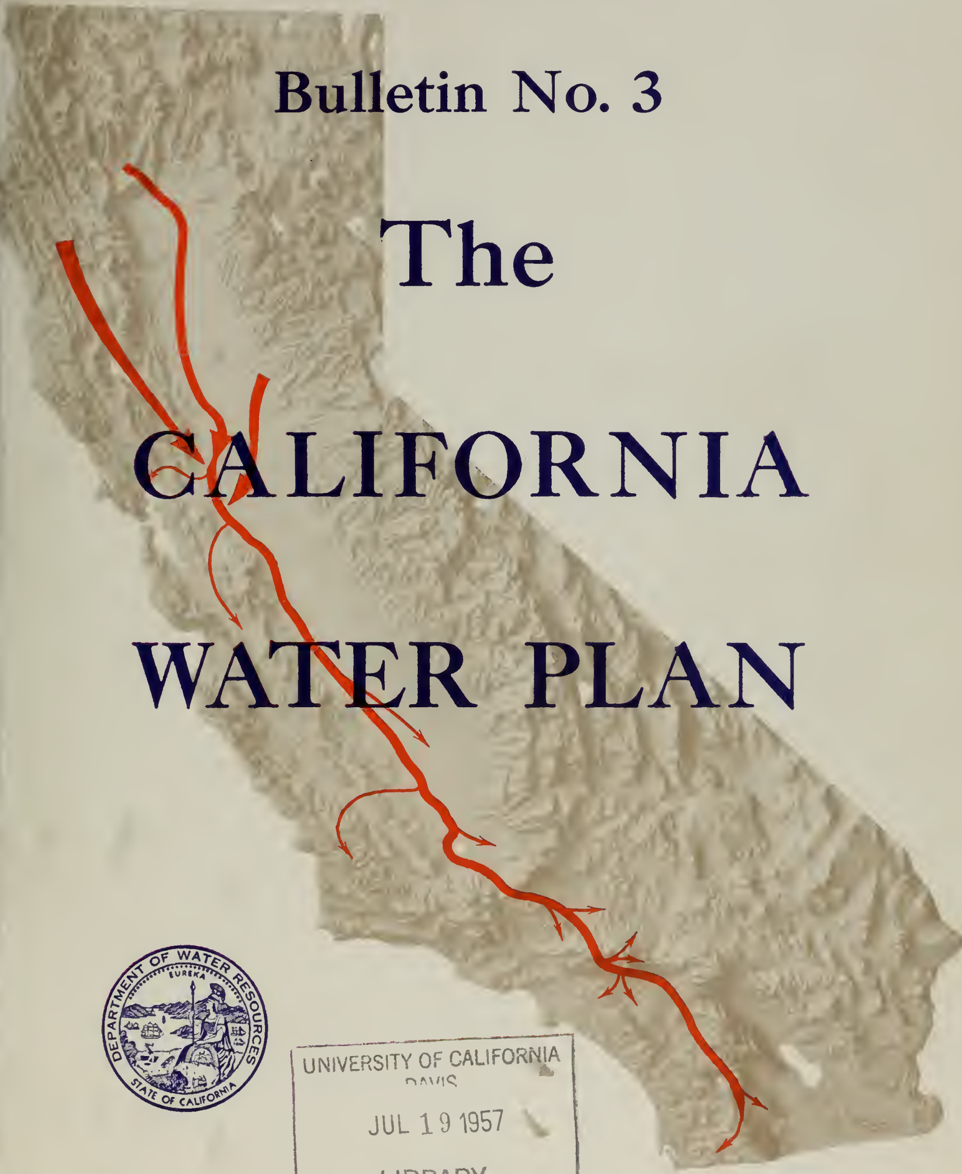
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

Bulletin No. 3

The CALIFORNIA WATER PLAN



GOODWIN J. KNIGHT
Governor

May, 1957

HARVEY O. BANKS
Director of Water Resources

STATE OF CALIFORNIA
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The CALIFORNIA WATER PLAN

GOODWIN J. KNIGHT
Governor

HARVEY O. BANKS
Director of Water Resources

May, 1957

This publication is dedicated to the memory of the late State Engineer of California, A. D. Edmonston.

Mr. Edmonston, with an interest transcending the requirements of his office, developed and vigorously propounded the fundamental concepts of state-wide comprehensive development of California's water resources.

Mr. Edmonston had acquired an interest in the State's water resources by 1924 when he entered State service. He was instrumental in the formulation of the State Water Plan of 1930, which led to the authorization and subsequent construction of the Central Valley Project.

As a direct result of Mr. Edmonston's dedication and resolution, the first unit of The California Water Plan and the first truly State-wide water development in California—the Feather River Project—has been brought to fruition by legislative authorization and initiation of construction.

A. D. EDMONSTON
1886-1957

FOREWORD

California is presently faced with problems of a highly critical nature—the need for further control, protection, conservation, and distribution of her most vital resource—water. While these problems are not new, having been existent ever since the advent of the first white settlers, never before have they reached such widespread and serious proportions. Their critical nature stems not only from the unprecedented recent growth of population, industry, and agriculture in a semiarid state, but also from the consequences of a long period during which the construction of water conservation works has not kept pace with the increased need for additional water. Unless corrective action is taken—and taken immediately—the consequences may be disastrous.

What are the principal water problems facing the people of California? The most recently and tragically demonstrated problem—the floods of December, 1955—is still vivid in the memory of all. Taking the lives of 64 persons, destroying and damaging homes, farms, businesses, and utilities to the tangible toll of $200,000,000, with great additional intangible losses to the general economy, the streams of northern and central California went on a rampage unparalled in recent history.

