the Mojave River Basin, work, consisting of stream gaging, measurements of percolation and ground water levels and surveys of areas of transpiration and evaporation, has been under way since the latter part of 1929.

The investigations in progress in the South Coastal Basin, comprising the drainage basins of the Los Angeles, San Gabriel and Santa Ana rivers, are being directed to an intensive study of the amount and availability for reuse of waste water. This involves not only a study of the salvage and reuse of sewage wastes, but also a determination, by means of extended ground water observations, of the most advantageous operation and maximum use of the underground reservoir capacity in order to attain the most effective and efficient utilization and coordination of local and imported supplies. This investigation, when completed, should furnish basic data for the determination and allocation of benefits which will accrue from the newly developed supplies made available in a final coordinated plan of utilization and operation.

In San Diego County, the investigations under way have included the establishment of stream gaging stations to determine the amount of water wasted into the ocean and the portion of such wastes which could be feasibly conserved; and also work in connection with the international division of the water supply of the Tia Juana River.

Conclusions.

1. A large surplus of regulated water could be provided in the Sacramento River Basin, over and above the full requirements of all its 3,874,000 acres of net irrigable lands, by the utilization of the physical works proposed herein for that basin, including the Trinity River diversion.
2. The invasion of saline water in the upper San Francisco Bay and Sacramento-San Joaquin Delta could be effectively and positively controlled to the lower end of the delta by fresh water releases from mountain storage reservoirs.

3. A salt water barrier located at any of the three typical sites investigated below the confluence of the Sacramento and San Joaquin rivers would not be necessary or economically justified as a unit of the State Water Plan.
4. The industrial, municipal and agricultural developments of the upper San Francisco Bay region could be adequately and dependably supplied with their fresh water requirements from the fresh water controlled channels of the Sacramento-San Joaquin Delta at a cost of less than half that required for equivalent service with a barrier. The proposed Contra Costa County conduit would adequately and economically serve the present needs.
5. The water supply in the San Joaquin River Basin is insufficient to meet the ultimate water requirements in that basin. Importation from the Sacramento River Basin, the logical source of a supplemental supply, would be required for full development of 5,150,000 acres of net irrigable area.
6. There are approximately 400,000 acres of highly developed irrigated land in the upper San Joaquin Valley which are overdrawing the water supply locally available. In order to prevent retrogression in this region, supplemental water must be imported from an outside source. These lands have not the financial capacity to bring in such a supply.
7. The units proposed for immediate development in the Great Central Valley and upper San Francisco Bay region (Kennett and Friant reservoirs, the San Joaquin River-Kern County canal, the Madera canal, Magunden-Edison pumping system and the Contra Costa County conduit) would furnish adequate water supplies for present needs in the Sacramento Valley, Sacramento-San Joaquin Delta and upper San Francisco Bay region, and upper San Joaquin Valley, would increase the degree of flood protection and improve navigation on the Sacramento River, and incidentally would generate an annual average of 1,696,800,000 kilowatt hours of hydroelectric energy.
8. A complete water supply for the habitable area of 2,000,000 acres in the South Pacific Coast Basin ultimately would require an importation of 1,800,000 acre-feet annually, on the average, from outside that basin, if no allowance were made for present and possible future use of sewage wastes.
9. Construction of the works proposed herein for the Santa Ana River Basin would save about 90 per cent of the flood waters now wasting into the ocean from that basin.
10. The units proposed for initial development in the Great Central Valley could not be financed from revenues obtained from the sale of water and electric energy. Income from other sources must be obtained in order to finance the development.
11. Many interests would be substantially benefited through the consummation of the Great Central Valley and upper San Francisco Bay project. If these benefits were assessed to those interests benefited, sufficient income might be derived therefrom to carry the additional financial burden not capable of being carried by revenues from the sale of water and electric energy.

12. The flood control and navigation benefits which would result from the operation of the units of the initial development in the Great Central Valley would be so substantial that financial participation may well be expected from the federal government.
13. The execution of a State Water Plan under the present status of the law might be long delayed by injunction suits by many claimants in many courts and might be made utterly burdensome by awards of excessive compensation in condemnation proceedings. A constitutional amendment should be drawn to provide a revised law of eminent domain, administered by an agency having state-wide jurisdiction and properly constituted and empowered, so that those entitled to compensation could be speedily and fairly provided for without undue difficulty, delay, or expense in the prosecution of the plan.

CHAPTER III

WATER RESOURCES OF CALIFORNIA

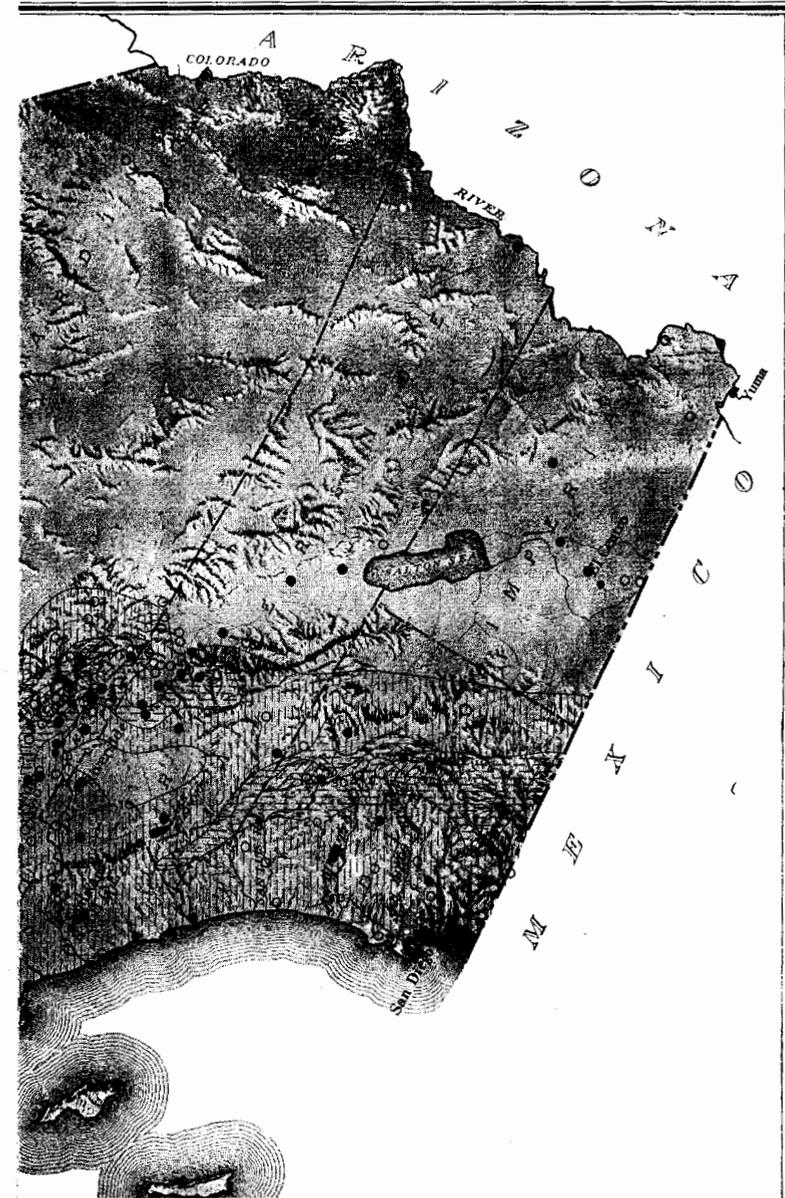
The climate of California is characterized by two fairly distinct seasons—the winter, or rainy season, and the summer, or dry season. The major portion of the precipitation occurs in the shorter winter season—from November to April—in the form of rain on the areas of lower elevation and as snow in the high mountain regions. Most of the run-off from the rain which falls on the lower areas and valleys finds its way quickly into the stream channels, while the snow in the higher mountain regions usually does not melt and appear as run-off until the late spring or early summer. The latter run-off forms the greater part of the stream flows during this period. It is estimated that more than three-fourths of the precipitation, taking the state as a whole, reaches the ocean within 45 days from the time of its occurrence.

A complete inventory of the waters of the state was made in previous investigations.* Estimates of the precipitation and of the run-off for the various hydrographic divisions of the state have been extended from 1921 to 1929 and are presented herein. In addition to the water available from streams within the state, water may be obtained for southern California from the Colorado River. The Boulder Canyon Project Act, passed by Congress on December 21, 1928, and later approved by the President, limits California's share in the allotment to the lower basin states under the Colorado River Compact to 4,400,000 acre-feet per annum consumptive use, plus one-half of any excess of surplus waters unapportioned by the compact. California's share includes the water necessary for present rights, as well as one-half of any deficiency which must be supplied to Mexico from the lower basin, if it shall become necessary to supply water to Mexico from waters over and above the surplus quantities as defined by said compact.

Precipitation.

Records of the precipitation in the state have been kept by the United States Weather Bureau and its predecessor, the Army Signal Corps, for many years. Starting with records at Sacramento and San Francisco in 1849 and at San Diego in 1850, the number of stations has gradually increased until there are at present a total of 335. The records at Sacramento, San Francisco and San Diego have been kept continuously since the date of the establishment of the stations. A number of stations have continuous records extending back to the late sixties or early seventies. Some of the older stations, however, have been discontinued. The precipitation stations that have been maintained by the United States Weather Bureau are shown on Plate I, "Geographical Distribution of Precipitation in California." The solid red dots indicate stations at which records are now being taken, and red open circles those stations which have been discontinued. The

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923.



GEOGRAPHICAL
DISTRIBUTION OF PRECIPITATION
IN
CALIFORNIA

geographical distribution of precipitation throughout the state is shown by the data compiled in Table 1, and also by the zones of variations on Plate I.

TABLE 1
GEOGRAPHICAL DISTRIBUTION OF PRECIPITATION

Values taken from Plate I

Basin	Range of mean seasonal precipitation in inches	
	Maximum	Minimum
North Pacific Coast.....	109	12
Sacramento River.....	90	12
San Joaquin River.....	55	5
San Francisco Bay.....	50	15
Central Pacific Coast.....	55	10
South Pacific Coast.....	48	10
Great Basin.....	55	2

Precipitation varies from a mean seasonal total of over 100 inches in the northwest corner of the state to almost zero in the southeast desert region. In the Sacramento Valley it ranges from about fifteen to twenty-five inches per season; in the San Joaquin Valley from five to fifteen inches; on the coastal plain of southern California from ten to twenty-five inches; and in the coastal valleys south of San Francisco Bay, from about ten to twenty inches. This indicates that the mean seasonal rainfall in the valley areas, where the largest portions of the state's crops are grown, is in most sections insufficient to bring the majority of crops to maturity even if it were properly distributed.

There is not only a very unequal distribution of precipitation throughout the state, but also a large variation in its amount from season to season. To illustrate the variation in total seasonal precipitation in different parts of the state, data for nine representative stations are shown in Table 2.

These data show that the maximum seasonal precipitation varies from 184 to 266 per cent, and the minimum from 12 to 52 per cent of the mean seasonal. Data also show that there are wet and dry periods of several years' duration. The seasonal precipitation is not always above normal in the wet periods, nor always below in the dry ones, but the average for the entire period is either above or below normal. The period of the last ten or twelve years has been a period of low average precipitation and the season of 1923-24 was one of the driest of record.

Practically all the precipitation occurs during the winter months. A few showers may occur during the summer, but they are usually of insufficient volume to produce substantial run-off. The winter rains begin as early as September in some years and may continue into May. However, the greater portion of the precipitation occurs in the period from November to April. Furthermore, the precipitation is not distributed uniformly throughout these months, but occurs in storms,

TABLE 2
VARIATION IN TOTAL SEASONAL PRECIPITATION AT NINE UNITED STATES WEATHER BUREAU STATIONS

Precipitation station	Basin	Elevation above sea level in feet	Period of record	Total seasonal precipitation in inches		
				Maximum	Minimum	Mean
Eureka.....	North Pacific Coast.....	62	January, 1887 to June, 1930.....	74.10	20.67	40.20
Red Bluff.....	Sacramento River.....	332	July, 1877 to June, 1930.....	53.22	11.27	24.41
Sacramento.....	Sacramento River.....	69	July, 1849 to June, 1930.....	36.35	4.71	18.18
San Francisco.....	San Francisco Bay.....	155	July, 1849 to June, 1930.....	49.27	7.42	22.21
Fresno.....	San Joaquin River.....	327	July, 1881 to June, 1930.....	19.45	4.96	9.54
Los Angeles.....	South Pacific Coast.....	438	July, 1877 to June, 1930.....	38.18	5.59	15.01
San Diego.....	South Pacific Coast.....	87	January, 1850 to June, 1930.....	25.97	3.75	9.73
Reno (Nevada).....	Great Basin.....	4,532	January, 1888 to June, 1930.....	15.36	3.79	8.06
Brawley (Imperial Valley).....	Great Basin.....	-105	January, 1909 to June, 1930.....	5.28	0.30	2.55

some of which are of sufficient length and magnitude to produce floods of major proportions. The monthly distribution of precipitation at nine representative Weather Bureau stations is shown in Table 3. The data on which this table is based are the precipitation records for the period of measurement.

During a previous investigation,* a careful study and analysis were made of the precipitation records for the entire state. Inquiry was made into the geographical distribution, magnitude and variation in occurrence, both seasonal and periodic, of precipitation in all sections of the state. An important part of the study was the relation of the precipitation in any one year to the normal or mean precipitation. From the results of the study, the state was divided into 26 precipitation groups or divisions having similar precipitation characteristics. The precipitation in a particular year at a station was expressed by a number representing the precipitation in per cent of normal and defined as the "index of seasonal wetness." Indices for each division were calculated from precipitation records at stations within the division. For stations with missing records, indices were estimated from records at other stations within the same or adjacent divisions. The index for each season in a particular division was taken as the arithmetical mean of the seasonal indices of wetness of the several stations in that division. Indices were calculated for the 26 precipitation divisions for the period 1871 to 1921. In the present investigation, they have been extended through the season of 1928-29. In making the extensions, the mean seasonal precipitation for each station was assumed as that for the fifty-year period 1871-1921, used in the previous study. The indices of seasonal wetness for the period 1871-1929 are given by divisions in Table 4. These indices are useful not only in showing the wide variation in precipitation by seasons, during the fifty-eight year period, but also in estimating run-off from unmeasured streams and measured streams with missing records, by developing a relation between seasonal run-off and seasonal index of wetness.

Run-off.

That portion of the seasonal precipitation which flows from the mountain and foothill drainage areas through natural channels, is defined as run-off. No account has been taken of the possible contribution to surface run-off from rainfall on the valley floor. Studies are in progress to determine the extent of such contribution. In some localities, this, together with ground water replenishment from rainfall on the valley floor, may constitute a considerable portion of the available water supply. However, in this report, because of the lack of definite information on the subject, this source has been disregarded in the estimates, except in the coastal basin of southern California. The run-off from the mountain and foothill areas only has been included for the remaining basins.

Although the first gaging stations were established on some of the major streams in 1878 under the direction of the State Engineer, these were abandoned in 1884. Consequently the longest continuous records of stream flow are those begun on a few major streams by the United States Geological Survey in 1894 and 1895. With the cooperation of

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923.

the state since 1903, this work has been continued and its scope extended to cover the flow from most of the major streams and many of their tributaries. Many records made by other federal agencies, municipalities, irrigation districts, and public utilities have been reported to the United States Geological Survey for publication. In all a total of 708 stream gaging stations, as shown on Plate II, "Forested Areas and Stream Gaging Stations in California," have been established. Many of these, however, were discontinued after only a few years of record so that on September 30, 1929, there were 300 active stations. Additional stations have been installed since that date, bringing the total active stations to 337 on September 30, 1930. The measurements at these stations, together with the precipitation records, have been the basis for estimating the run-off.

Topographically, the area of the state is divided into seven basins as shown on Plate III, "Geographical Distribution of Water Resources and Agricultural Lands in California." The run-off from six of these finds its way, if not intercepted, to the Pacific Ocean. This constitutes 95 per cent of the run-off. Practically all of the run-off from the seventh, the Great Basin, has no outlet to the ocean.

A previous report* presented run-off estimates based upon all available stream flow records up to and including the season 1920-21. For the streams on which no stream flow records were available, the run-off was estimated from relations of seasonal precipitation and run-off established for areas of similar characteristics. The second method also was used to fill in periods of missing records on measured streams.

In this investigation, study has been given to a review and extension of these estimates up to and including the season of 1928-29. A summary of these estimates of run-off for the forty-year period 1889-1929 for each stream or stream group of each basin of the state is given in Table 5. The mean seasonal run-off also is given for the twenty-year period 1909-1929; ten-year period 1919-1929; and for the five-year period 1924-1929. For the state as a whole, the mean for the forty-year period is 71,400,000 acre-feet, 1.6 per cent less than for the fifty-year mean for the period 1871-1921 given in Bulletin No. 5; the mean for the twenty-year period 61,100,000 acre-feet, 15.8 per cent less than for the fifty-year mean; the mean for the ten-year period 53,500,000 acre-feet, 26.3 per cent less than for the fifty-year mean; and the mean for the five-year period 57,100,000 acre-feet, 21.3 per cent less than for the fifty-year mean. The table also shows the amount and year of occurrence of maximum seasonal run-off for each stream and stream group during the forty-year period; the amount and year of occurrence of minimum seasonal run-off and minimum average flow for the month of August for each stream of record. The maximum seasonal run-off for the entire state during the forty-year period is estimated at 168,000,000 acre-feet in 1889-90, and the minimum during the same period at 19,000,000 acre-feet in 1923-24.

The average monthly distribution of seasonal run-off is given in Table 6 for five representative streams. These figures in each instance are based on the period of actual stream flow measurement.

* Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923.

DIVISION OF WATER RESOURCES

TABLE 4
INDICES OF SEASONAL WETNESS FOR 26 PRECIPITATION DIVISIONS¹

Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1871-72	81	111	110	104	125	116	126	141	123	120	122	130	124	129	127	119	119	120	119	125	79	69	68	56	72	155
1872-73	75	53	54	62	79	63	74	74	65	75	86	79	79	76	69	91	74	75	74	59	56	56	72	94	65	46
1873-74	71	85	83	60	103	120	106	118	118	100	87	86	101	89	87	87	100	100	100	95	84	84	134	148	170	162
1874-75	62	51	51	69	73	82	66	72	74	64	61	69	72	52	73	83	64	64	64	64	96	96	79	84	58	90
1875-76	73	154	118	166	110	112	122	124	124	124	154	131	112	129	147	123	124	125	124	147	125	125	117	123	102	124
1876-77	197	69	73	92	59	60	61	63	53	62	34	43	52	32	32	30	60	53	43	35	27	28	44	59	46	43
1877-78	84	182	115	132	164	142	96	98	81	93	113	129	143	128	149	108	109	140	100	138	116	147	146	137	129	126
1878-79	81	92	87	105	116	78	104	105	85	104	78	79	109	109	77	59	41	25	36	51	63	56	75	52	56	58
1879-80	150	107	100	131	118	91	123	125	125	125	105	99	109	109	91	95	134	137	90	106	128	145	134	117	112	123
1880-81	181	127	115	113	104	83	107	112	80	108	87	107	111	82	103	94	122	96	118	97	73	66	86	73	81	73
1881-82	121	75	80	101	78	65	95	88	120	103	85	87	70	86	82	65	69	83	56	87	76	44	68	63	82	69
1882-83	74	75	76	90	78	70	80	79	48	82	88	87	83	94	77	92	85	88	72	85	69	65	80	54	83	62
1883-84	158	98	92	92	75	99	113	112	123	118	135	125	107	159	124	158	178	181	138	178	214	204	251	229	225	61
1884-85	119	58	83	66	55	54	77	92	68	73	67	66	62	105	64	71	78	71	66	72	58	65	61	68	78	33
1885-86	165	124	107	142	119	125	116	114	93	115	129	115	128	124	123	133	169	123	110	150	141	167	147	120	150	64
1886-87	118	69	90	99	63	64	63	72	96	75	68	70	71	77	60	50	88	86	72	83	120	120	92	74	70	72
1887-88	91	116	75	76	90	78	64	54	82	64	64	73	73	85	84	59	67	86	80	100	118	134	110	127	110	114
1888-89	116	104	69	74	75	91	100	78	46	76	74	98	96	92	81	74	92	78	89	118	146	146	127	128	153	99
1889-90	162	198	178	157	150	177	180	182	227	169	174	192	195	204	192	178	153	119	130	192	166	180	229	164	153	99
1890-91	95	66	81	82	66	93	77	77	101	77	86	86	85	95	84	80	79	87	83	89	99	94	88	117	130	150
1891-92	89	77	88	101	85	92	103	83	67	90	90	91	90	88	87	93	102	107	96	72	70	104	77	78	111	89
1892-93	128	117	101	104	120	138	125	121	162	123	132	139	117	146	129	130	101	94	95	128	139	107	117	117	98	137
1893-94	93	92	158	110	115	80	89	95	115	104	122	111	96	84	87	81	83	88	58	45	41	101	52	68	67	67
1894-95	100	125	83	100	145	149	125	136	123	124	148	147	138	136	138	137	119	139	122	110	99	126	116	138	130	92
1895-96	116	120	120	99	114	117	131	125	120	114	104	106	115	97	93	100	82	91	81	90	70	104	53	58	60	53

STATE WATER PLAN

Season	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1896-97	113	97	112	101	105	110	106	111	109	110	124	112	110	105	102	111	107	125	114	99	107	96	102	116	117	92
1897-98	67	68	60	72	67	54	66	64	69	59	62	57	62	50	48	48	56	54	62	34	34	30	46	58	54	36
1898-99	71	68	68	74	87	80	84	84	108	86	89	91	82	89	86	73	82	82	81	71	51	33	40	47	54	52
1899-00	93	102	119	118	100	110	114	106	111	106	103	104	105	86	106	134	137	102	107	73	86	103	58	58	72	77
1900-01	102	112	121	121	117	108	114	114	111	112	129	121	105	117	109	109	137	102	124	142	142	142	111	102	96	135
1901-02	85	131	95	120	122	129	107	85	83	100	97	91	113	96	93	86	75	97	96	80	83	87	63	69	79	87
1902-03	77	108	105	114	101	95	95	94	106	99	108	105	128	98	89	100	81	71	78	78	61	84	110	116	110	46
1903-04	118	144	173	147	151	126	140	139	106	137	108	105	128	98	89	73	81	71	78	73	61	63	56	61	51	65
1904-05	80	121	115	92	116	141	109	103	79	100	108	124	122	115	128	135	132	118	147	130	148	140	123	140	148	148
1905-06	99	117	118	91	119	132	139	133	121	138	139	120	122	121	125	144	148	169	189	113	124	154	125	135	147	122
1906-07	131	123	135	110	126	119	153	138	171	150	148	144	131	137	164	160	131	123	131	147	160	140	139	138	115	122
1907-08	73	85	82	79	78	75	76	72	71	66	71	64	72	73	82	74	81	90	109	93	97	81	78	88	84	131
1908-09	102	147	123	117	145	126	136	130	113	124	119	124	135	133	142	152	114	165	142	144	158	117	128	117	111	145
1909-10	77	82	93	94	88	83	87	99	106	95	98	93	85	84	102	99	95	102	104	102	102	63	87	97	98	123
1910-11	113	100	97	118	99	110	126	127	150	129	133	121	110	133	122	125	132	103	117	152	119	113	105	105	98	144
1911-12	65	76	118	89	72	61	59	60	57	60	62	64	59	64	76	65	73	76	85	77	79	101	75	81	81	87
1912-13	80	81	90	84	87	79	77	72	71	67	58	52	68	45	49	48	66	67	79	46	78	85	74	61	66	103
1913-14	123	140	135	109	141	156	130	120	135	120	117	128	152	125	142	152	123	131	140	163	96	156	156	141	103	257
1914-15	62	130	115	122	132	143	99	101	104	111	114	126	128	128	141	145	124	111	174	147	128	128	110	136	148	117
1915-16	86	106	102	103	102	105	99	104	121	104	94	120	105	105	122	136	123	153	121	118	136	135	129	146	151	209
1916-17	88	76	80	75	78	81	83	87	84	89	82	78	75	82	87	83	88	98	107	108	111	111	94	91	97	131
1917-18	58	66	65	68	59	66	58	61	67	67	77	77	53	54	54	64	64	62	80	84	117	117	83	86	86	92
1918-19	69	86	110	101	89	94	80	85	92	91	89	105	99	111	114	100	81	88	109	82	75	75	61	73	77	91
1919-20	60	48	56	55	51	57	54	64	64	70	76	66	53	65	76	82	91									

TABLE 5
SEASONAL RUN-OFF FROM MOUNTAIN AND FOOTHILL DRAINAGE AREAS*

Stream	Area of drainage basin in square miles	Seasonal run-off in acre-feet				Maximum of 40-year period		Minimum of period of record		Minimum average measured flow in August for period of record	
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929	Seasonal run-off in acre-feet	Season	Seasonal run-off in acre-feet	Season		
											In second-feet	Year
North Pacific Coast Basin:											
Smith River.....	627	3,261,000	3,007,000	2,868,000	3,142,000	5,417,000	1899-90	1,437,000	1919-20	1,670	1918
Klamath River.....	2,320	3,729,000	3,537,000	3,059,000	3,903,000	7,101,000	1899-90	1,561,000	1923-24	411	1924
Shasta River.....	803	252,000	219,000	205,000	209,000	591,000	1899-90				
Scott River.....	813	550,000	490,000	461,000	547,000	1,233,000	1899-90				
Salmon River.....	734	1,307,000	1,191,000	1,121,000	1,294,000	2,466,000	1899-90				
Trinity River.....	2,965	4,467,000	3,736,000	3,708,000	3,603,000	9,646,000	1899-90				
Redwood Creek.....	275	805,000	749,000	708,000	780,000	1,299,000	1899-90				
Mad River.....	457	1,169,000	1,017,000	937,000	1,051,000	1,877,000	1899-90				
Ed River.....	3,547	6,030,000	5,255,000	4,671,000	5,737,000	10,080,000	1913-14				
Bear Creek.....	82	217,000	199,000	186,000	210,000	370,000	1899-90				
Mattole River.....	264	1,015,000	856,000	891,000	980,000	1,723,000	1899-90				
Noyo River Group.....	780	1,319,000	1,068,000	1,000,000	1,169,000	2,620,000	1899-90				
Navarro River.....	273	364,000	317,000	295,000	346,000	796,000	1899-90				
Guadalupe River Group.....	623	792,000	692,000	644,000	753,000	1,691,000	1899-90				
Russian River.....	1,508	1,399,000	1,068,000	895,000	1,102,000	2,974,000	1905-04				
Leguinitas Creek.....	84	82,700	71,400	66,300	78,400	188,000	1899-90				
Salmon Creek Group.....	230	105,000	88,400	81,700	97,900	258,000	1899-90				
Bolinas Creek Group.....	158	33,300	27,700	26,200	31,200	96,100	1899-90				
Total for North Pacific Coast Basin.....											
		16,543	26,797,000	23,658,500	21,906,200	25,033,500					
Sacramento River Basin:											
Sacramento River at Red Bluff.....	9,268	9,354,000	7,898,000	6,775,000	7,351,000	22,700,000	1889-90	3,294,000	1923-24	2,900	1924
Mill Creek Group.....	971	1,131,000	903,000	809,000	872,000	2,610,000	1889-90				
Butte Creek Group.....	251	464,000	332,000	337,000	337,000	1,178,000	1889-90				
Feather River.....	3,627	5,201,000	4,271,000	3,594,000	3,652,000	13,278,000	1889-90				
Honcut Creek Group.....	314	194,000	144,000	125,000	138,000	622,000	1889-90				
Yuba River.....	1,200	2,653,000	2,240,000	2,083,000	2,143,000	6,908,000	1889-90				
Dry Creek.....	79	48,600	38,800	35,600	37,100	137,000	1889-90				
Bear River.....	262	402,000	328,000	298,000	298,000	1,212,000	1889-90				
Coon Creek Group.....	210	34,700	25,500	23,300	23,300	124,000	1889-90				
American River.....	1,919	3,069,000	2,624,000	2,267,000	2,284,000	8,749,000	1889-90				
Red Bank Creek Group.....	109	79,400	68,700	67,500	79,300	202,000	1889-90				
Elder Creek Group.....	414	512,000	302,000	305,000	368,000	872,000	1889-90				
Shoey Creek.....	710	354,000	379,000	316,000	368,000	1,442,000	1889-90				
Willow Creek Group.....	394	100,000	86,900	85,300	99,600	265,000	1889-90				
Catche Creek at Oopsy dam site.....	996	762,000	595,000	531,000	634,000	2,125,000	1889-90				
Putah Creek.....	885	442,000	332,000	273,000	324,000	1,239,000	1889-90				
Total for Sacramento River Basin.....											
		16,543	26,797,000	23,658,500	21,906,200	25,033,500					

San Joaquin River Basin

Orestimba Creek Group.....	1,340	120,000	102,000	87,200	78,600	450,000	1889-90				
Panoche Creek.....	295	28,400	24,200	14,000	13,200	106,000	1889-90				
Cantua Creek.....	208	12,600	11,300	6,100	5,500	54,400	1889-90				
Los Gatos Creek.....	1,119	9,400	8,400	4,800	4,300	41,300	1889-90				
Tejon Creek Group.....	1,341	88,600	74,700	43,900	41,000	306,000	1889-90				
Caliente Creek.....	471	37,300	28,900	21,900	22,100	108,000	1905-06				
Kern River.....	2,410	725,000	691,000	505,000	466,000	2,474,000	1915-16	202,000	1923-24	96	1924
Deer Creek.....	576	45,500	38,600	32,300	35,300	158,000	1905-06				
Tule River.....	110	19,500	16,500	13,400	12,600	56,200	1905-06				
Yokoh Creek Group.....	390	135,000	113,000	87,200	77,600	492,000	1905-06	25,600	1923-24	0	1924
Kaweah River.....	98	14,200	12,000	10,000	10,900	49,600	1905-06				
Limekiln Creek Group.....	514	443,000	355,000	311,000	291,000	1,100,000	1889-90				
Kings River.....	201	60,600	52,600	46,000	49,700	175,000	1905-06				
Dry Creek.....	1,694	1,889,000	1,580,000	1,321,000	1,226,000	4,250,000	1889-90				
San Joaquin River (Upper).....	48	4,100	3,600	3,000	2,600	12,700	1889-90				
Cottonwood Creek.....	1,631	1,995,000	1,699,000	1,405,000	1,333,000	4,620,000	1889-90				
Fresno River.....	270	63,400	56,300	46,300	38,900	168,000	1889-90				
Chowchilla River.....	66	4,600	3,900	3,200	2,700	15,900	1889-90				
Dutchman Creek Group.....	238	70,900	56,200	56,900	55,100	195,000	1889-90				
Mariposa Creek.....	103	13,200	9,400	5,700	5,900	31,500	1889-90				
Owens Creek.....	66	6,700	4,500	4,300	4,400	48,200	1889-90				
Bear Creek.....	71	7,800	5,300	5,100	5,200	29,700	1889-90				
Burns Creek Group.....	171	25,400	18,700	18,300	18,800	80,200	1889-90				
Merced River.....	1,054	1,115,000	944,000	814,000	765,000	2,745,000	1889-90				
Tuolumne River.....	59	8,200	6,500	6,300	6,500	32,900	1889-90				
Wild Cat Creek Group.....	41	8,400	6,200	6,000	6,200	28,700	1889-90				
Littlejohn Creek.....	122	14,900	11,100	10,700	11,100	44,900	1889-90				
Mariposa Creek Group.....	394	227,000	191,000	131,000	115,000	708,000	1906-07	23,700	1923-24	0	1924
Calaveras River.....	632	853,000	726,000	626,000	618,000	2,063,000	1889-90				
Mokelumne River.....	285	97,600	75,600	75,900	70,500	277,000	1889-90				
Sutter Creek Group.....	534	407,000	346,000	289,000	282,000	1,151,000	1889-90				
Cosumnes River.....											
Total for San Joaquin River Basin.....											
		18,178	11,980,000	10,159,600	8,546,900	8,137,000					
San Francisco Bay Basin:											
Petaluma Creek Group.....	129	77,100	62,400	58,400	75,900	263,000	1889-90				
Sonoma Creek tributaries.....	29	34,200	27,600	27,600	34,200	124,000	1889-90				
Napa River tributaries.....	268	118,000	92,700	88,700	118,000	419,000	1889-90				
Sutro Creek Group.....	125	51,600	43,500	40,200	51,700	193,000	1889-90				
Mt. Diablo Creek Group.....	200	71,200	54,200	50,200	53,000	263,000	1889-90				
San Pablo Creek.....	17	12,600	10,200	10,200	11,200	59,500	1889-90				
San Leandro Creek.....	44	19,100	14,100	14,100	15,200	70,900	1889-90				
Claremont Creek Group.....	83	25,300	18,000	14,800	16,600	116,800	1889-90				
San Lorenzo Creek.....	38	17,200	13,000	12,200	12,500	63,700	1889-90				
Alameda Creek.....	654	130,000	104,000	68,900	63,700	547,000	1889-90				
Mission Creek Group.....	27	25,800	18,400	17,200	17,200	115,000	1889-90				
Penitencia Creek.....	22	5,400	4,000	3,500	3,900	22,700	1889-90				
Total for San Francisco Bay Basin.....											
		1,817	1,198,000	1,015,960	854,690	813,700					

TABLE 5—Continued
SEASONAL RUN-OFF FROM MOUNTAIN AND FOOTHILL DRAINAGE AREAS*

Stream	Area of drainage basin in square miles	Seasonal run-off in acre-feet				Maximum of 40-year period		Minimum of period of record		Minimum average measured flow in August for period of record	
		Mean for 40-year period 1889-1929	Mean for 20-year period 1909-1929	Mean for 10-year period 1919-1929	Mean for 5-year period 1924-1929	Seasonal run-off in acre-feet	Season	Seasonal run-off in acre-feet	Season		
											In second-feet	Year
San Francisco Bay Basin—Continued											
Coyote River.....	197	73,200	49,600	32,800	27,300	351,000	1889-90	900	1923-24	0	1924
Guadalupe River.....	52	20,700	15,100	11,600	47,700	94,000	1889-90				
Los Gatos Creek Group.....	121	65,600	52,400	45,200	14,500	219,000	1889-90				
San Francisco Creek.....	38	21,400	18,000	14,500	16,500	64,200	1889-90				
San Mateo Creek Group.....	84	38,000	28,700	26,500	29,600	129,000	1889-90				
Total for San Francisco Bay Basin.....	2,219	824,400	633,600	526,100	599,800						
Central Pacific Coast Basin¹											
Jalama Creek Group.....	242	46,500	45,300	28,400	27,400	138,000	1889-90				
Santa Ynez River.....	797	187,000	166,000	72,700	59,000	608,000	1889-90	11,800	1928-29	0	1929
San Antonio Creek.....	138	21,400	20,300	11,500	11,200	75,200	1889-90				
Santa Maria River.....	1,634	183,000	151,000	71,500	59,300	943,000	1889-90				
San Luis Obispo Creek Group.....	1,019	202,000	177,900	109,000	103,000	853,000	1889-90				
Salinas River tributaries.....	4,042	873,000	760,000	454,000	431,000	3,770,000	1889-90				
Pajaro River tributaries.....	1,070	267,000	225,000	151,000	136,000	1,112,000	1889-90				
Sacramento River.....	324	274,000	226,000	188,000	185,000	916,000	1889-90				
Pescadero Creek Group.....	222	194,000	156,000	142,000	154,000	599,000	1889-90				
Total for Central Pacific Coast Basin.....	9,488	2,247,900	1,926,600	1,228,100	1,165,900						
South Pacific Coast Basin											
Tia Juana River.....	246	27,800	33,200	36,500	38,000	172,000	1915-16				
Olney River.....	104	8,100	10,900	9,200	10,200	87,000	1915-16				
Sage River.....	181	18,000	23,600	23,200	28,300	161,000	1915-16				
San Diego River.....	207	36,300	40,300	43,000	39,100	201,000	1915-16				
Santa Ysabel Creek.....	126	33,800	37,600	37,600	42,000	172,000	1915-16	1,700	1924-25	0	1925
Santa Luis Rey River.....	325	54,900	59,300	50,600	46,900	309,000	1915-16	8,200	1924-25	1	1924
Santa Margarita River.....	600	30,700	31,000	30,300	24,600	125,000	1921-22				
San Jacinto River tributaries.....	330	45,200	45,400	30,200	24,600	218,000	1915-16	1,000	1924-25	0	1924
Santa Ana River tributaries.....	1,167	323,000	349,000	273,000	182,000	1,361,000	1889-90	44,100	1898-99	25	1902
San Gabriel River tributaries.....	369	161,000	162,000	132,000	85,700	610,000	1889-90	11,800	1898-99	74	1900
Los Angeles River tributaries.....	342	86,100	72,000	52,000	26,200	418,000	1889-90				
Malibu River Group.....	379	53,000	51,800	33,200	31,900	158,000	1889-90				
Santa Clara River tributaries.....	1,387	173,000	168,000	104,000	92,700	600,000	1889-90				
Ventura River.....	226	63,400	38,900	38,900	35,900	174,000	1889-90				
Total for South Pacific Coast Basin.....	6,078	1,114,300	1,145,700	893,700	709,200						
Great Basin²											
Tule Lake Group.....	901	196,000	136,000	116,000	117,000	750,000	1889-90				
Goose Lake Group.....	275	22,200	15,200	12,700	12,900	82,400	1889-90				
Coville Lake Basin.....	24	4,300	3,400	3,100	3,100	12,300	1889-90				
Surprise Valley Group.....	379	67,400	53,400	48,900	49,100	190,000	1889-90				
Madeline Plains Group.....	548	85,700	65,500	59,100	60,900	257,000	1889-90				
Snake Creek Group.....	188	29,100	25,000	19,900	20,300	89,200	1889-90				
Eagle Lake Group.....	498	67,200	47,700	41,700	42,300	234,000	1889-90				
Honey Lake Group.....	1,507	254,000	190,000	170,000	172,000	780,000	1889-90	27,200	1923-24	130	1926
Lake Tahoe Basin.....	499	277,000	185,000	158,000	192,000	1,198,000	1889-90	102,000	1923-24	212	1926
Truckee River.....	447	513,000	419,000	348,000	354,000	1,443,000	1889-90	77,000	1919-20	5	1920
West Fork Carson River.....	67	117,000	99,700	94,200	91,200	276,000	1889-90	67,900	1923-24	17	1924
East Fork Carson River.....	323	318,000	269,000	239,000	237,000	868,000	1889-90				
West Walker River.....	405	316,000	251,000	205,000	199,000	1,079,000	1889-90				
East Walker River.....	411	289,000	208,000	119,000	73,800	1,031,000	1889-90				
Mono Lake Group.....	166	214,000	180,000	164,000	154,000	402,000	1889-90				
Adobe Meadows Group.....	453	55,600	63,400	31,300	37,200	285,000	1913-14				
Owens River (Upper).....	524	250,000	218,000	165,000	141,000	427,000	1889-90	116,000	1928-29	106	1929
Bishop Creek Group.....	446	333,000	321,000	288,000	285,000	570,000	1889-90				
Owens Lake Group.....	216	81,700	75,800	58,000	44,300	158,000	1915-16				
Mojave River.....	211	94,800	96,600	91,300	81,100	255,000	1906-07				
Antelope Valley Group.....	119	26,200	23,500	18,400	17,700	85,900	1889-90				
Whitewater River.....	269	12,800	12,600	12,200	10,300	40,200	1889-90				
Total for Great Basin.....	8,876	3,624,000	2,955,800	2,462,800	2,395,200						
Grand total for state.....	82,752	71,388,300	61,072,700	53,483,500	57,067,900						

*See Bulletin No. 5, "Flow in California Streams," Division of Engineering and Irrigation, 1923, for streams included in the groups.

¹ Run-off from this basin largely physically unavailable for use in the state as a whole.

² Klamath River near Requa.

³ Shasta River near Montague.

⁴ Trinity River at Lewiston.

⁵ Eel River near Scotia.

⁶ Santa Ana River near Mentone.

⁷ San Gabriel River near Aausa.

⁸ Portion of the run-off from this basin now used outside of the state.

⁹ Run-off from North Pacific and Central Pacific Coast basins largely physically unavailable for use in the state as a whole, and a portion of that from the Great Basin is now used outside of the state.

TABLE 6
AVERAGE MONTHLY DISTRIBUTION OF SEASONAL RUN-OFF FOR TYPICAL MAJOR STREAMS

Based on data for period of stream flow measurement

Month	Mean run-off of Ed River at South, 1910-1929		Mean run-off of Sacramento River at Red Bluff, 1892-1929		Mean run-off of American River at Yuba City, 1904-1929		Mean run-off of San Joaquin River at Mant and Hanford, 1894-1901 and 1907-1929		Mean run-off of San Gabriel River at Azusa, 1893-1929	
	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total	In acre-feet	In per cent of seasonal total
October	18,600	0.43	316,000	3.63	24,400	0.87	23,800	1.34	2,000	1.72
November	286,000	6.64	496,000	5.69	59,200	2.11	30,600	1.72	2,400	2.06
December	532,000	12.35	664,000	7.62	115,000	4.10	41,400	2.33	7,600	6.53
January	920,000	21.33	1,182,000	13.57	293,000	10.46	87,500	4.92	16,800	14.43
February	1,062,000	25.11	1,484,000	17.03	343,000	12.24	90,700	5.10	20,800	17.87
March	596,000	13.81	1,403,000	16.10	440,000	15.70	142,000	7.99	28,000	24.06
April	558,000	12.95	1,077,000	12.36	508,000	18.12	245,000	13.78	16,800	14.43
May	228,000	5.24	756,000	8.68	552,000	19.69	444,000	24.97	9,700	8.33
June	59,000	1.36	461,000	5.29	339,000	12.09	422,000	23.74	5,400	4.64
July	15,800	0.37	325,000	3.73	92,200	3.29	173,000	9.73	3,200	2.75
August	7,100	0.16	280,000	3.21	15,200	0.79	53,200	2.99	2,100	1.80
September	7,700	0.18	269,000	3.09	15,200	0.54	24,700	1.39	1,600	1.38
Total	4,309,100	100.00	8,713,000	100.00	2,803,200	100.00	1,777,900	100.00	116,400	100.00

Return and Ground Waters.

In the plan for the development of the state's water resources, a part of the water supplies considered available for use is that water returning to the natural stream channels and to the underground reservoirs from irrigation applications and from other uses. In certain areas, the water, once used for irrigation, domestic or other purposes, returning to the streams, either as direct surface drainage or as inflow from the ground water basin, is available for reuse on lands at lower elevations along the streams and may constitute a large portion of their water supply. Records and measurements taken in the Sacramento and San Joaquin valleys during recent years indicate these return flows may range from fifteen to more than forty per cent of the water diverted from the streams. This water does not all return to the streams immediately and the return from irrigation water therefore is not all available for reuse for that purpose in the same season. It is estimated, however, that 60 to 75 per cent of this water returns to the streams during the irrigation months with a regimen that approximately synchronizes with the irrigation demand and that the remainder returns about uniformly throughout the other months of the year.