Not so spectacular, but nonetheless significant, and constantly evident, is the problem of water deficiency in many areas of the State. A critical need for supplemental water supply now exists in many areas, including: Alameda, Santa Clara, and San Benito Counties; the east, west, and south portions of the San Joaquin Valley; Antelope Valley; Santa Maria Valley and Ventura County. The ground water basins in these areas are being pumped to the point of dangerous overdraft which threatens their welfare. There have been, for many years, severe overdrafts on the ground water basins in the South Coastal Area in Los Angeles, Orange, San Bernardino, and Riverside Counties. An acute need for additional water exists in San Diego County, which will be temporarily alleviated by the construction of an additional aqueduct to convey presently surplus Colorado River water, as now authorized by The Metropolitan Water District of Southern California and the San Diego County Water Authority. The supply which can be made available to the South Coastal Area under rights to Colorado River waters, while not now fully utilized, will be fully committed and used by about 1970. By 1975, or possibly much earlier, all of southern California will need more water. Moreover, many of the mountainous areas, such as the Upper Feather River Basin and portions of the North Coastal Area, need water development works, not only for municipal and irrigation water but also to maintain stream flow for preservation of fish and wildlife, and to enhance the recreational potential, an important economic asset.

The urgency of California's water problems can best be illustrated by citing the example of the recent rapid growth of the State. In 1940, just before the beginning of World War II, California had a population of about 6,900,000. By 1950 this population had increased to about 10,600,000, and by 1955 it had increased an additional 23 per cent to more than 13,000,000. In 1957 the population reached 14,000,000. Coincidentally, the use of water per capita has increased significantly and will continue to grow. In 1950 the estimated seasonal shortage of developed water in California was about 2,700,000 acre-feet, largely representing an overdraft on ground water storage. By 1955, water requirements had increased an additional 3,000,000 acre-feet per season. Allowing for the yield from new construction during the intervening period and for increase in the delivery of constructed works to their full potential wherever possible, the deficit aggregated nearly 4,000,000 acre-feet per year. Although the bulk of this supplemental water is needed for irrigation purposes, substantial quantities are required for urban and domestic uses.

Based upon reasonable forecasts of growth of the State during the next decade, it is indicated that the net shortage of developed water supply could amount to more than 10,000,000 acre-feet per season by 1965, taking into account increasing importations and deliveries from presently developed water sources.

The need for solution of the present and future water problems of California is clear. It is also clear from a study of the past history of water development in the State that the future growth of California will now depend upon a coordinated state-wide program for water development. The authorized Feather River Project, the first truly state-wide project, will be the first major step in this direction. However, even if the project were constructed and in operation today and serving all areas of water deficiency, it would barely overcome the deficiencies of the present. In other words, the large water supply to be gained from the Feather River Project is fully needed today. Furthermore, unless we assume that the population remains at present levels, one or more additional projects of comparable size should be rapidly planned for construction in the near future. This fact should be cause for concern, for there is no reason to believe that our phenomenal recent rate of growth will slow down now or in the near future. The responsibility of immediate initiation of a state-wide water development planning and construction program is particularly acute because of the often-demonstrated time lag between the planning stage and the financing and construction stage of any large-scale project.

The State Legislature in 1947 authorized comprehensive state-wide investigations and studies, which have culminated, after 10 years of intensive effort, in "The California Water Plan," a master plan to guide and coordinate the planning and construction by all agencies of works required for the control, protection, conservation, and distribution of California's water resources for the benefit of all areas of the State and for all beneficial purposes.

What does "The California Water Plan" purport to do?

1. It evaluates the water supply available to California and describes the places and characteristics of its occurrence.

2. It estimates the water requirements, both present and future, for all purposes for each area of the State, as best as can be foreseen now.

3. It points out (a) the watersheds where present estimates indicate surplus waters exist over and above the future needs for local development, and gives an estimate of such surplus, and (b) the areas of deficiency and the estimated deficiency for each such area.

4. It outlines existing and prospective water problems in each area of the State.

5. It describes the beneficial uses to which the remaining unappropriated waters of the State should be put for maximum benefit to the people of all areas of the State.

6. It suggests the manner in which the waters of the State should be distributed for the benefit and use of all areas.

7. It proposes objectives toward which future development of the water resources of the State should be directed in all areas of the State, and suggests broad patterns for guidance toward these objectives.

8. It defines these objectives in terms of potential physcial accomplishments, which may be used to measure the merits of projects proposed for construction by any agency.

9. Finally, it demonstrates that the waters available to the State of California, including the State's rights in and to the waters of the Colorado River, are not only adequate for full future development of the land and other resources of the State, but also that physical accomplishment of these objectives is possible.

The California Water Plan must be implemented by a state-wide program for the construction of projects needed to control and supply water wherever and whenever the need arises and as projects are found feasible. Physical works for the control, protection, development, and use of water do not pertain solely to the so-called "areas of deficiency." There are few areas which do not now or will not require physical works for the development of water resources. The job is a big one, and will require the combined efforts of the Federal Government, the State Government, and local agencies, as well as private entities and individuals, with the State logically taking a leading role in administration and coordination as well as financing and construction.

The Feather River Project, the initial unit of The California Water Plan, must be started immediately, and other projects must follow in the near future. The California Water Plan, a coordinated master plan, should be accepted as the general framework or pattern for future water development in the State. Finally, and this cannot be emphasized too strongly, solution of the water problems of California lies in the construction of physical works—not alone in laws and reservations of water, however necessary these may be as steps in the process.

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ABBREVIATIONS: **t**, tap; **c**, center; **b**, bottom; **r**, right; **l**, left.

APPENDIXES

At the present time the Department of Water Resources plans to publish appendixes on those considerations basic to the formulation of The California Water Plan and on certain other factors affecting the Plan. There follows a listing of these proposed appendixes, together with a general statement of their scope.

A. Detailed engineering report on The California Water Plan, describing local and interbasin transfer projects on an individual basis.

B. Basic assumptions, criteria, and procedures employed in formulating The California Water Plan.

C. General geology of California, geologic conditions affecting the location and design of engineering works, and ground water geology.

D. Utilization of ground water storage capacity, with particular reference to conjunctive operation of surface and underground reservoirs.

E. Factors involved in maintenance of water quality.

F. Effects of The California Water Plan on fish, wildlife, and recreation.

G. Flood problems and existing project works; flood control accomplishments of The California Water Plan.

H. Economic and financial aspects of The California Water Plan.

I. Water rights and attendant legal considerations and implications with respect to The California Water Plan.

J. Potentialities of other means of increasing water supplies, such as sea-water conversion, waste-water reclamation, artificial increase of precipitation, and watershed management.

K. Relationship of future power sources and energy requirements to The California Water Plan.

LETTER OF TRANSMITTAL

HARVEY O. BANKS
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GOODWIN J. KNIGHT
GOVERNOR

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STATE OF CALIFORNIA
Department of Water Resources
SACRAMENTO

May 6, 1957

HONORABLE GOODWIN J. KNIGHT, *Governor, and*
Members of the Legislature of the
State of California

GENTLEMEN:

I have the honor to transmit herewith Bulletin No. 3 of the Department of Water Resources, entitled "The California Water Plan," as authorized by Chapter 1541, Statutes of 1947.

Bulletin No. 3 presents a master plan to guide and coordinate the activities of all agencies in the planning, construction, and operation of works required for the control, development, protection, conservation, distribution, and utilization of California's water resources for the benefit of all areas of the State and for all beneficial purposes.

It is believed that The California Water Plan provides the basis for achieving the most effective and comprehensive development of California's water resources. It is concluded that California does have enough water, including the State's present rights in and to the waters of the Colorado River, to satisfy the ultimate water needs if the available resources are wisely controlled, conserved, and distributed. The full solution of California's water problems thus becomes essentially a financial and engineering problem.

Bulletin No. 3 contains recommendations that The California Water Plan be accepted by the Legislature as the general and coordinated master plan for the progressive and comprehensive future development of the water resources of California by all agencies; that adequate funds be provided by the Legislature for a continuing, more detailed study under the California Water Development Program; that positive assurances be provided, to the maximum practicable extent, by constitutional amendment and legislative enactments, that water required to meet all future beneficial uses in all areas of the State will be available in adequate quantity and quality when and where needed; that a long-range water development fund and enabling policies to assure the financing and construction of needed water development works in California be established; that the financing and construction of the authorized Feather River Project be expedited; and that other presently needed water development works be undertaken immediately.

Very truly yours,

Harvey O. Banks
Director

LETTER OF TRANSMITTAL

GOODWIN J. KNIGHT
GOVERNOR

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STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
STATE WATER BOARD

May 8, 1957

MR. HARVEY O. BANKS, *Director*
Department of Water Resources
401 Public Works Building
Sacramento, California

DEAR MR. BANKS:

The State-wide Water Resources Investigation, which culminated in The California Water Plan, was conducted under the direction of the State Water Resources Board, predecessor to the State Water Board, from its inception as provided in Chapter 1541, Statutes of 1947, until creation of the Department of Water Resources on July 5, 1956.

Although the name and responsibilities of the Board have been changed, membership on the two Boards has been continuous. Consequently, the members of the State Water Board, as a Board and individually, have the greatest interest in Bulletin No. 3, which presents The California Water Plan.

This bulletin, which joins the years of work of the engineers, the efforts of the Board members and countless others, the findings of the public hearings, and the advice and counsel of the Board of Engineering Consultants, has been reviewed by and has the approval of the State Water Board.

Very truly yours,

Clair A. Hill

Clair A. Hill
Chairman

REPORT OF THE BOARD OF ENGINEERING CONSULTANTS

May 8, 1957

Mr. Harvey O. Banks, *Director,*
Department of Water Resources,
P. O. Box 1079,
Sacramento 5, California

Subject: Bulletin No. 3—The California Water Plan

Dear Mr. Banks:

This Board of Consultants was first retained on January 6, 1956 by the State Water Resources Board to review Bulletin No. 3, The California Water Plan. Upon establishment of the Department of Water Resources in July 1956, you reappointed the same members and assigned the same duties. Five meetings of this Board were held prior to July 1956 and six meetings thereafter.

This Board of Consultants endorses the principle of long-range planning for full development and use of the water resources of California, where such plans are subject to continuing review. However, The California Water Plan, as presented in Bulletin No. 3, includes projects of doubtful economic justification and works of unproven physical feasibility.

This Bulletin properly calls attention to the fact that the irrigation of desert areas involving net pumping lifts of several thousand feet is not now and may never be within the limits of economic justification and financial feasibility. This Board believes that further study should be given to the extent and cost of the works that would be needed to supply water for the irrigation of such desert areas and that more positive estimates should be made of the cost of an Aqueduct System designed to serve all other areas and purposes throughout the State.

This Board of Consultants endorses your recommendations: (a) that more detailed investigation and study be made of component features of The California Water Plan to determine their need, engineering feasibility, economic justification, financial feasibility, and recommended priority of construction; and (b) that there be continuing review, modification, and improvement of The California Water Plan in the light of changing conditions, advances in technology, additional data, and future experience. Such studies should include determination at then current price levels of: the capital and annual costs per acre-foot of water for its development and delivery within each hydrographic unit for use within the same area; and the capital and annual costs per acre-foot of water for its development in areas of surplus and its transportation and delivery to each area of shortage.

This Board of Consultants is confident that there is enough water in northern California, surplus to all potential local needs, to satisfy all requirements for additional water in the San Francisco Bay Region, in the San Joaquin Valley, in the Central Coastal area, and south of the Tehachapi Mountains. It believes that continuing development of these water resources as needed is essential to the future welfare of this State.

Accordingly, this Board recommends that the Legislature receive The California Water Plan as an evolving, continuing, coordinated proposal for the progressive and comprehensive future development of the water resources of California, and that this plan be commended to all agencies concerned with the development of these resources. This Board further recommends that no specific project be authorized for construction prior to detailed investigation of its engineering feasibility, economic justification, and financial feasibility.