The suitability of this return water for reuse is an important element in the plan, because the return water constitutes a substantial part of the total available water supply. During the past year, the Water Resources Branch of the United States Geological Survey chemically analyzed samples of water taken during the low water season on many of the principal streams of the state. Among these were analyses of the water in the Sacramento and San Joaquin rivers during the low water season when practically the entire flow comprised return water from irrigation. These preliminary analyses showed that the return water in these streams under present conditions is entirely satisfactory chemically for municipal, irrigation and industrial use and can be classified as "good."

Another water supply which can be made available is that collected and reregulated in the underground basins. Water from surface application and rainfall which is not used by the growing crops or natural vegetation, and also from seepage from stream channels, percolates into these basins and is available for use by means of pumping unless it drains back into the streams as return water as above described. These basins not only collect the return water and make it available for reuse on some other area, but also act as underground reservoirs for cyclic storage, thereby making excess waters of one season available for use in seasons of deficiency in surface supplies. This method of regulation and reuse is of particular importance in the upper San Joaquin Valley, the coastal basins of southern California, the Santa Clara Valley and numerous smaller basins, all of which depend upon pumped ground water for a supply.

CHAPTER IV

WATER REQUIREMENTS

The variety of uses of water in California possibly exceeds that of any other state in the Union. These include domestic, municipal, irrigation, salinity control, industrial, navigation, power development, hydraulic mining and recreational uses. Recreational and navigation uses result in no actual consumption of water, and, in most instances, do not alter the regimen of the stream. Other uses, like power development and hydraulic mining, while altering the regimen of the stream, also do not consume any water. The uses of water for municipal, industrial and domestic purposes are similar, as these uses are largely confined to the more thickly populated areas. Naturally, the use of water increases per unit of area with increase in density of population. For domestic service alone, the unit use is practically the same within small cities as for irrigation. For industrial and commercial areas, the amount of water used may be somewhat larger than the irrigation requirements of an equivalent area. As densities of population and industrial development increase, unit water requirements also will increase. At present only areas around San Francisco Bay and in the metropolitan area of Los Angeles have become so thickly populated that the water requirements are greater than for an equivalent irrigated area. Water for irrigation is, and probably will continue to be, the largest single use of water in the state. At present more than 90 per cent of the water used is for irrigation purposes. Irrigation is practiced in nearly every section of the state, but the greatest use for this purpose is in the Great Central Valley, on the Pacific slope of southern California and in the Imperial and Santa Clara valleys.

There is considerable variation both as to rate and period of use of water for various purposes. For irrigation, the period of use varies in different parts of the state with different climatic conditions. The greater part of the irrigation demand, especially in the Great Central Valley, occurs during the months of March to October. However, in certain areas, particularly in southern California, irrigation is practiced during the entire year, and in other areas water is used to a minor extent for irrigation during the winter months. The rate of demand for irrigation varies from month to month during the irrigation season, and reaches a maximum monthly demand of one-eighth to one-quarter of the total seasonal requirements in midsummer. For municipal, industrial and power development purposes, the period of use of water is usually continuous throughout the year. The rate of use, however, varies from month to month. For domestic and industrial purposes it ranges from a minimum during the winter of about 80 per cent to a maximum during the summer of about 125 per cent of the average monthly use during the year. For power development, the use of water varies considerably for different power systems, but, under existing conditions of operation, an average range is from a maximum of about 20 per cent above to a minimum of 20 per cent below the average monthly use during the year. For hydraulic mining, the

period of use during the year varies with conditions of water supply and climate, but may be continuous throughout the year with a comparatively uniform rate of use from month to month if the above conditions permit. In all of the foregoing uses there also are wide variations in the rate of use from day to day during the month and at different hours of the day.

Water requirements for any particular area vary with the use to which the water is put, not only in total amount and in monthly demand but also with the point at which the water is measured. The geographic position of the source of supply in relation to point of use, methods of conveyance, the extent of the area to be supplied and the opportunity afforded for reuse of water controlled by topographic, geographic and geologic conditions are factors that have an important bearing on water requirements.

For these reasons some variation in treatment of the problem of requirement and supply for different areas has been necessary. The variation in treatment has in turn necessitated the use of different terms defined as follows:

“Gross allowance” designates the amount of water diverted at source of supply.

“Net allowance” designates the amount of water actually delivered to the area served.

“Consumptive use” designates the amount of water actually consumed through evaporation, transpiration by plant growth and other processes.

“Net use” designates the sum of the consumptive use from artificial supplies and irrecoverable losses.

In an area as large as California, where the uses and methods of use are so many and so varied and where the conditions—topographic, geographic and geologic—are so varying, it is practically impossible to place the water requirements for all areas on the same basis. In some areas the source of supply is located at the point of use. In this instance, the gross allowance and the net allowance are the same. In other areas, where underground capacity is available and reuse of water can be effectively and efficiently practiced, net use controls the amount of water required. In areas where it is not possible or practicable to practice reuse, the net allowance becomes the net use.

In the following sections of this chapter are presented the water requirements in each of the seven basins into which the state has been divided.

North Pacific Coast Basin.

In the North Pacific Coast Basin the precipitation and run-off are larger per unit area than in any other basin of the state. Some irrigation is practiced and some water also is used for domestic, municipal and mining purposes. A large surplus in water supply, over and above its ultimate needs, exists in this area. The area of agricultural lands is relatively small. These lands were outlined during the investigation of 1921. No further survey has been made during the present investigation to determine the portion of these agricultural lands that would be feasible of irrigation. Based on the information obtained, however, in classifying the lands in the Sacramento and San Joaquin valleys and adjacent foothills, it is estimated that not more than 80 per cent of the gross agricultural land embracing 421,000

acres would ever be irrigated. This percentage is considered liberal for this basin. Calculated upon this basis the total net area which might ultimately require an irrigation supply would be 337,000 acres. It is estimated that the net use in this basin would be 1.8 acre-feet per acre and the gross allowance 3.0 acre-feet per acre. Based on these rates the total net use of water for irrigation would be 607,000 acre-feet and the gross allowance 1,011,000 acre-feet per season. In addition to irrigation, water would be required for other purposes. No estimates have been made for such uses.

Sacramento River Basin.

The uses of water in the Sacramento River Basin include all of those mentioned at the beginning of this chapter. Of these, the use for irrigation purposes does and probably will continue to predominate, and has, therefore, been used as the basis for estimating the water requirements of the basin. It is believed that the total requirements estimated upon this assumption are adequate for complete future development of the basin.

In order to determine the area of land in the basin which might ultimately require water for irrigation, a survey was made to classify all of the lands in the Sacramento Valley and adjacent foothills on the basis of their adaptability for irrigation. This survey was more comprehensive than a soil survey since it involved the elements of soil texture, presence of alkali and topography. An area of 8,750,000 acres was examined. The standards used divide the valley lands into five classes. They are described briefly as follows:

Class 1. Lands not limited in the feasibility of irrigation or in crop yield by the elements of soil texture, alkali or topography.

Class 2. Lands which, because of the presence of alkali, hardpan, roughness, heavy brush or by other factors, are limited in the feasible extent of irrigation development.

Class 3. Lands which, because of extremely hummocky or hog-wallow character, shallow soils and channel cut topography, in addition to the limitations in class 2, are further limited in the feasible extent of irrigation development.

Class 4. Lands of dubious value except for pasture and gun clubs and possibly some rice culture.

Class 5. Lands of no present or potential agricultural value.

Table 7 summarizes the lands of the entire Sacramento Valley floor by classes in accord with the foregoing standards.

TABLE 7
CLASSIFICATION OF LANDS ON SACRAMENTO VALLEY FLOOR, EXCLUDING THE
SACRAMENTO-SAN JOAQUIN DELTA

Class	Gross area	
	In acres	In per cent of total
1.....	1,735,000	47.1
2.....	945,000	25.6
3.....	575,000	15.6
4.....	248,000	6.7
5.....	185,000	5.0
Total.....	3,684,000	100.0

Mountain valleys and foothill lands were not classified on strictly the same basis as the valley floor, but the quality of the soil and topography governed the percentage of irrigable land which might come under irrigation at some future time. Without regard to economic feasibility, it was determined before the inclusion of any of these areas that it was physically possible to furnish them a water supply.

Table 8 presents, by sections, the gross agricultural lands and net irrigable areas obtained by applying factors to the gross areas. The Delta of the Sacramento and San Joaquin rivers, although only about one-third lies in the Sacramento River Basin, is included herein since a large part of its water supply would come from this basin under the plan for ultimate development.

TABLE 8
SUMMARY OF GROSS AGRICULTURAL AND NET IRRIGABLE AREAS IN SACRAMENTO
RIVER BASIN, INCLUDING THE SACRAMENTO-SAN JOAQUIN DELTA

Section	Gross agricultural area		Net irrigable area	
	In acres	In per cent of total	In acres	In per cent of total
Valley floor.....	3,499,000	54.4	2,640,000	61.9
Foothill area.....	2,099,000	32.6	922,000	21.6
Mountain valley.....	416,000	6.5	312,000	7.3
Sacramento-San Joaquin Delta.....	421,000	6.5	392,000	9.2
Total.....	6,435,000	100.0	4,266,000	100.0

includes 9,000 acres of land formerly reclaimed, flooded at time of survey of 1929, but subject to reclamation.

As compared with these net areas that will ultimately require water for irrigation, it is estimated that there were 1,076,000 acres, or about one-quarter of the total net irrigable area, irrigated in 1929. Of this area there were 872,000 acres on the Sacramento Valley floor and in the Sacramento-San Joaquin Delta, 66,000 acres in the foothill areas, and 138,000 acres in the mountain valleys.

The ultimate water requirements for the net area of irrigable lands on the valley floor were estimated by methods developed during the investigation. The net areas were derived from the land classification by applying various percentages to the gross areas of the four classes of agricultural land. Study also was made to estimate the probable acreage that ultimately would be planted to each kind of crop and the probable locations of these plantings. By combining these several calculations, the net area that ultimately would be planted to each crop was estimated. The net allowance for each crop was obtained by applying the unit net allowance, estimated from the best available information, to the net irrigable area for that crop. The total net allowance for the entire net irrigable area was obtained by totaling the net allowances for the several crops. The total gross allowance was estimated by increasing the amount of the total net allowance by 50 per cent to provide for conveyance and application losses.

The ultimate water requirements of the net area of irrigable lands in the foothill and mountain valleys have been estimated by using the requirement per unit of area as determined by the investigations of

1921.* The gross allowances were based on the assumption that the water required for the net use amounts to 60 per cent of the water diverted, 40 per cent returning to the stream.

Since the distribution of irrigation water to the lands in the foothills and on the valley floor would in general require long conduits, with large resultant conveyance losses, the water requirements for these areas would be the gross allowance. Most of the water lost during transportation would find its way to the stream channels and be available for reuse on lands at lower elevation or in the Sacramento-San Joaquin Delta.

Because of the method of irrigation used in the Sacramento-San Joaquin Delta, it is a difficult matter to differentiate between gross and net allowances and net use. For this reason, values for net use only are used as the basis of the estimates of water requirements. The value for the net use per unit of area is not given because the ultimate total requirement of 1,200,000 acre-feet is divided among irrigation use, evaporation from the delta channels, transpiration from tulle and other natural vegetation and evaporation from levees and uncultivated land surfaces. It is estimated that during the irrigation season, the ultimate total net use of water for all demands on the entire area will average about 2.6 acre-feet per acre, and the total net use for irrigation only will average about 2.3 acre-feet per acre.

The total estimated allowances and uses in acre-feet and the average in acre-feet per acre in these areas are shown, by sections, in Table 9.

TABLE 9

ULTIMATE SEASONAL WATER REQUIREMENTS OF IRRIGABLE LANDS IN SACRAMENTO RIVER BASIN, INCLUDING THE SACRAMENTO-SAN JOAQUIN DELTA

Section	Net irrigable area in acres	Gross allowance in acre-feet		Net allowance in acre-feet		Net use in acre-feet	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Valley floor.....	2,640,000	9,033,000	3.42	6,025,000	2.28	5,190,000	1.97
Foothill areas.....	922,000	2,305,000	2.50	1,383,000	1.50	1,383,000	1.50
Mountain valleys.....	312,000	936,000	3.00	562,000	1.80	562,000	1.80
Sacramento-San Joaquin Delta..	392,000	1,200,000	-----	1,200,000	-----	1,200,000	-----
Total.....	4,266,000	13,474,000	-----	9,170,000	-----	8,335,000	-----

Control of Salinity in Sacramento-San Joaquin Delta.

A study of variation of salinity in upper San Francisco Bay and the Sacramento-San Joaquin Delta and its control by fresh water releases has been under way since 1929. The detail results of this investigation are presented in a separate report,† and are briefly summarized in the following paragraphs.

The channels of the Sacramento-San Joaquin Delta form a part of the tidal basin of San Francisco Bay. The regimen of these channels is affected by tidal action, the extent and magnitude of which is dependent at any particular time upon the amount of stream flow discharging through the channels into the bay. During summer periods of low

* Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1923.

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

stream flow the effect of tidal action on these channels is a maximum and is characterized by the rise and fall and flood and ebb of the channel waters. As stream flow increases with the winter season and floods occur, these tidal effects are diminished and often eliminated from all or a large portion of the delta channels; and during extreme floods the effect of tidal action may be partially eliminated from a large portion of the waters of the upper bay.

The waters of San Francisco Bay are a combination of the salt waters of the ocean, which enter the bay through the Golden Gate, and the fresh waters of the Sacramento and San Joaquin rivers and local streams of the San Francisco Bay region, which discharge into the bay. The salinity of the water resulting from this combination is extremely variable, both geographically and during different periods of the year, and depends upon the amount of fresh water discharged by the streams into the bay. In general the more saline waters are found in the lower bay nearest the ocean, the fresher waters in the upper bays and tidal estuaries and channels through which the fresh water enters the bay, while in between are found gradual gradations of salt to fresh water.

The pulsating action of the ocean tides accompanying the tidal flow into and out of the tidal basin of San Francisco Bay exerts a positive force tending to push upstream and mix the more saline waters from the lower bay with the fresher waters of the upper bay, with a resulting upstream advance of salinity. Opposed to this action, stream flow resists this upstream advance of salinity and tends by its action to push the fresher waters downstream. The relative magnitude of these two opposing forces exerted by tidal action and stream flow controls the advance and retreat of salinity in the upper portions of the tidal basin into which the fresh water stream flow enters. The force exerted by tidal action toward advancing salinity upstream is measured by the total amount of tidal flow into and out of the basin. Since the amount of tidal flow passing any section decreases the farther the section is upstream and the smaller the tidal volume becomes in the basin above the section, the effect of tidal action in advancing salinity decreases progressively upstream.

The salinity at any point in the tidal basin is constantly changing with the rise and fall of the tide. Wide variations occur during a tidal cycle, amounting to as much as 200 per cent above and 80 per cent below a mean value. The maximum salinity during a tidal cycle occurs at time of slack water following higher high tide and the minimum at time of slack water following lower low tide. The salinity at any time during a tidal cycle is directly related to the height of the tide above lower low water, increasing in direct proportion to the height of the tide above its lower low stage.

Salinity increases only slightly with depth. The maximum variation found from surface to bottom for water with a salinity about half that of ocean water was three-tenths per cent increase per foot of depth. The amount of increase is gradually less as the water becomes either more fresh or more salty.

There is little lateral variation in the salinity of water in any channel in the delta. The waters in the entire channel are quite uniform in

saline content at any particular time, except for a slight tendency toward increase in salinity at greater depths. There is no evidence of high concentrations of salt water creeping along either the bottom or sides of any channel.

The salinity conditions in the upper bay and delta region during any season are characterized by marked cyclic variations which result directly from the variations in stream flow entering the basin. The maximum retreat of salinity and the farthest downstream advance of fresh water is practically coincident each season with the maximum flood flows. As the stream flow decreases with the approach of summer, the salinity gradually advances upstream until the maximum advance and degree of salinity at any point is reached in late summer, some time after the minimum stream flow for the season occurs. The salinity starts to retreat as soon as the stream flow has increased sufficiently above its minimum summer flow and continues as the stream flow increases with the coming of winter, until it again reaches a point of maximum retreat during the period of maximum flood run-off.

The invasion of saline water from the lower bay into the upper bay and lower delta is a natural phenomenon which has occurred each year as far back as historical records go. The magnitude and extent of saline invasion varies widely from year to year as a direct result of the wide variations in the total amount and distribution of seasonal stream flow entering the delta and upper bay. It is approximately related to the total seasonal stream flow into the delta, the records indicating that the drier the season and the smaller the total amount of stream flow entering the delta, the greater will be the advance of salinity and the smaller will be the retreat of salinity. The magnitude and extent of invasion of salinity during the summer period of low stream flow, however, are more closely related to the total amount of summer stream flow into the delta. Records show that the smaller the total amount of stream flow into the delta during the summer period of June 15 to September 1, the farther upstream will be the advance of salinity and the greater will be the degree of salinity reached at any point in the upper bay and delta channels.

The actual occurrence of advance or retreat of salinity at any point or channel section in the upper bay or delta region is dependent upon the rate of stream flow passing the section and the initial degree of salinity present in the water at and below the particular point at any time. For any particular degree of salinity at any particular point or channel section there is a rate of stream flow which will equalize the action of the tides and control or prevent the advance of salinity. If at any time the rate of flow is less than the required amount for control for the particular degree of salinity, the salinity will tend to advance to points farther upstream and to increase to greater degrees at the particular point or channel section. If, on the other hand, the rate of flow is greater than the control flow, the salinity will tend to retreat to points downstream and to decrease to smaller degrees at the particular point or channel section. At any particular section, the rate of stream flow required to control or prevent the advance of salinity increases as the degree of salinity at the particular point or channel section decreases. For any particular degree of salinity the rate of flow required to control

or prevent the advance of salinity becomes smaller the farther upstream the point or channel section.

The maximum extent of advance of salinity and the maximum degrees of salinity reached in any season at various points in the upper bay and delta channels is directly related to the amount and variation of rate of daily stream flow into the delta and of daily consumptive use of water in the delta by crops, natural vegetation and evaporation from open water. The consumptive use of water in the delta is estimated to vary from a minimum of 400 second-feet (in winter) to a maximum of 3700 second-feet (in August), with an average consumption during July and August of 3500 second-feet. In order to control or prevent the advance of salinity at any point in the upper bay and delta region the rate of inflow into the delta must exceed the amount of water consumed above the particular point by an amount sufficient to equalize the action of the tide in its tendency to advance salinity upstream.

The last thirteen years have been a period of subnormal precipitation and stream flow. Moreover, during this period there have been increases in irrigation developments and diversions on the Sacramento and San Joaquin river systems. As a result of the combined effect of subnormal stream flow and increased upstream irrigation diversions, the stream flow into the delta has been greatly diminished. This has had the effect of causing abnormal invasions of salinity into the upper bay and delta region during certain years of this period. The maximum invasion of salinity occurred in the summer of 1924, when the water in the channels of nearly one-half of the delta at the time of maximum invasion of salinity during the summer season was not suitable for irrigation use. In the dry years of 1920 and 1926 about one-fifth of the delta was similarly affected. During the remainder of the last ten years the extent of invasion has not been serious, similarly affecting only three to nine per cent of the delta.

The extent of invasion of salinity into the delta is naturally controlled by stream flow. When stream flow is sufficient, no invasion of magnitude occurs. It is evident, therefore, that the invasion of salinity into the delta can be positively prevented artificially by means of releases of fresh water into the delta at rates and in amounts equivalent to natural flow, which the records show has actually and positively prevented and controlled the advance of salinity.

In order to control the advance of salinity, a supply of water flowing into the delta must be provided sufficient in amount, first, to take care of the consumptive use in the delta and, second, an additional amount flowing into Suisun Bay sufficient to repel the effect of tidal action in advancing salinity. The studies show that the practicable degree of control by means of fresh water releases would be a control at Antioch sufficient to limit the increase of salinity at that point to a mean degree of not more than 100 parts of chlorine per 100,000 parts of water, with decreasing salinity upstream. In order to effect a positive control of salinity at Antioch to this desired degree, a flow of 3300 second-feet in the combined channels of the Sacramento and San Joaquin rivers past Antioch into Suisun Bay would be required. This would necessitate a maximum gross rate of inflow into the delta at the time of maximum consumptive use of water in the delta in midsummer of about 7000 second-feet. The studies show that it would be impracticable,

because of the much greater amounts of water required, to control salinity by means of fresh water releases to this degree at a point farther downstream. The point and degree of control proposed would not only fully protect the delta from invasion of salinity to a harmful degree, but also would permit the diversion of water from the channels of the delta for the fresh water needs of the industries, municipalities and agricultural lands in the upper bay region. Fresh water of high quality with a saline content of ten parts or less of chlorine per 100,000 parts of water would be available with this proposed control in the channels of over 90 per cent of the delta area.

The annual amount of water required to control salinity as proposed would total 2,390,000 acre-feet. However, only a portion of this water would be released from storage, because, even under the conditions of ultimate development in the proposed State Water Plan, a portion of the water required for control of salinity would be contributed each year from unregulated run-off. In years of large stream flow, this unregulated run-off would constitute a large portion of the total supply required. With stream flow into the delta such as occurred in the last ten-year period and with the present consumption of water in the delta, the additional amount of water required to supplement the available supply during this period would have averaged 384,000 acre-feet per year, varying from a minimum of 149,000 acre-feet in the more normal years to a maximum of 850,000 acre-feet in the extremely dry year of 1924. This water requirement would have been in excess of the consumptive demands in the delta.

San Joaquin River Basin.

Like the Sacramento River Basin the principal demand for water in the San Joaquin River Basin is for irrigation. Due to smaller rainfall, irrigation is more essential for crop production than in the Sacramento River Basin. This fact accounts in part for the larger irrigation development in the San Joaquin Valley. The ultimate future water requirements for this area are estimated on the basis of those for agricultural use. Under conditions of ultimate development, the total seasonal requirement will be in direct proportion to the area of land available and susceptible of development under irrigation.

As might be expected in a basin so great in extent, there are wide variations in the types and grades of agricultural land. For this reason it was necessary to make a complete classification of all the lands in the basin. In making the field survey the entire floor of the valley was examined and classified to the extent of 7,933,000 acres. The foothill areas on the eastern rim of the valley, aggregating 977,000 acres, also were examined and classified on the same basis as those in the Sacramento River Basin. This makes a total of 8,910,000 acres examined and classified in the San Joaquin River Basin, exclusive of the San Joaquin portion of the Sacramento-San Joaquin Delta. This area is included in the Sacramento River Basin total in Table 8.

The basis for the classification of the lands in the San Joaquin Valley is similar to that in the Sacramento Valley. The survey comprehends the determination of the suitability of the lands for profitable development under irrigation. It was more comprehensive than a soil survey since it involved the elements of soil texture, presence of alkali and

topography. The lands on the valley floor were placed in the following five general classes:

Class 1. Lands not limited in the feasibility of irrigation or in crop yield by the elements of soil texture, alkali or topography. These are lands capable of good yield at reasonable costs of preparation.

Class 2. Lands placed in a grade below class 1 because of the presence of hardpan, roughness, alkali, or other factors. These are lands of medium ability to carry irrigation costs.

Class 3. Lands which, by present standards, do not justify irrigation with regulated water supplies, but which may eventually come into class 2 with improvements in methods of alkali removal or reduction in cost of leveling. These are lands not now suitable for irrigation, but for which the conditions may not justify a present conclusion as to the permanence of this limitation.

Class 4. Lands suitable only for pasture with flood irrigation and of too poor quality to be utilized for the usual crops.

Class 5. Lands considered as permanently nonirrigable by any reasonable or probable future standards. The poor quality of the land may be due to alkali, shallow depth of soil, hardpan, roughness or steepness, or a combination of these factors.

Table 10 summarizes, by classes, the lands of the entire San Joaquin Valley floor, excluding the San Joaquin Delta, in accord with the foregoing standards:

TABLE 10
CLASSIFICATION OF LANDS ON SAN JOAQUIN VALLEY FLOOR, EXCLUDING
THE SACRAMENTO-SAN JOAQUIN DELTA

Class	Gross area	
	In acres	In per cent of total
1.....	3,950,000	49.8
2.....	1,726,000	21.8
3.....	1,175,000	14.8
4.....	391,000	4.9
5.....	691,000	8.7
Total.....	7,933,000	100.0

The foothill areas, as in the Sacramento River Basin, were not classified on the same basis as the valley floor, but the quality of soil, topography and physical possibility of furnishing a water supply to them were given consideration in estimating the percentage of irrigable land that at some future time might come under irrigation.

Table 11 presents, by sections, the gross agricultural lands and net irrigable areas obtained by applying factors to gross areas of lands falling in classes 1, 2, 3 and 4. The figures of net irrigable area include all lands which, on the basis of classification adopted, might at some future time produce crops, but without consideration of availability or cost of a water supply. Class 5 land is not included. The San Joaquin portion of the Sacramento-San Joaquin Delta has been included with irrigable lands of the Sacramento River Basin.

TABLE 11

SUMMARY OF GROSS AGRICULTURAL AND NET IRRIGABLE AREAS IN SAN JOAQUIN RIVER BASIN, EXCLUDING THE SACRAMENTO-SAN JOAQUIN DELTA

Section	Gross agricultural area		Net irrigable area	
	In acres	In per cent of total	In acres	In per cent of total
Valley floor.....	7,242,000	88.1	5,324,000	93.3
Foothill areas.....	977,000	11.9	380,000	6.7
Total.....	8,219,000	100.0	5,704,000	100.0

As compared with the above net areas that may ultimately require water for irrigation, it is estimated that there were 2,033,000 acres, or about one-third of the total net irrigable area, irrigated in 1929.

In estimating the ultimate water requirements of the San Joaquin Valley, it has been necessary to take into account the marked difference between the upper and lower portions thereof in the adequacy of local tributary streams to meet the ultimate irrigation demand. For the purposes of this report the upper San Joaquin Valley is the southern portion of the valley extending on the east side as far north as the Chowchilla River and on the west side to a line extending from Mendota to Oro Loma. The lower San Joaquin Valley is the remaining portion of the valley lying north of this line.

Upper San Joaquin Valley—The upper San Joaquin Valley is an area in which the tributary run-off is inadequate to meet the ultimate water requirements and in which full development will be possible only with the importation of waters from more distant sources. Along the eastern side of the valley, the topographic and geologic characteristics of the basin are such that extensive underground storage capacity is available. The development of ground water supplies drawn from such storage adds to the effective utilization of the tributary run-off to the extent that it may be efficiently utilized within the particular area. Where adequate storage is available, the required inflow may be estimated upon the basis of net use. On the western slope of the valley a large body of fine land overlies subsoils of such chemical constituents that the use of shallow ground water would be injurious to irrigated crops. Therefore, the application of water to these lands must be upon the basis of actual plant needs and the net allowance should closely approximate net use. This area has extremely limited local water resources and if developed extensively would require the importation of practically all of its supply.

On the eastern slope of the valley, records, continuous in most areas since 1921, of the extent of irrigation development effected through the utilization of surface and ground water supplies, together with those of the conditions of underground storage, afford the basis for estimating the average net use. A study of this subject, based on data collected for all the developed areas along the eastern side of the valley and covering the period 1921-1929, was made. These data consist of the record of seasonal surface inflow, the total area irrigated each year from

surface and underground sources and the records of observations for varying periods of the depth to ground water in some 4000 wells scattered throughout the region.

Based upon an analysis of these data it is concluded that, while use varies for different crops, a reasonable estimate of the average seasonal net use for the types of crops now grown is two acre-feet per acre. This figure is supported by results obtained in a large district situated in the lower San Joaquin Valley where measurements of surface diversion into the district, the measured outflow and the area of irrigated land permitted the calculation of the net use per acre. For the foregoing reasons, the water requirements of the upper San Joaquin Valley are estimated on the basis of an average seasonal allowance of two acre-feet per acre to the net area of irrigable land.

This basis of estimating the water requirement for the area does not mean that the actual delivery of water upon irrigated land would be at a uniform rate or restricted to two acre-feet per acre. On the contrary it is recognized that, dependent upon the kind of crop served, the type of soil and subdrainage conditions, seasonal applications of water would vary from a minimum of less than two acre-feet per acre to a maximum of perhaps as much as 100 per cent in excess of that figure. In any case, the only water actually used is that which supplies the needs of plant transpiration and surface evaporation. On non-absorptive soils, applications in excess of these needs result in surface run-off to adjacent lands or drainage systems. On absorptive soils such excess applications are, to a large extent, accounted for by deep percolation losses, which constitute one of the principal sources of replenishment to the underlying ground water. In areas where it is feasible to recover these deep percolation losses by pumping from underground sources, the application of the water so recovered to the irrigation of additional lands constitutes a reuse of the original supply and makes for a high degree of utilization, the limit of which is reached when the net use of water equals the consumptive use. The essential element of such a plan of utilization is the availability of underground storage capacity of magnitude sufficient to absorb all available waters, and so located that water drawn therefrom can be utilized upon overlying or adjacent lands.

Consideration has been given to possibilities of ultimate harmful concentration of mineral salts in a ground water supply utilized as contemplated. This result is not considered possible, owing to the chemical characteristics of the water supply, the unavoidable ground water outflow (and consequent free circulation) involved in the net use allowances, and the extent of surplus and waste from tributary surface supplies. It is obvious that the greater the area involved the more flexible the plan becomes, since waters not readily utilizable in one part of the area may be shifted to others through the medium of this underground storage.

Underlying practically the entire eastern side of the upper San Joaquin Valley, underground storage capacity, sufficient with available feasible surface storage to effect practically full regulation of the tributary water supplies, is available. Under any plan for the full development of this area, the utilization of this underground storage

capacity is considered an essential element. It is deemed feasible by the use of this underground storage capacity to effect such a degree of utilization of all waters, both local and imported, that the net use on irrigated land will not exceed two acre-feet per acre.

Lower San Joaquin Valley—The lower San Joaquin Valley, with the exception of the extreme northern portion on the eastern side, is an area in which the local supplies to areas now under irrigation are generous in amount and dependable in their occurrence. These supplies are afforded by the San Joaquin River and its east side tributaries. For the areas on which these local supplies are now utilized, and for unirrigated irrigable land similarly situated the estimate of total ultimate water requirements has been made upon a basis similar to that used in the Sacramento Valley, where a gross allowance is made to all lands which might at some time be irrigated.

For rim lands above existing irrigation development on the west side of the valley, now without water supply, the ultimate water requirements are estimated in accordance with the practice in adjacent pumping projects and upon the same basis as used for similar lands in the upper San Joaquin Valley.

Based upon these per acre values and the net area of all irrigable lands, the ultimate seasonal water requirements have been estimated by sections and are set forth in Table 12.

TABLE 12

ULTIMATE SEASONAL WATER REQUIREMENTS OF IRRIGABLE LANDS IN SAN JOAQUIN RIVER BASIN, EXCLUDING SACRAMENTO-SAN JOAQUIN DELTA

Section	Net irrigable area in acres	Gross allowance in acre-feet		Net allowance in acre-feet		Net use in acre-feet	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Upper San Joaquin Valley	3,648,000	7,296,000	2.0	7,296,000	2.0	7,296,000	2.0
Lower San Joaquin Valley	1,676,000	4,968,000	3.0	3,651,000	2.2	3,019,000	1.8
Foothill areas	380,000	1,062,000	2.8	773,000	2.0	637,000	1.7
Total	5,704,000	13,326,000		11,720,000		10,952,000	

¹An average seasonal gross allowance of 2.5 acre-feet per acre, or more, is provided on canal-irrigated areas.

San Francisco Bay Basin.

In estimating the ultimate water requirements of the San Francisco Bay Basin, a study was made to determine the character of the ultimate development likely to take place in this area. Unlike the Sacramento and San Joaquin River basins, the area within the San Francisco Bay Basin includes densely populated metropolitan districts and large industrial and suburban sections, which occupy a considerable portion of the area subject to development. Predictions as to the future character and magnitude of development in this region are necessarily attended with uncertainty. It appears, however, that much of the area bordering San Francisco Bay will develop into a densely populated metropolitan and industrial district. On the other hand, it may be expected that a portion of the more favorably situated agricultural lands in the larger valleys within the basin, such as the

Santa Clara, Livermore, Ygnacio, Clayton, Suisun, Napa and Sonoma valleys, will continue in the future to be devoted principally to agricultural use.

The San Francisco Bay Basin, which includes all of the area draining into the bay below the confluence of the Sacramento and San Joaquin rivers, embraces a gross area of about 4000 square miles, consisting of 3500 square miles of land and 500 square miles of open water in the bays. A study has been made of the entire basin for the purpose of estimating the ultimate utilization of the area. Of the total gross area, about 2000 square miles consists of mountains and rolling hills and minor valleys, which are not likely ever to come into intensive development of any kind. The balance of the land area of about 1500 square miles, or approximately 1,000,000 acres, comprises the major valleys and areas bordering the bay which probably will be intensively developed in the future. This area was classified as urban, suburban, industrial and rural. It is estimated that of the total gross area, a net area of 870,000 acres will, at some future time, require water service if it is to be developed.

The ultimate water requirements of the basin are based upon the predictions of the utilization of the areas as heretofore described, and upon estimates of use of water per unit of area. In metropolitan areas the water requirements are approximately in direct proportion to the density of population. Statistics on water consumption, population and areas in the cities of California and of the United States, indicate that the water requirements for urban and suburban areas, expressed in feet depth per annum, range from an average of about one foot for a population density of ten persons per acre to about four and a half feet for a density of population of forty persons per acre. The future water requirements of such areas have, therefore, been estimated on the basis of predicted density of population in the several urban districts of the San Francisco Bay region.

The water requirements of industrial districts have been estimated on the basis of available statistics of consumption and area for present industrial districts in the bay region and other cities of California and the United States. The water requirements for industries vary widely, depending upon the type of industry and the intensity of development. The data on industrial water consumption in the upper bay area obtained during this investigation,* was given particular weight in estimating the unit water requirements for the ultimate predicted industrial district. The amounts used in estimating the industrial water requirements vary from two to five feet in depth per annum in the various areas of the bay region. Inasmuch as the water supplied for urban, suburban and industrial use are generally conveyed to the areas in pipe lines, conveyance losses are small and hence the gross allowance for these purposes is approximately equal to the net allowance. In the more densely populated areas, little opportunity is afforded for reuse of return water.

For the rural or agricultural areas of the basin, the ultimate water requirements have been estimated on the basis of the best data available as to the amount of water required for irrigation in the several

*Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources.

areas. The net allowances are estimated for the assumed irrigable areas and range from 1.25 feet in depth per season for the Santa Clara Valley and the valleys north of San Pablo Bay to two feet in depth per season for the Livermore Valley and the areas north and south of Suisun Bay. The gross allowance is based upon the net allowance, with the addition to the latter of estimated conveyance losses in serving the several areas.

Table 13 summarizes, by type of district development, the gross area and the gross allowance for ultimate water requirements of the San Francisco Bay Basin.

TABLE 13
ULTIMATE ANNUAL WATER REQUIREMENTS OF SAN FRANCISCO BAY BASIN

Districts	Water service area in acres		Gross allowance in acre-feet	
	Gross	Net	Total	Average per acre
Urban and industrial.....	207,000	207,000	493,000	2.4
Suburban and rural.....	791,000	663,000	1,242,000	1.6
Total.....	998,000	870,000	1,735,000	1.7

The average annual gross allowance for the entire area is 1.7 feet depth or acre-feet per acre, equivalent to a uniform demand of about 1550 million gallons per day, or about 2400 second-feet.

Central Pacific Coast Basin.

The Central Pacific Coast Basin is that portion of the state extending southeasterly from the San Francisco Bay Basin to Ventura County and draining directly into the ocean.

The water requirements for this basin, as for the Sacramento River and San Joaquin River basins, are based on agricultural use.

Detailed investigations have just been begun in this basin and the area of irrigable land has not been determined with any degree of accuracy. The water requirements are based on areas of irrigable land estimated in previous investigations.* It is estimated that there is a gross area of 770,000 acres susceptible of irrigation in this basin. Assuming that 80 per cent of this area ultimately would be brought under irrigation and assuming a gross allowance of 2.5 acre-feet per acre and a net allowance of 2.0 acre-feet per acre per season, the total seasonal requirements would be 1,540,000 acre-feet gross allowance, and 1,232,000 acre-feet net allowance. Due to the applied water being largely obtained by pumping from underground sources, the net allowance is the important factor in considering the supply for this basin. Such pumping allows the direct return to ground water of the excess amount applied upon the lands and the subsequent reuse of this excess as required, either in the same season or in the following seasons.

South Pacific Coast Basin.

The South Pacific Coast Basin is the Pacific slope of southern California, including Ventura County and extending to the Mexican

*Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1923.

boundary. It comprises all or portions of six counties, namely, Ventura, Los Angeles, Orange, San Bernardino, Riverside and San Diego. The total area of the basin is about 6,750,000 acres. The total population of the six counties in 1930 was 2,800,000, of which nearly all were living on the Pacific slope. This is one-half of the entire population of the state.

Much of the agricultural land in the basin is now intensively cultivated. Residential settlement is encroaching upon the irrigated and irrigable area, and this encroachment undoubtedly will continue to increase. On the other hand, lands unsuitable for agriculture also are being urbanized. Industrial development is, and probably will continue to be, an important element in determining the water demand. The total gross habitable area is estimated at 2,400,000 acres. Of this, it is estimated the total net habitable area is 2,000,000 acres, which includes all lands which might at some future time be utilized for urban, suburban, industrial or agricultural purposes and for which a water supply must be provided if development is to extend over this entire area.

In estimating the water requirements for this basin, consideration was given to the type of development which probably will take place in the various localities within the basin and to other factors. Requirements are based on the assumption that a substantial part of the entire net habitable area of 2,000,000 acres ultimately would be urbanized with industrial development located therein.

Ventura County and the South Coastal Basin* are characterized by the presence of absorptive formations in the valleys which form large underground storage basins. These furnish an unusual opportunity for reuse of return waters for municipal, irrigation and industrial purposes. In these areas, particularly in the South Coastal Basin, there also is a considerable contribution to the surface run-off and to ground water from the rainfall on the valley floor. In the upper valleys of this basin a further contribution is made by sewage effluent from the numerous cities therein. Additional contributions to the ground water could be obtained by reclaiming sewage from urban areas and transporting it to suitable areas where it could be introduced underground. All of these things, in addition to the conservative methods employed in the application of irrigation water, make for a small net use of water in these areas. In southern Orange County and San Diego County, there are few absorptive areas and therefore a small reuse from underground basins, although this could be further developed. However, because of the methods used for the conveyance and application of water, there also is a small net use of water in this area.

The ultimate water requirements for the 2,000,000 acres of net habitable area in this basin are estimated to be 3,340,000 acre-feet per year gross allowance, and 3,000,000 acre-feet per year net use. In this basin, as in the Central Pacific Coast Basin, the net use is the important factor for consideration in estimates of water supply.

Great Basin.

The area designated as the Great Basin in this report is that part of California lying east of the Sierra Nevada and also that part naturally tributary to the Colorado River.

*See Bulletin No. 32, "South Coastal Basin," Division of Water Resources, 1930

With the exception of the investigation in the Mojave River Basin, no detail study was made of this basin. The water requirements are based on areas of irrigable land and rates of use estimated in previous investigations.*

Assuming that 80 per cent of the gross agricultural area of 3,600,000 acres ultimately would be brought under irrigation, the gross allowance would be 10,000,000 acre-feet per season.

Entire State.

The areas to be served and the gross annual water requirements for the entire state, estimated on the foregoing bases, are summarized in the following table:

TABLE 14
SUMMARY OF ULTIMATE GROSS WATER REQUIREMENTS FOR ENTIRE STATE

Basin	Water service area in acres		Annual water requirements in acre-feet ¹
	Gross	Net	
North Pacific Coast.....	421,000	337,000	1,011,000
Sacramento River.....	6,435,000	4,266,000	15,864,000
San Joaquin River.....	8,219,000	5,704,000	13,326,000
San Francisco Bay.....	998,000	870,000	1,735,000
Central Pacific Coast.....	770,000	616,000	1,540,000
South Pacific Coast.....	2,400,000	2,000,000	3,340,000
Great Basin.....	3,600,000	2,880,000	10,000,000
Totals.....	22,843,000	16,673,000	46,816,000

¹ Actual use is much less than gross allowance. A considerable portion would be available for reuse in some basins.

² Includes requirements for salinity control (see pp. 79 and 80).

*Bulletin No. 6, "Irrigation Requirements of California Lands," Division of Engineering and Irrigation, 1923.

CHAPTER V

MAJOR UNITS OF ULTIMATE STATE WATER PLAN

In the formulation of a plan for development of the state's water resources, inquiry must be made into the relation of available water supply to ultimate needs. It has been estimated that the mean run-off of California's streams for the forty-year period 1889-1929, is about 71,000,000 acre-feet per season and that the total gross potential water service area is approximately 23,000,000 acres. If all this water could be conserved and applied to this area, it would amount to a depth per season of about three feet, an adequate amount for average municipal, industrial and agricultural purposes. However, in comparing the water supply to the agricultural lands in each of the seven hydrographic basins of the state it is found that 37.6 per cent of the state's water originates in the North Pacific Coast Basin, which contains only 1.9 per cent of the agricultural lands, whereas only 1.4 per cent of the water originates in the South Pacific Coast Basin, which contains 10 per cent of the land.

The distribution of water supply and agricultural land is illustrated on Plate III. The figures thereon show clearly, for each basin, the relation between these two resources. They do not, however, furnish a definite comparison between total water supply and total needs because the requirements of the present and future metropolitan areas and industrial districts in the San Francisco Bay and South Pacific Coast basins are not included under the standard of measurement established by the extent of agricultural land. These areas require substantial amounts of water.

A more definite relation between total water requirements and water supply is summarized, by basins, in Table 15.

TABLE 15
WATER SUPPLY AND REQUIREMENTS BY BASINS

Basin	Annual gross water requirements in acre-feet ¹	Seasonal run-off in acre-feet			
		40-year mean, 1889-1929	20-year mean, 1909-1929	10-year mean, 1919-1929	5-year mean, 1924-1929
North Pacific Coast ²	1,011,000	26,797,000	23,659,000	21,906,000	25,034,000
Sacramento River.....	15,864,000	24,801,000	20,593,000	17,920,000	19,027,000
San Joaquin River.....	13,326,000	11,980,000	10,160,000	7,547,000	8,137,000
San Francisco Bay.....	1,735,000	824,000	634,000	526,000	600,000
Central Pacific Coast.....	1,540,000	2,248,000	1,927,000	1,228,000	1,156,000
South Pacific Coast.....	3,340,000	1,114,000	1,146,000	894,000	709,000
Great Basin ²	10,000,000	3,624,000	2,958,000	2,463,000	2,395,000
Total.....	46,816,000	71,388,000	61,075,000	53,484,000	57,068,000

¹ Actual use is much less than gross allowance. A considerable portion would be available for reuse in some basins.

² Run-off from this basin largely physically unavailable for use in the state as a whole.