Respectfully submitted,

Board of Consultants

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ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government and of the State of California, by cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

Bureau of Reclamation, United States Department of the Interior
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Federal Power Commission
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Geological Survey, United States Department of the Interior
Soil Conservation Service, United States Department of Agriculture
California Department of Fish and Game
California Department of Public Works, Division of Highways
California Public Utilities Commission
University of California at Berkeley and at Davis
East Bay Municipal Utility District
Hetch Hetchy Water Supply, Power and Utilities Engineering Bureau, City of San Francisco
The Metropolitan Water District of Southern California
Department of Water and Power, City of Los Angeles
San Diego County Water Authority
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ORGANIZATIONAL CHANGES

The State-wide Water Resources Investigation, resulting in the formulation of The California Water Plan, was authorized by the State Legislature in 1947 and initiated on September 5, 1947, under direction of the former State Water Resources Board. Royal Miller was Chairman of the Board at the inception of the investigation, being succeeded by C. A. Griffith who, in turn, was succeeded by Clair A. Hill.

Changes in the membership of the Board were occasioned by the deaths of Messrs. L. S. Ready and B. A. Etcheverry; the retirements of Messrs. Royal Miller, H. F. Cozzens, C. A. Griffith, and R. V. Meikle; and the subsequent appointments of Messrs. Hill, W. P. Rich, A. Frew, and W. Penn Rowe. Upon the redesignation of the State Water Resources Board as the "State Water Board" on July 5, 1956, Messrs. John P. Bunker, Kenneth Q. Volk, and Everett L. Grubb were appointed as members, and W. Penn Rowe resigned to accept an appointment with the newly created State Water Rights Board.

Phil D. Swing is the only member of the State Water Board who has had continuous service since creation of the State Water Resources Board in 1945.

Edward Hyatt was State Engineer and Secretary of the State Water Resources Board at the inception of the State-wide Water Resources Investigation in 1947. The significant broadening of state policy relating to flood control and water conservation, encompassed in the State Water Resources Act of 1945, largely reflected Mr. Hyatt's enlightened and progressive thinking in these matters.

As State Engineer from 1927 to 1950, Mr. Hyatt directed the surveys which culminated in formulation of the State Water Plan, predecessor to The California Water Plan. Moreover, he was instrumental in initiation of the investigations which led to The California Water Plan, and determined many of the concepts upon which it is based.

A. D. Edmonston succeeded Mr. Hyatt as State Engineer in 1950. He vigorously carried forward the work on The California Water Plan, and was directly responsible for the authorization of the Feather River Project as the initial unit of the Plan. He retired on November 1, 1955.

Harvey O. Banks succeeded Mr. Edmonston and remained State Engineer until July 5, 1956, when the office of State Engineer was abolished and the Department of Water Resources was created.

The State-wide Water Resources Investigation was conducted successively under the general direction of Assistant State Engineers A. D. Edmonston; P. H. Van Etten, until his retirement on June 15, 1951; Thomas B. Waddell, until his retirement on November 1, 1955; and William L. Berry, until July 5, 1956, when the Department of Water Resources was created. Since the latter date, the organization of the Department has been as shown on page XVII.

During the final phase of the State-wide Water Resources Investigation, culminated by the preparation of this bulletin, a major change in the status of this organization has taken place pursuant to Chapter 52, Statutes of 1956, effective on July 5, 1956. The statute created the State Department of Water Resources, which succeeded to and was vested with all of the powers, duties, purposes, responsibilities, and jurisdiction in matters pertaining to water or dams formerly vested in the Department and Director of Public Works, the Division of Water Resources of the Department of Public Works, the State Engineer, and the Water Project Authority. The Department of Water Resources also succeeded to and was vested with the powers, duties, purposes, responsibilities, and jurisdiction of the Department of Finance under Part 2 of Division 6 of the Water Code.

In addition, the former State Water Resources Board was redesignated the "State Water Board," and was placed within the Department of Water Resources to confer with, advise, and make recommendations to the Director with respect to any matters and subjects under his jurisdiction.

Finally, the State Water Rights Board was created, which board succeeded to and was vested with all of the powers, duties, purposes, responsibilities, and jurisdiction formerly vested in the Department and Director of Public Works, the Division of Water Resources of the Department of Public Works, and the State Engineer, regarding the adjudication of water rights, and the issue, denial, or revocation of permits or licenses to appropriate water.

It should be pointed out at this time that the authority and responsibilities of the former State Water Resources Board, relative to the conduct of the State-wide Water Resources Investigation, special investigations, and the preparation of this bulletin, are now vested wholly in the Department of Water Resources.

SYNOPSIS

This is the final of a series of three bulletins setting forth the results of the State-wide Water Resources Investigation, which has been in progress for the past 10 years under provisions of Chapter 1541, Statutes of 1947. This investigation entailed a three-fold program of study to evaluate the water resources of California, to determine present and probable ultimate water requirements, and to formulate plans for the orderly development of the State's water resources to meet its ultimate water requirements. Funds to meet the cost of the investigation were provided by the cited statute and subsequent budgetary acts of the Legislature.

The first phase of the State-wide Water Resources Investigation comprised an inventory of data on sources, quantities, and characteristics of water in California. The results are available in State Water Resources Board Bulletin No. 1, "Water Resources of California," published in 1951. This bulletin comprises a concise compilation of data on precipitation, runoff of streams, flood flows and frequencies, and quality of water throughout the State.

The second phase dealt with present and ultimate requirements for water. The associated report, State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," was published in 1955. This study comprised determinations of the present use of water throughout the State for all consumptive purposes, and forecasts of ultimate water requirements based in general on the capabilities of the land to support further balanced development.

The final phase of the State-wide Water Resources Investigation is presented herein as "The California Water Plan." Bulletin No. 3 describes a comprehensive master plan for the control, protection, conservation, distribution, and utilization of the waters of California, to meet present and future needs for all beneficial uses and purposes in all areas of the State to the maximum feasible extent. The Plan is designed to include or supplement rather than to supersede existing water resource development works, and does not interfere with existing rights to the use of water.

The objective in the formulation of The California Water Plan has been to provide a logical, engineering basis for future administration of the water resources of the State and for coordination of the efforts of all entities engaged in the construction and operation of water development projects, to the end that maximum benefit to all areas and peoples of the State may ultimately be achieved.

The California Water Plan includes local works to meet local needs in all portions of the State. It also includes the California Aqueduct System, an unprecedented system of major works to redistribute excess waters from northern areas of surplus to areas of deficiency throughout the State. The Plan gives consideration to water conservation and reclamation; to flood control and flood protection; to the use of water for agricultural, domestic, municipal, and industrial purposes; to hydroelectric power development; to salinity control and protection of the quality of fresh waters; to navigation; to drainage; and to the interests of fish, wildlife, and recreation. It contemplates the conjunctive operation of surface and ground water reservoirs, which operation will be essential to regulation of the large amounts of water ultimately to be involved.

The very magnitude of the task involved in formulation of The California Water Plan was such that detailed surveys and studies, and economic and financial analyses, could not be undertaken in this initial phase of investigation. At this stage of its development, therefore, the Plan must be regarded as no more than a broad and flexible pattern into which future definite projects may be integrated in an orderly fashion. As additional data and experience are gained, as technology advances, and as future conditions change in manners that cannot be foreseen today, The California Water Plan will be substantially altered and improved. However, the basic concept of the Plan as a master plan to meet the ultimate requirements for water at some unspecified but distant time in the future, when the land and other resources of California have essentially reached a state of complete development, will remain unchanged.

Voluminous data and information have been compiled and assembled in connection with preparation of The California Water Plan. It is realized that the need of the general public, on the one hand, is for a summary report with a minimum of technical detail but containing all of the information essential to an adequate understanding of the Plan. The need of engineering and other professional people, on the other hand, is for more detailed technical information which would be of minor interest to the general public. Therefore, publication has been set up to meet these separate needs—Bulletin No. 3 itself to meet the general need and the several appendixes to Bulletin No. 3 to meet the engineering and other technical needs.

Bulletin No. 3 consists of a summary report on The California Water Plan. It discusses available water resources, present and probable ultimate water requirements, and associated problems. It describes the development works that may be necessary to meet local requirements, and the interbasin transfer facilities which could convey water from nothern areas of surplus to major areas of deficiency in the central and southern parts of the State. It also discusses briefly the basic considerations in implementation of The California Water Plan and the possible accomplishments accruing therefrom.

The several appendixes will present a more detailed engineering report on The California Water Plan, reports on geology and other technical subjects, as well as reports by other agencies concerned in specific phases of the investigations. All of these appendixes are listed in the Table of Contents and are described in more detail in Chapter I.

It should be mentioned at this time that although the publication of Bulletin No. 3 completes the State-wide Water Resources Investigation, it by no means signifies the termination of planning activities by the Department of Water Resources. Rather, it marks only the beginning of an intensive and continuing program of study of the needs for specific local and state-wide water development projects, analysis of their economic justification and financial feasibility, and determination of the recommended priority of their construction, using The California Water Plan as a general guide. This study program, known as the "California Water Development Program," will enable the planning endeavor to keep pace with the needs of a rapidly growing State.

CHAPTER I

INTRODUCTION

Today, the future agricultural, urban, and industrial growth of California hinges on a highly important decision, which is well within the power of the people to make. We can move forward with a thriving economy by pursuing a vigorous and progressive water development planning and construction program; or we can allow our economy to stagnate, perhaps even retrogress, by adopting a complacent attitude and leaving each district, community, agency, or other entity to secure its own water supply as best it can with small regard to the needs of others. The choice of these alternatives is clear. The need for coordinated planning on a state-wide basis has long been realized. Comprehensive plans have been formulated and reported upon in the past, and noteworthy accomplishments have been achieved by local enterprise and private and public agencies. But despite the great water development projects constructed in the past, California's water problems continue to grow day by day.

The construction of highways, schools, hospitals, and other public works has greatly accelerated since the end of World War II. However, to supply its necessary water, California is relying for the most part on works which were designed to meet the needs as anticipated 20 to 30 years ago. These facts are now becoming known and more generally understood by the people. It is apparent to most that the continued growth and prosperity of California is dependent upon prompt and substantial efforts by the responsible local governmental agencies, the State, and the Federal Government to ensure that the planning and construction of water development projects keeps pace with the growing needs for water.

The population of California has continued to grow at a phenomenal rate, and irrigated agriculture and industrial activity have increased proportionately. This recent rapid expansion of the economy has occurred largely in areas of inherent water deficiency, thus intensifying the problem in those areas. While in most instances the increases in water requirements are physically being met, they are provided for by drawing on diminishing ground water reserves in order to meet the deficiency. Such perennial overdraft has been increasing rapidly in recent years and has resulted in accelerated lowering of ground water levels in many parts of the State.

Effects of these overdrafts are presently manifested in the intrusion of sea water into the principal pumping aquifers of a number of coastal ground water basins, and the threat of such intrusion into others. Certain inland ground water basins have experienced degradation in quality of their fresh waters by mixture with underlying entrapped connate brines (i.e., salt water entrapped when the formation was deposited) or other waters of undesirable mineral quality. Furthermore, overdraft conditions may result in an accumulation of excess minerals or salts in a ground water basin, which in a period of time may degrade the water quality beyond acceptable limits. Thus, it is evident that continuing overdrafts will not only drastically reduce the reserves in storage, with possible exhaustion in some cases, but in many instances will irreparably damage the immensely valuable ground water reservoirs unless supplemental water supplies are developed.

While experiencing problems of water deficiency on the one hand, California is presently faced with the anomaly of other problems of the exact opposite nature—that of periodic floods which result in major damage and loss of life. Ironically, in many cases the same areas suffering deficiency in water supplies are besieged with winter floods when the water, so urgently needed for the economy, wastes to the ocean, accomplishing nothing but damage and grief. Historically, agricultural and urban development has occurred largely in valleys and on plains inherently subject to flooding. With the intensification of agriculture and expansion of urban and industrial areas, future flood problems will become more severe unless remedial action is taken.

Concurrently with the expanding population and increasing irrigation and industrial development in the valleys and metropolitan areas of the State, there has been increasing pressure for enhancement of fish and wildlife resources and for the provision of adequate recreational opportunities, particularly in the hill and mountainous areas. If these needs are to be adequately met, provision must be made therefor in future water development through development of water areas and live streams.