³ Portion of the run-off from this basin now used outside of the state.

⁴ Includes requirements for salinity control (see pp. 79 and 80).

This comparison of the water supply and requirements indicates a large excess of water over the needs of the North Pacific Coast Basin, some excess in the Sacramento River Basin and a deficiency in supply in the other basins, if each is considered as a unit. Before it can be

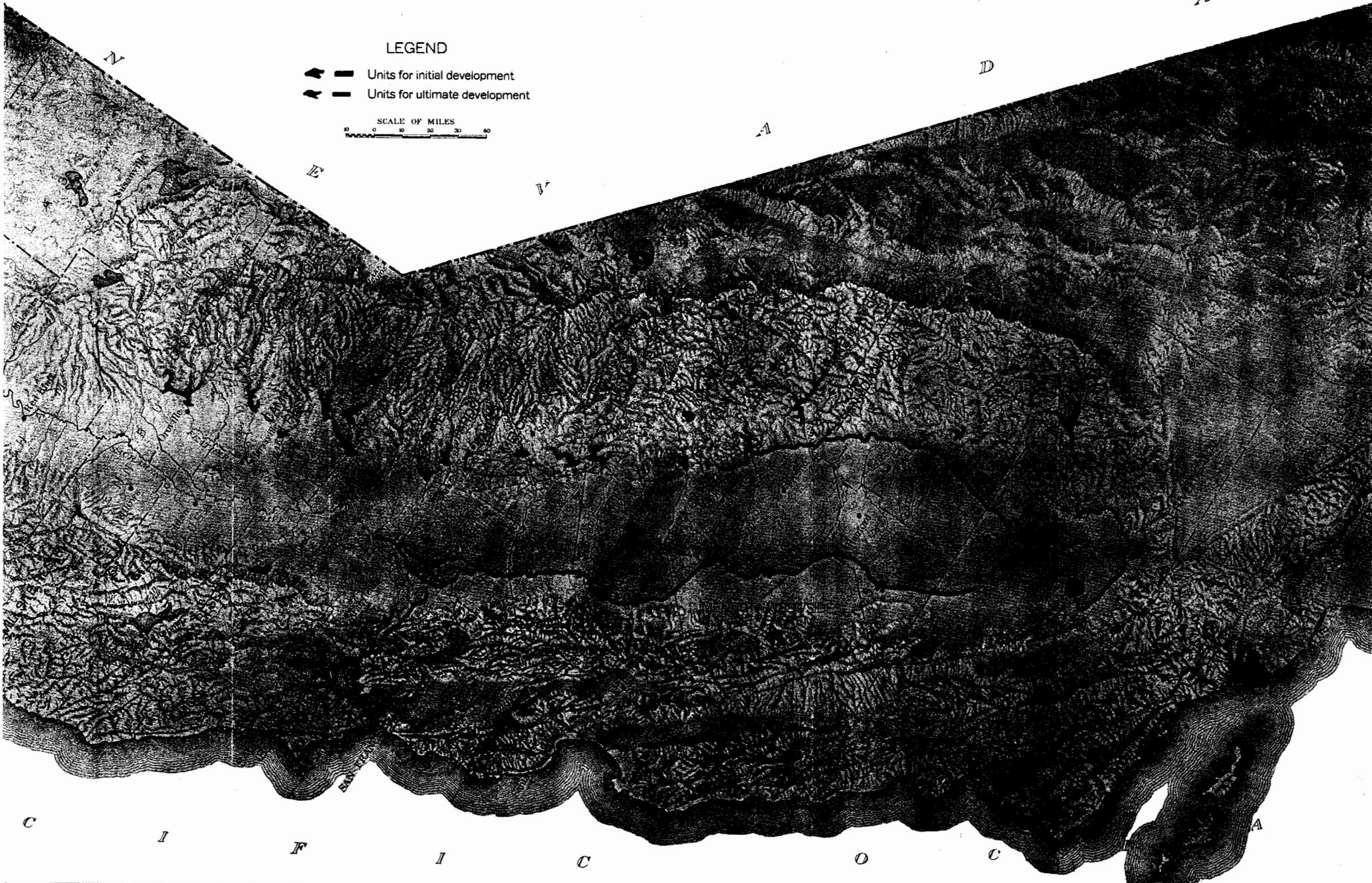
definitely determined that such an excess exists, however, inquiry must be made, particularly in the Sacramento River Basin, to determine the degree of synchronism existing between supply and demand. This determination can be accomplished only by a study of operation of physical works to equate the stream flow so as to be in consonance with the demand for water in its several uses.

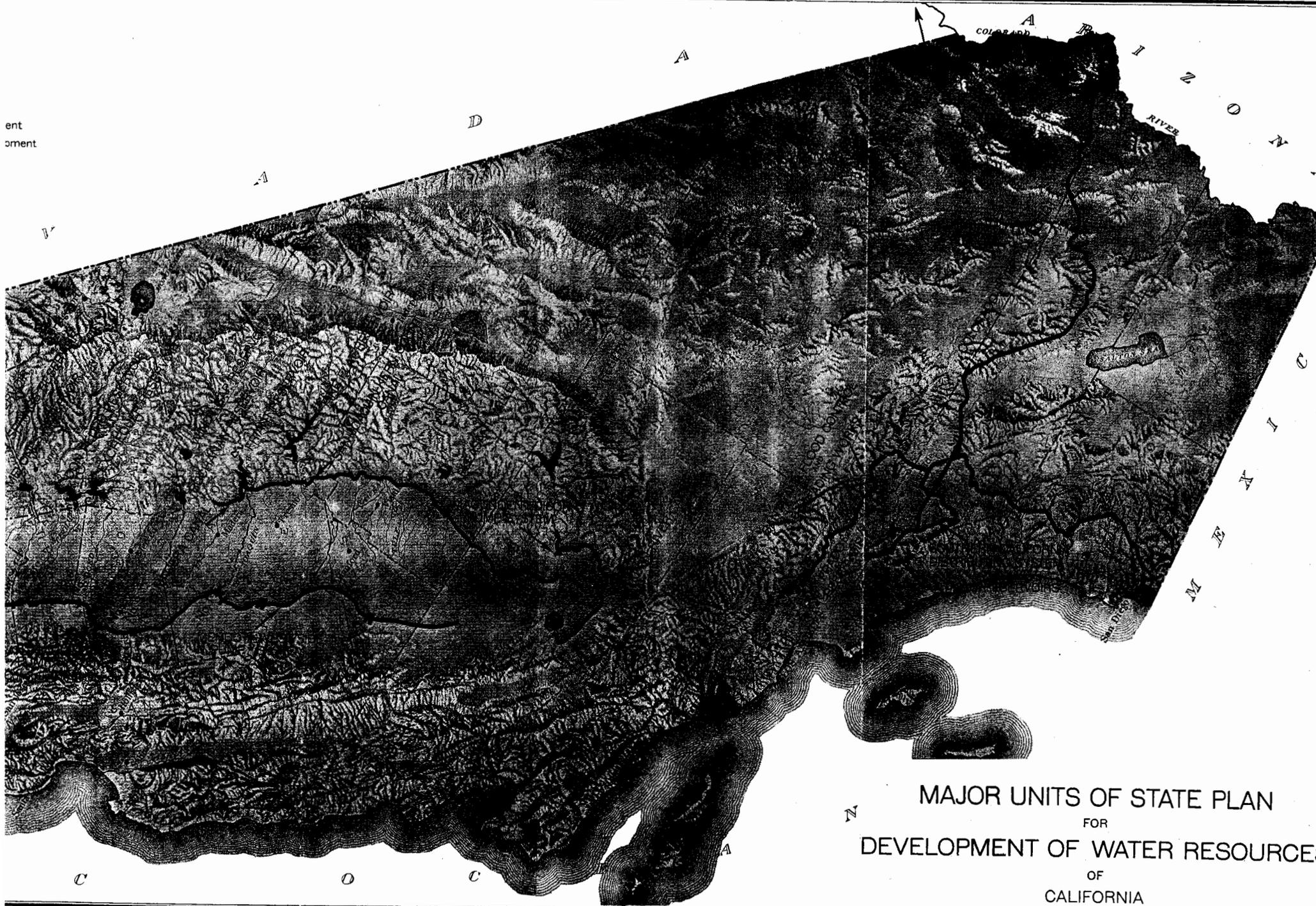
A plan must be formulated not only to overcome the unequal geographical distribution of water supply with respect to needs, but also to so regulate the seasonal distribution that the availability of supply will be simultaneous with the demand. Such a plan has been formulated for the larger and more important divisions of the state. Under this plan the basins favored with water in excess of their needs would be furnished a completely regulated supply in accordance with the requirements for their ultimate development. Waters in excess of these requirements would be conveyed to areas of deficiency and there used to supplement local waters and afford those areas supplies adequate to meet the requirements for their future development. The primary physical features of this plan are storage reservoirs, both surface and underground, to be used in regulating the available runoff, and conduits for the conveyance of the supply from points of origin to areas of use. In conjunction with the surface reservoirs, hydroelectric power plants would be utilized in some cases to generate electric energy incidental to the primary use of the reservoir. Returns from the sale of such electric energy would carry a substantial portion of the total annual cost of the project. In particular instances the surface reservoirs also would be utilized to reduce flood flows, improve navigation and control salinity.

The plan as formulated and presented in this report is limited in its scope. It includes only the major units for the principal geographical divisions of the state. The locations of these units are shown in Plate IV, "Major Units of State Plan for Development of Water Resources of California." Other units, both constructed and to be constructed, are necessary and essential parts of any comprehensive plan for the development of the state's waters. Additional reservoirs, which would increase the degree of control and perfect the utilization, can be built. Many distributary conduits and other accessory works not shown in this report also will be necessary. A plan has not been presented for the entire state. However, the one that is presented provides a system of physical works which would make available a water supply for the benefit of 75 per cent of the agricultural area, 90 per cent of the taxable wealth and 90 per cent of the population of the state. Certain portions of the area affected by this plan and other areas of the state are still under investigation. The work in progress in these areas is described in Chapter IX.

Great Central Valley.

The Great Central Valley of California includes both the Sacramento and San Joaquin River basins and, in this portion of the report, is considered as one geographic division, since plans for the development of the water resources of the two basins and their greatest utilization are closely related. Because of the small water supply in proportion to the ultimate water requirements for full development





in the San Joaquin River Basin, there will be a deficiency in supply therein. This is particularly true in the upper valley where a large part of the area is highly developed, where surface water is now utilized to the maximum degree possible without regulation, and where there is, in some localities, a serious overdraft even at present on the ground water supply. In the Sacramento River Basin on the other hand, there is a surplus of water over its ultimate needs. The logical source of an additional supply for the San Joaquin River Basin is in the surplus water of the Sacramento River Basin.

Surface Storage Units—To make the surface water supply of both basins available for use in the desired quantities and at the proper time, would require both surface and underground storage to regulate the winter and spring run-off of the major streams so as to meet the demand for irrigation and other uses. Conduits would be required to convey the surplus water from the Sacramento River Basin to the areas of deficient supply in the San Joaquin Valley.

The major units of the plan in the Sacramento River Basin are all surface storage reservoirs. Conduits necessary for distribution of water from these reservoirs within the basin are not included as they are considered to be a feature for local development. In connection with some of the reservoirs, power plants and afterbays are proposed where the power developed can be made to defray a portion of the expense and thereby reduce the cost of water for irrigation and other purposes. The reservoirs on the major streams also would be used to regulate and reduce flood flows, improve river navigation and control salinity in the lower delta. These storage units are ten in number and include the following reservoirs:

Kennett on Sacramento River; Oroville on Feather River; Narrows on Yuba River; Camp Far West on Bear River; Folsom, Auburn and Coloma on American River; Millsite on Stony Creek; Capay on Cache Creek; and Monticello on Putah Creek.

In addition to these reservoirs in the Sacramento River Basin, it is proposed to divert water into the Sacramento Valley from the Trinity River by a tunnel through the Trinity Mountains. In connection with this diversion, storage would be provided in the Fairview reservoir on Trinity River.

Power plants are proposed in connection with the Kennett, Oroville, Narrows, Folsom, Auburn and Coloma reservoirs and the Trinity River diversion.

It may be noted that no reservoir is included in the above list for the lower canyon of the upper Sacramento River above Red Bluff. The value of a reservoir in this location has long been recognized as it would be in a position to control the entire run-off of the upper Sacramento River, nearly one-third of which originates below Kennett reservoir. Diligent search for a favorable dam site has been made prior to and during the present investigation by both federal and state agencies. Four sites, including three at Iron Canyon immediately above Red Bluff and one at Table Mountain about ten miles further upstream, have been drilled and geologized. Information developed at the sites thus far explored indicates that the foundation conditions are unsatisfactory for a masonry dam and doubtful for an earth fill or rock fill dam. Furthermore, the desirability of a large earth or rock fill dam

impounding 1,000,000 to 3,000,000 acre-feet on the main Sacramento River above the entire Sacramento Valley also is open to serious question. Although the investigations to date have not disclosed a suitable dam site for such a large reservoir on this stretch of the stream, it is believed the importance of such a reservoir justifies further search and exploration work.

Another reservoir site investigated in the upper Sacramento River basin is one whose dam site is on the Pit River below the mouth of the McCloud River. The reservoir site lies within the area which would be flooded by a dam constructed at the Kennett site and is therefore not an auxiliary reservoir thereto. Its advantage over the Kennett site is that the large cost of relocating the Southern Pacific Railroad would be obviated. Its disadvantage is that, being located on the Pit River, it would not be in a position to control the run-off from the Sacramento River and several minor streams which constitutes 20 per cent of the run-off tributary to the Kennett reservoir, and furthermore would have much less value than the Kennett reservoir for controlling floods in the Sacramento River below Red Bluff. The dam site has not been explored by core drilling or other means. A preliminary geological examination indicates a favorable foundation for a main dam across the Pit River, but a much less favorable foundation for a necessary auxiliary dam on the left abutment for reservoirs of capacities comparable to Kennett reservoir. The foundations at the Kennett dam site have been proved to be very satisfactory. A combination of a reservoir at the Pit River site with one in the lower canyon of the Sacramento River near Red Bluff might be more attractive than the Kennett reservoir if it were definitely proven that safe dams could be constructed at these locations. The uncertainty of constructing a safe dam at the Pit River site to a height that would create a reservoir of capacity adequate to meet immediate and ultimate water requirements in accord with the State Plan in the Sacramento River Basin and the infeasibility of coordinating the two developments because of the overlapping of the two sites, lead to the conclusion that the reservoir on the Pit River should not be considered now as an alternate for the Kennett reservoir.

The major units of the plan in the San Joaquin River Basin consist of surface storage reservoirs and conveyance systems with pumping plants as required. Since the San Joaquin River Basin has a supply inadequate to meet the ultimate demand for agricultural purposes, it is proposed to operate the entire system in such a way as to most effectively utilize all local waters to meet such agricultural demand. This would be accomplished in the upper San Joaquin Valley by utilizing the large natural underground reservoir capacity to the greatest advantage. Power development, flood control and navigation are incidental and secondary in importance to this principal objective.

The surface storage reservoir units are thirteen in number, namely, Nashville on Cosumnes River; Ione on Dry Creek, a tributary of Mokelumne River; Pardee on Mokelumne River; Valley Springs on Calaveras River; Melones on Stanislaus River; Don Pedro on Tuolumne River; Exchequer on Merced River; Buchanan on Chowchilla River; Windy Gap on Fresno River; Friant on San Joaquin River; Pine Flat on Kings River; Pleasant Valley on Tule River; and Isabella on Kern River.

Power plants are proposed at Melones, Don Pedro, Friant and Pine Flat reservoirs. The Exchequer and Pardee reservoirs with power plants are included in the plan as already constructed and are assumed to be operated for the purposes for which they were designed. The Valley Springs reservoir would be enlarged from 76,000 acre-feet to 325,000 acre-feet capacity, reserving 165,000 acre-feet of space in the reservoir for flood control purposes. At the Melones and Don Pedro reservoirs, it is proposed to construct new dams downstream from the existing ones, creating reservoirs of larger capacity, and to reconstruct and enlarge the power plants.

Flood control features are included in the Kennett, Oroville, Narrows, Camp Far West, Folsom, Auburn, Coloma, Nashville, Melones, Don Pedro, Friant, Pine Flat and Isabella dams.

Table 16 summarizes, for both basins, the salient features of the storage units, including the height of dam, capacity of reservoir, installed capacity of power plant, if any, and estimated capital cost, with and without power features. The foundations of nine of the dam sites have been explored at least preliminarily and all have been examined by a geologist and reports rendered thereon. The dam sites drilled or on which other exploratory work has been done are Kennett, Folsom, Millsite, Ione, Valley Springs, Buchanan, Windy Gap, Friant and Pine Flat. Actual surveys of each dam and reservoir site listed have been available for the investigation. Several hundred sites have been examined and from these sites those shown in Table 16 have been selected as major units of the State Water Plan. Preliminary plans for each dam and all appurtenant works have been prepared. The cost of the dam for each reservoir is based on a gravity-concrete section, except for the dams of the Capay, Ione and Pleasant Valley reservoirs, which are estimated as earth fill sections, and the dam for Millsite, which is estimated as a concrete slab-buttress type. These estimates are based on present day prices of construction and on the assumption that each unit would be constructed in one step. If based upon the assumption of progressive development, the cost would be substantially greater than set forth herein. Allowances have been made for rights of way and all improvements flooded. There also is included an allowance of 25 per cent for contingencies and overhead, and interest at 4½ per cent compounded semiannually during the period required for construction.

Conveyance Systems—In formulating a plan for the conveyance from the Sacramento River Basin of the water required to supplement the available local supplies in the San Joaquin River Basin for full development of the latter area, many alternate plans were investigated.

Among these was a plan with a gravity canal extending from the Feather River to Kern River. This plan would involve no exchange of water supplies. It would deliver water directly to areas on the eastern slope of the upper San Joaquin Valley in need of additional water supplies, but would not furnish any water to the undeveloped areas on the western slope. Its intake on the Feather River would be above the major reservoir in this drainage area, from which originates a large part of the potential surplus waters of the Sacramento River Basin. The capital cost for a 3000 second-foot conduit for this plan would be in the neighborhood of \$200,000,000.

TABLE 16
ULTIMATE MAJOR STORAGE UNITS OF STATE WATER PLAN IN GREAT CENTRAL VALLEY

Reservoir	Stream on which reservoir is located	Height of main dam in feet	Capacity of reservoir in acre-feet	Installed capacity of power plants in kilovolt amperes	Capital cost	
					Excluding power features	Including power features
Kennett.....	Sacramento River.....	520	5,967,000	450,000	\$100,500,000	\$122,500,000
Oroville.....	Feather River.....	580	1,705,000	314,000	126,400,000	147,700,000
Narrowa.....	Yuba River.....	580	865,000	160,000	45,600,000	53,000,000
Camp Far West.....	Bear River.....	180	151,000		6,500,000	6,500,000
Auburn.....	American River.....	440	831,000	110,000	24,000,000	30,600,000
Coloma.....	American River.....	345	766,000	60,000	13,400,000	18,400,000
Folsom.....	American River.....	190	355,000	125,000	9,500,000	19,500,000
Fairview.....	Trinity River.....	365	1,436,000	193,000	44,600,000	62,000,000
Milliste.....	Stony Creek.....	135	115,000		3,200,000	3,200,000
Capeay.....	CACHE Creek.....	170	378,000		5,500,000	5,500,000
Monticello.....	Putah Creek.....	150	130,000		2,600,000	2,600,000
Nashville.....	Cosumnes River.....	270	281,000		7,400,000	7,400,000
Ione.....	Dry Creek.....	120	610,000	18,750	8,600,000	8,600,000
Pardee.....	Mokelumne River.....	343	222,000		7,600,000	7,600,000
Valley Springs.....	Calaveras River.....	200	328,000	488,000	22,200,000	23,900,000
Melones.....	S Stanislaus River.....	460	1,090,000	*120,000	26,500,000	27,700,000
Don Pedro.....	Tuolumne River.....	455	1,000,000	31,250	26,500,000	26,500,000
Eschequer.....	Merced River.....	307	279,000		2,900,000	2,900,000
BuCHANAN.....	Chowchilla River.....	147	84,000		2,300,000	2,300,000
Windy Gap.....	Fresno River.....	206	62,000	40,000	3,000,000	3,000,000
Friant.....	San Joaquin River.....	252	400,000	40,000	1,600,000	\$16,000,000
Fine Flat.....	Kinga River.....	274	400,000	40,000	1,600,000	11,600,000
Pleasant Valley.....	Tule River.....	125	39,000		2,800,000	2,900,000
Isabella.....	Kern River.....	190	353,000		5,700,000	5,700,000
Total.....			17,817,000	1,730,000	492,200,000	595,900,000

* Cost of entire Trinity River diversion to Sacramento River Basin.

** Present installed capacity 27,000 kilovolt amperes.

*** Present installed capacity 33,740 kilovolt amperes.

**** Exceeds capacity 270,000 acre-feet.

***** Includes \$1,600,000 for cost of 30,000 kilovolt ampere power plant which would be amortized in ten years, and \$500,000 for the cost of a 10,000 kilovolt ampere power plant to be constructed on the Mokelumne River.

the Mokelumne River to utilize the power drop at the dam into that canal after water is no longer available for the larger plant.

A second plan investigated, which would involve the exchange of water supplies on the upper San Joaquin River, was a 3000 second-foot conduit extending from the Folsom reservoir on the American River to Mendota on the San Joaquin River where canals, which now serve large irrigated areas in the lower San Joaquin Valley, head. The cost of the conduit for this plan is estimated at \$60,000,000. Both of the foregoing schemes would divert water above riparian owners in the Sacramento Valley, which, in the light of present knowledge of the operation of the riparian doctrine, appears infeasible.

A third plan studied was a direct pumping system from the delta channels of the Sacramento and San Joaquin rivers to the upper San Joaquin Valley, without exchange of supplies. Still another scheme investigated was the exchange of supplies from one stream to another on the east side of the valley from Feather River to Kern River. Preliminary studies of this latter plan indicate that not only would it be more costly than the one adopted, but it also would involve water right adjustments on each stream, which appear impracticable.

After a study of these various methods of exporting water from the Sacramento River Basin and also many modifications of the plan set forth herein, a plan has been adopted and set forth in this report providing for the diversion of water from the delta. This would be accomplished by means of a pumping system on the San Joaquin River and the exchange of a portion of the water for San Joaquin River water, which would be diverted at the Friant reservoir, located 61 miles upstream and 308 feet higher in elevation than the point of delivery of imported water at Mendota. The water diverted at Friant would be used on lands on the eastern slope of the upper San Joaquin Valley. The lands on the western slope of the upper valley would be served by an extension of the pumping system from Mendota. The advantages of the plan are many. Both the capital and annual costs would be much less than for conveyance by any other method. Diversion in the Sacramento-San Joaquin Delta would be effected below all the riparian lands in the Sacramento River Basin. The flexibility of the plan would be of great advantage. The source of the water supply would be the delta, the temporary catch basin of all the run-off and return water from 42,900 square miles of drainage area, which comprises 74 per cent of the entire area of the Sacramento and San Joaquin River basins and contributes 91 per cent of the run-off of the two basins. Water developed in any part of the two basins north of the upper San Joaquin River would naturally find its way to this catch basin. A pumping lift of more than 300 feet would be saved over the direct pumping plan. It would lend itself more readily to progressive development with minimum expenditures and it would interfere least with present rights and interests. These great advantages would not be attained by any scheme that does not utilize the delta as a source of supply, and only in part, if not combined with exchange with San Joaquin River water.

The conveyance channels, natural and constructed, which would be required for the exportation and delivery of water from the Sacramento River Basin to the lands of the San Joaquin River Basin, would extend from the Sacramento River at the head of Snodgrass Slough to the southern extremity of the San Joaquin Valley.

Beginning at the northerly end of the conveyance system, a new connecting channel, in conjunction with a suitable diversion structure in the Sacramento River, is proposed to carry from the Sacramento River to the San Joaquin River Delta the water required to meet the four-fold demand of salinity control, delta consumptive use, agricultural and industrial use in Contra Costa County, and exportation to the San Joaquin Valley. It would consist of an artificial channel dredged from the Sacramento River, at a point just below Hood, to the head of Snodgrass Slough, from which point this natural channel would be utilized, with improvements, to Dead Horse Island. At that point a triple connection would be made with the North and South Forks of the Mokelumne River and Georgiana Slough, all three of which would be utilized from there to the San Joaquin River at Central Landing. The length of this cross connection, designated as the Sacramento-San Joaquin Delta cross channel, by the shortest route would be 24 miles.

From Central Landing to the first unit of the pumping system below Mossdale bridge, it is proposed to utilize three main channels, each about 30 miles in length. The most easterly of these channels would be the Stockton Deep Water Channel and the San Joaquin River. The other two main channels would be Old River and Salmon Slough, and Middle River with artificial connections already constructed, such as the Victoria-North Canal and the Grant Line Canal. With some enlargement in portions of these channels, the conveyance capacity would be adequate to meet the requirements of the delta irrigation use and that of exportation to the San Joaquin River Basin.

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

From the pond above Plant No. 5 it is proposed to depart from the river with a constructed canal extending southerly along the most favorable topography. By means of three pumping lifts in a distance of seven miles the water would be raised to an elevation of 137 feet at the discharge of Plant No. 8 and would continue a distance of sixteen miles to Plants No. 9 and No. 10, about five miles west of Los Banos. An exchange would be made with existing systems serving lands lying below Plant No. 9. From the discharge of Plant No. 10, at an elevation of 180 feet, the canal would extend southerly about 38 miles to the Mendota weir, delivering water to an elevation of 159 feet. The total distance from Pumping Plant No. 1 to Mendota weir would be 135 miles.

The pond above the Mendota weir would be the source of supply for lands now served by diversion at and near this point. The Chowchilla and Columbia lands on the east side of the river, now served by canals of heavy grade with higher points of diversion, would be served by a

new canal constructed from the Mendota weir. A small part of the Columbia area would be served by pumping from the Mendota pool.

The delivery of imported waters to Mendota, to meet the demand of existing rights, would make possible the diversion at the Friant reservoir of the flow of the San Joaquin River for use on the eastern slope of the upper San Joaquin Valley. To effect such diversion it is proposed to construct, in addition to the Friant reservoir, two main canals, one on each side of the San Joaquin River. The Madera canal, with a diversion capacity of 1500 second-feet, on the north side of the river would extend for eighteen miles to the channel of the Fresno River. The San Joaquin River-Kern County canal on the south side of the stream would extend southward along the eastern rim of the valley a distance of 165 miles. With a diversion capacity of 3000 second-feet at the Friant reservoir, it would cross in turn the channels of the Kings, Kaweah, Tule and Kern rivers, terminating at the Kern Island Canal with a capacity of 500 second-feet.

In order to utilize Kern River waters released by the importation of new supplies, it would be necessary to construct the Kern River canal with a diversion point near the mouth of the canyon on the south side of the stream and extending under the Kern Mesa and thence around the south end of the valley to Buena Vista Valley. The diversion capacity of this canal would be about 1500 second-feet and the total length 75 miles.

To make water available for the good land lying on the western slope of the upper San Joaquin Valley would require a pumping system extending from Mendota Pool to Elk Hills. Water for this area would be imported through the San Joaquin River pumping system. An essential element of such a system would be a conveyance channel, which, for full development, would be 100 miles long and have a capacity varying from 4500 to 500 second-feet. Located along the lower edge of the irrigable lands, this canal would terminate at an elevation of 250 feet.

Table 17 summarizes the data for the major conveyance units of the Great Central Valley. It may be noted that the aggregate length of the channels and conduits is 549 miles and the total estimated cost \$88,000,000.

TABLE 17
ULTIMATE MAJOR CONVEYANCE UNITS OF STATE WATER PLAN IN
GREAT CENTRAL VALLEY

Unit	Maximum capacity in second-feet	Length in miles	Capital cost
Sacramento-San Joaquin Delta cross channel.....		24	\$4,000,000
San Joaquin River pumping system.....	8,000	167	28,500,000
Madera canal.....	1,500	18	2,500,000
San Joaquin River-Kern County canal.....	3,000	165	28,000,000
Kern River canal.....	1,500	75	9,000,000
Mendota-West Side pumping system.....	4,500	100	16,000,000
Total.....		549	\$88,000,000

Summary—In Table 18 are summarized the estimated costs of the ultimate major units, both storage and conveyance, of the State Water Plan in the Great Central Valley.

TABLE 18
SUMMARY OF COSTS OF ULTIMATE MAJOR UNITS OF STATE WATER PLAN
IN GREAT CENTRAL VALLEY

Units	Capital cost	
	Excluding power plants	Including power plants
Reservoirs—		
Sacramento River Basin.....	\$381,800,000	\$471,500,000
San Joaquin River Basin.....	110,400,000	124,400,000
Conveyance systems.....	88,000,000	88,000,000
Total.....	\$580,200,000	\$683,900,000

Underground Reservoirs—Utilization of underground storage is growing increasingly important throughout the state. In the upper San Joaquin Valley, the South Coastal Basin, Ventura County, the Santa Clara Valley and most of the Central Pacific Coast valleys, underground storage now is being utilized to a large extent. Where suitable underground storage is available and a proper control of draft and replacement are exercised, it is a most flexible, efficient and economical means of conserving and utilizing water over a period of years.

Due to the importance of this subject, a geologic study was made of the entire Great Central Valley to locate underground storage areas, to estimate their capacity and to determine the practicability of their utilization for the storage and extraction of water supplies in irrigation development. This study reveals that the areas of available capacities are extensive, particularly in the upper San Joaquin Valley, but limited in their effective utilization due to the lack of readily available surplus water for their charge and recharge. In the San Joaquin Valley, the underground storage reservoir areas are confined to the eastern slope, principally to the alluvial cones and flood plains of the major streams. The surface soil and the geologic formation on the western slope and in the trough of the valley are of such character that no utilizable underground capacity exists. In the Sacramento Valley, the potential capacity is comparatively large, but it has not been utilized as extensively as in the San Joaquin Valley.

The surface areas of the ground water storage reservoirs were estimated through field examination of the physical characteristics of surface soils and the application of geologic reasoning, checked and aided as to subsurface characteristics by the penetration records of several hundred wells. The depth of pervious formations was estimated in this manner. The maximum usable storage capacity was limited by economic pumping lifts and the availability to the irrigable areas. The drainage factor of the favorable formations is probably more open to question than any other, as but few actual tests on comparable material are available. Results of experimental work furnish a measure for estimating the free water content of various types of alluvial material and soils. The materials logged in the well penetration records available were evaluated and estimates made of the average effective capacity of the soil column per foot of water table lowering. These estimates were checked with actual results obtained through tests in areas known to be somewhat comparable and factors were deduced. The

total usable capacities of the ground water reservoirs in the various sections of the valley were estimated and are shown in Table 19, first between a depth of ten feet below ground surface and the underground water level of 1929, and second, between depths of ten and fifty feet below ground surface. Within some of these areas a greater depth of water table lowering than fifty feet, on the average, would be desirable and probably economically warranted at the end of a long dry period. There also is included in the table, for the upper San Joaquin Valley, the estimated underground capacity between the depth of ten feet below ground surface and assumed limit of economic pumping.

TABLE 19
USABLE UNDERGROUND CAPACITY IN GREAT CENTRAL VALLEY

Section	Capacity in acre-feet		
	Between depth of 10 feet below ground surface and ground water levels of 1929	Between depths of 10 and 50 feet below ground surface	Between depth of 10 feet below ground surface and assumed limit of economic pumping
Upper San Joaquin Valley.....	9,000,000	14,000,000	20,000,000
Lower San Joaquin Valley.....	160,000	3,000,000	.....
Sacramento Valley.....	.....	3,000,000	.....
Total.....	.....	20,000,000	.....

In proportioning the physical works of the plan for the Sacramento and the lower San Joaquin valleys, no account was taken of the availability of potential underground capacity in these basins. However, if it were operated in conjunction with surface storage, a greater use could be made of the run-off of the tributary streams. In the upper San Joaquin Valley, full account was taken of the available underground capacity in the design of the works to serve this region. Both local and imported supplies must be husbanded if the fullest practicable utilization for beneficial purposes and maximum economy are to be attained. To accomplish the desired results would require the operation of the underground reservoir in a specific manner similar to that of a surface reservoir. A large portion of the gross draft upon the ground water would be through the medium of privately owned pumping plants, and, in order to maintain a balance in supply and draft over long periods throughout the area, it would be necessary that works for the distribution of surplus waters and pumping equipment in strategic locations be under the control of recognized local public agencies.

The utilization of this underground capacity affords the cyclic storage necessary in the plan for the full practical development of the eastern slope of the upper San Joaquin Valley. The average seasonal water supply capable of being diverted with the works proposed from the San Joaquin River for the forty-year period 1889–1929 is 1,720,000 acre-feet. Of this total 355,000 acre-feet would be diverted northward to the Madera area and the remainder, or 1,365,000 acre-feet, to the south. This latter amount is a supply adequate to supplement the local sources for practically full development of the eastern slope of the

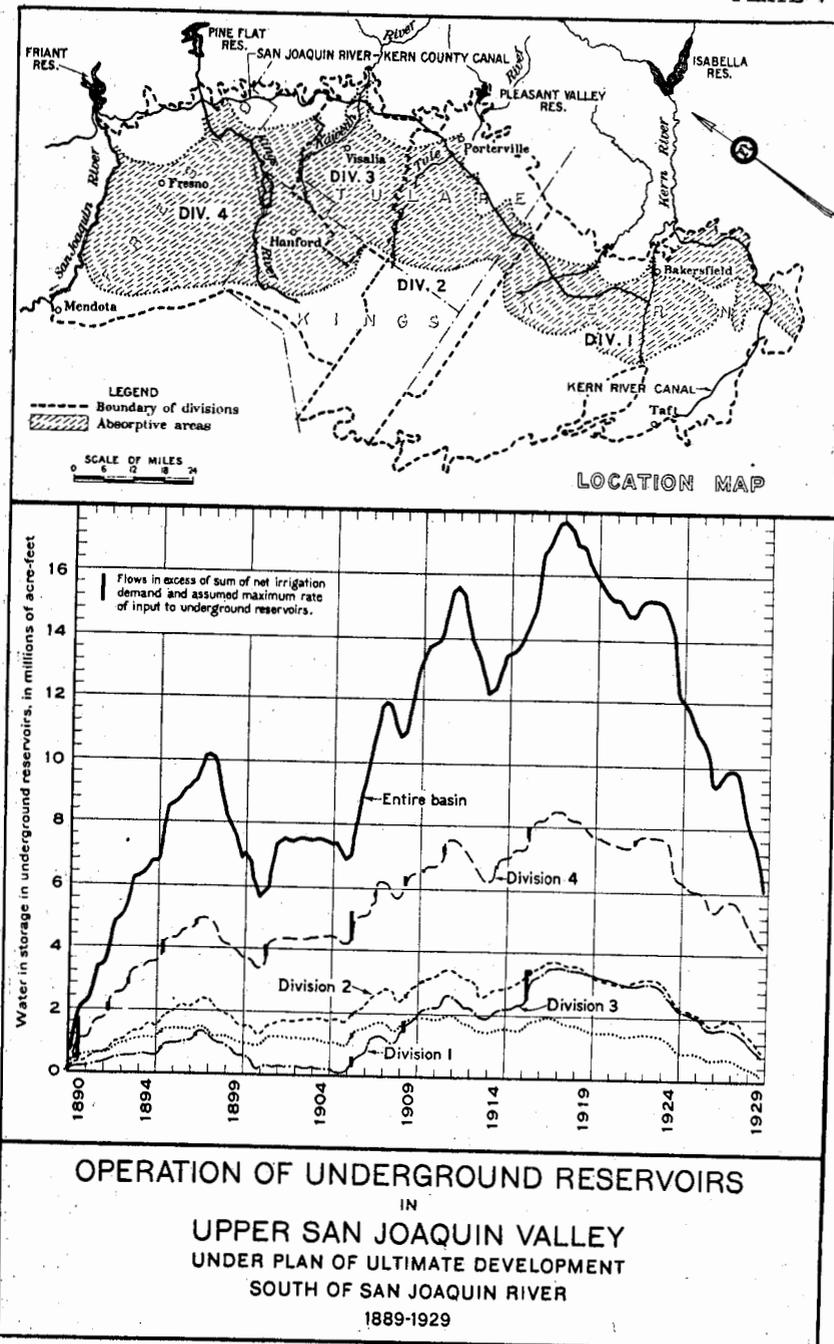
valley. Furthermore, it is the least expensive supply available for importation. Its utilization through the combined means of surface distribution systems and underground reservoirs would constitute the cheapest, most flexible and dependable plan of any that has been suggested or investigated to furnish the required additional water supply to this region.

Based upon studies of the geologic and ground water conditions of this area, it is estimated that within the assumed limits of economic utilization for cyclic storage there is available a total underground capacity of some 20,000,000 acre-feet, of which 18,000,000 acre-feet is located south of the San Joaquin River. This would require the lowering of the ground water levels below a depth of 50 feet in portions of this area. In accordance with the recognized principles of reservoir analysis, a detailed month by month study of the operation of the underground water reservoirs was made for the forty-year period 1889-1929, using as sources of supply not only the imported waters, but also those contributed by local sources. The net draft upon a reservoir would be the consumptive demand of the area. The results of this study show that, in addition to meeting the total demand of the area, the supply would be sufficient to build up the underground storage.

The operation of the underground reservoirs in the several selected divisions on the eastern slope of the upper San Joaquin Valley is graphically illustrated on Plate V, "Operation of Underground Reservoirs in Upper San Joaquin Valley under Plan of Ultimate Development South of San Joaquin River, 1889-1929." Assuming an empty underground reservoir at the beginning of the season of 1889-90, the storage on hand would have mounted from zero to 10,000,000 acre-feet by 1897. From 1897 to 1900 it would have been drawn down to 6,000,000 acre-feet, to mount almost continuously to 15,000,000 in 1911. From 1911 to 1913 it would have decreased to 12,000,000, to increase again to nearly 18,000,000 in 1917. From 1917 to the end of the period in the fall of 1929 the decrease of storage on hand would have been almost continuous to 6,000,000 acre-feet. Thus, through the utilization of the available underground capacity in this area there would be attained the regulatory effect of a cyclic storage capacity of 18,000,000 acre-feet, a result impracticable of accomplishment by surface reservoirs.

The plan of utilizing ground water reservoirs as a source of irrigation supply is not new. It has been practiced for many years in the upper San Joaquin Valley. However, quality of land, rather than adequacy of supplies, has been the factor controlling irrigation development of this type, and the result in many localities has been a net draft in excess of the average seasonal replenishment. Little or no consideration has been given in the development of these areas to the possibility of systematic artificial replenishment of the ground water reservoirs.

Along the eastern slope of the lower San Joaquin Valley the chief ground water problem is one of drainage. It is an area of plentiful supplies, and liberal allowances to the lands result in relatively high water levels. These are being controlled in some areas by the use of wells and pumping plants. By utilizing pumped water for the peak demands of the irrigation season in these areas, effective use could be made of the underground storage capacity and a more uniform draft



upon surface reservoirs could be made. This method of operation would have advantages on a system where hydroelectric power is generated.

Navigation—The Sacramento and San Joaquin rivers form natural waterways extending northerly and southerly from the upper San Francisco Bay into the Great Central Valley. These waterways play an important part in the commercial activities in these regions. Projects for the maintenance and improvement of navigation on both of these rivers have been adopted by Congressional enactment. The operation of major units of the State Plan in the interest of navigation would materially improve and extend navigation on both of these streams.

The water-borne commerce on these rivers is large. On the Sacramento River, from 1,000,000 to nearly 2,000,000 tons have been handled each year for the past ten years, and on the lower San Joaquin River, nearly 1,000,000 tons. Large investments have been made in terminal facilities utilized by nearly 100 individuals or companies operating freight and passenger vessels.

Improvement of the navigation facilities on the lower sections of the rivers is now in progress. On the San Joaquin River, a ship channel with a depth of 26 feet is under construction from upper San Francisco Bay to Stockton. From the mouth of the Sacramento River to the city of Sacramento, a navigable depth of ten feet is being maintained by dredging and other means.

Above the cities of Sacramento and Stockton, the navigation condition should be improved. In the low water season of each year, navigation is greatly impaired from Sacramento to the head of navigation at Chico Landing, a distance of 138 miles. With the reservoirs of the plan in operation, particularly Kennett, a satisfactory navigable depth of from five to six feet could be maintained from Sacramento to Chico Landing. On the San Joaquin River above Stockton, navigation has been practically abandoned. It could be restored by the incorporation of locks in the dams of the pumping system proposed and utilization of the lakes formed by the dams. A depth of six feet could be afforded to Salt Slough, nine miles above the Merced River and 95 miles from the Stockton Ship Canal, by the plan proposed. If it should be desirable to extend navigation farther upstream to Mendota, the benefits to accrue from such an extension might justify altering of the location of the proposed pumping system for irrigation by following the river to this point.

Flood Control—Protection against floods may be afforded by either of two methods or by a combination of the two. One of these is to confine the flood waters to natural and artificial channels by means of levees. The other is to reduce the flood flows to amounts that can be safely carried by the stream channels, by storing the excess flows in reservoirs and releasing them at such a rate as not to overtax the channel capacities. A combination of the two methods would permit lower levees along the channels than with operation under the first method above, and also would require smaller reservoir space than with the second method alone. With reservoir control, levees are usually necessary.

Prevention of flood damage by means of leveed channels has long been used in the Sacramento Valley and the Sacramento-San Joaquin Delta, and to a lesser extent in the San Joaquin Valley. The Flood Control Project in the Sacramento Valley, using leveed stream and by-pass channels, has been largely completed, except for the Butte Basin and the upper Feather River. It is likely the levees along the Feather River will be completed before the Oroville reservoir, which could give flood regulation, is constructed. The levees provided by the project in the Sacramento Valley will not give full protection against exceptionally large floods which might occur at long intervals. A higher degree of flood protection could be obtained for the lands in this valley, however, with the reservoirs on the major streams operated for flood control. To do this would require the reservation of space in the reservoir for flood control purposes and its operation in a specific manner through the utilization of the flood control features in the dam. The amount of space in any reservoir which would be held in reserve would vary with the degree of control desired, with the normalcy of the season, and with the time of the year.

In the San Joaquin Valley, reclamation by levees and large flood channels is not as feasible as in the Sacramento Valley because of the small area reclaimed after deducting the overflow channels. Flood control by storage in reservoirs offers a means of regulating floods to flows of such magnitude that narrower channels and lower levees could be used, thereby permitting the reclamation of the present overflowed lands.

The reservation of space and its operation for flood control is proposed under the State Plan in each of the major reservoirs on the more important streams. In Table 20 there is shown a list of the streams on which flood control by reservoirs is proposed, the maximum reservoir space required to regulate floods to certain controlled flows, the amounts of these controlled flows and the frequency with which the controlled

TABLE 20
RESERVOIR SPACE REQUIRED FOR CONTROLLING FLOODS
TO CERTAIN SPECIFIED FLOWS

Reservoir	Stream	Point of control	Maximum reservoir space employed in acre-feet	Controlled flow in second-feet	Number of times controlled flow would be exceeded on the average
Kennett.....	Sacramento River.....	Red Bluff.....	512,000	125,000	Once in 14 years
Oroville.....	Feather River.....	Oroville.....	321,000		
Narrows.....	Yuba River.....	Smartsville.....	100,000	70,000	Once in 100 years
Camp Far West.....	Bear River.....	Wheatland.....	272,000	20,000	Once in 100 years
Folsom, Auburn and Coloma.....	American River.....	Fair Oaks.....	50,000	80,000	Once in 250 years
Nashville.....	Cosumnes River.....	Michigan Bar.....	300,000	15,000	Once in 100 years
Ione.....	Dry Creek.....	Galt.....	56,000	5,000	Once in 100 years
Pardee.....	Mokelumne River.....	Clements.....	121,000	10,000	Once in 100 years
Calaveras.....	Calaveras River.....	Jenny Lind.....	0	25,000	Once in 100 years
Melones.....	Stanislaus River.....	Knights Ferry.....	165,000	15,000	Once in 100 years
Don Pedro.....	Tuolumne River.....	La Grange.....	204,000	15,000	Once in 100 years
Exchequer.....	Merced River.....	Exchequer.....	214,000	25,000	Once in 100 years
Friant.....	San Joaquin River.....	Friant.....	59,000	15,000	Once in 100 years
Pine Flat.....	Kings River.....	Piedra.....	75,000	15,000	Once in 100 years
			80,000	15,000	Once in 100 years

¹ Floods which would cause flows in excess of 10,000 second-feet in the Mokelumne River at Clements would be diverted from the Pardee Reservoir to Dry Creek by the Jackson Creek spillway and the water stored in Ione reservoir.
² Mean daily flow on day of flood crest. Floods would be controlled to 125,000 second-feet maximum flow exceeded once in 100 years, except when this amount is exceeded by uncontrolled run-off between Kennett reservoir and Red Bluff. Flows greater than 125,000 second-feet would continue for only a short time.

flows would be exceeded. The operation of these reservoirs for flood control would not materially impair their value for conservation purposes, nor materially decrease the amount or value of the electric energy generated by water released from them.

The operation of all the foregoing reservoirs specifically for flood control, employing the reservoir space assigned to each reservoir for the purpose of controlling floods to the specified flows, would result in a substantial reduction of floods and in an increased degree of protection to the areas subject to overflow, particularly those within the Sacramento Flood Control Project, and therefore would decrease the potential annual flood damages in those areas. The following table sets forth, for various points on the main stream channels, the crest flood flow exceeded once in 100 years, except as noted, with and without reservoir control. These flows in the Sacramento Valley are those that would obtain with the completed Flood Control Project, including the reclamation of Butte Basin. In the San Joaquin Valley, the flows without reservoir control are those that would obtain with levees constructed along the San Joaquin River from Herndon to the delta to form a channel of sufficient width to care for these flows and reclaim the remaining land now subject to overflow. The flows with reservoir control are those that would obtain with the same channel, but with the flood flows from the larger streams controlled by means of regulation in the major reservoir units of the State Plan in this basin to those shown in Table 20 at the foothill gaging stations. If reclamation of the valley lands by means of levees was not effected until after the reservoirs with flood control features were completed, a narrower flood channel along the river could be constructed because of the smaller regulated flows. Under this condition, however, the flows might be slightly larger than those shown in the last column of Table 21, since the reduction of quantities by storage in the narrower channel might be less and the rate of concentration somewhat greater.

TABLE 21
FLOOD FLOWS IN GREAT CENTRAL VALLEY WITH AND WITHOUT
RESERVOIR CONTROL

Stream	Crest flood flow in second-feet, exceeded once in 100 years on the average	
	Without reservoir control	With reservoir control
Sacramento River at Red Bluff.....	303,000	187,000
Sacramento River at Red Bluff (flow exceeded once in 14 years on the average).....	218,000	125,000
Sacramento River at Colusa.....	370,000	250,000
Sacramento River at Colusa (flow exceeded once in 14 years on the average).....	254,000	170,000
Sacramento River below city of Sacramento.....	670,000	535,000
Feather River below confluence with Yuba River.....	400,000	201,000
Feather River below confluence with Bear River.....	430,000	226,000
San Joaquin River below confluence with Merced River.....	70,000	50,000
San Joaquin River below confluence with Tuolumne River.....	103,000	64,000
San Joaquin River below confluence with Stanislaus River.....	133,000	82,000
Sacramento and San Joaquin rivers at confluence.....	780,000	596,000

¹ Mean daily flow on day of crest of flood.

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

Operation and Accomplishments of Plan—Analyses have been made of all the major units in the Great Central Valley, both storage and conveyance units, and the underground storage capacity in the upper San Joaquin Valley, operated coordinately for various purposes through the eleven-year period 1918–1929. This was a period of the lowest average run-off of any of the same length of which there is definite knowledge. It includes the season of 1923–24, the driest of record. Studies were made in accord with three methods of operation which, together with their accomplishments, are as follows:

Method I.

1. The amount of water utilized for storage and regulation in the major reservoir units was obtained by deducting from the full natural run-off of the streams entering the Great Central Valley, the net use of 2,283,000 acre-feet per season for an adequate and dependable irrigation supply for 1,439,000 acres of land, being the net irrigable mountain valley and foothill lands lying at elevations too high to be irrigated by gravity from the major reservoir units, thus providing for the ultimate needs of these areas, and also deducting 448,000 acre-feet per year for the water supply of the city of San Francisco. An additional amount of 224,000 acre-feet per year also was furnished the San Francisco Bay Basin from Pardee reservoir on the Mokelumne River.
2. Reserve storage space would have been held in the reservoirs listed in Table 20 for controlling floods. The amount of this space and the regulated flow to which floods on each stream would have been controlled also are shown in the same table. This control of floods on the major streams would have resulted in an increased degree of protection for areas subject to overflow in both the Sacramento and San Joaquin Valleys.
3. Stored water would have been released from the major reservoir units in such amounts and at such times as to supplement unregulated flows and return waters to make water supplies available for the following purposes:
 - a. A supply of 9,033,000 acre-feet per season, gross allowance, without deficiency, available in the principal streams for the irrigation of all of the net area of irrigable lands of all classes—2,640,000 acres—on the Sacramento Valley floor.
 - b. A supply of 1,200,000 acre-feet per season, without deficiency, for the irrigation of all the net area of 392,000 acres of irrigable lands and for unavoidable losses in the Sacramento-San Joaquin Delta.
 - c. A flow maintained in the Sacramento River sufficient to provide required depths for navigation as far upstream as Chico Landing, with improvement in present depths upstream to Red Bluff.
 - d. A fresh water flow of not less than 3300 second-feet past Antioch into Suisun Bay, which would have controlled salinity to the lower end of the Sacramento-San Joaquin Delta.
 - e. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent in those areas dependent upon local supplies, made available for the

irrigation of all the net area of 1,810,000 acres of land of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley below the major reservoirs.

- f. A supply of 4,700,000 acre-feet per season, without deficiency, made available for the irrigation of a net area of 2,350,000 acres of class 1 and 2 lands on the eastern and southern slopes of the upper San Joaquin Valley. This would have been accomplished by the utilization of underground storage capacity in conjunction with the major reservoir and conveyance units proposed.
- g. A supply of 520,000 acre-feet per season in all years, except 1924 when there would have been a deficiency of 14 per cent, made available for the irrigation of a net irrigable area of 260,000 acres lying entirely on the western slope of the upper San Joaquin Valley.
- h. A water supply and channel depth in the San Joaquin River sufficient to provide navigation as far upstream as Salt Slough, nine miles above the Merced River.
- i. A supply of 403,000 acre-feet per season, except for a deficiency of 18.5 per cent in 1924, in that portion—323,000 acre-feet—allotted to irrigation use, made available in the Sacramento-San Joaquin Delta for use in the San Francisco Bay Basin. This amount, together with full practicable development of local resources and annual importations of 224,000 acre-feet from the Mokelumne River and 448,000 acre-feet from the Tuolumne River and an importation from the Eel River, would have given an adequate and dependable supply for the ultimate development of this basin.
- j. The generation of more than five billion kilowatt hours of electric energy annually, on the average.

Table 22 shows, with the operation of the plan under Method I, the net flow into the Sacramento-San Joaquin Delta, the amount required from this water for all uses in the delta and adjacent uplands, the amounts required for supplemental supplies for irrigation in the San Joaquin Valley and for irrigation and other uses in the San Francisco Bay Basin, the amount of water which would flow past Antioch into Suisun Bay for salinity control, the surplus water which would reach the delta, in addition to that for all requirements, and the total amount of water which would flow into Suisun Bay after all requirements have been satisfied. The amounts shown for net flow into delta from the San Joaquin Valley in Table 22 include such portions of the regulated and unregulated water from the reservoirs and return waters intercepted by the San Joaquin River pumping system before reaching the delta as could be used in supplying "crop land" rights or additional new lands in this valley, obviating the pumping of that portion of this supply from the delta. "Crop lands" are those lands suitable for growing crops and which are now or probably will be served in the near future by diversion under existing rights from the San Joaquin River above the mouth of the Merced River.

TABLE 22
ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY WITH MAJOR UNITS OF STATE PLAN IN GREAT CENTRAL VALLEY OPERATED UNDER METHOD I.*

Year	Net flow into delta in acre-feet ¹			Requirements from net flow into delta in acre-feet					Surplus water above all requirements in acre-feet	Total flow into Suisun Bay in acre-feet
	From Sacramento Valley, including areas east of delta ²	From San Joaquin Valley, excluding areas east of delta ³	From both valleys	Total gross allowance for delta and adjacent uplands	Salinity control to lower end of delta	Full irrigation supply for "crop lands" in San Joaquin Valley having rights to water to be diverted at Friant ⁴	Irrigation supply for additional new lands in San Joaquin Valley	Supplemental supply for San Francisco Bay Basin		
1918	8,946,000	968,000	9,917,000	1,551,000	2,389,000	896,000	520,000	408,000	4,158,000	6,547,000
1919	10,111,000	968,000	11,079,000	1,551,000	2,389,000	896,000	520,000	408,000	5,320,000	7,709,000
1920	7,862,000	957,000	8,819,000	1,551,000	2,389,000	896,000	520,000	408,000	3,054,000	5,449,000
1921	14,743,000	965,000	15,708,000	1,551,000	2,389,000	896,000	520,000	408,000	9,949,000	12,338,000
1922	13,729,000	1,592,000	15,321,000	1,551,000	2,389,000	896,000	520,000	408,000	9,562,000	11,051,000
1923	8,754,000	1,050,000	9,804,000	1,551,000	2,389,000	896,000	520,000	408,000	4,045,000	6,434,000
1924	6,109,000	869,000	6,978,000	1,551,000	2,389,000	896,000	446,000	343,000	1,347,000	3,742,000
1925	8,299,000	942,000	9,241,000	1,551,000	2,389,000	896,000	520,000	408,000	3,482,000	5,871,000
1926	9,361,000	777,000	10,138,000	1,551,000	2,389,000	896,000	520,000	408,000	4,379,000	6,768,000
1927	15,595,000	917,000	16,512,000	1,551,000	2,389,000	896,000	520,000	408,000	10,753,000	13,142,000
1928	12,599,000	968,000	13,567,000	1,551,000	2,389,000	896,000	520,000	408,000	7,802,000	10,197,000
Average	10,555,000	998,000	11,553,000	1,551,000	2,390,000	896,000	513,000	398,000	5,805,000	8,195,000

*See page 105 for explanation of Method I.

¹ Includes regulated and unregulated water from reservoirs and return waters. The amounts shown for the San Joaquin Valley include such portions of these waters intercepted by the San Joaquin River pumping system before reaching the delta as could be used in supplying "crop land" rights or additional new lands in this valley obviating the pumping of that portion of this supply from the delta.

² Areas east of delta includes the watersheds of the Cosumnes, Mokelumne and Calaveras Rivers.

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

TABLE 23
MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY WITH MAJOR UNITS OF STATE PLAN IN GREAT CENTRAL VALLEY OPERATED UNDER METHOD I.
1918-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1918-1929	
	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet
January	1,157,000	1,360,000	227,000	440,000	795,000	998,000
February	4,546,000	4,729,000	372,000	562,000	1,497,000	1,682,000
March	1,874,000	2,077,000	108,000	306,000	1,625,000	1,905,000
April	877,000	1,073,000	0	196,000	263,000	459,000
May	504,000	707,000	0	203,000	331,000	534,000
June	199,000	396,000	0	194,000	155,000	351,000
July	0	203,000	0	203,000	0	203,000
August	0	203,000	0	203,000	0	203,000
September	7,000	203,000	0	196,000	5,000	201,000
October	133,000	356,000	129,000	332,000	134,000	337,000
November	763,000	869,000	253,000	449,000	480,000	976,000
December	685,000	866,000	253,000	456,000	543,000	746,000
Total	10,753,000	13,142,000	1,347,000	3,742,000	5,895,000	8,195,000

Although there would be a large surplus in every year, most of it would occur in the winter months from unregulated run-off. During the summer months there would be just sufficient water released from the reservoirs to care for all needs. Table 23 shows the amounts of surplus water in the delta and the total flow into Suisun Bay, by months, for the years of maximum and minimum run-off and the average for the period 1918-1929. It may be noted that there would have been no surplus in July and August of any year under this method of operation.

Method II:

The method of operation would have been the same as numbers 1, 2 and 3 under Method I, except that more water would have been furnished to supply additional irrigable lands along the west side of the upper San Joaquin Valley. There also would have been a larger deficiency in supply to lands in the San Joaquin Valley, other than those dependent upon local supplies, and to lands in the San Francisco Bay Basin, than under Method I. Water supplies would have been made available under this method of operation for the following purposes:

- a. Same as a under 3 in Method I.
- b. Same as b under 3 in Method I.
- c. Same as c under 3 in Method I.
- d. Same as d under 3 in Method I.
- e. A supply of 5,342,000 acre-feet per season, gross allowance, with a maximum seasonal deficiency of 35 per cent, made available for the irrigation of all the net area of 1,810,000 acres of irrigable land of all classes in the lower San Joaquin Valley, including 134,000 acres of foothills on the eastern side of the valley, below the major reservoirs.
- f. Same as f under 3 in Method I.
- g. A supply of 1,570,000 acre-feet per season, with a maximum deficiency of 35 per cent, made available for the irrigation of all the net irrigable area of 785,000 acres of class 1 and 2 lands lying on the western slope of the upper San Joaquin Valley.
- h. Same as h under 3 in Method I.
- i. Same as i under 3 in Method I, except that the deficiency in the supply for irrigated lands would have been 35 per cent in 1924.
- j. The generation of more than five billion kilowatt hours of electric energy annually, on the average.

Table 24 shows the same items for the operation of the plan under Method II as shown in Table 22 for the plan of operation under Method I. Table 25 gives similar data on monthly surplus and flow into Suisun Bay under Method II as are presented in Table 23 for Method I. It may be noted there would be less surplus water in the delta, and more months when there would be no surplus, than with the plan of operation under Method I.

TABLE 24
ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY WITH MAJOR UNITS OF STATE PLAN IN GREAT CENTRAL VALLEY OPERATED UNDER METHOD II,* 1918-1929

Year	Net flow into delta in acre-feet ¹			Requirements from net flow into delta in acre-feet						Surplus water above all requirements in acre-feet	Total flow into Suisun Bay in acre-feet
	From Sacramento Valley, including area east of delta ²	From San Joaquin Valley, excluding area east of delta ³	From both valleys	Total gross allowance for delta and adjacent uplands	Salinity control to lower end of delta	Full irrigation supply for "crop lands" in San Joaquin Valley having rights to water to be diverted at Friant ⁴	Irrigation supply for additional new lands in San Joaquin Valley	Supplemental supply for San Joaquin Bay Basin			
1918.....	9,726,000	988,000	10,694,000	1,551,000	2,389,000	896,000	1,570,000	403,000	3,885,000	6,274,000	
1919.....	9,953,000	988,000	10,921,000	1,551,000	2,389,000	896,000	1,570,000	403,000	4,112,000	6,501,000	
1920.....	8,146,000	957,000	9,103,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,288,000	4,683,000	
1921.....	13,915,000	985,000	14,890,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,071,000	10,460,000	
1922.....	13,651,000	1,592,000	15,243,000	1,551,000	2,389,000	896,000	1,570,000	403,000	8,434,000	10,823,000	
1923.....	8,693,000	1,050,000	9,743,000	1,551,000	2,389,000	896,000	1,570,000	290,000	2,934,000	5,323,000	
1924.....	6,081,000	760,000	6,841,000	1,551,000	2,389,000	583,000	1,020,000	403,000	1,062,000	3,397,000	
1925.....	8,727,000	942,000	9,669,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,860,000	5,249,000	
1926.....	8,957,000	777,000	9,734,000	1,551,000	2,389,000	896,000	1,570,000	403,000	2,925,000	5,314,000	
1927.....	15,351,000	917,000	16,278,000	1,551,000	2,389,000	896,000	1,570,000	403,000	9,469,000	11,858,000	
1928.....	13,339,000	988,000	14,307,000	1,551,000	2,395,000	896,000	1,570,000	403,000	7,498,000	9,893,000	
Average.....	10,595,000	988,000	11,583,000	1,551,000	2,390,000	896,000	1,520,000	392,000	4,862,000	7,252,000	

*See page 109 for explanation of Method II.

¹Includes regulated and unregulated water from reservoirs and return waters. The amounts shown for the San Joaquin Valley include such portions of these waters intercepted by the San Joaquin River pumping system before reaching the delta as could be used in supplying "crop land" rights or additional new lands in this valley, obviating the pumping of that portion of this supply from the delta.

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

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

TABLE 25
MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY WITH MAJOR UNITS OF STATE PLAN IN GREAT CENTRAL VALLEY OPERATED UNDER METHOD II. 1918-1929

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

The same analysis from which the foregoing results for Method II were obtained shows that by the utilization of the physical works proposed herein for the Sacramento River Basin, including the Trinity River diversion, regulated supplies, without deficiency in amount and dependable in time, could have been made available in the principal streams to irrigate all of the net irrigable lands—2,640,000 acres—in the Sacramento Valley, after allowing a gross diversion of 3,241,000 acre-feet, with a net use of 1,945,000 acre-feet per year, for the irrigation of a net irrigable area of 1,234,000 acres of foothill and mountain valley lands in the Sacramento River Basin. The analysis also shows that there would have been a large surplus of water in every year, over and above these needs, in the basin above the Sacramento-San Joaquin Delta. Some of this surplus water would have been contributed directly by releases and spill from the reservoirs and the remainder would have been that returning to the streams from water applied for irrigation on the valley floor, or foothills at elevations higher than the reservoirs, but draining directly to the valley floor. The portion of this surplus water not used in or diverted from the Sacramento-San Joaquin Delta would have wasted into the ocean. A large part of this surplus, however, could have been put to beneficial use in all years, except in the winter months when a portion would have wasted. The tabulation in Table 26 gives the amounts of water contributed by the reservoirs and the surplus available in the delta for the maximum and minimum years and the average annual for the eleven-year period 1918-1929.

The ultimate average annual requirements for the Sacramento-San Joaquin Delta and salinity control would amount to 3,590,000 acre-feet. A portion of this would be contributed by water from the San Joaquin Valley streams, but if the entire amount had been obtained from Sacramento Valley waters during the eleven-year period there still

TABLE 26
SURPLUS WATER IN SACRAMENTO RIVER BASIN

	Amount of water in acre-feet		
	Maximum year, 1927	Minimum year, 1924	Average annual for period 1918-1929
Releases and spill from major reservoir units.....	19,837,000	10,608,000	15,141,000
Gross requirements for lands on Sacramento Valley floor.....	9,033,000	9,033,000	9,033,000
Surplus from releases and spill.....	10,804,000	1,575,000	6,108,000
Return water—from valley floor.....	3,843,000	3,843,000	3,843,000
Return water—from foothills above reservoirs.....	341,000	341,000	341,000
Total surplus available in delta.....	14,988,000	5,756,000	10,292,000

would have been surpluses in the maximum and minimum years of 11,399,000 and 2,164,000 acre-feet, respectively, and an average annual surplus for the period of 6,702,000 acre-feet.

Method III.

In the accomplishments with the two foregoing methods of operation, the Sacramento Valley would have received an irrigation supply without deficiency. Another study was made for the same eleven-year period 1918-1929 with a method of operation which would be the same as under Method II, except that an additional supply of 1,500,000 acre-feet annually would have been made available in the Sacramento-San Joaquin Delta in accord with a uniform demand. This additional supply would have resulted, however, in some additional deficiencies and less wasted surplus, and would have been 35 per cent deficient itself in 1924. It would have been obtained with a maximum deficiency of 22 per cent in the supply to the Sacramento Valley and with the same maximum deficiencies in the supplies for the areas in the San Joaquin Valley and San Francisco Bay Basin as in Method II.

In all of the foregoing methods of operation, the accomplishments would be obtained with the use of only the major units of the State Water Plan. Investigations have been made of other reservoir sites in the Sacramento River Basin upstream from the major reservoirs, and on streams on which no major reservoirs are proposed, to determine the possibilities of obtaining additional regulated flows. It is found that the yield in irrigation water from the Feather River could be increased more than 450,000 acre-feet per year and the yield from the Yuba River probably as much as 170,000 acre-feet per year by the use of other known reservoir sites. A relatively small additional yield also could be obtained from the American River and some of the small streams entering the Sacramento Valley from the east and west side foothills. If it should be demonstrated that a safe dam could be constructed in the lower canyon of the Sacramento River, near Red Bluff, to create a reservoir with a capacity of about 1,000,000 acre-feet, an additional regulated supply of over 600,000 acre-feet could be obtained from this river. A still further increase in yield could be obtained with a greater storage capacity.

A preliminary study indicates that it would be physically feasible to divert 500,000 acre-feet annually from Eel River into the Sacramento River Basin without impairment of the present uses on the upper reaches of the stream. If 200,000 acre-feet annually from this source were furnished the San Francisco Bay Basin to fully supplement other supplies available to that area, 300,000 acre-feet annually still would be available for use in the Great Central Valley. The cost of this supply would not exceed that obtainable from some of the major reservoir units of the State Plan in the Great Central Valley. It also is physically possible to divert a substantial supply from the upper Klamath River into the upper Sacramento River drainage basin. No studies have been made, however, to determine the amount that could be so diverted, or the economic feasibility of the plan.

San Francisco Bay Basin.

The principal unit located in the San Francisco Bay Basin, and included in previous reports* to the Legislature, in the plan for the maximum utilization and conservation of the state's water is a salt water barrier below the confluence of the Sacramento and San Joaquin rivers.

The intended primary functions of a barrier would be to prevent the invasion of saline water into upper San Francisco Bay and the Sacramento-San Joaquin Delta, act as a diversion dam for the exportation of water to the upper San Joaquin Valley, and, by the creation of a fresh water lake, provide a means of diversion of fresh water supplies for the industrial, metropolitan and agricultural areas of the upper San Francisco Bay region.

From 1924 to 1926, an investigation was made of a barrier by the United States Bureau of Reclamation in cooperation with the state. That investigation pertained to the physical aspects. The report† concluded that it was physically feasible to construct a barrier either in Carquinez Strait or at Point San Pablo. However, no conclusion was reached as to its economic feasibility.

The present investigation has been directed to the economic aspects of a barrier. This has involved, as an essential feature, a study of alternate plans, with and without a barrier, to provide for the basic necessities of salinity control and dependable fresh water supplies for the upper San Francisco Bay and Sacramento-San Joaquin Delta region, in order to determine, if possible, the most feasible and economical plan for serving the present and ultimate water demands and facilitating the development of industries, municipalities and agriculture in the area. The study has included a consideration of the advantages and disadvantages of a barrier to local developments, operations and activities which would be affected, and the necessity and economic feasibility of a barrier, not only as a means for serving the needs of the upper bay and delta region, but also as a unit for attaining the maximum conservation and utilization of the state's water resources.

* Bulletin No. 4, "Water Resources of California," Division of Engineering and Irrigation, 1923.
 Bulletin No. 9, "Supplemental Report on Water Resources of California," Division of Engineering and Irrigation, 1925.
 Bulletin No. 12, "Summary Report on the Water Resources of California," Division of Engineering and Irrigation, 1927.
 † Bulletin No. 22, "Report on Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, California," Division of Water Resources, 1929.

Special reports have been prepared on particular phases of the investigation by men especially well qualified thereon. The United States War Department also has been making an investigation of the barrier, including particularly studies of navigation, flood control, silt movement and tidal action. The basic data and other information so far developed by the War Department have been made available for use in the preparation of this report.

Closely allied with the investigation of a salt water barrier has been a study of salinity conditions and control in upper San Francisco Bay and the Sacramento-San Joaquin Delta region. The results of ten years of investigation and records on salinity have formed the basis for an exhaustive analysis of its variation and control. Estimates have been completed of the amount of stream flow required for control and prevention of invasion of saline water for various points and degrees of control. The results of this salinity investigation are presented in detail in another report.* The control of salinity by fresh water released from storage reservoirs is an alternate plan to that by a salt water barrier.

Out of the several available sites for a barrier, three typical ones have been selected for the economic studies in this investigation, namely, an upper site at Chipps Island, an intermediate site at Dillon Point in Carquinez Strait, and a lower site at Point San Pablo. Foundation conditions at the two latter sites are favorable for construction of a barrier. Conditions are not so favorable at Chipps Island site. However, preliminary studies indicate that a dam, founded on long piles, could be constructed. Estimated costs, including navigation and flood control features, are given in Table 27. For the Dillon Point and Point San Pablo sites the estimates are based upon the plans presented in a previous report,† but with certain minor modifications. The plans for the Chipps Island site, upon which the cost estimate is based, are similar to those for the other sites, but modified to meet the foundation conditions. These costs include an allowance for contingencies and overhead, and interest during construction at 4½ per cent compounded semiannually for a construction period of six years. This table also sets forth the estimated annual cost of a barrier at each site. These figures include interest at 4½ per cent per annum, maintenance, depreciation, and amortization on a four per cent forty-year sinking fund basis.

TABLE 27
CAPITAL AND ANNUAL COST OF A SALT WATER BARRIER

Site	Cost	
	Capital	Annual
Chipps Island.....	\$40,000,000	\$3,300,000
Dillon Point.....	50,000,000	3,900,000
Point San Pablo.....	75,000,000	5,600,000

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

† Bulletin No. 22, "Report on Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers, California," Division of Water Resources, 1929.

The industrial area along the shores of upper San Francisco Bay is a most attractive district for the location of heavy industries, as evidenced by the growth during the past five years. Its rate of growth has been one-third greater than the average for California and five times as great as that of the average for the United States as a whole. All of the location factors for industries are favorable with the one exception of water. This needs correction. At present the industries obtain part of their supply from wells, part from public utilities and part from the bay itself. During the summer and fall months, the water in the bay becomes brackish and then is only suitable for cooling purposes. Moreover, some of the well supplies have turned saline, which further limits the dependability of fresh water supply.

The present use of water by the industries is about 16 million gallons per day for boiler and process, and about 65 million gallons per day for cooling and condensing purposes. Of the above amounts, about 13 million gallons a day for boiler and process and 38 million gallons a day for cooling and condensing purposes are used by the industries above the Dillon Point site. At the present time the average cost of water per thousand gallons for boiler and process use is about twelve cents for the entire area and seven cents for the industries above Dillon Point site, and the average cost of cooling water is about two and one-tenth cents for the entire area and two cents for the industries above Dillon Point. The use of salt or brackish water for cooling or condensing purposes is satisfactory and its cost is low. On the other hand, fresh water for boiler and process use is relatively high in cost and limited in dependability of supply. A lower cost with additional dependability would be desirable.

Along the shores of upper San Francisco Bay are a number of urban and suburban districts. Water supplies for these cities and towns are obtained locally from wells and streams and at certain periods of the year from Suisun Bay. Antioch obtains its supply from the San Joaquin River near its mouth. A public utility obtaining its supply both from wells and from Suisun Bay serves several cities and towns in Contra Costa County. Water rates to the consumer vary from 10 to 73 cents per 1000 gallons, with a prevailing rate probably equal to the average of these limits, for all systems.

The Sacramento-San Joaquin Delta has a gross area of nearly one-half million acres of the richest agricultural land in the state. The menace of saline water invasion has tended to depreciate land values, particularly in the lower end of the delta where the salinity situation is most aggravated. A salt water barrier would, if supplemented by release of stored fresh water, solve the salinity problem for the delta. On the other hand, levee maintenance and drainage pumping costs would be increased because of a higher constant barrier lake level than the average water level at present in the delta. A barrier would not have any appreciable effect on increasing the flood heights in the delta. It is believed by the best informed on the delta situation that if the salinity menace were removed and dependable fresh water conditions provided by some method of salinity control, land values and average crop returns in the lower part of the delta would tend to increase.

Adjoining Suisun and San Pablo bays, there is a gross area of 130,000 acres of marsh lands about equally divided between the two bays. In the Suisun Bay area about 46,000 acres are reclaimed, of which only 5000 acres are farmed. In San Pablo Bay area there are also about 46,000 acres reclaimed, of which 24,000 acres are farmed. A large part of these lands have been unsuccessfully farmed due to the saline conditions. These lands, if furnished with a fresh water supply, might be completely reclaimed and brought into agricultural production. This would involve the building of levees and drainage works and removal of salt from the soil, all of which would be difficult and expensive.

If the economic conditions become sufficiently favorable to permit the expenditures required to put these marsh lands into agricultural production, their reclamation and utilization could be effected either with or without a barrier. Preliminary studies of the works and operations involved in carrying out a complete reclamation development indicate a high barrier lake level would be a detriment by reason of more difficult and expensive drainage operations; and that a plan of reclamation providing for the leveeing off of the marsh lands from the bay without a barrier could be carried out and permit the regulation of water inside at a more favorable level, thus eliminating the detriment of a high barrier lake level.

Adjacent to upper San Francisco Bay, there are upland areas, below the assumed limit of present economic pumping lift of 150 feet, totaling 246,000 acres, about 118,000 acres of which are contiguous to Suisun Bay and about 128,000 acres contiguous to San Pablo Bay. About 190,000 acres are suitable for irrigation development and 12,000 acres may be classified as urban and industrial areas. Some of the areas now under irrigation are deficient in water supply. Others, such as Napa Valley, appear to have sufficient local water, if properly conserved and applied, to meet their ultimate development. Some of these areas, particularly the Ygnacio Valley, are in need of a supplemental supply.

A large amount of sewage and industrial waste now is discharged into the upper bays. Under present conditions, tidal action assists in its removal with little, if any, nuisance resulting therefrom. Moreover, this method of disposal, under similar conditions to the present, would probably be satisfactory for an indefinite period. However, if sewage and industrial waste, in the increasing amounts to be expected with the future growth of industries and urban districts, were discharged into a barrier lake, it would pollute the water to such an extent that its availability for use would be quite limited without construction of disposal and treatment works involving substantial expenditures to prevent such pollution.

Navigation in upper San Francisco Bay would be affected by a barrier. Locks would be required in a barrier structure for the passage of ships. This could be easily accomplished, however, with some loss of time. Navigation above a barrier would be improved somewhat due to the removal of tidal currents.

In connection with the fishing industry, studies indicate that a serious detrimental effect might result from a salt water barrier. It would offer an obstruction to the free migration of fish into and out

of the bay and rivers and would reduce the brackish areas which, it is reported, are necessary to the young fish fry.

The industrial water front structures in the upper bay area have been seriously affected during the past ten years or more by an infestation of marine borers, such as the teredo, which attack and destroy timber piles in salt water. For the existing structures, the bulk of the damage has already occurred and capital investments made to replace the timber piles by more resistant types. A change to fresh water conditions, however, probably would effect savings in the maintenance costs of present structures and in capital expenditures of future ones.

Salinity Control and Water Service for the Upper Bay Area—A portion of the ultimate water requirements of the San Francisco Bay Basin could be supplied from the Sacramento-San Joaquin Delta. This appears to be not only the nearest, but the most feasible source of water supply to take care of the future ultimate requirements of the upper San Francisco Bay area. A portion of the area already is served from this source. In order to make this source of supply available, provision must be made to control the invasion of saline water into the upper bay and delta so that a dependable and adequate fresh water supply can be obtained. This objective could be attained either by a salt water barrier or by means of fresh water releases without a barrier. Studies have been made to estimate the relative value and cost of these two alternate plans.

The effective storage capacity of a barrier lake is relatively small. The level at which water could be held is limited, both as to its maximum and minimum elevation. The maximum elevation is controlled by the height which the levees in the delta could continuously withstand, to about three feet above mean sea level; or approximately mean high tide level in the delta. The minimum elevation is controlled partly by the required navigation depths for the Stockton Ship Canal to about one and one-half feet above mean sea level, or approximately mean tide level in the upper San Joaquin Delta. The minimum level is controlled also in part by the necessity of holding the lake level as high as possible above mean tidal levels below a barrier in order to obtain effective operating conditions required for flushing out infiltrating salt water. Although the total storage capacity of a barrier lake is relatively large, the portion thereof that could be utilized is small because of the foregoing limitations and probably should not exceed a range of one foot. The usable storage capacity for this range would be as follows:

TABLE 28
USABLE STORAGE CAPACITY IN A BARRIER LAKE

Site	Capacity in acre-feet for one foot of range
Chippis Island.....	45,000
Dillon Point.....	75,000
Point San Pablo.....	155,000

Control of salinity with a salt water barrier would require substantial amounts of fresh water to provide for barrier operation and unavoidable losses from a barrier lake. A large part of the fresh water required with the usual type of locks is directly due to the necessity of operating locks in a barrier structure for the passage of vessels. During lockage operations, salt water from below the barrier would be discharged into the lake and seek its lower levels, and, unless removed, would progressively replace and pollute the fresh water therein. Large amounts of fresh water therefore would be required to flush out this salt water. Lockage operations also would result in direct losses of fresh water from the lake. The operation of fish ladders and leakage around flood and lock gates would require additional amounts of fresh water. The creation of a barrier lake, with a large area of water surface and extensive marginal vegetation, would result in large evaporation and transpiration losses which could not be prevented and must be supplied as a part of the water requirements for salinity control with a barrier. Evaporation from the lake surface would be from five to eight inches in depth per month during the summer. Transpiration from the areas of natural vegetation, especially tules and cat-tails, would be of considerably greater magnitude per unit area. At present, there are large unreclaimed areas in the marsh lands adjacent to Suisun and San Pablo bays and also large areas of uncultivated lands enclosed in levees on which various kinds of natural vegetation grow. The consumptive demands of this vegetation would have to be supplied from a barrier lake. Even under future complete reclamation and cropping of these marsh lands, the extent of marginal vegetation and the amount of transpiration would be considerable. All of these water requirements are of special importance in the period of low summer stream flow when supplies would have to be released from mountain storage.

Table 29 shows the estimated water requirements for salinity control with a barrier under both present and future conditions, including amounts for barrier operation and unavoidable evaporation and transpiration losses from a barrier lake. The water requirements for present conditions are based upon present water-borne traffic and estimates by U. S. Army Engineers. The amounts of water required for lockage and flushing both for present and future (25 years hence) water-borne traffic and for leakage are estimates which were submitted by the Division Engineer of South Pacific Division, U. S. War Department. The unavoidable losses, evaporation and transpiration, are estimated as an average for the months of July, August and September. Evaporation, for both present and future conditions, is based on losses from a barrier lake below the delta. Transpiration, for present conditions, is estimated for the present vegetation on the marsh lands of Suisun and San Pablo Bay and, for future conditions, for the vegetation on marginal areas which would remain permanently unreclaimed after the marsh lands have been fully reclaimed and put into agricultural production.

If a barrier were constructed, it appears obvious that the locks would be designed, if possible, so as to prevent the entrance of salt water into a barrier lake. A modification in the design and operation of the navigation locks, such as salt clearing devices, might materially

TABLE 29
WATER REQUIREMENTS FOR SALINITY CONTROL WITH A BARRIER

Site	Water requirements in second-feet	
	Present conditions	Future conditions
Chippe Island.....	1,300	2,800
Dillon Point.....	2,300	2,650
Point San Pablo.....	5,550	7,500

decrease the water requirements for lockage and flushing. Studies indicate that the use of such devices in place of the usual type of locks might reduce the water requirements for future conditions to perhaps less than half those shown in the table, however, with increased capital and annual costs. On the other hand a volume of water-borne traffic greater than estimated for 25 years hence might be expected. The uncertainty of the volume and character of future traffic makes it impossible to estimate closely the water required ultimately for lockage and flushing purposes. However, any possible reduction in these requirements below the amounts shown would not affect the conclusions set forth in this report.

The plan for salinity control by fresh water releases without a barrier is based upon a study of the variation and control of salinity in the upper bay and delta. It is concluded from this study that the invasion of saline water into the delta can be positively prevented and salinity controlled by provision of a fresh water supply sufficient to maintain a flow in the two rivers of not less than 3300 second-feet past Antioch into Suisun Bay. With such a control at the mouth of the rivers, a source for diversion of a fresh water supply of equivalent dependability and quality to that which could be provided in a barrier lake would be provided in the channels of the delta and not far distant from the upper bay area.

The control of salinity by means of fresh water releases, as proposed, does not rest upon theory, but is supported by the actual observed occurrence of natural control which has been effected by stream flow, as shown by the detailed records of the past ten years. It offers not only a positive and dependable means of controlling salinity, but also a method that would be feasible and economical of consummation. Under the proposed plan of control, saline conditions in the upper bay region would be greatly improved over those which have occurred during the last ten to thirteen years and would tend to approach the equivalent of conditions which naturally occurred prior to the extensive development of irrigated agriculture and reclamation in the Sacramento and San Joaquin valleys.

Exportation of water from the Sacramento River across the delta and up the San Joaquin River can be accomplished either with or without a barrier. The present investigation shows that a barrier is not necessary as a means of effecting this transfer. With an adequate water supply provided for the control of salinity at the lower end of the delta, and with additional channel capacity connecting the Sacramento River to the San Joaquin Delta, there would be no physical

impediment to the transfer and diversion of water up the San Joaquin River.

As a means of providing water service for the ultimate needs of the industrial, municipal and agricultural areas of the upper bay region, the two alternate plans of salinity control are fundamentally the same. In both plans, conduits would be required to transport the water to the areas served in the upper bay region. The only salient difference between the physical features of the two plans of service would be in the length and size of conduits. Either plan would render equally favorable service. The determination of the better plan must, therefore, rest upon the question of cost. Preliminary estimates on a strictly comparable basis have been made of the major conduit units and works for alternate plans of development, with and without a barrier. The proposed works would furnish equivalent service and accomplishments, with and without a barrier, at each of the three sites. In the plan without a barrier, the cost of additional levees and works assumed as necessary for reclaiming the marsh lands adjoining Suisun and San Pablo bays and also the cost of a connecting channel between Sacramento and San Joaquin rivers are included. The plans provide only for main conduits extending from the source of supply, whether from the delta or a barrier lake, both north and south of the bay and designed to serve the areas. Based upon this study, it is estimated that a plan of ultimate development with conduits extending from the lower delta, together with additional works for the reclamation of the marsh lands of Suisun and San Pablo bays and channel enlargements in the delta, would involve a capital expenditure of less than half that required for an equivalent development with a barrier; and that the annual cost, including interest, amortization, operation, maintenance and depreciation, also would be less than half that with a barrier. Plans for the major conduits required for ultimate service to the San Francisco Bay Basin are not shown herein, but preliminary studies and cost estimates, which show their physical feasibility, have been made and are presented in another report.*

The plan for serving the upper bay area by conduits from the delta is a flexible one and lends itself to progressive development with minimum expenditures. Thus, without the large capital cost required for a barrier, initial conduit units extending from controlled fresh water channels of the delta could be constructed with relatively small capital outlays to take care of immediate water requirements. Such initial conduit units later could be enlarged and extended as future demands increase, and likewise other conduit units could be added.

The foregoing figures for salinity control, with and without a barrier, indicate that some saving in water would be effected by a barrier at Chipps Island site, and at Dillon Point site under present and assumed future conditions. At Point San Pablo site no water could be saved, even under present conditions. Greater savings could be effected through utilization of salt clearing devices. However, such amounts of water as might be saved by a barrier could be supplied from the major reservoirs of the Sacramento Valley at an annual cost per acre-foot ranging from about \$1.00 from the Kennett Reservoir to \$3.33

* Bulletin No. 28, "Economic Aspects of a Salt Water Barrier Below Confluence of Sacramento and San Joaquin Rivers," Division of Water Resources.

from the Oroville reservoir, with an average from all reservoirs of about \$2, or considerably less than the cost with a barrier. (See Table 30.)

A study of the ultimate water requirements and sources of supply for the San Francisco Bay Basin indicates that, in addition to the water supply obtainable from a complete feasible development of all local water resources in the basin and the imported supplies from Hetch Hetchy and the Mokelumne River, about 600,000 acre-feet of water would be required annually. This could be partially supplied from Eel River. All or the greater portion of this additional supply could be obtained from the Sacramento-San Joaquin Delta, especially that required for the upper bay area. The studies of water supply, yield and demand for the Great Central Valley show that ample supplies of water would be available with the operation of the major units of the ultimate State Water Plan to meet all demands in the Great Central Valley and delta, including salinity control to the lower end of the delta, and also an amount sufficient to meet a considerable part of the additional demands of the San Francisco Bay Basin. Such savings in water as might be effected by a barrier would not be needed to provide a complete supply for the Great Central Valley and San Francisco Bay Basin. Furthermore, regulated water supplies in addition to those that could be provided by the major reservoir units of the State Plan in the Great Central Valley, could be furnished in amounts greater than the possible water savings with a barrier and at much smaller cost by development of other known reservoir sites on the Feather and Yuba rivers.

The conclusions of the investigation as to the feasible and economical method of controlling invasion of saline water and making available an adequate and dependable source of water supply for the upper bay area are summarized as follows:

1. It would be physically feasible to construct a salt water barrier at sites in Carquinez Strait and at Point San Pablo. Foundation conditions at the Chipps Island site are not as favorable for constructing a barrier at this location. The capital cost of the barrier would vary with the location and type of structure from \$40,000,000 to \$75,000,000 and the annual cost corresponding to the same would vary from \$3,300,000 to \$5,600,000.
2. The amount which might be contributed from highway funds towards the building of a barrier, by reason of present facilities and savings effected, is small in comparison with the total cost of a barrier and can not be considered a controlling factor in selecting the site, methods of financing or time of construction; and the combination of a highway crossing with a salt water barrier is not economically warranted.
3. The furnishing of an adequate and dependable cheap fresh water supply for industrial use would no doubt prove an attraction to heavy users of industrial water and probably would stimulate industrial growth in the upper bay area. If this were accomplished by the assistance of a barrier with a fresh water lake maintained by adequate water supplies furnished from mountain storage reservoirs, the attraction might be still further enhanced. However, the large expenditure required for a barrier might result in these benefits being entirely offset by the burden in additional taxes the local

industrial area might have to assume as its share of a barrier cost. Moreover, other competing industrial areas naturally would offer counter-attractions, such as comparable water rates, and hence it can not be expected that there would be any rapid influx of industries to locate on a barrier lake. Therefore, in so far as fresh water supply is a factor in industrial development, the essential requirement would be the furnishing of adequate fresh water supplies by the consummation of the most practicable plan that can be devised.