The magnitude of the foregoing water problems may be better appreciated by referring to Plate 1, entitled "Present Water Problems." The 1947 Legislature, recognizing these problems and appreciating the role of water in the future of the State, directed that the water resources and present and future water requirements of California be studied and evaluated, and that plans be formulated for the orderly development of the State's water resources to meet its ultimate water requirements. This directive initiated the "State-wide Water Resources Investigation," which has been under way for the past 10 years, culminating in the preparation of this bulletin.

BASIS AND AUTHORITY FOR STATE-WIDE WATER DEVELOPMENT PLANNING

The principle of state-wide planning for development of California's water resources is no innovation. Development of the water resources of California has long been recognized as a primary responsibility of the State. Expressions of state policy regarding water supply development are found in the State Constitution and numerous court decisions. The State Water Code incorporates the following pertinent sections which constitute the basis for a state-wide water development plan:

"100. It is hereby declared that because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such water is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. . . .

"102. All water within the State is the property of the people of the State, but the right to the use of water may be acquired by appropriation in the manner provided by law.

"104. It is hereby declared that the people of the State have a paramount interest in the use of all the water of the State and that the State shall determine what water of the State, surface and underground, can be converted to public use or controlled for public protection.

"105. It is hereby declared that the protection of the public interest in the development of the water resources of the State is of vital concern to the people of the State and that the State shall determine in what way the water of the State, both surface and underground, should be developed for the greatest public benefit.

"12578. It is hereby declared that the people of the State have a primary interest in the control and conservation of flood waters, prevention of damage by flood waters, the washing away of river and stream banks by floods, and in the determination of the manner in which flood waters shall be controlled for the protection of life and property and the control, storage, and use of the State's water resources in the general public interest.

"12579. It is hereby declared that recurrent floods on streams and rivers, and other waterways of the State, causing loss of life and property, disruption of commerce, interruption of transportation and communications, and wasting of water, are detrimental to the peace, health, safety, and welfare of the people of the State. The control, storage and full beneficial use of flood waters, and the prevention of damage by flood waters, and the washing away of river and stream banks by floods are proper functions and activities of the State, in cooperation with counties, cities, state agencies and public districts, and in cooperation with the United States, or any of its departments or agencies.

"12580. It is further declared that the State should engage in the study and coordination of all water development projects, including flood control projects, undertaken by counties, cities, state agencies and public districts, and the United States or any of its departments or agencies in order that such allocations and appropriations as are made by the State Legislature for such purposes will be expended upon those projects which are most beneficial to the State, and which will bring maximum benefits to the people of the State from the expenditure of public funds, and also that the State should participate in the construction of flood control works and projects and render beneficial aid thereto, when the benefits are in excess of the estimated cost.

"12581. In studying water development projects, full consideration shall be given to all beneficial uses of the State's water resources, including irrigation, generation of electric energy, municipal and industrial consumption of water and power, repulsion of salt water, preservation and development of fish and wildlife resources, and recreational facilities, but not excluding other beneficial uses of water, in order that recommendations may be made as to the feasibility of such projects and for the method of financing feasible projects.

"12582. Fish and wildlife values, both economic and recreational, shall be given consideration in any flood control or water conservation program. . . ."

To implement state policy, the State Water Resources Board was established by legislative enactment in 1945, and was endowed with broad powers to initiate and conduct investigations of the water resources of the State. The Board was vested with the responsibility for conduct of the State-wide Water Resources Investigation by Chapter 1541, Statutes of 1947. Funds were provided in the 1947-48 budget for commencement of the investigation, and the Budget Acts of 1948 and subsequent years have made appropriations for completion of the investigation and for preparation of reports thereon.

During the final phase of the State-wide Water Resources Investigation, major functions of the State Water Resources Board were radically changed by provisions of Chapter 52, Statutes of 1956. This statute created the Department of Water Resources which succeeded to the responsibilities of the former Board for initiating and conducting water resources investigations.

THE STATE-WIDE WATER RESOURCES INVESTIGATION

The State-wide Water Resources Investigation has been conceived and developed as a fundamental, comprehensive survey, designed to serve as the basis for a logical and orderly pattern of development of the State's water resources. The first phase of the investigation consisted of an inventory of the basic water resources of California. All available data on sources, quantities, and characteristics have been evaluated, and the results are presented in State Water Resources Board Bulletin No. 1, "Water Resources of California," published in 1951. This bulletin contains a compilation of data on precipitation, natural stream runoff, flood flows and frequencies, and quality of water throughout the State.

The second major phase of the State-wide Water Resources Investigation dealt with present and ultimate requirements for water. Its findings are published in State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," June. 1955. This bulletin includes determinations of the present use of water throughout the State for all consumptive purposes, and presents forecasts of probable ultimate requirements based, in general, on the capabilities of the land to support further development. The bulletin also discusses implications of nonconsumptive requirements for water as they relate to planning for the future.

The foregoing studies provide basic data for the third and concluding phase of the State-wide Water Resources Investigation, presented herein. This phase correlates the determinations of water resources and ultimate requirements established in Bulletins Nos. 1 and 2, and, based on these findings, formulates The California Water Plan for satisfying these requirements, insofar as practicable, as well as for the solution of the State's many other water problems.

PREVIOUS STATE-WIDE PLANNING

The State-wide Water Resources Investigation, although the first truly comprehensive effort to evolve a complete state-wide plan for ultimate water supply development, has been preceded by a number of studies that approach it in scope and magnitude.

The first broad investigation of the irrigation problem of California was made by a board of commissioners authorized by Congress and appointed by the President. The commission's report on "The Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of the State of California" was published by the House of Representatives in 1874 as Ex. Doc. No. 290, Forty-third Congress, First Session. It outlined a hypothetical irrigation system for the San Joaquin, Tulare, and Sacramento Valleys. Other investigations by federal and state agencies followed during the next several decades, the most noteworthy of which were made by Wm. Ham. Hall, State Engineer from 1878 to 1889. His reports contain meteorological and stream flow data, with notes on irrigation, drainage, and flood control, all of which proved of great value in planning water developments in the years that followed.