4. The primary function of a salt water barrier would be to prevent the invasion of saline water into the upper bay and thus provide a convenient source of diversion of a fresh water supply for industrial, agricultural and domestic use in the upper bay area. A barrier in itself would not create the water supplies required either for present or future needs of the area. Its function as regards water service would be primarily that of a diversion structure from above which fresh water supplies developed on the Sacramento and San Joaquin rivers could be diverted for various useful purposes. Moreover, in order to control salinity with a barrier, substantial quantities of fresh water must be furnished from upstream storage developments in much greater amounts than the usable storage in a barrier lake to provide for barrier operation (lockage, flushing and leakage losses) and unavoidable losses (evaporation and transpiration) from a barrier lake. Therefore, the necessity and desirability of a barrier as a means of controlling salinity and serving the fresh water demands of the upper bay area must be determined on the basis of the comparative cost of a plan of salinity control and water service with a barrier and an alternate plan without a barrier providing equivalent service and accomplishments.
5. Control of salinity and a dependable fresh water supply for the upper bay area could be provided with equal certainty without a barrier by means of fresh water released from storage reservoirs. With salinity controlled at the mouth of the river in this manner, not only would the delta be fully protected, but also a fresh water supply equivalent in dependability and quality to that with a barrier could be made available in the channels of the delta and not far distant from the upper bay area.
6. A barrier is not necessary for the exportation of water from the Sacramento River to the San Joaquin Valley above the delta. With salinity controlled at the lower end of the delta by fresh water releases and with additional channel capacity connecting the Sacramento River to the San Joaquin Delta, there would be no physical impediment to the transfer and diversion of water up the San Joaquin River.
7. A barrier would not be essential to the feasibility of reclaiming the marsh lands adjacent to Suisun and San Pablo bays.
8. A barrier would probably effect substantial savings in the capital and annual costs of water front structures in the barrier lake above, but such savings might be more than offset by losses entailed in delays to navigation, additional costs of drainage and levee maintenance in the delta and bay marsh lands, and possible damage to

the fishing industry. Moreover, construction of a barrier would precipitate a sewage and industrial waste disposal problem which would require substantial expenditures for construction of disposal and treatment works for its solution.

9. The proposed alternate plan of salinity control by means of fresh water releases without a barrier, providing conduits from the delta to serve the ultimate fresh water demands of the upper bay area, additional works of channel enlargement between the Sacramento River and San Joaquin Delta and works for the reclamation of bay marsh lands, could be consummated for a capital and annual cost of less than half that required for a plan of equivalent scope and service with a barrier. It would have the additional advantage of requiring immediate expenditures of but a small fraction of the cost of a barrier for amply serving the needs of the immediate future. Moreover, it would lend itself to a program of progressive development with expenditures made only as required to keep pace with the growing demands, thus keeping both capital and annual costs to a minimum for the progressive and ultimate stages of development.
10. All present and ultimate fresh water requirements and the complete development of the ultimate potentialities of industries, municipalities and agricultural lands in the upper San Francisco Bay region would be provided for under the proposed alternate plan of development and service, with salinity controlled to the lower end of the delta by fresh water releases from mountain storage. The plan would include main conduits extending westerly from the delta along the north and south sides of the bay, located and designed to serve the fresh water demands in the upper bay area. The upper bay channels would continue to serve as outlets for sewage and industrial waste and as a source of supply for cooling and condensing water for industries, with advantages resulting for both purposes. Preliminary designs and studies of the proposed plan demonstrate its physical feasibility and economical advantage, and give assurance of satisfactory service. The proposed alternate plan would not disturb the present status of developments and operations in the upper San Francisco Bay and delta region and, to a large extent, would restore fresh water conditions in upper San Francisco Bay equivalent to those existing under natural conditions before the expansion of irrigation in the Great Central Valley.
11. Water in the amounts that might be saved in controlling salinity with a barrier would be available and could be furnished at considerably less cost from mountain storage reservoirs. Therefore, the conservation efficiency and value of a barrier would be small in comparison with the cost.
12. The final conclusion of this investigation of a salt water barrier located at any of the three typical sites is that this structure is not necessary or economically justified as a unit of the State Water Plan.

South Pacific Coast Basin.

The water problems in the South Pacific Coast Basin comprise the largest practicable conservation of the supplies originating within the basin, the acquisition of additional supplies to make up local deficiencies and protection against flood damage.

The estimated annual water requirements for ultimate development in the basin are 3,340,000 acre-feet gross allowance and 3,000,000 acre-feet net use. The mean total run-off from local mountain and foothill areas is 1,114,000 acre-feet per year for the forty-year period 1889-1929; 1,146,000 acre-feet per year for the twenty-year period 1909-1929; 894,000 acre-feet per year for the ten-year period 1919-1929; and 709,000 acre-feet per year for the five-year period 1924-1929. The total water supply, however, can not be conserved and utilized. Wastes and irrecoverable losses will occur regardless of the conservation measures taken. In addition to the surface run-off it is estimated that an average of about 350,000 acre-feet per year will be contributed to the ground water supply from rainfall on the valley floors. The safe utilizable yield from all local resources is estimated at 1,200,000 acre-feet per year, but this is not uniformly distributed, San Diego County especially having a small proportion as compared to water demands.

The term "net use" in the case of metropolitan areas includes sewage wastes into the ocean. Conditions in much of the South Pacific Coast Basin are favorable to use of the sewage after purification and, in fact, that from several cities in Los Angeles, Riverside and San Bernardino counties now is being used, either directly after it has discharged into surface streams or by pumping from ground water to which the effluent has percolated after having been spread upon the gravels. The sewage from the metropolitan area of Los Angeles now approximates 160,000 acre-feet annually and will continue to increase in amount. It now discharges into the ocean. In view of the question surrounding the reclamation and reuse of sewage, it is not possible with present knowledge to evaluate the amount which may ultimately be usable, but whatever of the present and future additional sewage wastes are saved will reduce the deficiency of 1,800,000 acre-feet, which is found by subtracting the estimated net safe yield from the estimated ultimate net use and which, if no local supply is available, must at some future time be imported if the ultimate water requirements of the entire potential habitable area are to be met.

Where pumping from underground basins, with consequent reuse of water, is the prevailing method of securing supplies, as is the case in a large part of South Pacific Coast Basin, there is a tendency for salt and alkali to concentrate in the underground water, which must be prevented by waste into the ocean. The amount of waste required for this can not be evaluated with present knowledge and, therefore, it is not certain that it has been fully cared for in the allowance of 3,000,000 acre-feet for "net use." Still another item is the reduction in percolation of rainfall to the underground basins when the surface is sealed by buildings and pavement, but this, in the case of ordinary urban area outside of the business district, may be less than usually supposed and it is believed this decrease is more than compensated for by

the increase of such percolation when brush is replaced by cultivated crops. No attempt is made to accurately evaluate these items. On the one hand they subtract from and on the other add to the apparent deficiency. It is believed the net result, if sewage reclamation and distribution is adopted, would be a considerable reduction in the amount of water which must ultimately be imported if the entire area, including habitable hills and foothills, is furnished a complete supply.

Importations of about 160,000 acre-feet per year now are being made by the city of Los Angeles from Owens River, and an extension of this project to Mono Basin is planned by the same agency to bring in an additional supply. These supplies are important. However, they would not be available for use in Santa Ana River Basin or in San Diego County, areas of extreme water shortage, and even if they could be thus widely distributed they would not be sufficient for ultimate needs.

A source of large supplemental supply is the Colorado River. No other has been studied in this investigation. The plans of the Metropolitan Water District of Southern California call for an aqueduct of 1500 second-feet diversion capacity from the Colorado River capable of delivering about 990,000 acre-feet per year to terminal storage in the district and approximately 900,000 acre-feet net delivery from terminal storage. The immediate future needs of the eleven cities* comprising the district will not require all of this amount. Other municipalities or organized districts can, under the terms of the district act, participate financially in the consummation of the project and share in its water supply. The total supply that can be obtained from full development on Owens River and in Mono Basin may be approximately 400,000 acre-feet. To import this supply would require the enlargement of the present Los Angeles aqueduct. Therefore, the total aggregate supply from both of these sources would be about 1,300,000 acre-feet per year. This may be the total ultimate importation required if reclamation of sewage wastes proves feasible. However, if such reclamation does not prove feasible, then perhaps as much as 500,000 acre-feet per year additional must be obtained at some future time if the entire habitable area from Ventura County south to the Mexican border is to be fully supplied.

Colorado River Aqueduct—Many routes have been studied for an aqueduct to import water from the Colorado River which would be controlled by the Boulder Canyon reservoir.

In 1926 a route was investigated by the state for an aqueduct from Black Canyon, the site of the Hoover dam, which would deliver water at San Jacinto on the Pacific slope of southern California at sufficient elevation so that practically the entire habitable area could be reached by gravity through distributary conduits. The city of Los Angeles and later the Metropolitan Water District have been engaged since 1922 in an exhaustive study of this subject. Many routes have been studied, among them that investigated by the state. A report on all of the investigations by the Metropolitan Water District has been prepared and recently published. The aqueduct route selected by the Engineering Board of Review of the district would leave the Colorado

* On September 1, 1930.

River 150 miles downstream from the Hoover dam. After an initial pumping lift of 539 feet with the Parker reservoir constructed, or 617 feet without it, to elevation 989 feet, the aqueduct would pass through Whipple Mountains in 12.3 miles of tunnel and thence in surface conduit for 51 miles via Rice to the Granite Mountains. It would pierce these mountains in a tunnel, followed almost entirely by surface conduit, with some short tunnels, to a point west of Shaver's Summit. A series of pumping lifts located in this section of the line would deliver water at the summit at elevation 1817 feet. At the intake of the last pumping plant, a natural reservoir (Hayfield) would be developed for equalization and stand-by purposes. West of Shaver's Summit, the aqueduct would be principally in tunnel along the face of the San Bernardino Mountains. It would cross the Coachella Valley in surface conduit and pass through the San Jacinto Mountains in tunnel, emerging on the Pacific slope near the mouth of Potrero Canyon, about midway between Banning and San Jacinto, at elevation 1548 feet. This point of emergence is almost identical with that of the route reconnoitered by the state. The total length of the aqueduct line to this point is about 206 miles, of which about 44 per cent is in tunnel. The total static pumping lift would be 1564 to 1601 feet, none of which would be recoverable in power drops to this point.

The route recommended by the Engineering Board of Review of the Metropolitan Water District for the aqueduct from the Potrero Canyon portal to terminal storage extends almost due west across San Jacinto and Perris valleys from the tunnel to the first terminal reservoir in Cajalco Canyon, a branch of Temescal Wash, between Corona and Elsinore. From this reservoir the route runs southwesterly to Temescal Wash and then northwesterly through the Santa Ana Mountains to the Santa Ana Canyon, which it crosses near the Orange County line. It then extends northwesterly through the Puente Hills to possible additional terminal storage in Brea Canyon, Walnut Creek, Puddingstone and Pine Canyon reservoirs. This line would consist mostly of tunnels and siphons, with five short lengths of surface conduit. Power could be developed below the Cajalco reservoir.

The capital cost of the complete aqueduct with a diversion capacity of 1500 second-feet is estimated by the Engineering Board of Review for the Metropolitan Water District to be \$199,618,000. This estimate does not include interest during construction, the cost of terminal storage reservoirs or distributary conduits.

Distributary Conduits—Ultimate development of the habitable lands would require distributary systems to San Diego County, Orange County and to the heads of the San Bernardino and San Gabriel basins and possibly into Ventura County, if the estimated ultimate deficiencies in water supply in these regions are to be satisfied in accord with the plan. In connection with these conduits, power could be developed at several drops. The general locations of these conduits, as found by the state's reconnaissance survey, are shown on Plate IV by black lines. Near the Potrero Canyon portal of the tunnel under the San Jacinto Mountains, two distributary conduits would take out, one leading southwesterly into San Diego County and the other northerly toward Riverside. This latter conduit would divide about halfway between the tunnel and

Riverside, one branch extending westerly and southerly to Lake Elsinore and from it through the Temescal and Santa Ana canyons to the coastal plain in Orange and Los Angeles counties, and the other branch extending northerly by way of Redlands into the San Bernardino Basin and thence around the rim of the valley lands toward Pasadena and the San Fernando Valley. These systems would consist of tunnels and surface conduit, with siphons across canyons and stream channels where required. These conduit routes have been reconnoitered, but no cost estimates have been prepared.

An alternate plan proposed by the city of San Diego is to divert water from the Imperial Valley canals and deliver it to that portion of San Diego County on the Pacific slope lying south of the Santa Margarita River drainage basin.

Conservation and Flood Control Work in Santa Ana River Basin—The plan for the conservation of water and control of floods in this basin is described on page 168 in Chapter VI.

North Pacific Coast, Central Pacific Coast and Great Basins.

No units of a State Plan are presented herein for development of the water resources of these basins. Investigations are in progress in these basins and are described in Chapter IX.

CHAPTER VI

INITIAL UNITS OF STATE WATER PLAN

Three important regions in the state have water problems which have become acute and which require immediate attention. These are upper San Francisco Bay, Sacramento-San Joaquin Delta and Sacramento Valley; upper San Joaquin Valley; and the Pacific slope of southern California. Plans are presented herein for meeting these immediate future needs. In the first area, the water shortage exists in the summer and fall months of nearly every year, with a large surplus naturally tributary and available to the affected area in other months. To correct this unsatisfactory situation, the only requirement is proper control, regulation and distribution of the tributary water. In the other two areas a different problem presents itself. Here are highly developed areas which are overdrawing the average water supplies naturally and legally available to them. There are no nearby sources which can be developed. The only method of relief must be in seeking supplies from outside sources.

Sacramento River Basin.

The water problem in the Sacramento River Basin is that of invasion of saline water into the upper San Francisco Bay and delta region. In months of low water flow from the Sacramento and San Joaquin rivers, saline water from the lower bay has, due to tidal action, invaded the upper reaches of Suisun Bay and far up into the many channels of the delta. As stated in Chapter V, this condition could be corrected by either of two general methods. One method would be the construction of a physical barrier at some strategic point below the affected area, together with sufficient mountain storage to be utilized to replenish the diminishing fresh water supply in a barrier lake. The second method would be to store water in a mountain reservoir during periods of plentiful run-off and later release it at the proper time and in sufficient volume to supplement the unregulated low water flow to prevent the invasion of saline water of a specified degree beyond a certain point. The practical limit of control with this method is the lower end of the delta. As shown in Chapter V, the first method is too costly and not economically justified. The second method only, therefore, will be considered as a means for controlling salinity.

Attendant with this situation, the flow in the Sacramento River during the summer months of subnormal years has been so low that navigation has been greatly hampered and distance of navigability has been much reduced. During several of the past dry years, particularly in 1920 and 1924, the irrigators drawing their supply from the Sacramento River have been forced to accept a deficient supply. Increased pumping costs also have resulted from the low discharge in the stream. All of these problems—salinity in the delta and upper San Francisco Bay regions, navigation, and deficiency in irrigation supply along the Sacramento River—are closely allied.

To control salinity by the method adopted, would require the storage of fresh water in reservoirs and its later release at the proper time and in sufficient volume into channels tributary to the delta. The amount of release would vary with the season and the month during the season and with the point and degree of control. To prevent the invasion of saline water into the delta, would require a flow past Antioch into Suisun Bay of not less than 3300 second-feet. With stream flow into the delta as it was during the last ten years and present consumptive use of water in the delta, the supplemental flow required for control of salinity and consumptive demands in the delta would have been 1,128,000 acre-feet in 1924, 825,000 acre-feet in 1920, 359,000 acre-feet in 1928 and 150,000 acre-feet in 1927.

The most advantageous location of a reservoir for the control of salinity would be in the San Joaquin River Basin because two-thirds of the water demands are in the San Joaquin River section of the delta, and further because the present low water inflow into the delta from the San Joaquin River is much less than from the Sacramento River, with only two existing channels, Georgiana Slough and Three Mile Slough, of limited capacity interconnecting the two rivers. The reservoirs in the upper San Joaquin Valley would not be available because the water developed by those units would be used within that area. A study of the major reservoirs of the State Water Plan in the lower San Joaquin River Basin reveals that only two, the Don Pedro and Melones reservoirs, have promise. Each has sufficient capacity to meet the salinity control demands, but, due to the fact that a substantial part of the potential yield of each now is attached to present developed areas, the resultant added yield of each as a unit would be too small to meet salinity requirements. Both taken together, however, would produce sufficient new water to meet the requirements, but at two or more times the net cost of obtaining the same quantity of water at the more favorable reservoirs in the Sacramento River Basin. Other combinations of smaller units with one of these reservoirs also could meet the requirement, but again at much higher costs than could be obtained in the Sacramento River Basin.

A study has been made to estimate the amount and net cost of regulated supplies that could be developed at the major reservoir units in the Sacramento River Basin. In Table 30 the amount of water that could be made available in accordance with an irrigation demand and the net cost per acre-foot thereof are given for each unit. The amount of new supplies in each instance is that obtainable, through development of storage, over and above present possible use from the stream under an irrigation demand schedule. The net cost of yield is the cost after allowance is made for power credit at those units where it would be profitable to install a hydroelectric power plant in order to defray part of the cost of the project.

Although the salinity control demand would vary somewhat from that for irrigation and the net cost per acre-foot would be different from that given, the figures are comparable as to relative costs of regulated water from the various units. To obtain these amounts, the units would be operated primarily to yield a maximum irrigation supply, modified slightly, however, to furnish a more dependable and valuable electric energy output.

TABLE 30
COST OF REGULATED IRRIGATION SUPPLIES AT MAJOR UNITS OF STATE PLAN
IN SACRAMENTO RIVER BASIN
Reservoirs Operated Primarily for Irrigation

Unit	Stream	Height of dam in feet	Capacity of reservoir in acre-feet	Seasonal irrigation yield in new water	
				In acre-feet	Average net annual cost per acre-foot
Kennett reservoir.....	Sacramento River.....	420	2,940,000	2,850,000	\$0.9
Kennett reservoir.....	Sacramento River.....	520	5,967,000	3,896,000	1.2
Oroville reservoir.....	Feather River.....	580	1,705,000	1,910,000	3.3
Narrows reservoir.....	Yuba River.....	580	853,000	899,000	2.4
Camp Far West reservoir.....	Bear River.....	180	151,000	130,000	3.10
Folsom, Auburn and Coloma reservoirs.....	American River.....		1,952,000	1,656,000	1.3
Trinity River diversion.....	Trinity River.....	365	1,436,000	555,000	2.4
Millite reservoir.....	Stony Creek.....	135	115,000	77,000	2.7
Capay reservoir.....	Cache Creek.....	170	378,000	155,000	2.1
Monticello reservoir.....	Putah Creek.....	150	130,000	96,000	1.9

¹ Irrigation water available in accordance with irrigation demand from water released primarily for the generation of power.
² Net annual cost after deducting from the total annual cost the estimated revenues from the sale of electric energy.

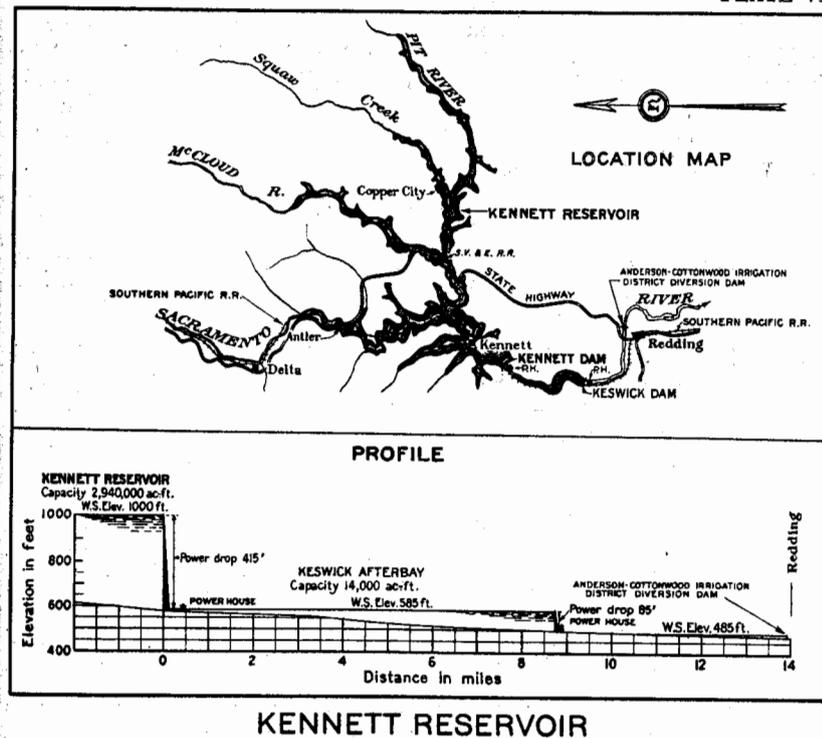
Only three units, each by itself, would be able to meet salinity control requirements in a year like 1924, under existing irrigation and storage developments in the Sacramento and San Joaquin River basins. These are Kennett reservoir on the Sacramento River, Oroville reservoir on the Feather River and the American River unit. If it is assumed that perfect salinity control would not be required in a year like 1924, then the Narrows reservoir on the Yuba River and the Trinity River diversion in conjunction with regulatory storage in Sacramento River Basin also would be capable of meeting the situation. Combination of smaller units by themselves or with the Trinity River diversion or Narrows reservoir also could effectively control salinity. However, a study of costs of new water for various units and combinations definitely shows that only two units are worthy of more detailed consideration, namely Kennett reservoir and American River unit.

Although salinity control is the immediate primary function of a reservoir in the Sacramento River Basin, other considerations are quite important. If the reservoir were located on the main Sacramento River, it could be operated to improve navigation on the river to the present head of navigation, and even above that point to perfect the irrigation supply of the lands now under irrigation along the river, to reduce the floods in the Sacramento Flood Control Project, and to make available in the Sacramento-San Joaquin Delta supplies for the delta and upper San Francisco Bay area and for the San Joaquin Valley. If the reservoir unit were located on a tributary of the Sacramento River, its value for navigation on the Sacramento River would be much less. However, it could perform the other functions if of sufficient output capacity. In selecting an initial unit of the State Plan in the Sacramento River Basin, all of these things must be given consideration.

Referring to the Kennett reservoir, it is seen that the ultimate height of dam would be 520 feet, and the storage capacity about 6,000,000

acre-feet. A detailed analysis of cost and performance of this reservoir for various heights of dam discloses that the economic height of dam, when consideration is given to all the demands that would be made on the reservoir, is 420 feet. It would meet all the foregoing requirements successfully at lesser cost than for any other size of reservoir at this location. The capacity of the reservoir would be 2,940,000 acre-feet. Flood control features capable of controlling floods to 125,000 second-feet would be included in the dam. A power house below the dam with installed capacity of 275,000 kilovolt amperes would be a part of the plan. Nine miles downstream, there would be an afterbay dam, together with a power plant. The capacity of the afterbay would be 14,000 acre-feet and of the power plant 50,000 kilovolt amperes. The total static head developed would be 500 feet. The reservoir would flood portions of the state highway and a main line of the Southern Pacific Railroad. The cost of relocating the railroad to clear a 520-foot dam is included in the estimate for the 420-foot dam. The total cost is estimated at \$84,000,000, including an allowance of 25 per cent for engineering, administration and contingencies, and interest during construction at 4½ per cent per annum compounded semiannually. A profile of the proposed development and a map showing its geographical location are shown on Plate VI, "Kennett Reservoir."

PLATE VI



On the American River, there would be three major reservoirs—Folsom, Auburn and Coloma—with an aggregate capacity of 1,952,000 acre-feet. There would be an afterbay below each reservoir. Included as a part of the American River unit, would be six power plants, one downstream from each major dam and afterbay. The total installed capacity would be 295,000 kilovolt amperes. The total cost of this unit, including power plants and flood control features in the dams, would be \$68,500,000, including overhead and interest during construction at the same respective rates as for the Kennett reservoir. Folsom and Auburn would be the more productive of the three reservoirs in water yield. These two reservoirs in themselves could meet the earlier requirements for an initial development, leaving Coloma to be constructed at a later date when additional water would be needed. The aggregate storage capacity of these two reservoirs would be 1,186,000 acre-feet and installed capacity of the power plants 235,000 kilovolt amperes. The total cost of this partial American River unit is estimated at \$50,100,000. A profile of the proposed development and a map showing its geographical location are shown on Plate VII, "American River Unit."

Detailed analyses have been made of these units, operated under various conditions to determine the better unit in the Sacramento River Basin for initial development in the State Plan. These analyses for Methods I and IV for the Kennett reservoir and for the same methods for the complete American River unit cover the forty-year period 1889-1929. The analyses for Methods II and III for the Kennett reservoir, for Methods II and III for the complete American River unit, and for Methods I and II for the partial American River unit were made only for the ten-year period of low average run-off, 1919-1929, but the average power outputs for these methods have been estimated for the forty-year period 1889-1929.

Kennett Reservoir

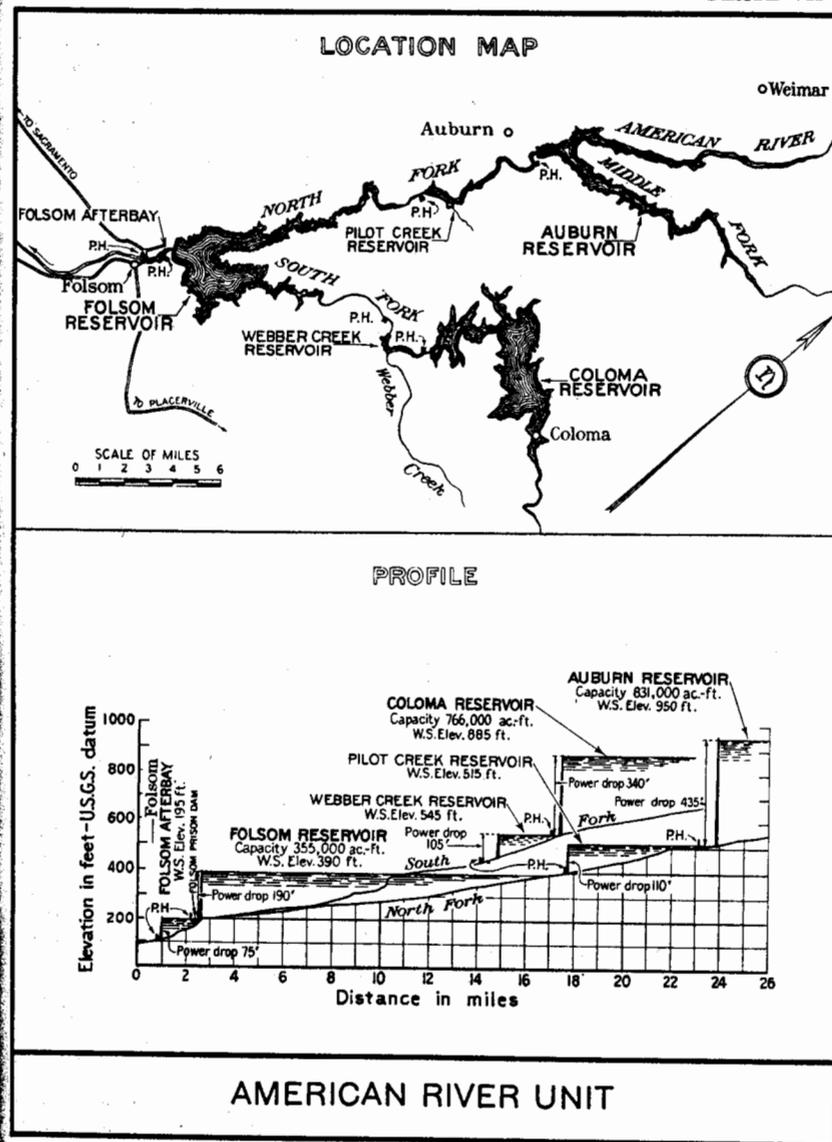
The four general methods of operation under which the Kennett reservoir was analysed, together with the accomplishments, are as follows:

Method I. Water would have been released from the reservoir in such a manner as to obtain the greatest possible revenue from the production of electric energy, all other uses of the water being incidental. The following would have been accomplished:

1. An annual average of 1,622,800,000 kilowatt hours of hydroelectric energy would have been generated.
2. Five hundred ninety-five thousand acre-feet of new water would have been made available, with a maximum deficiency of 35 per cent in the driest year, for use in accord with the irrigation demand in the Sacramento Valley.
3. There would have been incidental benefits to navigation, flood control and salinity control.

Method II. Space would have been reserved in the reservoir for flood control, and stored water would have been released in a manner so as to supplement the flows from unregulated streams and from return

PLATE VII



irrigation water to make water available for irrigation, navigation, salinity control and power generation. The following would have been accomplished:

1. The space reserved in the reservoir each season for flood control would have reduced flood flows to 125,000 second-feet.
2. A navigable depth on the Sacramento River of five to six feet would have been maintained from the city of Sacramento to Chico Landing, with a substantial increase in depths from this latter point to Red Bluff.

3. Irrigation demands on the Sacramento River above Sacramento would have been supplied, without deficiency, up to 6000 second-feet maximum draft in July. A full irrigation supply would have been furnished in all years to all lands along the Sacramento River above the delta. There would have been over 700,000 acre-feet more water available for these lands in 1924.
4. An irrigation supply, without deficiency, would have been furnished the Sacramento-San Joaquin Delta for its present requirements.
5. A fresh water flow of not less than 3300 second-feet would have been maintained past Antioch into Suisun Bay, controlling salinity to the lower end of the Sacramento-San Joaquin Delta.
6. A water supply, without deficiency, would have been made available in the delta for the developed industrial and agricultural areas along the south shore of Suisun Bay in Contra Costa County.
7. An annual average of 1,591,800,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

Method III. Space would have been reserved in the reservoir for flood control, and stored water would have been released in such manner as to supplement the flows from unregulated streams and from return irrigation water to make water available for irrigation, navigation, salinity control and power generation. The following would have been accomplished:

Items 1, 2, 3, 4, 5 and 6, same as under Method II.

7. An irrigation supply, without deficiency, would have been made available in the Sacramento-San Joaquin Delta* sufficient in amount to fully supply the "crop lands" now being served from the San Joaquin River above the mouth of the Merced River. This would have been conveyed to these lands by the San Joaquin River pumping system and would have made possible the exportation of all the available supply in the San Joaquin River at Friant if the "grass land" rights on the San Joaquin River above the mouth of Merced River had been purchased.
8. An annual average of 1,581,100,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

Method IV. Water would have been released from the reservoir in such manner as to supplement the flow at Red Bluff to make available a maximum possible irrigation supply at that point. Hydroelectric energy would have been generated with the water released from the reservoir under the irrigation demand schedule. The following would have been accomplished:

1. Two million eight hundred fifty thousand acre-feet of new water would have been made available annually, with a maximum deficiency of 35 per cent in the driest year, for use in accordance with the irrigation demand in the Sacramento Valley.

* See footnotes to Table 34.

2. An annual average of 1,285,000,000 kilowatt hours of hydroelectric energy would have been generated.
3. There would have been incidental benefits to navigation, flood control and salinity control.

Complete American River Unit

The four methods of operation under which the American River unit was analysed, together with the accomplishments, are as follows:

Method I. Water would have been released from the reservoirs in such manner as to obtain the greatest possible revenue from the production of electric energy, all other uses of the water being incidental. The following would have been accomplished:

1. An annual average of 1,052,400,000 kilowatt hours of hydroelectric energy would have been generated.
2. Five hundred twenty-four thousand acre-feet of new water would have been made available, with a maximum deficiency of 35 per cent in the driest year, for use in accordance with the irrigation demand in the Sacramento Valley.
3. There would have been incidental benefits to flood control, salinity control and navigation.

Method II. Space would have been reserved in the reservoirs for flood control, and stored water would have been released in such manner as to supplement the flows from unregulated streams and from return irrigation water to make water available for irrigation, salinity control, and power generation. The following would have been accomplished:

1. The space reserved in the reservoirs each season for flood control would have reduced flood flows to 80,000 second-feet maximum flow at the U. S. Geological Survey gaging station at Fair Oaks.
2. A fresh water flow of not less than 3300 second-feet would have been maintained past Antioch into Suisun Bay, controlling salinity to the lower end of the Sacramento-San Joaquin Delta.
3. An irrigation supply, without deficiency, would have been furnished the Sacramento-San Joaquin Delta for its present requirements.
4. A water supply, without deficiency, would have been made available in the delta for the developed industrial and agricultural areas along the south shore of Suisun Bay in Contra Costa County.
5. An annual average of 972,500,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

Method III. Space would have been reserved in the reservoirs for flood control, and stored water would have been released in such manner as to supplement the flows from unregulated streams and from return irrigation water to make water available for irrigation, salinity control, and power generation. The following would have been accomplished:

Items 1, 2, 3 and 4, same as Method II.

5. An irrigation supply, without deficiency, would have been made available in the Sacramento-San Joaquin Delta* sufficient in amount to fully supply the "crop lands" now being served from the San Joaquin River above the mouth of the Merced River. This would have been conveyed to these lands by the San Joaquin River pumping system and would have made possible the exportation of all the available supply in the San Joaquin River at Friant.
6. An annual average of 951,700,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

Method IV. Water would have been released from the reservoirs in such manner as to make available a maximum possible irrigation supply at Folsom. Hydroelectric energy would have been generated with the water released from the reservoirs under the irrigation demand schedule. The following would have been accomplished:

1. One million six hundred fifty-six thousand acre-feet of new water would have been made available annually, with a maximum deficiency of 35 per cent in the driest year, for use in accordance with the irrigation demand in the Sacramento Valley.
2. An annual average of 898,800,000 kilowatt hours of hydroelectric energy would have been generated.
3. There would have been incidental benefits to flood control, salinity control, and navigation.

Partial American River Unit

The American River unit, using only the Folsom and Auburn reservoirs and their afterbays, also was analysed under two methods of operation which, together with their accomplishments, are as follows:

Method I. Space would have been reserved in the reservoirs for flood control, and stored water would have been released in such manner as to supplement the flows from unregulated streams and from return irrigation water to make water available for irrigation, salinity control, and power generation. The following would have been accomplished:

1. The space reserved in the reservoirs each season for flood control would have reduced flood flows to 100,000 second-feet maximum flow at the U. S. Geological Survey gaging station at Fair Oaks.
2. A fresh water flow of not less than 3300 second-feet would have been maintained past Antioch into Suisun Bay, controlling salinity to the lower end of the Sacramento-San Joaquin Delta.
3. An irrigation supply, without deficiency, would have been furnished the Sacramento-San Joaquin Delta for its present requirements.
4. A water supply, without deficiency, would have been made available in the delta for the developed industrial and agricultural areas along the south shore of Suisun Bay in Contra Costa County.

* See footnotes to Table 34.

5. An annual average of 762,500,000 kilowatt hours of hydroelectric energy would have been generated, incidental to other uses.

Method II. Space would have been reserved in the reservoirs for flood control, and stored water would have been released in a manner so as to supplement the flows from unregulated streams and from return irrigation water to make water available for irrigation, salinity control, and power generation. The following would have been accomplished:

Items 1, 2, 3 and 4, same as under Method I above.

5. An annual irrigation supply of 500,000 acre-feet, with a deficiency of 31 per cent in 1924, would have been made available in the Sacramento-San Joaquin Delta* for the supply of the "crop lands" now being served from the San Joaquin River above the mouth of the Merced River. This supply would have been conveyed to these lands by the San Joaquin River pumping system and would have made possible the exportation of a like amount of water from the San Joaquin River at Friant.
6. An annual average of 730,000,000 kilowatt hours of hydroelectric energy would have been generated, incidental to the other uses.

Under Methods I, II and III for the Kennett reservoir, Methods I, II and III for the "Complete American River Unit," and Methods I and II for the "Partial American River Unit," the run-off from the basin considered available at each unit was that impaired by present upstream development. Under Method IV for both the Kennett reservoir and the "Complete American River Unit," the run-off considered available was that impaired by estimated ultimate future upstream development.

The gross annual cost and the net annual cost, after deduction of anticipated revenue from the sale of electric energy, for each of the various methods of operation have been estimated for each unit. The bases for estimating annual costs are as follows:

Interest, in per cent	4.50
Amortization of capital investment (forty-year sinking fund basis at four per cent), in per cent of capital cost	1.05
Depreciation—	
Lands and improvements flooded, in per cent of capital cost	0
Dams, in per cent of capital cost	0.30
Power plants, spillway gates, flood control gates and appurtenances (forty-year sinking fund basis at four per cent), in per cent of capital cost	1.05
Taxes	0
Operating expenses and maintenance—	
Dam and reservoir	\$20,000 to \$100,000
Power plant	\$10,000 plus \$0.65 per kilovolt ampere of installed capacity.

In Table 31 is set forth a financial comparison of the units on the foregoing bases.

* See footnotes to Table 34.

TABLE 31
FINANCIAL COMPARISON OF KENNETT RESERVOIR AND AMERICAN RIVER UNIT
FOR VARIOUS PLANS OF OPERATION

Unit	Stream	Height of dam in feet	Storage capacity of reservoirs in acre-feet	Installed capacity of power plant in kilovolt amperes	Capital cost of reservoirs, dams, power plants and afterbays	Method of operation	Gross annual cost of operation	Average annual electric output in kilowatt hours	Average annual revenue from sale of electric energy ¹	Average net annual cost not covered by revenue from sale of electric energy	Seasonal irrigation yield in new water acre-feet in acre-feet	Average net annual cost per acre-foot of new water
Kennett reservoir and afterbay	Sacramento River	420	2,940,000	325,000	\$84,000,000	I	\$5,297,000	1,622,800,000	\$4,414,000	\$883,000	595,000	\$1.48
						II		1,581,800,000	4,218,000	1,079,000		
						III		1,581,100,000	3,828,000	1,471,000		
						IV		1,285,000,000	2,480,000	2,817,000	2,850,000	0.99
Complete American River unit—Folsom, Auburn and Coloma reservoirs, including afterbays	American River		1,952,000	295,000	68,500,000	I	4,484,000	1,052,400,000	3,441,000	1,043,000	594,000	1.99
						II		972,500,000	3,219,000	1,265,000		
						III		951,700,000	2,779,000	1,705,000		
						IV		898,800,000	2,301,000	2,183,000	1,686,000	1.32
Partial American River unit—Folsom and Auburn reservoirs, including afterbays	American River		1,186,000	235,000	50,100,000	I	3,302,000	762,500,000	2,463,000	899,000		
						II		730,000,000	1,828,000	1,474,000		

¹The estimated values of electric energy at the power plants are based on the cost of producing an equivalent amount of electric energy of the same characteristics with a steam-electric plant located in the area of consumption, taking into account the cost of transmission from point of generation to the load center, and are the lowest values resulting from several methods of evaluation.

The advantages of the American River unit over the Kennett reservoir are:

1. The capital investment for partial development would be \$34,000,000 less and for complete development \$15,500,000 less.
2. It could be constructed progressively.
3. The initial block of hydroelectric energy would be 48 per cent of that at Kennett, thus lessening the problem of power absorption.
4. It would be in a position to control floods on the American River to a degree that would greatly benefit the project of the American River Flood Control District and to a lesser extent the Sacramento Flood Control Project. With either the partial or complete unit, floods would be controlled to 100,000 second-feet or less, exceeded not oftener than once in 250 years, on the average, whereas the crest flow of the March 25, 1928, flood was 184,000 second-feet.
5. Water would be released below all of the riparian lands in the Sacramento River Basin above the city of Sacramento. The riparian acreage along the American River is small.
6. No major improvements would be flooded and therefore there would be less interference with existing interests.
7. The net annual cost of the partial development would be less, if revenues from sale of electric energy alone are considered, with no participation by the federal and state governments or other interests or agencies.

The advantages of the Kennett reservoir over the American River unit are:

1. It would be in a position to control floods on the Sacramento River, thus giving an added degree of protection to a large portion of the lands in the Sacramento Flood Control Project. Flows would be reduced to 125,000 second-feet mean daily flow on the day of the flood crest, measured at Red Bluff, exceeded once in fourteen years, on the average. The controlled flow exceeded once in 100 years, on the average, would be 187,000 second-feet due to the uncontrolled run-off between Kennett reservoir and Red Bluff, but flows in excess of 125,000 second-feet would be of short duration. The maximum flood flow of record at Red Bluff was 278,000 second-feet on February 3, 1909.
2. It would improve navigation facilities in the Sacramento River for 190 miles above the city of Sacramento.
3. It would furnish a full water supply to lands along the Sacramento River above Sacramento now under irrigation or having water rights. There would have been over 700,000 acre-feet of additional water available for these lands in 1924.
4. Both navigation and flood control benefits would be greater than with the American River unit.
5. If the reservoirs were operated primarily for irrigation, one and three-quarters times the amount of new water would be developed at three-fourths the cost per acre-foot.

It is seen from Table 31 that to meet salinity control, delta and immediate upper San Francisco Bay requirements only, the partial American River unit, comprising Folsom and Auburn reservoirs only, would meet these demands at a net annual cost \$270,000 less than the Kennett reservoir. However, to meet these requirements and also

make available 500,000 acre-feet of irrigation water per season for the San Joaquin Valley (with a deficiency of 31 per cent in 1924), the net annual cost would be \$1,474,000, as compared to \$1,471,000 with Kennett reservoir operated for the same requirements, except that the latter would make available 896,000 acre-feet per season, without deficiency, for the San Joaquin Valley. If Kennett reservoir were operated to make available only 500,000 acre-feet per season for the San Joaquin Valley, the difference in net annual cost would be even more in its favor. To meet the first requirements and also to make water to the extent of 896,000 acre-feet per season available in the delta for exportation, the Auburn and Folsom reservoirs would not be large enough and Coloma reservoir also would be required. With these three reservoirs in the American River unit, the net annual cost would be \$234,000 greater than for the Kennett reservoir. If there were no demand for several years for additional waters in the upper San Joaquin Valley over what could be obtained from the initial step of the development, Auburn and Folsom reservoirs would be able to meet the other demands and construction of Coloma reservoir could be deferred. If the period of deferment were less than eleven years, the Kennett reservoir would be the more economic unit to construct; if the deferment period were greater than eleven years, the American River unit would be the better. This period of deferment is based on the average annual costs for a forty-year amortization period and average annual revenues from power estimated for the forty-year period 1889-1929.

After careful consideration of all the foregoing advantages and disadvantages of each unit and in view of the possibility that water, in addition to that necessary for initial uses, would be required for exportation to the San Joaquin Valley during the earlier years of operation of the plan, and of the greater benefits that would accrue to the greater number of interests, particularly navigation and flood control, it is believed the first unit in the State Plan in the Sacramento River Basin should be the Kennett reservoir.

The methods of operation of the Kennett reservoir and its accomplishments already have been given. Studies have been made for the period 1919-1929 to estimate the amount of water which would have reached the Sacramento-San Joaquin Delta with the reservoir operated under Methods II and III, the amount that would have been surplus after all requirements were satisfied from this water, and the flows into Suisun Bay. The results of these studies are shown in Tables 32 to 35.

Table 32 shows the net annual amounts of water reaching the Sacramento-San Joaquin Delta with the Kennett reservoir operated under Method II, the amount required from this water for all purposes in the delta, the amount of water which would have flowed past Antioch into Suisun Bay for salinity control, the amount of water available for irrigation and industrial use in the San Francisco Bay Basin, the surplus water which would have reached the delta, in addition to that for the above requirements, and the total amount of water which would have flowed into Suisun Bay, including that required for salinity control. Table 33 is given to show the distribution of these surpluses and flows into Suisun Bay by months, in the years of maximum and of minimum run-off and the average for the whole period. This table shows no, or

TABLE 32
ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY WITH KENNETT RESERVOIR OPERATED AS AN INITIAL UNIT UNDER METHOD II*
1919-1929

Year	Net flow into delta in acre-feet ¹			Requirements from net flow into delta in acre-feet				Surplus water above all requirements in acre-feet	Total flow into Suisun Bay in acre-feet
	From Sacramento Valley	From San Joaquin Valley	Total from both valleys	Total gross allowance for delta	Salinity control lower end of delta	Industrial and irrigation use in developed areas along south side of Suisun Bay	Total		
1919	16,340,000	2,769,000	19,109,000	1,083,000	2,389,000	44,000	3,516,000	16,593,000	17,982,000
1920	12,625,000	2,312,000	14,937,000	1,083,000	2,395,000	44,000	3,522,000	11,415,000	13,810,000
1921	22,041,000	4,440,000	26,481,000	1,083,000	2,389,000	44,000	3,516,000	22,965,000	25,354,000
1922	19,755,000	6,997,000	26,752,000	1,083,000	2,389,000	44,000	3,516,000	23,236,000	25,628,000
1923	12,339,000	4,116,000	16,455,000	1,083,000	2,389,000	44,000	3,522,000	12,939,000	15,328,000
1924	7,302,000	1,108,000	8,410,000	1,083,000	2,395,000	44,000	3,522,000	4,888,000	7,283,000
1925	15,617,000	3,432,000	19,049,000	1,083,000	2,389,000	44,000	3,516,000	15,533,000	17,922,000
1926	14,819,000	2,190,000	17,009,000	1,083,000	2,389,000	44,000	3,516,000	13,483,000	15,862,000
1927	24,714,000	4,688,000	29,402,000	1,083,000	2,389,000	44,000	3,516,000	23,886,000	28,274,000
1928	17,216,000	3,285,000	20,511,000	1,083,000	2,395,000	44,000	3,522,000	16,989,000	19,384,000
Average	16,277,000	3,535,000	19,812,000	1,083,000	2,391,000	44,000	3,518,000	16,294,000	18,685,000

*See page 109 for explanation of Method II.
¹ Includes regulated water from Kennett, Friant and existing reservoirs, unregulated run-off and return waters.

TABLE 33
MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY
WITH KENNETT RESERVOIR OPERATED AS AN INITIAL UNIT UNDER METHOD II
1919-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1919-1929	
	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet
January	2,621,000	2,794,000	613,000	816,000	1,794,000	1,997,000
February	7,514,000	7,697,000	1,038,000	1,228,000	3,142,000	3,328,000
March	3,883,000	4,096,000	533,000	736,000	2,674,000	2,877,000
April	4,096,000	4,262,000	492,000	688,000	2,537,000	2,753,000
May	2,904,000	3,107,000	64,000	267,000	2,174,000	2,377,000
June	1,853,000	2,049,000	10,000	206,000	1,088,000	1,284,000
July	239,000	442,000	0	203,000	201,000	404,000
August	118,000	321,000	0	203,000	87,000	290,000
September	177,000	373,000	63,000	259,000	150,000	346,000
October	348,000	551,000	364,000	567,000	350,000	553,000
November	1,179,000	1,378,000	762,000	958,000	888,000	1,094,000
December	1,084,000	1,287,000	979,000	1,182,000	1,209,000	1,412,000
Total	25,890,000	28,274,000	4,888,000	7,283,000	16,294,000	18,685,000

TABLE 34
ANNUAL WATER REQUIREMENTS AND SURPLUS IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY
WITH KENNETT RESERVOIR OPERATED AS AN INITIAL UNIT UNDER METHOD III
1919-1929

Year	Net flow into delta in acre-feet ¹			Requirements from net flow into delta in acre-feet					Total flow into Suisun Bay in acre-feet
	From Sacramento Valley	From San Joaquin Valley	Total from both valleys	Total gross allowance for delta	Salinity control to lower end of delta	Full irrigation supply for "crop lands" in San Joaquin Valley having rights to water to be diverted at Friant ²	Industrial and irrigation use in developed areas along south side of Suisun Bay	Total		Surplus water above all requirements in acre-feet
1919	16,337,000	2,769,000	19,106,000	1,083,000	2,389,000	896,000	44,000	4,412,000	14,694,000
1920	12,642,000	2,312,000	14,954,000	1,083,000	2,395,000	896,000	44,000	4,418,000	10,536,000
1921	21,999,000	4,440,000	26,439,000	1,083,000	2,389,000	896,000	44,000	4,412,000	22,027,000
1922	19,728,000	6,997,000	26,725,000	1,083,000	2,389,000	896,000	44,000	4,412,000	22,313,000
1923	12,306,000	4,116,000	16,422,000	1,083,000	2,389,000	896,000	44,000	4,412,000	12,011,000
1924	7,031,000	1,108,000	8,139,000	1,083,000	2,389,000	896,000	44,000	4,412,000	3,721,000
1925	15,407,000	3,432,000	18,839,000	1,083,000	2,389,000	896,000	44,000	4,412,000	14,427,000
1926	15,231,000	2,190,000	17,421,000	1,083,000	2,389,000	896,000	44,000	4,412,000	13,009,000
1927	24,904,000	4,688,000	29,592,000	1,083,000	2,389,000	896,000	44,000	4,412,000	25,180,000
1928	17,128,000	3,295,000	20,423,000	1,083,000	2,395,000	896,000	44,000	4,418,000	16,005,000
Average	16,271,000	3,535,000	19,806,000	1,083,000	2,391,000	896,000	44,000	4,414,000	15,392,000

¹See page 112 for explanation of Method III.

²Includes regulated water from Kennett, Friant and existing reservoirs, unregulated run-off and return waters. The amounts shown for the San Joaquin Valley include such portions of these waters intercepted by the San Joaquin River pumping system before reaching the delta as could be used in supplying "crop land" rights in this valley, obviating the pumping of that portion of this supply from the delta.

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

TABLE 35
MONTHLY DISTRIBUTION OF SURPLUS WATER IN SACRAMENTO-SAN JOAQUIN DELTA AND FLOW INTO SUISUN BAY
WITH KENNETT RESERVOIR OPERATED AS AN INITIAL UNIT UNDER METHOD III
1919-1929

Month	Year of maximum run-off, 1927		Year of minimum run-off, 1924		Average for period 1919-1929	
	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet	Surplus water above all requirements in acre-feet	Flow into Suisun Bay in acre-feet
January	2,701,000	2,904,000	534,000	737,000	1,752,000	1,955,000
February	7,485,000	7,670,000	871,000	1,091,000	3,125,000	3,311,000
March	3,531,000	4,034,000	442,000	645,000	2,451,000	2,854,000
April	3,951,000	4,147,000	384,000	580,000	2,371,000	2,667,000
May	2,745,000	2,948,000	0	293,000	2,065,000	2,268,000
June	1,690,000	1,888,000	0	196,000	1,440,000	1,536,000
July	87,000	300,000	0	293,000	94,000	297,000
August	10,000	213,000	0	293,000	4,000	207,000
September	100,000	296,000	50,000	246,000	79,000	275,000
October	320,000	523,000	280,000	463,000	314,000	517,000
November	1,047,000	1,243,000	505,000	701,000	785,000	981,000
December	1,292,000	1,405,000	675,000	875,000	1,212,000	1,413,000
Total	25,180,000	27,569,000	3,721,000	6,116,000	15,392,000	17,783,000

only a small, surplus in the summer months, but large quantities of fresh water in excess of those required for salinity control in eight or nine months of the year. These excess flows would improve the salinity condition in upper San Francisco Bay, making it practically equivalent to natural conditions existing before expansion of irrigation and reclamation development in the Great Central Valley.

Table 34 shows the corresponding results for the operation of the Kennett reservoir under Method III, except that in this case the amount of water available for irrigation supply for lands in the San Joaquin Valley also is shown. It may be noted that the amounts of surplus water and total flow into Suisun Bay would be smaller than under Method II because of the allowance for the San Joaquin Valley. However, they are still substantial quantities. Table 35 contains the same information for Method III as is presented in Table 33 for Method II.

San Francisco Bay Region.

The portion of the San Francisco Bay region which appears to be most in need of a supplemental water supply to take care of immediate requirements and shortages in the local resources is the part of Contra Costa County lying south of Suisun Bay.

At present the industries in the Pittsburg-Antioch area, which use large quantities of fresh water for process and boiler purposes, obtain their water supply partly from wells and partly from the river. Both sources are limited under present conditions. The annual invasion of saline water into the upper bay region renders the waters in the bay and adjacent channels so salty that this source usually can not be used for fresh water requirements during several months of the year. Wells have been developed in this area to supply fresh water needs from underground sources, but the waters in many of them have turned salty by reason of some cause as yet undetermined. There appears to be an urgent need for an adequate and dependable fresh water supply to serve the industries in this area.

The agricultural development in this section is suffering from an insufficient water supply which can not be remedied by additional development of local water resources. Underground water levels have receded during the last ten years to such an extent that the orchards and vineyards, which previously, under natural conditions, have been successfully operated without irrigation, are now in need of irrigation. There are at present 18,000 acres of cultivated lands in the Ygnacio and Clayton valleys near Concord and Walnut Creek, of which only about 3500 acres are under irrigation from underground water supplies. The present irrigation draft, combined with the draft of the public water supply company and industries diverting water from underground sources in the valley, are 50 per cent greater than the average annual underground supply available under natural replenishment from the tributary streams. Due to the large drop in the water table, there appears to be a demand for an extension of irrigation and it is estimated that a gross area of 7000 acres in the Ygnacio and Clayton valleys might be expected to use an irrigation supply if available.

In addition, there is a highly developed agricultural area south of the San Joaquin River and east of Antioch, with a gross area of about

6000 acres, which would be benefited by irrigation. It is evident that there has been a lack of adequate moisture for the orchards and vineyards in this area.

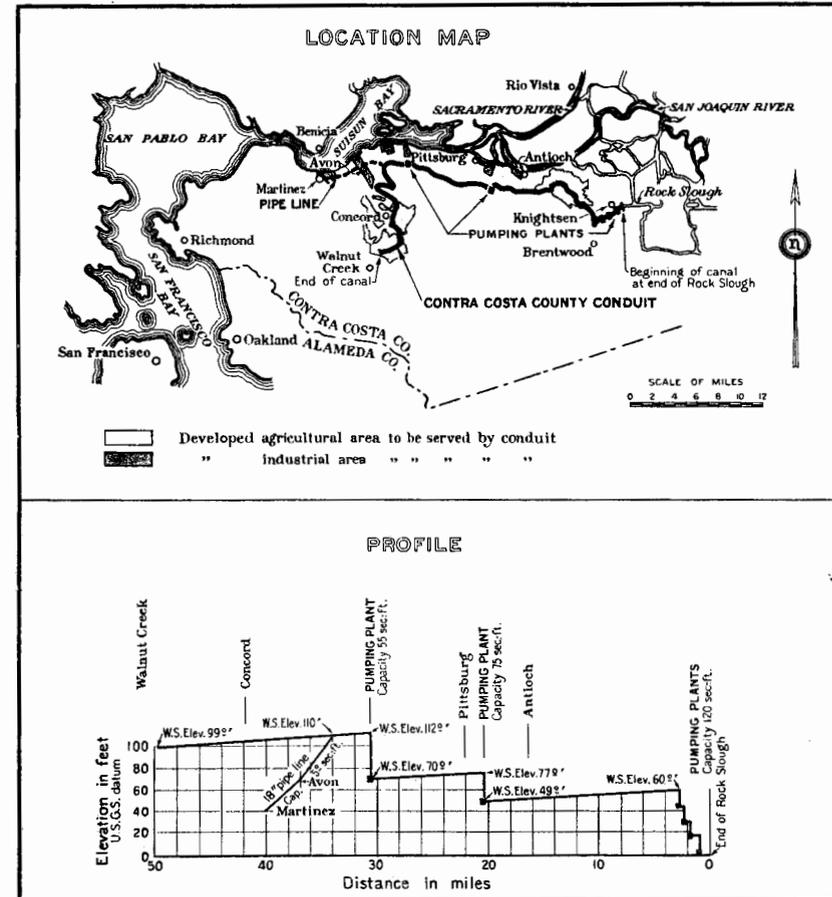
Studies and preliminary designs, including cost estimates, have been made for a conduit to serve the combined water demands of the industries and agricultural developments for the portion of Contra Costa County above described. This conduit and its relation to the agricultural and industrial areas, which it is designed to serve, are shown on Plate VIII, "Contra Costa County Conduit." It would have a point of diversion near Knightsen, at the westerly end of Rock Slough, and, with a succession of pumping plants, extend westerly on the south side of Suisun Bay and into the Clayton and Ygnacio valleys, with a total length of about 50 miles.

The capacity of the conduit is based upon the irrigation of 80 per cent of the gross area of about 13,000 acres of agricultural lands, with a maximum monthly requirement of 25 per cent of the total seasonal irrigation requirements, assumed at two acre-feet per acre, requiring a maximum rate of 86 second-feet; and an industrial fresh water demand of 34 second-feet, an amount estimated as ample to take care of the water requirements for the entire area from Antioch to Martinez for ten years or more. The present consumption of fresh water for process and boiler purposes by the industries in Contra Costa County in the Antioch-Martinez area amounts to about 13 million gallons per day or approximately 20 second-feet. The industries estimate that their fresh water demands will increase about 70 per cent by 1940, or to an amount of 22 million gallons per day, or approximately 34 second-feet. The plans for the initial unit have been designed to care for this combined demand.

The conduit would have a capacity of 120 second-feet at the head and decrease in successive steps to a minimum capacity of about 20 second-feet at the lower or westerly end. The elevation at which water would be held at various sections of the conduit is shown on the hydraulic profile on Plate VIII. Considerable pressure would be available for delivery of water supplies to the existing industries. Its elevation in relation to the agricultural lands is fixed on the basis of economy in operation and maintenance cost. Additional works and small pumping plants would be required to serve certain limited areas which lie above the main conduit. A branch pipe line from Bay Point to Martinez would serve the industries in this portion of the area. The total estimated cost of the initial unit is \$2,500,000. This includes an amount of 25 per cent to cover contingencies and administration, legal and engineering expenses, and interest at $4\frac{1}{2}$ per cent per annum for a construction period of one year.

The annual cost of water delivered from this conduit would depend upon the amount used. If it be assumed that the entire industrial and irrigation supply which the conduit is designed to deliver would be used, the total annual cost would be \$300,000 for the delivery of 43,500 acre-feet. This includes interest at $4\frac{1}{2}$ per cent, amortization at four per cent on a forty-year sinking fund basis, depreciation, maintenance and operation, including electric energy pumping charges. On this basis the cost of water at the conduit would be two and one-tenth cents per thousand gallons, or \$6.90 per acre-foot.

PLATE VIII



The plan for this initial unit to serve the upper Contra Costa County area is a reasonable and economical one and its consummation would meet the water requirements of this area for several years to come.

Upper San Joaquin Valley.

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

A study has been made of the ground water conditions in the five southern counties, namely, Madera, Fresno, Tulare, Kern and Kings. For convenience of study and in estimating amounts of depletion of ground water, areas within the first four counties were divided into ten major ground water units, namely, Madera, Fresno-Consolidated, Alta, Kaweah, Lindsay, Tule-Deer Creek, Earlimart-Delano, McFarland-Shafter, Rosedale and Edison-Arvin. The locations of these units are shown on Plate IX, "Ground Water Units and Developed Areas With Deficient Water Supply in Upper San Joaquin Valley." Lands under irrigation, developed areas with deficient water supply and initial units of State Plan for immediate development in upper San Joaquin Valley also are shown on the plate.

The Madera unit is bounded on the north by the Chowchilla River and on the south by the San Joaquin River. Its eastern limit is along the line of the Santa Fe Railroad and it extends westward an average distance of fifteen miles to the limits of the higher class lands. The gross area of the unit is 343 square miles and the area irrigated in 1929 was 81,000 acres. The Fresno-Consolidated unit includes the total combined area of the two irrigation districts from which its name is derived and a small additional area under pumping development just west of these districts. It extends from the San Joaquin River to the Kings River and has a gross area of 700 square miles, of which 321,800 acres were irrigated in 1929. The Alta unit lies immediately south of the Kings River and its boundaries coincide approximately with those of the Alta Irrigation District. The gross area is 191 square miles, of which an average area of 79,000 acres was irrigated during the period 1921-1929. The Kaweah unit includes that portion of the Kaweah Delta served by surface waters from that stream. Its northern limit is at Cottonwood Creek and the southern limit two miles south of the Fifth Standard Parallel near Waukena. The eastern limit is about two miles east of Exeter and the western limit one mile east of the east line

of Range 22 East at Waukena. The gross area is 468 square miles and the average area irrigated is 133,700 acres. The Lindsay unit lies just south and east of the Kaweah unit. It includes a large portion of the Lindsay-Strathmore Irrigation District and all of Township 20 South, Range 26 East. The gross area is 64 square miles and the irrigated area 22,000 acres. The Tule-Deer Creek unit is bounded on the north by the Kaweah and Lindsay units, along the line of the Fifth Standard Parallel. It extends southward about sixteen miles to a line two miles north of Earlimart. The eastern limit is near Porterville and the western limit is four miles east of Angiola. The gross area is 373 square miles, of which an average area of 67,400 acres is irrigated. The Earlimart-Delano unit includes the pump developed areas around those two towns. It is bounded on the north by the Tule-Deer Creek unit and extends southward for eleven miles to an east and west line three miles south of the north line of Kern County. The eastern limit is along the Southern Pacific branch line between Richgrove and Ducor and the western limit is the west line of Range 25 East. The gross area is 150 square miles and the area irrigated in 1929 was 30,500 acres. The McFarland-Shafter unit extends southward from the Earlimart-Delano unit, a distance of 21 miles, to the Seventh Standard Parallel. The eastern boundary is about two miles east of the Southern Pacific Railroad and the state highway and the western limit is the west line of Range 24 East. The gross area is 310 square miles and the average area irrigated during the period 1921-1929 has been 49,800 acres. The Rosedale unit lies immediately south of the Seventh Standard Parallel and extends southward for a distance of five and one-half miles. Its eastern limit is along the Kern River near Bakersfield and the western boundary is near Rio Bravo. The gross area is 79 square miles and the average area irrigated during the period 1920-1929 has been 12,300 acres. The Edison-Arvin unit includes the pump irrigated areas lying above the East Side Canal on the south side of Kern River. Its northern limit is that of the developed area between Bakersfield and Edison from which it extends southward, a distance of fourteen miles, to the south line of Township 31 South. The eastern limit is that of the intensive development around Arvin and on the cone of Caliente Creek. The gross area of the unit is 51 square miles and the area irrigated in 1929 was 20,000 acres.

For all units the studies cover the eight-year period 1921-1929. In the Kern County units, the records covered the nine-year period 1920-1929 but in order to make the studies in all of the units comparable the eight-year period was used throughout. Data on some 4000 wells distributed over the entire area, were available for the study. Utilizing all the available data, an analysis was made, year by year, of ground water conditions in each unit for the period 1921-1929. The results of the analysis are given in Table 36. In this table are set forth for each unit the total and average seasonal depletion of ground water and also the area of the unit and the average area irrigated for the period studied.

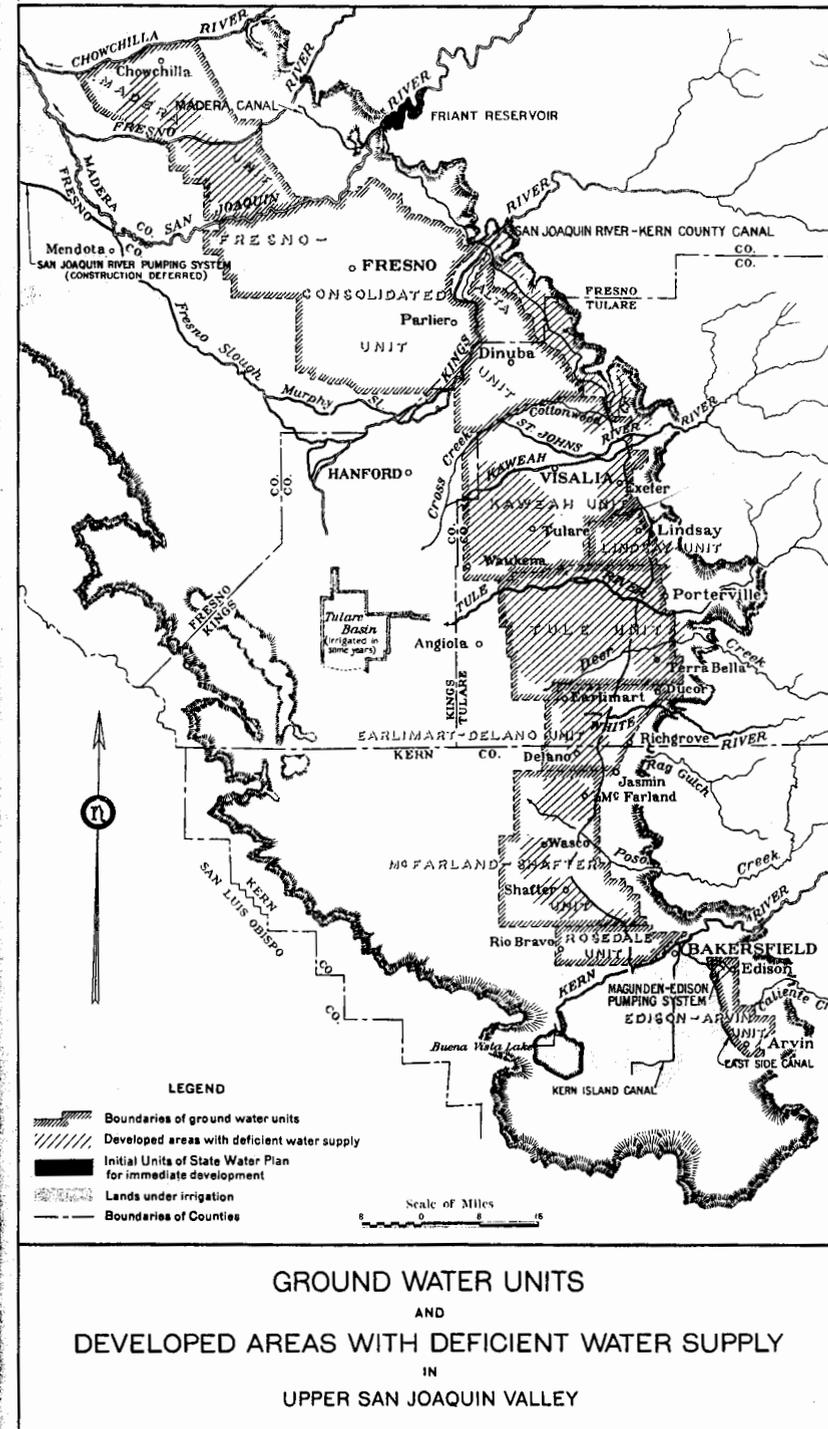


TABLE 36
CHANGE IN VOLUME OF GROUND WATER IN UPPER SAN JOAQUIN VALLEY
BY GROUND WATER UNITS
1921-1929

Unit	Area of unit in square miles	Average area irrigated in acres	Depletion of ground water in acre-feet	
			Total	Average per season
Madera.....	343	89,000	487,000	61,000
Fresno-Consolidated.....	700	319,900	586,000	71,000
Alta.....	191	79,000	161,000	20,000
Kaweah.....	468	133,700	732,000	92,000
Lindsay.....	64	22,000	148,000	19,000
Tule-Deer Creek.....	373	67,400	447,000	56,000
Earlimart-Delano.....	150	21,200	400,000	50,000
McFarland-Shafter.....	310	50,100	491,000	61,000
Rosedale.....	79	12,000	69,000	9,000
Edison-Arvin.....	51	18,600	103,000	13,000

The boundaries of ground water units have been selected in each case to include irrigated lands with a common source of water supply, whether from surface or underground development. By a study, year by year, during the period 1921-1929, of the collected data on monthly surface inflow, irrigated area and change in ground water level for each ground water unit, it has been possible to estimate the average seasonal inflow required to support the existing irrigation development and prevent a continuous recession of the ground water. The seasonal inflow into any particular area is defined as that part of the tributary run-off actually entering the area, less known exportations and surface outflow from the area. Since ground water is a form of cyclic storage, fluctuations in level are permissible from year to year so long as the minimum levels do not increase pumping lifts beyond the economic limit. The fact that, during a period of subnormal inflow, a lowering in the ground water has occurred in an area of pumping development does not necessarily mean that it is an area with a supply inadequate to meet existing irrigation demands. If, however, the long-time available mean seasonal inflow to the ground water unit is less than that estimated as the mean requirement, it is concluded the area is one of deficient local supply as now utilized. On this basis, the conditions in each ground water unit have been studied and the total and mean seasonal depletion of ground water storage estimated. Estimates of depletion in each unit are for the entire area. In some units, portions of the area, due to their favorable position on the schedule of utilization of local surface supplies, are without deficiency, even in periods of subnormal run-off. In such units the ground water contour maps for each year of record show clearly, by cones of depression in the water table, where the overdraft upon the ground water is greatest. It is not feasible, however, to exactly define the boundary of the area of deficiency, to say what part of the overdraft is due to pumping in adjacent areas, nor is it safe to assume that, upon the introduction of an imported supply to relieve the deficiency, new lands around the fringe will not come under development.

For these reasons no attempt has been made to lay down the exact boundaries of the areas of deficiency within each ground water unit,

but only to indicate their general location and to estimate the requirement for imported water to restore the balance between supply and draft.

The depletion of ground water for the period 1921-1929 in the several ground water units, as set forth in Table 36, reflects the relation between the inflow and the net draft during the period of ground water record. It so happens that the entire range of continuous observations of ground water conditions falls within a period of subnormal run-off. The occurrence of a year of normal run-off during this dry cycle is sharply reflected in the ground water conditions in some of the units.

It is not sufficient to use the data of a series of dry years alone in determining which of the ground water units have inadequate local supplies. Examination also must be made of the relation between average seasonal inflow during the recent period of depletion and the seasonal inflow for various periods. However, in this investigation in estimating the seasonal inflow to a certain area for periods longer than that of ground water measurement, a somewhat different basis was used. Under this procedure the inflow was taken as the part of the estimated tributary run-off practicable of utilization through the full use of existing physical works and underground storage, less exportation and surface outflow from the area, as under present conditions of development. The exportation and surface outflow records considered were obtained from outflow data for seasons of corresponding run-off during the period of measurement. For the purpose of setting up such a comparison Table 37 has been prepared. In this table the average seasonal depletion of ground water occurring during the period of continuous record, 1921-1929, and the corresponding inflow for the same period are shown for each unit. It is obvious the depletion of the underground storage represents an overdraft upon the available supply, and therefore the sum of this depletion and the inflow for the same period is the value of the average seasonal inflow which would have been adequate to maintain stable ground water conditions during this period. The summations shown in the last column are for the purpose of determining whether each unit is one of permanent deficiency in local supply. The quantities in this column may be compared with the average seasonal inflow for each of the five, eight, twenty and forty-year periods ending in 1929. The average seasonal inflows set forth in the table for the Tule-Deer Creek unit for the various periods contain a supply for about 5000 acres of developed lands lying east of the unit and for which no records of ground water or diversion are available. Similarly for the Kaweah unit, the figures of average seasonal inflow contain a supply for 3600 acres lying east of the unit. It was impracticable to segregate the use on these two particular areas from the total inflows which should be done to obtain exact figures for the inflow into the respective units. However, this approximation does not affect the conclusions as to the deficiencies in supply in these units.

The Madera Unit—The Madera unit is one in which the draft upon the ground water evidently exceeds the replenishment that would be effected even over a forty-year period including both wet and dry cycles. During the eight-year period 1921-1929, the irrigated area in this unit increased from 60,000 to 81,000 acres. The sources of water supply now utilized in this area are the Chowchilla and Fresno rivers, augmented

TABLE 37

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

Ground water unit	Average seasonal depletion in ground water, 1921-1929, in acre-feet	Average seasonal inflow to ground water unit in acre-feet				Required average seasonal inflow to prevent depletion in acre-feet ¹
		40-year period 1889-1929	20-year period 1909-1929	8-year period 1921-1929	5-year period 1924-1929	
Madera.....	81,000	144,200	121,000	111,400	101,400	172,400
Fresno-Consolidated.....	71,000	770,000	680,000	537,000	588,200	608,000
Alta.....	20,000	225,000	182,000	133,900	145,300	133,900
Kaweah.....	92,000	370,000	297,000	250,800	248,200	342,800
Lindsay.....	19,000	(²)	(²)	13,900	14,000	44,000
Tule-Deer Creek.....	56,000	155,000	130,000	92,300	87,100	148,300
Earlimart-Delano.....	50,000	4,000	3,500	2,800	2,800	52,800
McFarland-Shafter.....	61,000	86,000	79,000	38,900	27,100	99,900
Rosedale.....	9,000	87,000	81,000	46,700	41,200	55,700
Edison-Arvin.....	13,000	37,000	29,000	23,600	22,100	36,600

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

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

by an importation of about 10,000 acre-feet each year from the Merced and San Joaquin River drainage areas. The average seasonal inflow available during this period was 111,400 acre-feet. With this inflow the average seasonal depletion of ground water was 61,000 acre-feet and that during the season 1928-29 was 146,000 acre-feet. The forty-year average seasonal inflow available is estimated as 144,200 acre-feet, or 32,800 acre-feet in excess of that during the period of ground water record. Comparing this with the 61,000 acre-feet of average seasonal depletion, it is obvious present development could not have been supported without an overdraft on the ground water storage.

The Fresno-Consolidated Unit—The data on the Fresno-Consolidated unit show no indication of permanent depletion of its ground water storage. The Fresno and Consolidated irrigation districts, which are included within this unit, have been under practically full irrigation development for some years. The Fresno district has extensive diversion rights of relatively early priority on Kings River and receives a more dependable water supply, both in amount and in distribution through the season, than other large areas on Kings River. From the inception of irrigation in this area to the beginning of the period of this study, the ground water had risen some 50 feet above its position prior to irrigation. This resulted in the water-logging of a considerable portion of the area now in the district and it is only with the development of pumping and the recent series of dry years that conditions favorable to the proper production of crops have been reached. The depth to ground water over the greater part of the Fresno district varies from ten to twenty-five feet. At the extreme northern edge of the district the depth to ground water ranges from 50 to 70 feet. The average total lowering in different parts of the district for the eight-year period of record was approximately six feet. The water rights of the Consolidated district furnish only a limited supply at medium to low stages of Kings River, but yield a large flow during the short

period of high water. This condition results in an unfavorable distribution of the season's total supply and for this reason practically all canal-irrigated lands are equipped for supplemental pumping. The average depth to ground water varies from ten to twenty-five feet, with an area of two or three sections on the bank of Kings River, just east of Parlier, having a depth of 50 feet. The average total lowering during the eight-year period varied from five to ten feet, with a small area near Kings River having a lowering of fifteen feet. The quantities in the table show that, while the seasonal inflow has been somewhat inadequate during the recent years of subnormal run-off, the average seasonal inflow for either the twenty or forty-year periods preceding 1929 could have supported the present development of the unit with a safe margin. For the five and eight-year periods the average deficiency in seasonal inflow into this unit was only about one-tenth of the full requirement.

The Alta Unit—The Alta unit, which consists principally of the Alta Irrigation District, is similar to the Fresno-Consolidated as to the sufficiency of its water supply, in that, for the long-time average, the inflow is adequate to support the present irrigation development, with the possible exception of an area of 5000 acres along its eastern rim. In this limited area a total lowering of ground water of from 25 to 35 feet occurred during the period of observation. In the central portion of the district the total lowering has been from five to fifteen feet and twenty-five feet in a very limited area. The present depth to ground water varies from fifteen to thirty-five feet. The data for this unit show that, with proper distribution of local supplies, the twenty and forty-year values of average seasonal inflow are adequate to meet the needs of the unit with a liberal margin of safety.

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

The Kaweah Unit—The Kaweah unit, including all of the area naturally dependent upon the Kaweah River for its water supply, is apparently one in which, over the forty-year period, the local sources of supply are adequate. However, the higher eastern portion of the unit around Exeter is so situated that it receives no portion of the available surface flow so that its principal source of ground water replenishment must be through relatively impervious materials from the west. A deep trough of depression in the ground water is

revealed by a study of ground water levels in this area. The total lowering during the period of record has been from 20 to 50 feet. The present depth to ground water is from 50 to 110 feet. This portion of the unit has relatively nonabsorptive soils and it is concluded an additional supply must be provided, chiefly in the form of surface application. At the extreme north edge of the unit, but slight lowering of the water table has occurred during the period of record. In the areas served by canals the lowering has been from five to fifteen feet. Farther from canal service and near the town of Tulare, extensive pumping development has resulted in a lowering of from 25 to 35 feet. While the tabular quantities show that the forty-year average seasonal inflow is adequate to support existing development, it is judged that its distribution throughout the area in accordance with existing rights probably will result in some permanent depletion.

The Lindsay Unit—The Lindsay unit lies between the deltas of the Kaweah and Tule rivers in a locality of small tributary inflow. It is devoted largely to citrus culture and is one of the oldest pumping areas in the San Joaquin Valley. It is relatively distant from the Tule and Kaweah rivers and out of the line of ground water movement from the deltas of these streams. The lack of any active source of ground water replenishment is shown by the rapid rate of lowering which has occurred. Practically the only source of inflow to this area during the period of record has been the seasonal importation of about 14,000 acre-feet pumped from a well field at the head of the Kaweah Delta by the Lindsay-Strathmore Irrigation District. The total ground water lowering during the period 1921-1929 averaged 55 feet, with a range of 25 to 75 feet. The present depth to ground water varies from 25 to 175 feet.

The Tule-Deer Creek Unit—The Tule-Deer Creek unit includes lands dependent upon the Tule River and Deer Creek for their ground water replenishment. A total average lowering of ground water during the eight-year period of record has been 23 feet. Along the main line of the Southern Pacific Railroad the depth to ground water varies from 50 to 70 feet. At the westerly edge of the unit the depth is about 30 feet and at the eastern rim of the unit southeast of Terra Bella the depth to ground water is 200 feet. Although the forty-year average seasonal inflow shows a slight excess above the average requirement for this area, the average seasonal inflows for the twenty, eight and five-year periods show marked deficiencies. It is concluded that this area is one requiring an imported supply. Over the southeastern portion of this unit the soil types are considered nonabsorptive and an imported water supply will have to be delivered, chiefly in accordance with a surface irrigation demand.

The Earlimart-Delano Unit—The Earlimart-Delano unit includes the east side valley lands from Earlimart and Ducor on the north to the southern limit of the Delano development in northern Kern County. This is an area of extremely limited tributary run-off. White River is the only stream draining higher foothill areas. Rag Gulch drains additional low foothill areas. All irrigation development is by pumping. The irrigated area increased from 11,600 acres in 1921 to 30,500 acres in 1929 and the tabulated figures show the great discrepancy

between available inflow and the overdraft to date. East of Delano a maximum lowering of the water table of 70 feet has occurred in the eight-year period, with a lowering of 50 feet shown for a large area. At the north end of the unit, depths to ground water range from 50 feet at Earlimart to 200 feet just east of Ducor, with a midway depth of 100 feet. At the south limit of the unit, the range is from 25 feet at the west to 200 feet near Jasmin on the east, with a midway depth of 125 feet just east of Delano. An examination of the seasonal inflows and the depletion of ground water in this unit shows that it requires an additional supply almost equal to its total irrigation needs for present development.

The McFarland-Shafter Unit—The McFarland-Shafter unit, bordering the Earlimart-Delano unit on the south, extends southward 21 miles and includes within its boundaries the highly developed areas around the towns of McFarland, Wasco and Shafter. These irrigated areas are dependent entirely upon a supply pumped from the underlying ground water. There also are some 60,000 acres of land lying for the most part above the pumping developments, which are properly located to receive surface irrigation from existing canals of large capacity but with diversion rights of late priority on the Kern River, included within the unit. With the exception of Poso Creek, which is estimated to contribute a long-time mean seasonal replenishment of 17,000 acre-feet to the ground water of this unit, the only source of replenishment for the ground waters underlying the pump-developed areas are the losses of conveyance and distribution from the supplies delivered through canals to the large area dependent upon surface irrigation. These canal-irrigated lands are in one ownership and, in past cycles of high run-off, have been liberally supplied with water, the effect of which during the period from 1880 to 1920 was to raise the natural water table about 50 feet. Pumping development began about 1910 and has continued steadily ever since. At approximately the same time the pumping draft reached proportions accounting for the average seasonal replenishment, a cycle of subnormal run-off began. The effect of these two conditions of steadily increasing draft and diminishing inflow is sharply reflected in the data for this unit. The maximum total lowering of the water table during the period of ground water record has been 40 feet at McFarland, about the same near Wasco, and about 30 feet at Shafter. The depths to ground water at these points, as of October, 1929, were from 50 to 100 feet at McFarland and from 50 to 75 feet in the vicinity of Wasco and Shafter.

The data for this unit indicate that even the forty-year average seasonal inflow would have been entirely inadequate to support existing development. The propriety of including these pumping areas in an immediate initial project may be questioned when it is remembered that careful studies of the Kern River area for a local project indicate that, if properly utilized through the combined medium of surface and ground water storage, the run-off of that stream is adequate to serve all the area now within the outlines of existing canal systems and dependent more or less directly thereon for a water supply. However, the existing status of the recognized diversion rights on the stream is such that, without construction of a complete system of regulatory works, no relief

can be expected from the receding ground water underlying the pumping areas of McFarland, Wasco and Shafter. The extension of a main importation canal past these areas would be a progressive step toward ultimate development and in order to afford relief to the Magunden-Edison area it would be necessary to construct the canal as far as Kern River, where exchange could be made with some of the existing rights. This extension also would be desirable for providing spillway facilities at the canal terminus. Taking into consideration all of these factors, it is concluded this area is one requiring an imported supplemental supply.

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

Canal Irrigated Area South of Kern River—South of the Kern River lies an agricultural area of some 100,000 acres which for forty years has been in the same general state of irrigation development. This area has an adequate supply under diversion rights of early priority on Kern River. The ground water problem in this area is one of drainage. With the recent series of dry years the ground water is at a depth of about ten feet from the ground surface.

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

The Edison-Arvin Unit—Contiguous to the East Side Canal area on the east lies the Edison-Arvin unit. This unit includes in its southern portion the entire area developed under pump irrigation on the cone of Caliente Creek and around the town of Arvin. In its northern portion it includes the citrus development around Edison and the area devoted to both citrus and deciduous fruits extending on both sides of the Southern Pacific Railroad from Edison westward past Magunden toward Bakersfield. The principal source of replenishment for the ground water of this unit is the run-off of Caliente Creek. The existence of a cone of depression under this area, caused by heavy pumping draft during the past five years, has lowered the water table under this area below that under the East Side Canal three miles

away. This condition can not long continue without appreciable movement of ground water from the canal area to the Arvin area. The total irrigation development under pumping on the Caliente Creek fan is 17,400 acres and the long-time mean yield of the tributary drainage area is 37,000 acre-feet. During the period of ground water record, 1920-1929, the average seasonal inflow from Caliente Creek is estimated as 22,900 acre-feet and under these conditions there has occurred a lowering of from ten feet to thirty feet with resulting depths, as of October, 1929, varying from 70 feet near the East Side Canal to 200 feet at the eastern limit of the development. The data indicate that even though the forty-year average inflow shows a slight excess over the mean requirement, the twenty-year average inflow is inadequate for a full supply. The northern portion of this unit, the area of permanent deficiency, can not avail itself of any of the local supply from Caliente Creek because of its relative elevation and impervious subsoil. Between the developed area around Arvin and that around Magunden and Edison there is an uncropped area underlain by a relatively high water table which separates the cones of depression underlying each of the developed areas.

A study of the geologic, run-off and ground water conditions of the Magunden-Edison area indicate that the principal source of replenishment is from the apex of the delta cone of the Kern River as that stream passes beyond the impervious toe of Kern Bluffs at Bakersfield, and from the East Side Canal. From Bakersfield to the bottom of the ground water depression underlying this development, the water table descends 50 feet in seven miles. From the East Side Canal the fall is about six feet in two miles. These slopes indicate some movement of ground water, but they have been created by a total lowering of 20 feet for the period of record, 1920-1929. This movement, however, is inadequate to support the existing development. It is estimated that a net area of 2600 acres in the Magunden-Edison area is in need of a supply of two acre-feet per acre, or a seasonal total of 5200 acre-feet.

Other Areas Studied—In selecting areas in need of immediate relief, those used for annual crops under canal irrigation varying in adequacy from year to year and those of high ground water, where good opportunities are afforded for pumping development, have not been included. Within these excluded classes fall Kern County areas in the Buena Vista Water Storage District, Pioneer Canal area, Buttonwillow and Semitropic ridges and the canal-irrigated areas above discussed in the McFarland-Shafter unit. The Kings County Canal area also falls in these classes. It lies immediately south of the Kings River channel and contiguous to the Kaweah unit on the west. The gross area is 159,000 acres served by gravity waters from the Kings River under the diversion rights of the Peoples, Last Chance and Lemoore canals. The water supply has been sufficient to cause high ground water under much of the area. Some supplemental pumping has obtained in recent years, but has not attained proportions comparable with the upper Kings River areas. During the recent years of subnormal run-off the water table has receded somewhat. In the fall of 1929, depths to ground water varied from ten to fifteen feet. In normal years drainage would be beneficial to this area.

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

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

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

24,000 acre-feet. The obvious source of replenishment of these ground water supplies is the outflow from the Fresno Irrigation District.

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

Estimation of Relative Deficiencies in Water Supply—The total depletion of ground water storage for a given period is not an absolute measure of the degree of water shortage in any particular area. Other factors must be given consideration. Therefore, in determining the developed areas in the upper San Joaquin Valley which need immediate relief in the form of a supplemental supply from an outside source, consideration and weight also have been given to the extent of the area under irrigation, the relative and total lowering of the ground water plane during the eight-year period 1921-1929, as well as the seasonal inflow for this and longer periods. The factors used in estimating the relative deficiencies in water supplies of the ground water units are shown in Table 38. For each unit the irrigated area, the average seasonal lowering of ground water, the required average seasonal inflow to prevent depletion and the average seasonal ground water depletion, expressed in total acre-feet, acre-feet per acre and per cent of required average seasonal inflow to prevent depletion, are given.