The most comprehensive recent investigations of the water resources of California were those made by the State Engineer under authority of acts of the Legislature in 1921, 1925, and 1929. First reports of these investigations were presented in Division of Engineering and Irrigation Bulletins Nos. 4, 5, and 6, and in Division of Water Resources Bulletins Nos. 9, 12, 13, 14, and 20. A report giving results of subsequent investigations, and outlining revised proposals, was published in 1930 as Division of Water Resources Bulletin No. 25, entitled "Report to Legislature of 1931 on State Water Plan." It outlined a coordinated plan for conservation, development, and utilization of the water resources of California. The plan was approved and adopted by the Legislature by Chapter 1185, Statutes of 1941, and designated the "State Water Plan." Division of Water Resources Bulletins Nos. 26, 27, 28, 29, and 31 outlined in greater detail project plans for coordinated development of the water resources of the Central Valley, and for water conservation and flood control in the Santa Ana River Basin. Bulletins Nos. 34, 35, and 36 dealt with collateral matters of water charges and costs and rates of irrigation development. Bulletin No. 31 discussed briefly the plans for diversion and transmission of Colorado River water to the South Coastal Basin under the project of The Metropolitan Water District of Southern California.

Contemporaneously with these studies by the State, agencies of the Federal Government, notably the Bureau of Reclamation and the Corps of Engineers, have conducted comprehensive studies of the development of water resources on various streams in California, particularly with respect to the Central Valley. The most noteworthy of these reports are: Senate Document 113, 81st Congress, First Session, "Central Valley Basin," by the U. S. Bureau of Reclamation, August 1949; and House Document No. 367, 81st Congress, First Session, "Sacramento-San Joaquin Basin Streams, California," by the Corps of Engineers, U. S. Army, 1949. It should be noted that none of these previous studies have envisioned the transfer of water from northern California to southern California.

CONCURRENT RELATED INVESTIGATIONS

A number of specific regional water resources investigations, complementing the state-wide studies, have been carried on concurrently by the Department of Water Resources and its predecessors. Some of these investigations utilized state funds entirely, while others were financed cooperatively by state and local interests. The planning for water development in those regions has been coordinated with and integrated into The California Water Plan. The features of the Plan in those regions of special investigation have been formulated and reported upon in more detail than are presented herein. The following bulletins present results of these regional studies.

California State Department of Public Works, Division of Water Resources. "Survey of Mountainous Areas." Bulletin No. 56. December, 1955.

——— "Santa Margarita River Investigation." Bulletin No. 57. June, 1956.

——— "Northeastern Counties Investigation, Report on Upper Feather River Service Area." (interim report) April, 1955.

——— "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan." February, 1955.

——— "Report to the California State Legislature on Putah Creek Cone Investigation." December, 1955.

California State Department of Water Resources. "Investigation of Upper Feather River Basin Development, Interim Report on Engineering, Economic, and Financial Feasibility of Initial Units." Bulletin No. 59. February, 1957.

——— "Interim Report to the California State Legislature on the Salinity Control Barrier Investigation." Bulletin No. 60. March 1957.

California State Water Project Authority. "Report to the California State Legislature on Feasibility of Construction by the State of Barriers in the San Francisco Bay System." March 1955.

California State Water Resources Board. "Santa Cruz-Monterey Counties Investigation." Bulletin No. 5. September, 1953.

——— "Sutter-Yuba Counties Investigation." Bulletin No. 6. September, 1952.

——— "Santa Clara Valley Investigation." Bulletin No. 7. June, 1955.

——— "Elsinore Basin Investigation." Bulletin No. 9. February, 1953.

——— "Placer County Investigation." Bulletin No. 10. June, 1955.

——— "San Joaquin County Investigation." Bulletin No. 11. June, 1955.

——— "Ventura County Investigation." Bulletin No. 12. October, 1953, Revised April, 1956.

——— "Alameda County Investigation." Bulletin No. 13. (preliminary report) July, 1955.

——— "Lake County Investigation." Bulletin No. 14. (preliminary report) October, 1955.

——— "Santa Ana River Investigation." Bulletin No. 15. (preliminary report) April, 1956.

——— "American River Basin Investigation, Report on Development Proposed for The California Water Plan." Bulletin No. 21. (preliminary report) June, 1955.

——— "Interim Report on Klamath River Basin Investigation, Water Utilization and Requirements." March, 1954.

——— "Interim Summary Report on San Luis Obispo County Investigation." October, 1955.

Other studies conducted by the Department and its predecessor agencies, the results of which are not yet available in final report form, include the following:

Cache Creek Watershed Investigation—Yolo County
Klamath River Basin Investigation
Northeastern Counties Investigation
Salinas River Basin Investigation
San Luis Obispo County Investigation
Shasta County Investigation

Data and information from the many other investigations conducted by the Department have been utilized. Pertinent investigations and plans of the U. S. Department of the Interior; the Corps of Engineers, U. S. Army; and the Department of Agriculture have been utilized and integrated into The California Water Plan.

THE CALIFORNIA WATER DEVELOPMENT PROGRAM

In order to plan intelligently for future development of California's water resources to meet increasing water needs, the investigation and study of water requirements, available resources, and potential water development projects must be a continuing process. This continuing need has been recognized, as is evidenced by legislative acts authorizing the Feather River Project provides for a multipurpose development, and, most recently, the Inventory of Water Resources, all of which are designated functions of the Department of Water Resources. These three investigations are discussed in the following sections. Complementing these investigations, and in close coordination therewith, the Department is engaged in an intensive and continuing program of study of the needs for specific projects, economic and financial analyses, and determination of recommended staging of construction. All of these investigations and studies collectively comprise the California Water Development Program, which incorporates subsequently authorized data gathering and planning activities.