Units now under development having comparatively small lowering of their ground water levels and an average seasonal inflow for the twenty-year period 1909-1929 adequate for complete replenishment thereof, have no permanent deficiencies of water supply even though the records for the 1921-1929 period indicate ground water depletion. A study of the data in Table 38 shows that the Fresno-Consolidated unit, Alta unit, excluding 5000 acres of rim land, and Rosedale unit fall in this classification. The Edison-Arvin unit, excluding 2600 acres in the Magunden-Edison area, also is placed in this classification although the estimated average inflow into the unit for the twenty-year period is slightly less than the estimated required average inflow to prevent depletion for the eight-year period. However, the average inflow, as estimated for a twenty-five year period 1904-1929, is adequate.

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

TABLE 38
FACTORS USED IN ESTIMATING RELATIVE DEFICIENCIES IN WATER SUPPLY OF IRRIGATED AREAS IN UPPER SAN JOAQUIN VALLEY—1921-1929

Unit	Average area irrigated in acres	Average seasonal lowering of ground water in feet	Required average seasonal inflow to prevent depletion in acre-feet ¹	Average seasonal ground water depletion		
				Total acre-feet	Acre-feet per acre	Per cent of required average seasonal inflow to prevent depletion
Madera.....	69,000	1.4	172,400	61,000	0.88	35
Alta-Foothill.....	16,000	.....	32,000	32,000	2.00	100
Kaweah.....	133,700	2.3	342,800	92,000	0.69	27
Lindsay.....	22,000	6.9	44,000	19,000	0.86	43
Tule-Deer Creek.....	67,400	2.8	148,300	56,000	0.83	38
Earlimart-Delano.....	21,200	4.2	52,800	50,000	2.36	95
McFarland-Shafter.....	50,100	3.1	99,900	61,000	1.22	61
Magunden-Edison.....	2,600	.....	5,200	5,000	2.00	100
Fresno-Consolidated.....	319,900	0.8	608,000	*71,000	0.22	12
Alta—						
Including 5000 acres of rim land.....	79,000	1.4	153,900	20,000	0.25	13
Excluding 5000 acres of rim land.....	74,000	.....	143,900	10,000	0.14	7
Rosedale.....	12,000	1.3	55,700	9,000	0.75	16
Edison-Arvin—						
Including 2600 acres in Magunden-Edison.....	18,600	2.9	36,800	13,000	0.70	36
Excluding 2600 acres in Magunden-Edison.....	16,000	.....	31,400	8,000	0.50	25

¹ Sum of average seasonal depletion and average seasonal inflow.

* Includes present known outflow of about 17,000 acre-feet supplying lands in James Irrigation District, for which a supplementary supply is provided in plan of proposed immediate initial development.

Units having lowering of ground water levels and a net use in excess of their twenty-year average seasonal inflow are considered as areas of deficient supply. The units in this classification are Madera, Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter. The indicated present seasonal net requirement in the Kaweah unit of about 2.5 acre-feet per acre is due partly to subirrigated undeveloped lands not included in the tabulated area and partly to an unavoidable unbalanced condition of supply and use in different portions of the unit, which result from limitations imposed by prior diversion rights in certain areas and low absorptive factors in others.

Areas Requiring an Imported Water Supply—Based upon the foregoing considerations, it is concluded that the developed areas in the ground water units in the upper San Joaquin Valley requiring an imported supplemental water supply are those given in Table 39 and delineated on Plate IX. The figures in the table for irrigated areas are for 1929, except for the Kaweah and Tule-Deer Creek units, which are the average areas irrigated during the eight-year period 1921-1929.

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

TABLE 39

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

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

The average seasonal deficiency in supply for the period 1921-1929, as set forth in the summary, is estimated at 387,000 acre-feet. The maximum deficiency in one season was about 680,000 acre-feet in 1928-29. The minimum seasonal deficiency was about 100,000 acre-feet in 1921-22, excluding the figures for the Madera and Kaweah units which had a surplus in that season. To meet the deficiency in supply and to provide for ground water replenishment, it is estimated that importations of from 500,000 to 600,000 acre-feet would be required annually on the average.

The Supplemental Imported Water Supply—It has been pointed out in Chapter V that the most logical source of a supplemental water supply for the upper San Joaquin Valley is the San Joaquin River. The water supply considered available for an initial step for the early relief of the areas of deficiency, is that which can be developed from the utilization of surplus waters of that stream and those available by purchase under rights now devoted to inferior use on "grass lands" served by diversions above the mouth of the Merced River. It is proposed to acquire these waters with due consideration for all existing rights that may be invaded in the process. Sufficient water could be obtained from these sources to meet the needs of the developed areas of deficient water supply at a cost less than that from any other source. By this plan, the importation of water from the delta of the Sacramento and San Joaquin rivers would not be required until there was a demand for additional waters to irrigate new lands. Construction of the San Joaquin River pumping system, therefore, could be deferred. However, it should be included in the plan as an initial unit for the sake of insurance, because a succession of years drier than has been experienced in the past would result in an available supply less than estimated on the basis of records of the past eight or twelve years and would necessitate installation of the pumping system.

The physical works proposed for delivering a supplemental water supply to the upper San Joaquin Valley areas in need of new water are:

1. Friant reservoir with a gross capacity of 400,000 acre-feet and a usable capacity of 270,000 acre-feet above elevation 467 feet, diversion elevation of San Joaquin River-Kern County canal.

2. San Joaquin River-Kern County canal to Kern River with a maximum diversion capacity of 3000 second-feet.
3. Madera canal with a maximum capacity of 1500 second-feet.
4. Magunden-Edison pumping system.
5. San Joaquin River pumping system (construction deferred).

The general locations of the physical works above listed are shown on Plate IV. To further delineate the features of this system, there is presented Plate X, "Profile of San Joaquin Conveyance System."

In conjunction with the physical works, it is proposed to utilize to the greatest practicable extent the natural underground reservoirs underlying a large portion of the area.

The amounts of water that could be made available for immediate relief of these areas through the physical works proposed have been estimated, month by month, over the forty-year period 1889-1929, utilizing the surplus water and water not attached to areas devoted to crop production served from the San Joaquin River above the mouth of Merced River. The flow at Friant was estimated on the assumption that the existing storage reservoirs, with an aggregate capacity of 335,000 acre-feet, above Friant reservoir would have been operated primarily for power purposes during the entire forty-year period.

In making the yield studies for the immediate initial development, it was assumed that the first demand upon the flow entering Friant reservoir would be to satisfy a schedule of monthly requirements of San Joaquin River "crop lands" served by diversion above the mouth of the Merced River. The maximum seasonal total of this demand is 895,700 acre-feet. Only water in excess of monthly requirements in accord with the schedule was assumed available for storage in Friant reservoir and for conveyance to the areas of deficiency. It further was assumed that an arrangement including the Madera area as a part of the area for immediate relief, and which would afford a supply adequate to maintain existing development, would be satisfactory to Madera Irrigation District, provided it be protected in the matter of its right to acquire and divert 350,000 acre-feet seasonally under the conditions of ultimate development. For the purposes of the study, it was assumed that the Madera area would receive 180,000 acre-feet seasonally, on the average, over the forty-year period 1889-1929. The remainder would be available for diversion to the areas south of the San Joaquin River.

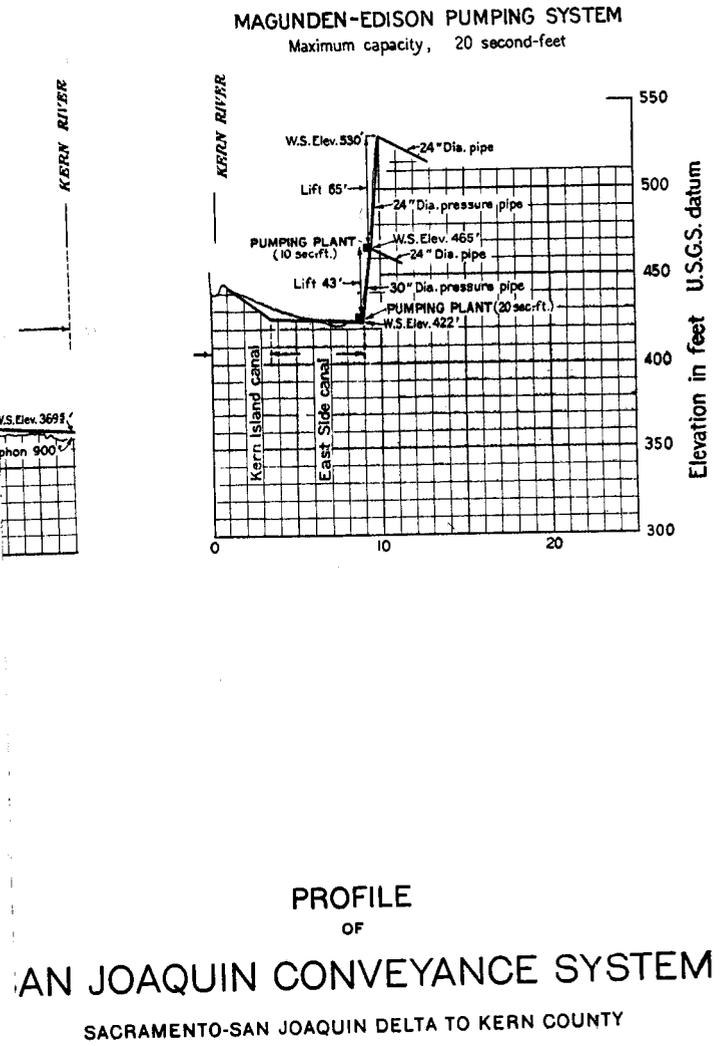
Table 40 shows, in the form of seasonal averages for various periods, a summary of the utilization of the waters of the San Joaquin River under the conditions of immediate initial development. For the forty-year period 1889-1929, the average seasonal supply available for the upper San Joaquin Valley is 1,032,000 acre-feet, of which the Madera area would have received 181,000 acre-feet. The average for the twenty-year period 1909-1929 is 839,000 acre-feet, of which the Madera area would have received 151,000 acre-feet. For the twelve, eight and five-year periods, the averages are, 602,000, 601,000 and 500,000 acre-feet, respectively, for the entire area and 107,000, 108,000 and 90,000 acre-feet, respectively, for the Madera area.

For the eight-year period 1921-1929 an average annual inflow of 108,000 acre-feet would have been available for use in the Madera area and 493,000 acre-feet for the areas south of the San Joaquin River.

TABLE 40
UTILIZATION OF FLOW OF SAN JOAQUIN RIVER AT FRIANT UNDER PLAN OF IMMEDIATE INITIAL DEVELOPMENT

	Average for the period in acre-feet						Maximum		Minimum				
	40-year period 1889-1929		20-year period 1909-1929		12-year period 1917-1929		8-year period 1921-1929		5-year period 1924-1929		Season	Amount in acre-feet	Amount in acre-feet
	1889-1929	1909-1929	1917-1929	1921-1929	1924-1929	Season	Amount in acre-feet	Season	Amount in acre-feet				
"Crop land" rights on San Joaquin River above mouth of Merced River.....	845,000	818,000	794,000	778,000	797,000	(1)	886,000	1923-24	461,000				
Division by Madera canal.....	181,000	151,000	107,000	108,000	90,000	1889-90	481,000	1912-13	31,000				
Division by San Joaquin River-Kern County canal.....	851,000	688,000	495,000	493,000	410,000	1889-90	1,697,000	1912-13	107,000				
Evaporation from Friant reservoir.....	12,000	12,000	11,000	11,000	11,000	1889-90	15,000	1912-13	10,000				
Uncontrolled flow past Friant dam.....	105,000	35,000	3,000	5,000	0	1889-90	1,442,000	(2)	0				
Total.....	1,994,000	1,704,000	1,410,000	1,395,000	1,308,000								

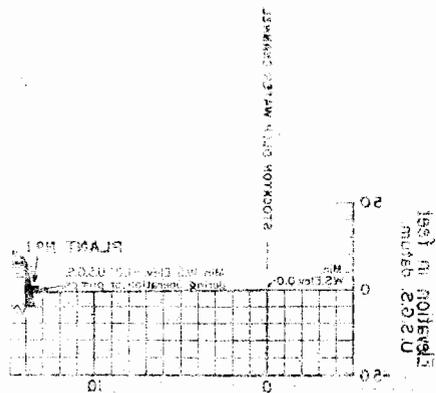
(1) 1889-90, 1890-91, 1891-92, 1892-93, 1894-95, 1900-01, 1905-06, 1906-07, 1908-09, 1910-11, 1913-14, 1915-16.
 (2) All seasons 1889-90 to 1928-29, except 1889-90, 1891-92, 1892-93, 1894-95, 1896-97, 1900-01, 1905-06, 1906-07, 1908-09, 1910-11, 1913-14, 1915-16, 1921-22.



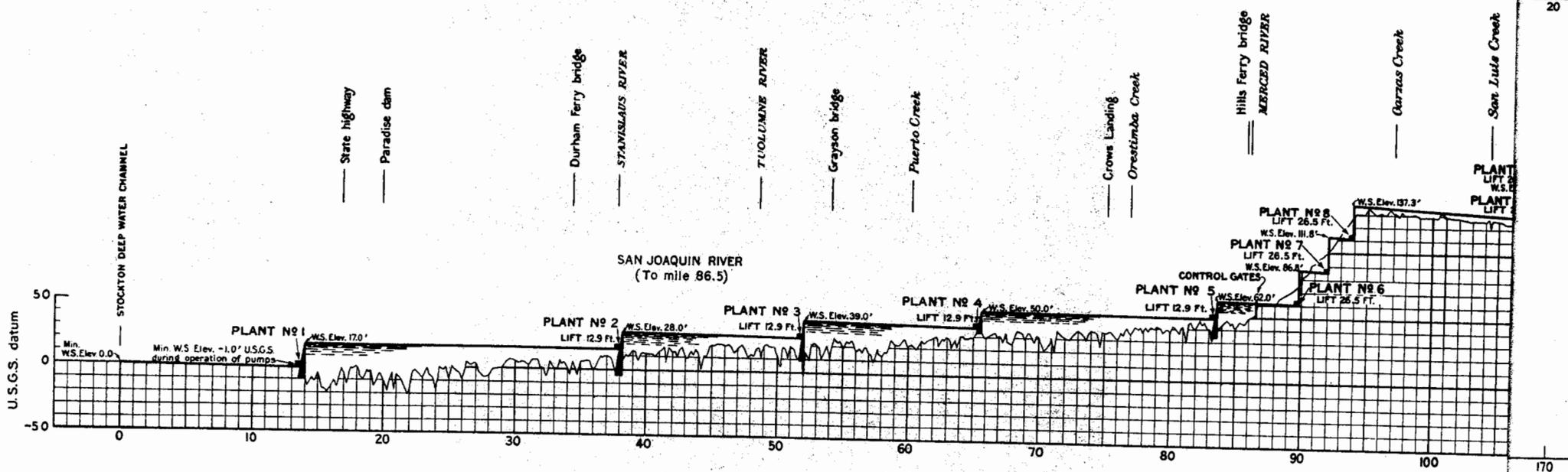
PROFILE
OF
SAN JOAQUIN CONVEYANCE SYSTEM
SACRAMENTO-SAN JOAQUIN DELTA TO KERN COUNTY

Referring to the summary of deficiencies in units requiring immediate relief, it is seen that the latter amount is sufficient to meet the estimated average seasonal deficiency—326,000 acre-feet—in the areas south of the San Joaquin River with an average seasonal excess of 167,000 acre-feet. This could be utilized to replenish the underground basins and to furnish a supply to the areas lying north of the lower Kings River and adjacent to the valley trough and which are troubled with mineralized ground water. The desirable amount for this latter purpose is not known. It is estimated, however, that 35,000 acre-feet annually, on the average, would be adequate, leaving 458,000 acre-feet to be distributed among the areas south of the Kings River. The desirable full surface supply for the impervious Alta-Foothill unit of 16,000 acres is estimated as 35,000 acre-feet, the Magunden-Edison area of 2600 acres as 6000 acre-feet, and the required additional supply for the Lindsay unit of 22,000 acres as 35,000 acre-feet. This would leave 382,000 acre-feet to be distributed among the ground water units having deficient sources of replenishment. The desirability of reducing the pumping lift by raising the water level in these areas varies with the depth of depletion. Therefore, the total lowering of the ground water levels during the period of record, 1921-1929, in addition to the volume depletion, was used as a factor in estimating the relative requirements for these ground water units under conditions of initial development. These requirements, including ground water replenishment, for Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter units are estimated as 103,000 acre-feet, 80,000 acre-feet, 104,000 acre-feet and 95,000 acre-feet, respectively. These relative quantities may be used for proportioning flows, which do not exceed the average for the period 1921-1929. A modification in seasons of large run-off would be required because of low rates of absorption in certain areas and the value of excess supply for reducing pumping lifts of local and imported water in highly absorptive areas. Furthermore, actual irrigation requirements would become the prime factor in determining redistribution when ground water in these areas would have been replenished.

Taking into consideration all of the foregoing factors which have been discussed, and also the methods of irrigation practiced in the several areas, it is believed the supply which could be obtained from the surplus waters and "grass land" rights in the San Joaquin River above the mouth of the Merced River, based upon the modified stream flow records for the period 1921-1929, is adequate to fully supplement the deficiencies in the available local supplies for maintaining present development, and that an equitable distribution of these waters for an average season of this period, in accord with the present needs, is as set forth in the two following tables.



SAN JOAQUIN RIVER PUMPING SYSTEM
 Maximum capacity, 3,000 second-feet



Referring to the summary of deficiencies in units requiring immediate relief, it is seen that the latter amount is sufficient to meet the estimated average seasonal deficiency—326,000 acre-feet—in the areas south of the San Joaquin River with an average seasonal excess of 167,000 acre-feet. This could be utilized to replenish the underground basins and to furnish a supply to the areas lying north of the lower Kings River and adjacent to the valley trough and which are troubled with mineralized ground water. The desirable amount for this latter purpose is not known. It is estimated, however, that 35,000 acre-feet annually, on the average, would be adequate, leaving 458,000 acre-feet to be distributed among the areas south of the Kings River. The desirable full surface supply for the impervious Alta-Foothill unit of 16,000 acres is estimated as 35,000 acre-feet, the Magunden-Edison area of 2600 acres as 6000 acre-feet, and the required additional supply for the Lindsay unit of 22,000 acres as 35,000 acre-feet. This would leave 382,000 acre-feet to be distributed among the ground water units having deficient sources of replenishment. The desirability of reducing the pumping lift by raising the water level in these areas varies with the depth of depletion. Therefore, the total lowering of the ground water levels during the period of record, 1921-1929, in addition to the volume depletion, was used as a factor in estimating the relative requirements for these ground water units under conditions of initial development. These requirements, including ground water replenishment, for Kaweah, Tule-Deer Creek, Earlimart-Delano and McFarland-Shafter units are estimated as 103,000 acre-feet, 80,000 acre-feet, 104,000 acre-feet and 95,000 acre-feet, respectively. These relative quantities may be used for proportioning flows, which do not exceed the average for the period 1921-1929. A modification in seasons of large run-off would be required because of low rates of absorption in certain areas and the value of excess supply for reducing pumping lifts of local and imported water in highly absorptive areas. Furthermore, actual irrigation requirements would become the prime factor in determining redistribution when ground water in these areas would have been replenished.

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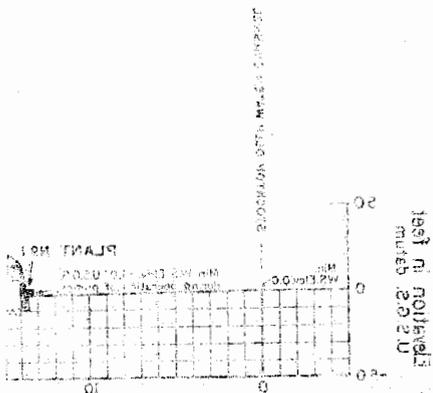


TABLE 41

DISTRIBUTION BY GROUND WATER UNITS OF WATER SUPPLY FOR AN AVERAGE SEASON OBTAINABLE FROM SURPLUS AND "GRASS LAND" RIGHTS OF SAN JOAQUIN RIVER—1921-1929

Unit	Average seasonal water supply available at Friant reservoir in acre-feet
Madera.....	108,000
Foothill, including 5,000 acres in Alta Irrigation District.....	35,000
Kaweah.....	103,000
Lindsay.....	35,000
Tule-Deer Creek.....	80,000
Earlimart-Delano.....	104,000
McFarland-Shafter.....	95,000
Magunden-Edison (portion of Edison-Arvin).....	8,000
Lower Kings River area.....	35,000
Total.....	601,000

Table 41 gives the distribution by ground water units and Table 42 the distribution by counties of the water obtainable from the San Joaquin River under the plan of immediate initial development. In Table 41 the figure for the Tule-Deer Creek unit includes a supplemental supply for about 5000 acres of developed land lying east of the unit. In this distribution it is assumed that lands in Kings County lying in and east of Tulare Lake now used chiefly for growing of annual crops could be furnished a supply either from the Kings River, if properly regulated, or from the lower absorptive areas of the Kaweah and Tule deltas which supply could be made available under the plan of immediate initial development. If it should prove desirable and necessary to furnish a direct surface supply to these lands, water would be available for that purpose, however, with a corresponding reduction in supply to some of the other areas. In Tulare Lake, there are about 50,000 acres of land used for grain and in the area to the east of the lake there are about 20,000 acres used principally for growing of cotton. These acreages vary from season to season. If allowed a full surface supply from the imported water for the irrigation of these crops, it is estimated that about 90,000 acre-feet per season would be adequate.

TABLE 42

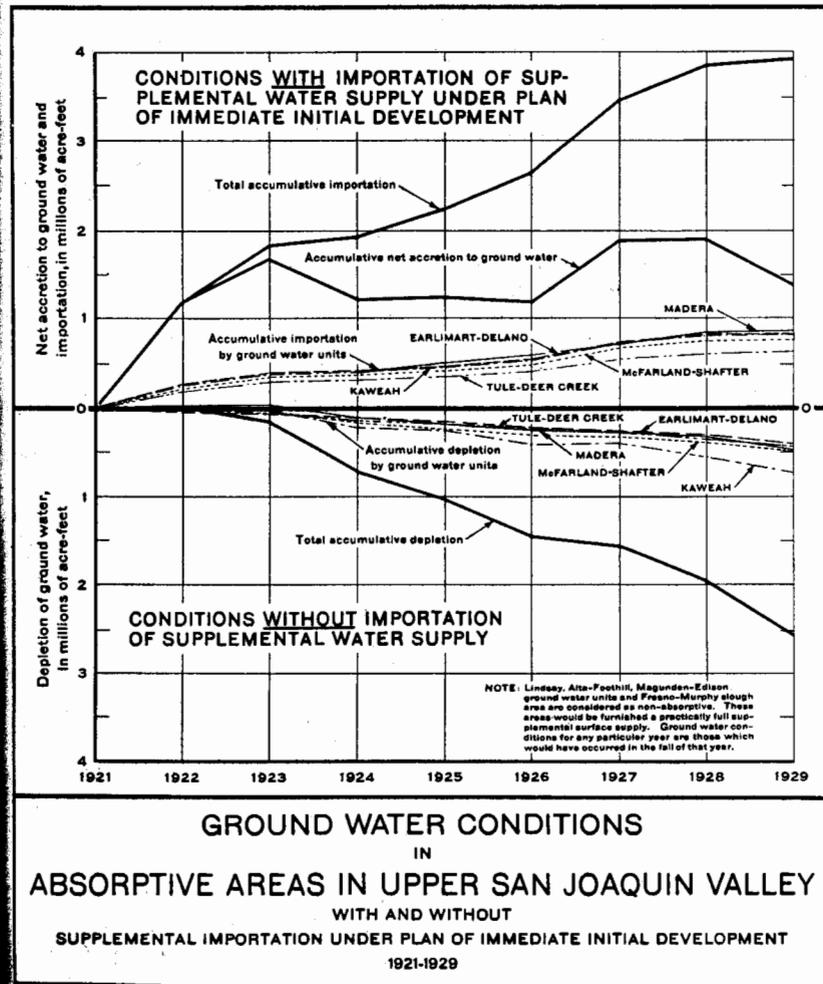
DISTRIBUTION BY COUNTIES OF WATER SUPPLY FOR AN AVERAGE SEASON OBTAINABLE FROM SURPLUS AND "GRASS LAND" RIGHTS OF SAN JOAQUIN RIVER—1921-1929

County	Average seasonal water supply available at Friant reservoir in acre-feet
Madera.....	108,000
Fresno.....	50,000
Tulare.....	318,000
Kern.....	125,000
Total.....	601,000

To illustrate the operation of the plan, Plate XI, "Ground Water Conditions in Absorptive Areas in Upper San Joaquin Valley," has

been prepared and is presented herein. It delineates, under conditions without importation of a supplemental supply, the accumulative depletion for each ground water unit and for the entire area, and also, under conditions with importation of a supplemental supply, the accumulative importation for each unit and the entire area, as well as the accumulative net accretion to ground water for the entire area. It is seen that with this plan in operation during the eight-year period 1921-1929 there would have been 1,361,000 acre-feet more water available in the underground reservoirs at the end of the period than at the beginning.

PLATE XI



It has been shown that, under the plan of immediate initial development, the average seasonal supplemental supply during the eight-year period would have been 601,000 acre-feet. The importation of this supply into the areas of deficiency not only would have more than

doubled the utilizable water supply of these areas, but also would have improved the characteristics of occurrence of the present deficient supplies. A substantial part of the seasonal inflow into these areas occurs now in months outside of the irrigation season. During the eight-year period 1921-1929, 41 per cent, on the average, so occurred, while 59 per cent occurred within the irrigation season. For the imported supplemental supply, the corresponding figures would have been 22 and 78 per cent, and with the combination of the local and imported supplies, 32 and 68 per cent respectively. Therefore, it is seen that with this plan not only would the present supplies have been more than doubled, but the characteristics of occurrence of the supply, as related to demand, would have been much improved.

The physical works for the initial development have been planned with the view not only of meeting the immediate needs, but also of being accordant with the requirements for ultimate development in the upper San Joaquin Valley. Careful consideration was given to the proper capacities of the Friant reservoir and San Joaquin River-Kern County canal. After many trial studies, involving yield and costs of various combinations of storage and diversion canal capacities, and after consideration was given to value of additional storage space for flood control and to flexibility of operation under conditions of initial development, it was concluded the economical and practical combination of canal and reservoir capacity for initial development would be 3000 second-feet and 270,000 acre-feet (net), respectively. These are the capacities for the ultimate development.

The Madera canal would have the same capacity—1500 second-feet—as for the ultimate development. It would leave the Friant reservoir at elevation 415 feet and extend northward eighteen miles to the Fresno River.

A small pumping system of 20 second-feet capacity is proposed to serve the Magunden-Edison area in Kern County. Kern River water, made available by exchange with San Joaquin River water, would be diverted from the East Side Canal.

A power plant would be installed at the dam of the Friant reservoir. It would have an installed capacity of 30,000 kilovolt amperes and would produce, on the average, 105,000,000 kilowatt hours annually utilizing "crop land" and waste waters.

The capital costs of the physical units of the initial plan proposed for the upper San Joaquin Valley, exclusive of cost of water rights and general expense, are given in Table 43. These costs include an allowance of 25 per cent for engineering, administration and contingencies and interest during construction at $4\frac{1}{2}$ per cent per annum, compounded semiannually.

TABLE 43
COST OF PHYSICAL WORKS OF INITIAL PLAN IN SAN JOAQUIN RIVER BASIN

Item	Capital cost
Friant dam, reservoir and power plant.....	\$15,500,000
San Joaquin River-Kern County canal (concrete lined).....	27,300,000
Madera canal (concrete lined).....	2,500,000
Magunden-Edison pumping system.....	100,000
San Joaquin River pumping system (construction deferred).....	15,000,000
Sacramento-San Joaquin Delta cross channel (construction deferred).....	4,000,000
Total.....	\$64,400,000

In making provision for proper utilization of imported water, consideration should be given to the method of distributing both the "in season" water falling within the irrigation demand and the excess flows not within the irrigation demand, both in and out of season, for replenishment of ground water storage. It is proposed that the "in season" water falling within the irrigation demand be supplied to the irrigated lands by means of surface conduits and ditches in accord with the demand for irrigation water. The water outside of the irrigation demand would be introduced underground, by application on absorptive lands for irrigation in greater quantities than net use requirements; through seepage losses from unlined canals and ditches, both existing and proposed; through absorption in stream beds of natural channels; and by the construction of spreading works or by other artificial means of accelerating percolation. The water thus introduced underground would be recovered later by pumping. Areas of ground water storage therefore would require wells and pumping plants as under present conditions of development and utilization of the local water supplies. Under the proposed plan, however, the proportion of the mean annual supply which would be obtained by pumping, as well as the average pumping lift, would be materially reduced.

South Pacific Coast Basin.

The immediate problem on the Pacific slope of southern California is to obtain additional supplies from local resources by greater conservation efforts and from sources outside of the basin so that the deficiency now being supplied by overdraft on certain of the underground reservoirs may be met.

Conservation of Local Water Resources—Since as much of the supply from local sources as can be conserved will be necessary in addition to imported water and since to obtain an additional supply from Mono Basin and the Colorado River will at best require several years, attention must be given to the conservation of these local supplies.

Opportunities for salvage exist in the flood water that escapes into the ocean during the periods of more severe storms, present waste of sewage into the ocean and evaporation from seeped lands. So effective is the capacity of the extensive underground basins existing in many parts in absorbing water from the stream channels crossing them, that three-fourths of all local supplies are now obtained by pumping from these basins and a large part of the remainder is from rising water flowing out of the basins.

Large cyclic storage is necessary, either in surface or underground reservoirs, if the variably occurring floods that constitute the last undeveloped increments of local waters are to become useful continuous supplies. Wherever extensive underground basins exist, the last increments of local water can be made available for use at less cost by utilizing the large storage capacity in these basins. Where the cyclic storage can be obtained underground, regulatory storage only is needed in surface reservoirs for controlling the flood waters so that they may be directed onto spreading grounds and sunk into the underground basins. The large additional capacity required for cyclic storage need be constructed in surface reservoirs only on those streams

on which extensive underground capacity does not exist. In addition to saving the cost of construction of large capacity in surface reservoirs, the use of the underground basins as the place for storage of the flood waters makes the conserved water available for use in the same way that it has been found most convenient to obtain present supplies and therefore no new distribution systems are needed.

Regulation of floods so that their waters may be sunk into the underground basins, to a certain extent accomplishes their control, as well as the conservation of their waters. However, a high degree of conservation may be attained in this manner without completely controlling the larger and more damaging floods. For this reason, if complete control is desired by the reservoir system, special attention must be given to construction and operation of reservoirs for this specific purpose. This system is particularly desirable in southern California, because it permits the use of smaller channels with shorter traffic crossings, involves a nominal waste of land and thus enables a more complete beneficial utilization of a rather limited area of valley lands.

Santa Ana River Basin Flood Control and Conservation Works—Plans for the conservation of water and control of floods in the Santa Ana River Basin are given in another report.* The principal features of the plan outlined in that bulletin are briefly described in the following paragraphs. Spreading works in addition to those presented herein have been or now are being constructed by local organizations.

Improvement of the San Antonio and Chino Creek channels by constructing levees and enlarging the cross-section to give a carrying capacity of 10,000 second-feet to the Santa Ana River is proposed.

Spreading works and settling basins are proposed on the debris cones at the debouchures of Cucamonga, Deer and Day creeks from the mountains to sink as much of the unused run-off as possible into the underground basin. In order to care for flood waters not controlled by the spreading works, channel construction or improvements are proposed where the present channels do not have sufficient capacity to carry the estimated flood discharges of 5000 second-feet from Cucamonga Creek and the 4000 second-feet from Deer and Day creeks, or 6000 second-feet below the confluence of the three.

Additional spreading works are proposed for the Lytle Creek cone to aid in the percolation of the unused and flood waters of that stream to the underground basin, but since Cajon Creek is naturally well cared for in this way no spreading works are proposed for it. From the crossing of the Santa Fe Railway on Lytle Creek, which is below the confluence of Lytle and Cajon creeks, to the Santa Ana River, works are proposed to control flood waters not absorbed by spreading. These works would consist of the improvement of the channel of the East Branch of Lytle Creek to carry 25,000 second-feet to its confluence with Warm Creek, which in turn would convey the flood water to the Santa Ana River. A debris dam also is proposed near the mouth of the mountain canyon of Lytle Creek.

A dyke is proposed to divert the waters from Devil Canyon into Lytle Creek channel. It also is proposed to construct a diverting dam on Waterman Creek, above the present spreading area, and a channel to

* Bulletin No. 31, "Santa Ana River Basin," Division of Water Resources, 1930.

carry its excess waters to Twin Creek, down which they would flow to Warm Creek. A protection levee also is proposed along the west side of Twin Creek to a point below Highland avenue. Several debris dams on Little Sand and Sand creeks are proposed to prevent the deposition of sand on orchards. It also is proposed to divert City Creek into the Santa Ana River by means of a low levee, in which gates would be installed for the diversion of water for spreading. On Mill Creek it is proposed to strengthen the present dam diverting to spreading works and construct a levee at the lower end of the spreading works to protect cultivated land. Levees are proposed along both sides of San Timoteo Creek from Redlands to the Santa Ana River, together with three debris dams in the vicinity of and above Redlands.

The works proposed for the upper Santa Ana River consist of spreading works and channel protection. A debris dam would be constructed above the Mentone gaging station and an area of 1230 acres of spreading grounds developed in the river wash between Redlands and East Highlands. Flexible revetments are proposed for the protection of the river banks on the north and south sides. The north side would be protected from the Pacific Electric Railroad crossing to the proposed diversion levee for City Creek. The south side would be protected for a distance of about 13,500 feet east of the railroad and west from it to the mouth of San Timoteo Creek.

The works proposed for the lower Santa Ana River are the construction of a reservoir in the lower Santa Ana Canyon for the storage of flood water, which would be released at such a rate that it might percolate into the underground basin, and the improvement of the channel between this reservoir and the ocean to carry off excess flood waters not controlled by the reservoir. Two reservoirs* also are proposed for construction on Santiago Creek to store the winter and flood run-off of that stream and release it for irrigation, both by direct diversion and by recharging the underground basin for pumping supplies.

It is estimated that construction of all of the works in the Santa Ana River Basin, above briefly described, would save about 90 per cent of the water now wasting into the ocean from this stream. They would, in addition, control larger floods on the main stream and its tributaries than any yet recorded. The cost of constructing these works is estimated as follows:

TABLE 44
COST OF FLOOD CONTROL AND SPREADING WORKS IN SANTA ANA RIVER BASIN

Location	Item	Cost
Upper Santa Ana River Basin—		
West End.....	San Antonio, Cucamonga, and Deer and Day creeks and Ontario flood channels; Cucamonga, and Deer and Day creeks spreading works.....	\$1,667,300
Lytle Creek.....	Flood channel, debris dam, mountain gravel storage, and spreading and revetment works.....	1,135,500
Miscellaneous creeks north of San Bernardino.....	Works on Devil Canyon, Waterman, East Twin, Little Sand, Sand and City creeks.....	178,400
Santa Ana River.....	Spreading works, debris dam, mountain gravel storage and bank protection.....	1,069,700
Mill Creek.....	Spreading works.....	42,800
San Timoteo Creek.....	Flood channel and protection.....	140,800
Subtotal, Upper Santa Ana Basin.....		\$4,234,500
Lower Santa Ana River Basin.....	Reservoir in lower Santa Ana Canyon and channel improvement and acquisition on Santa Ana River below reservoir, and reservoirs on Santiago Creek.....	\$12,000,000
Total, Santa Ana River Basin.....		\$16,234,500

* This is the plan formerly proposed by Orange County Flood Control District. A report, dated April, 1931, by a special board of engineers retained by this district to restudy the plan, proposes one reservoir.

Los Angeles County—In Los Angeles County, work has been under way by Los Angeles County Flood Control District for several years on a plan for the control of floods by storage and channel correction and improvement. This work will aid in conserving water by detaining flood peaks, thereby extending the time of run-off which will allow more percolation into the underground basins.

Ventura County—Investigations of the conditions in Ventura County have not yet been carried to a point where it is advisable to lay out a plan for caring for either present or future needs.

Colorado River Aqueduct—The route and units of the Colorado River aqueduct have been described in Chapter V. The initial development, as recommended by the Engineering Board of Review of the Metropolitan Water District of Southern California, would have a delivery capacity of 800 second-feet, which is about 580,000 acre-feet per year. The tunnels and surface conduits would be constructed to the full capacity of 1500 second-feet, but pressure siphons and pumping plants would be constructed for only 800 second-feet. The Parker dam and its appurtenances would be deferred. Clarification works, however, would be installed at the intake on the Colorado River in lieu of the Parker reservoir. Provision would be made for terminal storage near the lower end of the aqueduct on the Pacific slope in the amount of 100,000 acre-feet. Suitable locations for reservoirs to provide this capacity are available along the aqueduct line in the Cajalco Canyon and the Puente Hills district. The total cost for the initial development, including terminal storage, as estimated by the Engineering Board of Review for the district, is set forth in Table 45. The figures do not include interest during construction.

TABLE 45

COST OF COLORADO RIVER AQUEDUCT

As recommended by Engineering Board of Review of Metropolitan Water District of Southern California

Item	Initial development
Investigations and designs.....	\$2,500,000
The aqueduct.....	146,222,000
Pumping and power plants and equipment.....	24,931,000
Clarification works.....	7,419,000
Terminal storage.....	17,500,000
Total.....	\$198,572,000

Summary.

The estimated costs of the units for initial development are summarized in the following table:

TABLE 46
SUMMARY OF COSTS OF UNITS FOR INITIAL DEVELOPMENT

Item	Cost
Great Central Valley—	
Kennett reservoir.....	\$84,000,000
Sacramento-San Joaquin Delta cross channel (construction deferred).....	4,000,000
San Joaquin River pumping system (construction deferred).....	15,000,000
Friant reservoir.....	15,500,000
Upper San Joaquin Valley conduits.....	29,900,000
Rights of way, water rights and general expense.....	8,000,000
Subtotal, Great Central Valley.....	\$166,400,000
San Francisco Bay Basin—	
Contra Costa County conduit.....	2,500,000
South Pacific Coast Basin—	
Colorado River aqueduct.....	\$198,800,000
Santa Ana River Basin flood control and conservation works.....	16,200,000
Subtotal, South Pacific Coast Basin.....	\$214,800,000
Total.....	\$373,700,000

¹ Estimate of Engineering Board of Review for Metropolitan Water District. Does not include interest during construction. Figures rounded to the nearest \$100,000.

² Figures rounded to the nearest \$100,000.

CHAPTER VII

ECONOMIC ASPECTS OF INITIAL UNITS OF
STATE WATER PLAN

A fundamental prerequisite to the execution of any unit of the State Water Plan must be a consideration of its economic soundness. Before any unit is adopted for execution, it should be definitely determined that the value of benefits, including collectible revenues therefrom, would exceed the cost. In some of the projects collectible revenues would be obtained from the sale of water and hydroelectric energy. In addition to revenues from actual use of water, however, there would be benefits which would accrue to many interests through the correction of the water shortage situation. Federal and state governments, the large metropolitan centers, cities, public and privately owned public utilities, industrial and commercial interests, individuals, and other interests, would be benefited to a varying degree. It is not within the province of this report, however, to determine the extent of these benefits, but only to set forth those interests which would be benefited and in what way. Therefore only the comparative amounts of annual costs and anticipated collectible revenues are presented herein.

Economic aspects of the three initial projects, Great Central Valley, Colorado River aqueduct and the Santa Ana River Basin are considered.

Great Central Valley Project.

For the Great Central Valley, including the Contra Costa County conduit in the upper San Francisco Bay Basin, the capital and gross annual costs of the units for both the immediate and complete initial development are set forth in tables on pages 173 and 174. The costs, in addition to the cost of the physical works, include allowances for rights of way, water rights and general expense amounting to \$7,000,000 for the immediate initial development and \$8,000,000 for the complete initial development. The annual costs include interest at 4½ per cent per annum, amortization on a forty-year sinking fund basis at four per cent per annum, depreciation, operation and maintenance. Annual revenues are based upon the sale of electric energy and water at prices determined by special studies undertaken in this investigation.

The values of the electric energy at the power plants of the Kennett and Friant reservoirs are based on the lowest of several estimates of the cost of producing an equivalent amount of electric energy of the same characteristics with a steam-electric plant located in the area of consumption, taking into account the cost of transmission from point of generation to load centers. An average rate of \$3 per acre-foot for irrigation water, measured at the main canal in the upper San Joaquin Valley, is based on the crop distribution shown by the 1929 crop survey in that area and on the permissible annual charges for irrigation water at the land for these crops, as set forth in another report.* Important factors, in arriving at this figure, were class of service, the costs of

* Bulletin No. 34, "Permissible Annual Charges for Irrigation Water in Upper San Joaquin Valley," Division of Water Resources, 1930.

surface distribution, of ground water utilization, and of pumping, both local and imported water, taking into account the reduction of pumping lifts which would be effected through ground water replenishment.

It is assumed that the water delivered by the Contra Costa County conduit for agricultural and industrial use would be sold at rates which would average \$6.90 per acre-foot (2.1 cents per 1000 gallons) or sufficient to meet the total annual cost of this unit. This would not include any portion of the cost of furnishing the supply in the delta or of keeping the delta channels fresh.

Predictions as to the time when the quantities of water supplies and electric energy developed by the initial units would be sold are uncertain, particularly irrigation and industrial supplies. The amount of electric energy generated probably could be absorbed over a period of four years. However, the factors entering into the utilization and sale of irrigation and industrial supplies are so numerous and diverse that no prediction as to the time of complete utilization has been attempted. The revenues from the sale of electric energy and water are estimated as the total amounts which would be realized when fully utilized and sold at the unit prices stated. Any deficiencies in revenues during the period of partial utilization would have to be provided by some other means. The net annual costs would be greater than calculated during this development period, but no attempt has been made to estimate the added cost.

A comparison of the annual costs and anticipated revenues from the sale of water and electric energy for the initial units for the Great Central Valley for both the immediate and complete stages of initial development are summarized below:

Item	Immediate Initial Development	
	Capital cost	Gross annual cost
CAPITAL AND ANNUAL COST—		
Kennett reservoir	\$84,000,000	\$5,297,000
Contra Costa County conduit.....	2,500,000	300,000
Friant reservoir.....	15,500,000	1,062,000
Madera canal.....	2,500,000	213,000
San Joaquin River-Kern County canal.....	27,300,000	2,225,000
Magunden-Edison pumping system.....	100,000	18,000
Rights of way, water rights and general expense.....	7,000,000	389,000
Total.....	\$138,900,000	\$9,504,000
ANNUAL REVENUES—		
Electric energy sales:		
1,591,800,000 kilowatt hours at \$0.00265.....	\$4,218,000	
105,000,000 kilowatt hours at \$0.0035.....	367,000	
Total electric energy sales.....	4,585,000	
Water sales:		
600,000 acre-feet for upper San Joaquin Valley, based on average for twelve-year period 1917-1929, at \$3 per acre-foot.....	\$1,800,000	
43,600 acre-feet for Contra Costa County conduit at \$6.90 per acre-foot.....	300,000	
Total water sales.....	\$2,100,000	
Total revenues, electric energy and water.....	\$6,685,000	\$6,685,000
NET ANNUAL COST IN EXCESS OF REVENUES.....		\$2,819,000

¹ Includes \$1,500,000 for cost of 30,000 kilovolt ampere power plant, the amortization of which, in a ten-year period, is included in the annual cost.

Complete Initial Development

Item	Capital cost	Gross annual cost	
CAPITAL AND ANNUAL COST—			
Kennett reservoir.....	\$84,000,000	\$5,297,000	
Sacramento-San Joaquin Delta cross channel.....	4,000,000	300,000	
Contra Costa County conduit.....	2,500,000	300,000	
San Joaquin River pumping system.....	15,000,000	2,500,000	
Friant reservoir.....	14,500,000	885,000	
Madera canal.....	2,500,000	213,000	
San Joaquin River-Kern County canal.....	27,300,000	2,225,000	
Magunden-Edison pumping system.....	100,000	18,000	
Rights of way, water rights and general expense.....	8,000,000	444,000	
Total.....	\$157,900,000	\$12,182,000	\$12,182,000

ANNUAL REVENUES—

Electric energy sales—			
1,581,100,000 kilowatt hours at \$0.00242.....	\$3,826,000		
23,000,000 kilowatt hours at \$0.0035.....	80,000		
Total electric energy sales.....		\$3,906,000	
Water sales:			
1,720,000 acre-feet for upper San Joaquin Valley, based on average for forty-year period 1889-1929, at \$3 per acre-foot.....	\$5,160,000		
43,500 acre-feet for Contra Costa County conduit at \$6.90 per acre-foot.....	300,000		
Total water sales.....		\$5,460,000	
Total revenues, electric energy and water.....		\$9,366,000	\$9,366,000
NET ANNUAL COST IN EXCESS OF REVENUES.....			\$2,816,000

¹ Does not include the cost of the 30,000 kilovolt ampere power plant of the immediate initial development, which would not be operated under the complete initial development, but does include a new 10,000 kilovolt ampere plant costing \$500,000 on the Madera canal, the amortization of which in a forty-year period is included in the annual cost.

Under the complete initial development, it may be noted that the water sales to the upper San Joaquin Valley are based on a delivery of 1,720,000 acre-feet annually. This is the estimated amount of water that could be obtained from the San Joaquin River at Friant under complete utilization of the waters of the stream (based on the forty-year period 1889-1929). It is the estimated amount which, together with the full practicable development of the local supplies, would be sufficient for development of practically all the class 1 and 2 lands on the eastern side of the upper San Joaquin Valley. This would mean the bringing in of new lands, which is not contemplated with the immediate initial development. However, if it should be desired to import more water than is contemplated under the immediate initial development, either for ground water replenishment or for additional supplies in areas with temporary deficiencies in surface supplies without further conservation of local supplies, the San Joaquin River pumping system would be required. Since it is impossible to forecast the amount of additional water that might be desired to be imported under these conditions, the anticipated revenues for a complete utilization of the full average supply of 1,720,000 acre-feet annually available from the San Joaquin River only is estimated for the complete initial development.

It may be seen from the financial statements that, with the immediate development, the net annual cost would be \$2,819,000 and with the complete initial development, \$3,000 less. Hence the cost per acre-foot of water for the complete development would be less with the entire deficit charged to water. However, if there were not the demand for the larger amount of water and the burden for the cost of the project should fall upon those who actually would use water, the cost

PROJECT FOR VARIOUS RATES OF INTEREST WITH FORTY-YEAR

Cost ^a	50-year amortization, 4 per cent sinking fund basis						40-year straight line amortization, no interest
	6 per cent	5 per cent	4½ per cent	4 per cent	3½ per cent	3 per cent	
\$6,462,000	\$5,456,000	\$4,965,000	\$4,486,000	\$4,022,000	\$3,564,000	\$2,422,000	
327,000	302,000	280,000	277,000	265,000	252,000	169,000	
1,261,000	1,091,000	1,007,000	924,000	842,000	762,000	215,000	
240,000	215,000	203,000	190,000	178,000	165,000	131,000	
2,610,000	2,279,000	2,117,000	1,959,000	1,804,000	1,652,000	1,255,000	
19,000	18,000	17,000	17,000	16,000	16,000	15,000	
468,000	396,000	361,000	328,000	291,000	256,000	175,000	
\$11,385,000	\$9,757,000	\$8,960,000	\$8,179,000	\$7,418,000	\$6,667,000	\$4,767,000	
6,685,000	6,685,000	6,685,000	6,685,000	6,685,000	6,685,000	6,685,000	
\$4,700,000	\$3,072,000	\$2,275,000	\$1,494,000	\$733,000	\$18,000	\$1,918,000	
\$6,462,000	\$5,456,000	\$4,965,000	\$4,486,000	\$4,022,000	\$3,564,000	\$2,422,000	
\$353,000	\$304,000	284,000	264,000	244,000	219,000	169,000	
327,000	302,000	280,000	277,000	265,000	252,000	169,000	
2,754,000	2,534,000	2,440,000	2,334,000	2,244,000	2,141,000	1,851,000	
1,067,000	966,000	828,000	750,000	673,000	597,000	415,000	
240,000	215,000	203,000	190,000	178,000	165,000	131,000	
2,610,000	2,279,000	2,117,000	1,959,000	1,804,000	1,652,000	1,255,000	
19,000	18,000	17,000	17,000	16,000	16,000	15,000	
532,000	452,000	412,000	372,000	332,000	292,000	200,000	
\$14,364,000	\$12,466,000	\$11,556,000	\$10,649,000	\$9,778,000	\$8,898,000	\$6,673,000	
9,366,000	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000	9,366,000	
\$4,998,000	\$3,100,000	\$2,190,000	\$1,283,000	\$412,000	\$468,000	\$2,693,000	

^a a new 10,000 kilovolt ampere power plant on the Madera canal, the amortization of which,

TABLE 47

CAPITAL AND ANNUAL COSTS OF IMMEDIATE INITIAL DEVELOPMENT AND COMPLETE INITIAL DEVELOPMENT FOR THE GREAT CENTRAL VALLEY PROJECT FOR VARIOUS RATES OF INTEREST AND FIFTY-YEAR AMORTIZATION PERIODS

	Capital cost							Annual cost ⁴										
	Interest rate							40-year amortization, 4 per cent sinking fund basis						50-year amortization, 4 per cent				
	6 per cent	5 per cent	4½ per cent	4 per cent	3½ per cent	3 per cent	No interest	6 per cent	5 per cent	4½ per cent	4 per cent	3½ per cent	3 per cent	6 per cent	5 per cent	4½ per cent	4 per cent	
Immediate Initial Development																		
Kennett reservoir	\$87,200,000	\$85,100,000	\$84,000,000	\$82,900,000	\$81,900,000	\$80,800,000	\$74,400,000	\$6,807,000	\$5,792,000	\$5,297,000	\$4,813,000	\$4,346,000	\$3,883,000	\$6,462,000	\$5,456,000	\$4,965,000	\$4,474,000	
Contra Costa County conduit	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,400,000	337,000	312,000	300,000	287,000	275,000	262,000	327,000	302,000	290,000	280,000	
Friant reservoir ¹	15,800,000	15,600,000	15,500,000	15,400,000	15,300,000	15,200,000	14,500,000	1,318,000	1,147,000	1,062,000	979,000	897,000	816,000	1,261,000	1,091,000	1,007,000	923,000	
Madera canal	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,400,000	250,000	225,000	213,000	200,000	188,000	175,000	240,000	215,000	203,000	191,000	
San Joaquin River-Kern County canal	28,200,000	27,600,000	27,300,000	27,000,000	26,700,000	26,400,000	24,600,000	2,722,000	2,388,000	2,225,000	2,066,000	1,909,000	1,756,000	2,610,000	2,279,000	2,117,000	1,955,000	
Magunden-Edison pumping system	100,000	100,000	100,000	100,000	100,000	100,000	100,000	19,000	18,000	18,000	17,000	17,000	16,000	19,000	18,000	17,000	16,000	
Rights of way, water rights and general expense	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000	7,000,000	494,000	424,000	389,000	354,000	319,000	284,000	466,000	396,000	361,000	326,000	
Total	\$143,300,000	\$140,400,000	\$138,900,000	\$137,400,000	\$136,000,000	\$134,500,000	\$125,400,000	\$11,947,000	\$10,306,000	\$9,504,000	\$8,716,000	\$7,951,000	\$7,192,000	\$11,385,000	\$9,757,000	\$8,960,000	\$8,176,000	
Total revenues, electric energy and water								\$5,282,000	\$3,621,000	\$2,810,000	\$2,031,000	\$1,268,000	\$507,000	\$4,700,000	\$3,072,000	\$2,275,000	\$1,474,000	
Net annual cost in excess of revenues																		
Complete Initial Development																		
Kennett reservoir	\$87,200,000	\$85,100,000	\$84,000,000	\$82,900,000	\$81,900,000	\$80,800,000	\$74,400,000	\$6,807,000	\$5,792,000	\$5,297,000	\$4,813,000	\$4,346,000	\$3,883,000	\$6,462,000	\$5,456,000	\$4,965,000	\$4,474,000	
Sacramento-San Joaquin Delta cross channel	4,100,000	4,000,000	4,000,000	4,000,000	4,000,000	3,900,000	3,800,000	369,000	320,000	300,000	280,000	260,000	240,000	\$353,000	\$304,000	\$284,000	\$264,000	
Contra Costa County conduit	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,400,000	337,000	312,000	300,000	287,000	275,000	262,000	327,000	302,000	290,000	280,000	
San Joaquin River pumping system	15,500,000	15,200,000	15,000,000	14,800,000	14,700,000	14,500,000	13,600,000	2,815,000	2,609,000	2,500,000	2,392,000	2,302,000	2,199,000	2,754,000	2,534,000	2,440,000	2,346,000	
Friant reservoir ¹	14,800,000	14,600,000	14,500,000	14,400,000	14,300,000	14,200,000	13,600,000	1,125,000	964,000	885,000	807,000	730,000	653,000	1,067,000	906,000	828,000	750,000	
Madera canal	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000	2,400,000	250,000	225,000	213,000	200,000	188,000	175,000	240,000	215,000	203,000	191,000	
San Joaquin River-Kern County canal	28,200,000	27,600,000	27,300,000	27,000,000	26,700,000	26,400,000	24,600,000	2,722,000	2,388,000	2,225,000	2,066,000	1,909,000	1,756,000	2,610,000	2,279,000	2,117,000	1,955,000	
Magunden-Edison pumping system	100,000	100,000	100,000	100,000	100,000	100,000	100,000	19,000	18,000	18,000	17,000	17,000	16,000	19,000	18,000	17,000	16,000	
Rights of way, water rights and general expense	8,000,000	8,000,000	8,000,000	8,000,000	8,000,000	8,000,000	8,000,000	564,000	484,000	444,000	404,000	364,000	324,000	532,000	452,000	412,000	372,000	
Total	\$162,900,000	\$159,600,000	\$157,900,000	\$156,200,000	\$154,700,000	\$152,900,000	\$142,900,000	\$15,008,000	\$13,112,000	\$12,182,000	\$11,268,000	\$10,391,000	\$9,502,000	\$14,364,000	\$12,466,000	\$11,556,000	\$10,648,000	
Total revenues, electric energy and water								\$5,642,000	\$3,740,000	\$2,816,000	\$1,900,000	\$1,025,000	\$136,000	\$4,998,000	\$3,100,000	\$2,190,000	\$1,280,000	
Net annual cost in excess of revenues																		

¹ Capital cost of this unit includes \$1,500,000 for all costs including interest and \$1,400,000 at no interest for cost of a 30,000 kilovolt ampere power plant, the amortization of which, in a ten-year period, is included in the annual cost.
² Capital cost of this unit does not include that of the 30,000 kilovolt ampere power plant of the immediate initial development, which would not be operated under the complete initial development, but does include \$500,000 for the cost of a new 10,000 kilovolt ampere power plant on the site.
³ Revenue in excess of annual cost.
⁴ Computed on capital costs for which interest rates during construction are the same as the interest rates used hereunder.

might be greater than with the immediate development. This would vary with the amount of water imported.

The foregoing estimates are based on financing the development at an interest rate of 4½ per cent per annum and on an amortization period of forty-years. To illustrate the added cost for both capital and annual costs with a higher rate of interest and the decreased cost with a lower rate of interest and for a fifty-year period of amortization, Table 47 is presented. The rates of interest vary from six per cent to interest free money. For all annual costs with interest, amortization is estimated on a four per cent sinking fund basis. With interest free money, it is estimated on a straight line basis for a forty-year period.

Many interests, other than those who actually would receive water in the upper San Joaquin Valley, also would be greatly benefited. In the Sacramento Valley there would be many beneficiaries. The reduction of floods on the Sacramento River would furnish an additional degree of protection to the overflow lands in the Sacramento Flood Control Project, resulting in a reduction of potential annual flood damages. The federal and state governments, the various districts and individual landowners would be interested in this feature. The improvement of navigation on the Sacramento River for 190 miles above the city of Sacramento is a feature in which the federal government would be interested and is a basis upon which it might be expected to participate financially. The furnishing of a full supply to the lands under irrigation along the Sacramento River and in the Sacramento-San Joaquin Delta would be of great benefit to the lands above the city of Sacramento in their being assured of an adequate supply in all years without being curtailed in their diversions because of navigation requirements or the possibility of being enjoined by the water users below the city of Sacramento. Some of the lands above Sacramento also would be benefited in all years, and particularly in dry years, by decreased pumping charges due to higher water levels in the Sacramento River channel. This would be a substantial sum in dry years. The city of Sacramento would be benefited as to the quality of its water supply, which it obtains from the Sacramento River. In all years, a flow of not less than 5000 second-feet would be passing the intake of its pumping plant. In 1920, the mean flow during one 24-hour period in July was as low as 440 second-feet. On this day there was a reversal of flow upstream amounting to a maximum of 2300 second-feet.

The control of salinity to the lower end of the Sacramento-San Joaquin Delta would relieve the salt water menace in that area and would furnish the irrigated lands a fresh water supply at all times. The furnishing of an adequate and suitable water supply to the industrial and agricultural areas along Suisun Bay not only would benefit the immediate area, but also the metropolitan areas of Oakland and San Francisco.

The relief afforded the upper San Joaquin Valley by the consummation of this plan would prevent the retrogression of a large area of agricultural land. The maintenance of these lands in production would prevent a loss of taxable wealth in the southern valley counties, help to restore agricultural credit, maintain and increase business in the communities of the affected areas and between those areas and the

large metropolitan centers, and assist in the protection of public utility and banking investments in these areas.

Colorado River Aqueduct and Santa Ana River Basin Projects.

The economic aspects of the Colorado River aqueduct and the Santa Ana River Basin projects are confined to the annual costs. No estimates are presented as to the revenues which might be expected from the sale of water and power because no definite information pertaining to these items is available.

The Engineering Board of Review for the Metropolitan Water District of Southern California has prepared an estimate of the annual cost of the aqueduct, which is presented below:

Interest at 4½ per cent on \$200,000,000.....	\$9,500,000
Taxes and insurance.....	250,000
Electric energy for pumping.....	3,367,000
Operation, maintenance, repairs and renewals.....	2,217,000
Storage in Boulder Canyon reservoir.....	272,000
Total annual charges.....	\$15,606,000

This annual cost is based on a diversion of 1500 second-feet, which would amount to some 1,086,000 acre-feet per year, or, according to the estimates of the Metropolitan Water District, about 990,000 acre-feet per year delivered into terminal storage on the Pacific Slope after deducting aqueduct losses, and 900,000 acre-feet net delivery from terminal storage.

The estimated capital cost of the physical works for the Santa Ana River project, designed both for the salvage of flood wastes and flood protection, is given in Table 48 for several different rates of interest during the period of construction. The table also shows the annual costs, including interest, depreciation, amortization, operation and maintenance. These costs are shown with amortization on both a forty-year and fifty-year, four per cent, sinking fund basis, with interest at the same rates as those used for the construction period. The annual cost also is shown for the project constructed without interest. This cost includes depreciation, operation and maintenance, and amortization on a forty-year straight line basis, but no interest on bonds.

TABLE 48
CAPITAL AND ANNUAL COSTS OF SANTA ANA RIVER BASIN PROJECT

	Interest rate in per cent						
	6	5	4½	4	3½	3	0
Capital cost.....	\$16,200,000	\$16,000,000	\$15,900,000	\$15,800,000	\$15,700,000	\$15,600,000	\$15,000,000
Gross annual cost, amortization on 40-year, 4 per cent sinking fund basis.....	1,466,000	1,288,000	1,200,000	1,114,000	1,028,000	944,000	-----
Amortization on 50-year, 4 per cent sinking fund basis.....	1,402,000	1,225,000	1,138,000	1,051,000	966,000	882,000	-----
Amortization on 40-year straight line basis.....	-----	-----	-----	-----	-----	-----	675,000

CHAPTER VIII

MAJOR LEGAL ASPECTS OF STATE WATER PLAN

Developments considered in preceding chapters would obviously effect vast changes in existing conditions of stream flow occurrence and distribution. The impounding of flood waters in mountain and foothill reservoirs would enable equalization of stream flow with consequent elimination or reduction of floods and consequent increase of flow during present periods of low discharge. Also, water would be exported from areas of surplus production and imported into areas of deficient supply and water naturally tributary to one area would be exchanged for water imported from another area. By means of such storages, equalizations of flow, exportations, importations and exchanges of water, flood control would be obtained and supplies would be provided for irrigation, navigation, salinity control, power development and other beneficial uses.

Initial Units of Plan.

The initial units heretofore proposed in the Great Central Valley and the San Francisco Bay Basin are Kennett reservoir in the Sacramento River; an industrial and irrigation canal taking out of the delta for supplying areas in Contra Costa County; a cross channel in the Sacramento-San Joaquin Delta and pumping plants, gates, ponds, and canals in the San Joaquin River and valley when necessary; Friant reservoir on the San Joaquin River; a canal northward from Friant reservoir to supply lands in Madera County; a canal southward from Friant reservoir to the Kern River and a small diversion southward from the Kern River. Purchase of so-called "grass land" water rights on the San Joaquin River is included so as to provide additional water for storage in Friant reservoir and for use in other areas.

Changes Resultant From Initial Units of Plan.

Kennett reservoir would be operated to reduce flood flows in the Sacramento River and for maintaining higher stream levels during other periods. This regulation or equalization of flow would reduce flood hazards, lessen frequency of occurrence and extent of overflow in areas now subject to inundation, lessen pumping lifts and costs during the irrigation season, provide a full supply for areas now under irrigation, maintain fresh water conditions in the Sacramento-San Joaquin Delta and afford a surplus of fresh water for exportation from the delta into the San Joaquin Valley and for supplying industrial and agricultural areas in Contra Costa County, as well as supplying valuable hydroelectric power developments and improving navigation.

The San Joaquin River pumping plants and canals, when constructed, would provide the means of importing surplus Sacramento River water into the San Joaquin Valley and enable the release of San Joaquin River water for exportation to the upper San Joaquin Valley.

Friant reservoir would store flood waters of the San Joaquin River for diversions to the Madera area and the upper portion of the San Joaquin Valley.

Purchase of "grass land" rights would remove an obstacle to Friant storage, as would the presence of Kennett waters in the delta region.

It is thus obvious that the initial units proposed would involve stream flow regulation, exportations of water, and exchanges of water.

Stream Flow Regulation by Means of Storage.

Opposed to readjustments of stream flow by storage is a fundamental doctrine of California water law which invests riparian landowners with the right to maintenance of stream flow undiminished, unaltered and according to present occurrence. The only exception is in favor of a correlative right of use by other riparian owners, but not even the riparian owner enjoys the right of storage. Furthermore the riparian owner is limited to use upon riparian lands. It is thus manifest that the riparian doctrine presents a serious obstacle to the operations proposed, whether by storage or exportation, and that the State Water Plan is fundamentally nonriparian in character.

A basic feature of the riparian doctrine is ownership of the entire stream by the riparian owners as tenants in common. They enjoy the right to enjoin nonriparian usage and prevent seasonal storage. Unlimited by any rule of reasonableness as against diversion to or usage upon lands other than those riparian to the source, entitled to an injunction without a showing of damage and empowered to prevent storages for release at periods of scant flow, these paramount proprietors, though the owners of relatively small acreages along the stream, may restrict usage to said acreages, though the water produced by the stream, if properly husbanded, would supply not only all that they can reasonably use, but also an abundance for nonriparian usage. That such is the law of riparian right has been recently affirmed by the Supreme Court of California in *Herminghaus vs. Southern California Edison Company*, 200 Cal., 1.

In the decision of the court in the case last cited it is suggested that public policy, public interest and a most liberal interpretation of the police power might be invoked in aid of the state itself were the state essaying to execute a general plan for the equitable adjustment of rights and uses in water in the interests of the whole people and for conservation, development and utilization of the water resources of California. Also, a constitutional amendment (Art. XIV, Sec. 3) added since the *Herminghaus* decision invokes the general welfare of the state in support of a declaration that riparian water rights shall be limited to amounts reasonably required for beneficial use and shall not extend to waste or unreasonable use or methods of use or diversion. Nevertheless the decision referred to is far from an assurance that it would be so held and the constitutional amendment in question must face a determined challenge and be construed by the Supreme Court of the United States in reference to the "due process" clause of the federal constitution before its validity or effect will be definitely established. Reliance upon the police power, either as indicated in the *Herminghaus* case or in Section 3 of Article XIV of the constitution, therefore is uncertain.

Other pertinent considerations are that only flood and freshest waters of very infrequent and inconsequential amounts are excluded from riparian control; that dedication to public use and prescription

are ineffectual against an alert and determined riparian owner; and that neither California decisions as to state authority over navigable waters with relation to riparian ownership, nor variant decisions elsewhere afford a sufficient basis upon which to rest a dependable conclusion. By this process of elimination eminent domain is suggested. This is the remedy offered by the court in the *Herminghaus* case and at least for the present affords the only certain means of removing the riparian impediment by legal process.

Exportation from Watershed.

As in the case of stream flow regulation by storage, so also in the case of exportation of water from a watershed does the riparian doctrine present formidable opposition in so far as exportations are attempted from points above riparian ownerships, and such exportations are apparently amenable only to an exercise of eminent domain.

There should be noted, however, a more or less prevalent notion that owners of nonriparian lands, which have never been irrigated, but which are irrigable, are possessed of a legal right by virtue of such ownership to prevent exportations for use out of the watershed in which their lands are situated. This idea is without foundation. Riparian ownership is limited to parcels bordering the stream and to such back lying parcels as have been carved out of such border parcels with a reservation of riparian right expressly provided. Neither are such owners appropriators. The doctrine of appropriation requires a taking and application of water to beneficial use, and furthermore, were they appropriators, they could not, as such, object to exportations from the watershed unless they were thereby deprived of water needed for beneficial use. The very doctrine of appropriation countenances exportation and many of the earliest appropriations in California involved exportations of water from the watershed source.

Exchanges of Water.

An exchange of existing supplies for an imported supply would be immediately involved in the plan proposed by virtue of substitution of Kennett storage releases into the delta in lieu of waters stored in and exported from Friant reservoir, and ultimately the initial unit would provide for pumping Sacramento River water up the San Joaquin River and canals and make it available so that further storages and exportations of San Joaquin River water would be permissible. Also water imported into the Kern River from Friant reservoir would be substituted in lieu of additional Kern River water taken through the East Side Canal.

The question of whether a water user or a riparian claimant may insist upon a supply of the water from the source to which his right is appurtenant or may be compelled to accept imported water in lieu thereof is thus squarely presented. There are decisions in other states holding in favor of such substitutions of water. Cases directly in point are the Idaho case of *Reno vs. Richards*, 178 Pac. 81; the Utah case of *United States vs. Caldwell*, 231 Pac. 434; and the Washington case of *State vs. American Fruit Growers, Inc.*, 237 Pac. 498. In so deciding, the courts in each of these states acted without reference to

the aforesaid decisions of the other courts, and, in so deciding, all the decisions involved considered principles of law established by California cases as in support of their decisions.

Upon analysis of the nature of the property right in water, which is that of a mere usufruct, and the right to mingle waters and use the channel of a stream as a medium of conveyance, and the right to change the point of diversion, place of use and purpose of use, and in view of the decisions cited, it is believed a substitution of water is legal, whether the opponent be a riparian owner or an appropriator.

Purchase of So-called San Joaquin Grass-Land Water Rights.

Under claim of riparian ownership and appropriations of early priority, a large area of grass and pasture lands lying between the Friant reservoir site and the mouth of the Merced River are irrigated by canals from and overflows of the San Joaquin River during stages of high flow. Inasmuch as this usage requires a great quantity of water for a relatively unimportant purpose, it is proposed to purchase these rights, and release the waters thereby acquired for storage in Friant reservoir and diversions therefrom northward to Madera County lands and southward into the areas of the San Joaquin Valley lying south of the San Joaquin River.

While it is true a purchaser of a riparian right may not by virtue of such purchase transfer usage to lands other than those in which the right purchased inheres, the effect of such a purchase is to eliminate the riparian vendor as an objector to such a transfer. On the other hand a purchaser of an appropriative right may change its place of use, point of diversion and purpose of use, subject to the condition of no injury to other vested rights. Thus such high-water flows as now are unavailable to storage because they are required for this grass or pasture land usage or flooding would be rendered legally usable for more valuable purposes after storage and diversion at Friant.

Underground Storage and Exportation Therefrom.

The canal leading southward from Friant reservoir would traverse areas wherein water may be released for spreading and sinking to underground storage. In this way the storage capacity of Friant reservoir may be supplemented during the nonirrigation season and additional supplies made available when needed by pumping from the underground basins. Such underground storage may be used either to supply areas overlying such basins, or may in part or entirely be pumped therefrom for exportation and use elsewhere during seasons of need. Underground storage and exportations from underground basins long have been in practice in southern California and judicial decisions have established the principles of law governing such methods of conservation and use.

Report of 1928 Legal Committee.

A committee of ten lawyers versed in water law and constitutional doctrines functioned as a subcommittee of the Joint Legislative Water Committee appointed by the 1927 Legislature. This legal committee's report is contained in the report of the legislative committee to the 1929 Legislature. A review of this legal committee's report reveals

that these attorneys considered "how the most extensive practicable use may be made of the waters of the state" and recognized that this involved "radical interference with the natural flow of our streams and underground waters, both by diversion and distribution of these waters in ways widely at variance with the course of nature."

The legal committee then considered the "fundamental water law of the state," which it declared to be the riparian right, and in view of the necessity of use upon areas nonriparian it proceeded to inquire into how the state might make this broader use consistent with the private riparian right to a full flow of the stream. It found that the riparian doctrine was firmly established by judicial decision, and, after reviewing the law pertinent to flood and freshet waters, dedication to public use and prescription, the police power, and navigable waters, concluded that eminent domain was the only certain remedy.

Three distinct procedures for the employment of this remedy were considered.

First, the present statutory method of a proceeding in the superior court, in which the judge decides all questions except the amount of compensation, which is fixed by a jury, unless a jury is waived by the parties, in which case the judge fixes compensation.

Second, a proposed method of fixing damage by an administrative body established by legislative enactment and authorized to make findings, subject to judicial review but prima facie evidence of amount of damage.

Third, a proposed judicial tribunal to administer eminent domain, as applied to water, created by constitutional amendment and functioning as does the Railroad Commission and Industrial Accident Commission when exercising judicial power, with its determinations to be conclusive as to questions of fact and its decisions reviewable by appellate courts on questions of law only.

Regardless of machinery employed, the committee warned of difficulty in that in most cases it will be desirable to take only excess water over and above that which the riparian owner reasonably requires by economical methods of diversion and use. The committee held, the plaintiff stating the quantity of water which he wishes to take, the question arises whether such a taking will only deprive the riparian owner of excess water which he really does not need or whether it will reduce the supply so that the demands of other riparian owners entitled to share the flow will render the same inadequate. The effect of taking any given amount can best be determined by an investigation of the entire stream and the needs of all parties upon it. Such an investigation will manifestly be impracticable and unbearably expensive in many instances. In view of this consideration the committee declared:

"Whatever procedure, therefore, is adopted, it should be adequate in some way to ascertain the amount of water which the riparian owner does require and in some way assure him of that quantity, and then, if necessary, condemn the right to take the surplus as against the legal right to the full flow of the stream."

A suggestion of the committee to meet this difficulty was condemnation of the entire riparian right, with a guarantee by the condemning party of a certain definite supply to be taken from the appropriation

of the condemning party. The committee recommended changes in the law of eminent domain which may be summarized as follows:

1. That unless a tribunal having state-wide jurisdiction is provided, the law should be amended to allow a condemnation proceeding to be brought in any county through which the stream flows so that relative rights to the stream can be determined by a single court in a single action.
2. That a taking be allowed upon security given to insure payment after valuation has been adjudged. Except in the matter of right of way condemnations by the state and certain agencies, the requirement at present is that compensation be first made and paid.
3. That a constitutional amendment authorizing compensation by substitution or physical adjustments in lieu of money compensation be provided. There are cases wherein such substitutions manifestly afford the only fair basis of compensation. Two illustrations are stated by the committee. Code amendments have been made relative to such compensation in the matter of relocation of structures, the making of crossings and the construction of fences.
4. That the entire code provisions relative to eminent domain should be overhauled and revised to eliminate the present chaotic and contradictory status occasioned by piecemeal amendments which have been enacted from time to time.
5. That irrigation be established as a public use and condemnation therefore be allowed to the would-be irrigator of nonriparian tracts.

Relative to a Constitutional Amendment in Aid of the Remedy by Eminent Domain.

In view of the recommendations of the legal committee above referred to, it is concluded that a comprehensive, detailed and specific constitutional amendment designed especially to care for all problems involved in a coordinated State Plan is advisable because of the complicated and novel problems thereby presented. Clearly no plan of such magnitude, expenditure and importance will be financially feasible unless certainty as to the power to execute it, the manner in which execution can be undertaken, and the approximate cost are known. It is believed that an explicit constitutional amendment will afford the greatest security against delays in execution and certainty as to the various factors which must be made known in advance. Considerations pertinent to such a constitutional amendment include:

1. A grant of plenary authority to the Legislature to enact a law of eminent domain relative to projects of a State Water Plan;
2. A water adjudication agency with state-wide and exclusive jurisdiction over suits to enjoin such projects or suits for damages on account thereof;
3. The conversion of injunction suits against projects into condemnation suits by the state agency administering such projects;
4. The combination in a single proceeding of all actions that pertain to interrelated rights;
5. The institution and prosecution before the water adjudication agency of condemnation proceedings either *in rem* versus all water rights claimed or versus particular rights;

6. The condemnation of all or a portion of a water right;
7. Findings of fact by the adjudication agency as to damages, offsetting benefits and compensation, which shall be conclusive;
8. A review of decisions of the water adjudication agency by the Supreme Court, only as to questions of law;
9. Awards of compensation either in money or in substituted benefits or physical adjustments;
10. An offset of any benefits deemed substantial, including such benefits as flood protection, salinity control, navigation, irrigation, ground water, higher stream levels and reduced pumping costs;
11. Compensation in whole or in part by a guarantee of maintenance of specified conditions which will make offsetting benefits definite and enable fixation of their value;
12. A taking by the project agency without first making compensation, and for a continuance of such taking upon security required by the adjudication agency in case of suit.

Conclusion.

Stated adversely the execution of a State Water Plan might, under the present status of the law, be long delayed by injunction suits by many claimants in many courts and might be made unduly burdensome by awards of excessive compensation in condemnation proceedings. Thus the riparian owner, with his claim of right to maintenance of the *status quo*, might interpose great embarrassment. In anticipation of such difficulties a revised law of eminent domain could be designed to meet all contingencies. In conclusion, it is submitted that an adequate law of eminent domain, administered by an agency having state-wide jurisdiction and properly constituted and empowered, should afford the means by which those entitled to compensation could be speedily and fairly provided for without undue difficulty, delay, or expense in the prosecution of a plan.

CHAPTER IX

INVESTIGATIONS IN PROGRESS

Investigations are in progress in several areas of the state. Insufficient data are available thus far to carry out studies of water requirements and supplies and to formulate plans of development and operation to serve the ultimate needs in these areas. In general, they include the more or less isolated valleys in the northern and southern part of the state and in the central coastal region, lying outside of the Great Central Valley and South Pacific Coast Basin. There also are important additional studies, however, being initiated in the South Pacific Coast Basin.

The areas now being investigated include, (1) Northeastern California, (2) Napa Valley, (3) Santa Clara Valley, (4) Salinas Valley, (5) Santa Barbara County, (6) Ventura County, (7) Mojave River and Antelope valleys, (8) South Coastal Basin, (9) San Diego County.

The type of development and the conditions of water supply and utilization in these various areas have markedly different characteristics and offer separate and distinct problems for solution. Except in the South Coastal Basin, the water problems are not usually as acute as in the major areas for which plans of development are presented in this report. However, in some of the areas additional water supplies must be provided in the near future if development is to continue. In most of the areas under investigation in the central coastal region and in southern California, water supplies are largely obtained from underground sources. In some of the areas, the underground water supplies already have been fully developed and utilized, whereas in others irrigation has been of comparatively recent origin and of small extent. In all of those areas in which the underground basins are the chief sources of water supply, the investigations necessarily include complete records of ground water levels and measurements of local streams.

Northeastern California.

The investigations in northeastern California include the area embraced in the counties of Siskiyou, Modoc, Lassen and Shasta. The principal streams of the region from which water supplies may be obtained include the Pit River and its tributaries, the tributaries of the Klamath River and numerous streams in the lake country of Modoc County. Many of these streams are fed by springs emanating from the lava beds. Irrigation developments thus far chiefly consist of gravity diversions from the surface streams. However, on the Pit River a large number of storage reservoirs have been constructed and are in operation to augment the natural stream supplies.

The investigations in progress in the area include the determination of water requirements, adjudication and distribution of available water supplies, and determination of the amount and source of supplemental water supplies required for ultimate needs. The Division of Water Resources (and the former Division of Water Rights) has adjudicated and is administering a great many of the major streams of the region.

These include Shasta River and Butte Creek in Siskiyou County, Hat, Burney, North Cow and Clover creeks in Shasta County, the Pit River in Lassen County and some ten streams in Modoc County. This work of adjudication and administration has generally resulted in increasing the extent and efficiency of utilization of the available water supplies, and thus has accomplished the equivalent to furnishing additional supplies.

Investigations in the upper Pit River Basin above Pittville were started in 1928 under cooperative agreement and joint financing between the state and Modoc and Lassen counties. The area being studied embraces about 3000 square miles, about two-thirds of which are situated in Modoc County and one-third in Lassen County. The principal agricultural areas involved are South Fork Valley, North Fork Valley, Hot Springs Valley, Big Valley and Ash Valley.

The field investigation includes the maintenance of about twenty stream gaging stations, and the collection of data relative to diversions, duty of water, climate, crop yields, reservoir sites, and extent of the irrigated and irrigable lands. In addition to the work originally planned, the state was called upon to administer all of the diversions from the main river in Big Valley during the 1930 irrigation season. This service was authorized by an agreement signed by all of the water users involved, and a similar agreement has been executed to provide for a continuation of the service during the 1931 season. These agreements and the administration thereunder may lead to an agreement permanently settling all of the water rights in Big Valley.

Napa Valley.

The Napa Valley investigation was initiated in November, 1929, at the request of the Board of Supervisors of Napa County and has as its object a determination of the facts with respect to the amount and availability of local water supplies. The work is covered by a cooperative agreement signed by Napa County and the Division of Water Resources looking toward a three-year investigation.

Continuous recording stream flow stations have been established on Napa River and Conn Creek. Readings are being taken at intervals on 80 wells distributed throughout Napa Valley. A series of intermittent stream flow measurements also are being taken on Napa River and Conn Creek to establish the behavior of those streams with respect to percolation and accretion at various stages and in various sections.

Santa Clara Valley (Santa Clara County).

The Santa Clara Valley investigation was initiated in January, 1930, by the execution of an agreement between Santa Clara Valley Water Conservation District and the Division of Water Resources looking toward a three-year investigation of the local water supplies of Santa Clara Valley. The investigation was prompted by apprehension over falling ground water levels. There has been a lowering over the past fifteen years of 64.5 feet in the general level of ground water in this area. As practically all the irrigation and domestic water used in the valley is pumped from underground sources there is great public concern over this situation, due to the increased costs of pumping

and the possibility of invasion of saline water from San Francisco Bay. The immediate purpose of the investigation is to determine the facts as to overdraft upon present underground water supply, the availability of local supplies to make good any overdraft which may exist, and possible means of accomplishing relief.

Continuous recording stream flow stations have been established on Guadalupe River, Alamitos Creek, Los Gatos Creek and Stevens Creek, and intermittent measurements have been made on those streams and Coyote River to establish the facts with respect to percolation.

Readings are being taken at intervals on some 250 wells distributed throughout the valley as far south as Morgan Hill to collect data on the behavior of ground water. Arrangements also have been made to obtain daily records of precipitation at various points in the valley.

Salinas Valley.

Work in the Salinas Valley thus far has consisted of establishing and maintaining two new gaging stations, including one on San Antonio Creek immediately above its confluence with the Salinas River and one on the Salinas River near Salinas. The program of the investigation in this valley includes studies of the underground basin, involving well measurements and determinations of percolation from the streams, together with a special consideration of the conditions affecting saline water intrusion from the ocean at the lower end of the valley.

Santa Barbara County.

The investigations in Santa Barbara County thus far have included only the establishment and maintenance of three stream gaging stations to measure the run-off into the Santa Maria Valley. To carry out the complete program of investigation, additional gaging stations in the Santa Maria Valley and on other streams in the county will be necessary, and studies of the underground water supplies will be required in all of the valleys within the county.

Ventura County.

The investigation in Ventura County was started in August, 1927. The principal stream systems of the county are the Ventura and Santa Clara rivers. The work has consisted of stream gaging measurements and determinations of ground water movement. Considerable basic data have been gathered on water supply and requirements, but complicated conditions render difficult the making of definite conclusions without much more basic data than are thus far available. Moreover, the entire period of investigation has been one of a succession of dry years, which has been unfavorable to obtaining conclusive data. While it is physically possible to bring supplies from an outside source to Ventura County, such importations would be extremely costly. The principal hope for full development of the agricultural resources in the county therefore lies in complete development of the waters of its two major streams by means of a fully coordinated plan, independent of imported supplies. Many reservoir sites exist, but these must be surveyed and

examined as to sufficiency of dam foundations and their cost estimated in order to determine their necessity and desirability in a plan of development.

Mojave River and Antelope Valleys.

The area comprising the Mojave River and Antelope valleys lies in the desert region east of the Coast Range Mountains of southern California in the westerly end of the Mojave Desert. Water supplies are limited in quantity and are largely utilized by pumping from underground sources. The amount of the available supply is uncertain and data are lacking on the amount of water now being used.

Investigation in the Mojave River Valley was started in October, 1929. Mojave River is the principal stream of the desert region of southern California. It rises on the north side of San Bernardino Mountains and is believed to have formerly reached Death Valley, but in recent times its water has been disposed of by evaporation in the sinks to the south of Death Valley. There are 8000 acres now irrigated in Mojave Basin and previous reports indicate that 325,000 acres are irrigable. The water supply is sufficient for only a fraction of the total area and development of any portion is complicated by legal questions involving riparian and underground water rights. Considerable areas of swamped and seeped lands along the river take their toll of water before the lower irrigated lands are supplied, further hindering an increase of development in this area.

The amount and occurrence of stream discharge from the mountains is fairly well determined and also, through previous investigations, the physical cost of irrigating considerable areas in the upper part of the basin can be approximated. There remain, however, matters of considerable importance which must be determined before comparative merits of alternate plans for utilizing the water can be made and it is to the solution of these that the present investigation is directed. Stream gaging, measurements of percolation and ground water movement, and surveys to determine waste of water at the sink in the lower end of the basin and from transpiration and evaporation within the basin itself are in progress. This work will be continued until sufficient data are obtained to complete studies of the amount and utilization of available water supply.

In the Antelope Valley, practically all water supplies at present utilized are obtained by pumping from the underlying underground basin into which surface streams from the adjacent hills sink. The work thus far under way consists of stream gaging at two gaging stations, one of which was established during the last year. Systematic observation of ground water levels also will be required to determine the safe yield of the underground basin.

South Coastal Basin.

Investigations under way in the South Coastal Basin, comprising the areas drained by the Los Angeles, San Gabriel and Santa Ana rivers, and the small drainage basins immediately west of the city of Los Angeles, are directed to a study of the amount of waste water and its availability for reuse. There is a considerable lack of uniformity in the physical features of these three drainage areas. The under-

ground basins in each are more or less related and as a whole form the South Coastal Basin, but there exist certain special conditions in each basin requiring special study and treatment. In some basins the natural recharge is insufficient, in others a deficiency is threatened, and in others there appears to be little danger of future deficiency. The salvage of waste water, the imminence of a new imported supply and the difficulties which will be encountered when an attempt is made to supplement the underground water supply and allocate the benefits therefrom, require an investigation more intensive than any previous one.

The investigation will include not only a study of the salvage and reuse of sewage wastes, but also a determination, by means of extended ground water observations, of the most advantageous operation and use of the underground reservoir capacity. Work is in progress to estimate the water requirements for various uses in the basin. A study is being made of the amount of water supply contributed to the underground basin by rainfall on the valley floors of the basin. In the Santa Ana River Basin the studies thus far indicate a seasonal rainfall of at least nineteen inches is required before penetration will be effected below the brush root zone, ten to fifteen inches on grass or weed covered lands, about twelve inches on citrus orchards and eleven to eighteen inches on deciduous orchards. In the Riverside area the data thus far obtained indicates there is no substantial contribution to the underground basin from rainfall. The soil is of the ancient alluvial type and the principal contributions come from surface run-off which is usually too small to result in any deep penetration, except possibly in heavily irrigated citrus orchards.

The investigation in the South Coastal Basin, when completed, should furnish basic data for the determination and allocation of benefits which would accrue from the newly developed water supplies made available under a coordinated plan of utilization and operation for both local and imported supplies.

San Diego County.

Work done thus far has been the establishment of additional gaging stations on the streams so that full information will be available on the present waste of water into the ocean and the amounts available at points where it can be conserved by surface reservoirs. Work also is being done in connection with the international division of the water of Tia Juana River.

APPENDIX

STATUTES DIRECTLY RELEVANT TO STATE WATER RESOURCES INVESTIGATIONS