Feather River Project

Many of the principles of The California Water Plan are embodied in the authorized Feather River Project, the initial unit of the Plan. The Feather River Project provides for a multipurpose development for firming water supplies, providing flood protection in the Feather River area, generating hydroelectric energy, and exporting surplus waters available in the Sacramento-San Joaquin Delta to areas of deficiency in the San Joaquin Valley, San

Francisco Bay Area, and southern California, with incidental fish, wildlife, and recreational benefits. This project was conceived by former State Engineer A. D. Edmonston and formulated by the former Division of Water Resources. It was first presented in 1951 in a publication of the State Water Resources Board entitled "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan." The Legislature authorized the project in 1951 and provided funds for additional studies, including preparation of plans and specifications. These further studies are published in a report on "Program for Financing and Constructing the Feather River Project as the Initial Unit of The California Water Plan," submitted in February, 1955.

The Legislature, by the Budget Act of 1956, appropriated $9,350,000 for continued engineering design and exploration, including the preparation of construction plans and specifications and providing for acquisition of right of way for some of the project features. The 1957 Legislature passed an urgency appropriation for $25,190,000 to commence relocation of the Western Pacific Railroad and U. S. Highway 40 Alternate out of the Oroville Reservoir area.

Salinity Control Barrier Investigation

The need and feasibility of physical barriers to salt-water inflow in the San Francisco Bay system has been evaluated by the Division of Water Resources, pursuant to the Abshire-Kelly Salinity Control Barrier Act of 1953, Chapter 1104, Statutes of 1953. Incorporated in the report entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System," March 1955, are provisions for conserving and developing waters presently being utilized for repulsion of sea water in the Sacramento-San Joaquin Delta. A conduit for conveying Sacrament River flow across the Delta is also proposed. These features, which are vital elements of The California Water Plan, are receiving further consideration through an extension of this study authorized by the Abshire-Kelly Salinity Control Barrier Act of 1955, Chapter 1434, Statutes of 1955. An interim report entitled "Salinity Control Barrier Investigation," March 1957, describes the recommended plan for accomplishing the foregoing objectives.

Inventory of Water Resources

Pursuant to Chapter 61, Statutes of 1956, the Department of Water Resources is conducting an investigation to determine in detail: the amount of water resources available in the separate watersheds in the State; the amounts of present and ultimate water required for beneficial uses in those watersheds; and, from the foregoing, the quantities of water, if any, available for export from the watersheds of origin. This investigation, which will continue over a period of years, will be accomplished in greater detail than has heretofore been undertaken and will serve as a basis for assuring reservation of adequate water resources for the areas of origin.

OTHER PROPOSALS FOR DEVELOPMENT OF THE STATE'S WATER RESOURCES

The increasing awareness of the present prevailing water problems, and of the need for state-wide development of California's water resources, has been manifested in a number of ideas or proposals paralleling The California Water Plan. In general, these proposals purport a common objective, that is, the transfer of surplus northern waters to southern areas of deficiency. However, they have been advanced without adequate engineering and geologic study. Furthermore, their objectives and scope, as compared with those of The California Water Plan, are inadequate.

One such proposal, which has been termed the "Gravity Plan," has received considerable publicity during recent years. This plan would convey water by gravity conduit extending from Shasta Dam southerly to the Merced River. There it would cross the San Joaquin Valley and would be pumped over the Coast Range, where it would continue by gravity conduit into southern California. It is a fact, however, that the water supplies involved in the Gravity Plan are not available in adequate quantity, nor in proper monthly distribution to enable operation of the plan.

Another serious shortcoming in the Gravity Plan and other similar proposals involves their conflict with presently vested water rights, and interference with existing projects of various agencies. These plans would involve exchanges of water which would be impossible of accomplishment.

All of these alternatives have been analyzed by the Department of Water Resources in the formulation of The California Water Plan, and those elements found feasible have been incorporated into the Plan.

SCOPE OF PLANNING PHASE OF STATE-WIDE WATER RESOURCES INVESTIGATION

The planning phase of the current State-wide Water Resources Investigation, broader in scope than that for earlier investigations, has as its objective the formulation of a long-range plan for the comprehensive development of the water resources of the entire State. It contemplates the full control, conservation, protection, distribution, and utilization of the water resources of California, both surface and underground, to meet present and future water needs for all beneficial purposes and uses in all areas of the State, insofar as practicable.

The scope of the planning phase includes studies of numerous physical and economic considerations necessary to the formulation of a realistic long-range water resource development plan. Use has been made of all available basic data and information pertinent to water supply, water requirements, characteristics of water service areas, hydroelectric power potentialities, flood control, fish and wildlife, recreation, drainage, water quality, physical features of dam sites and conduit routes, physical characteristics of ground water basins, construction methods, construction costs, and trends of social, economic, and technological advancement. These basic data have been utilized in an analytical process involving engineering design, cost estimates, and economic selection from alternative project proposals. Throughout the process a substantial measure of engineering judgment has been necessary, tempered by knowledge of the limitations of the information on hand, and with awareness of inherent unknowns in planning for the indefinite future.

One of the most outstanding aspects of the planning phase of the State-wide Water Resources Investigation is the consideration of unprecedented interbasin projects, by means of which large quantities of surplus water could be regulated and transported long distances from areas of surplus to areas of deficiency. These projects are of such scope and magnitude as to constitute in the aggregate a very real but not impossible challenge to the future of California. Of equal significance is the planning for local projects to meet present and future local water needs. Such projects are often intimately involved with the major export-import works. In areas of ultimate water deficiency, the distribution and use of additional supplies that may be developed locally would be coordinated with that of imported supplemental waters. In areas of ultimate surplus, works for local water service would be fully coordinated with those for export. In the case of all projects, involving either major or minor works, full consideration has been given to existing developments and interests and to vested water rights.

Formulation of The California Water Plan was based upon the concept of optimum utilization of the water resources of the State. It involves, where possible, the use of multipurpose reservoirs to gain their several advantages, including economy of construction and the conservation of project sites. Favorable dam and reservoir sites are rare and it is essential that the potentialities of each site be utilized to the maximum feasible extent. Water supplies would be developed and conserved for irrigation, municipal, and industrial purposes. Furthermore, the works would provide for flood control and flood protection; production of hydroelectric energy; quality control; salinity control; enhancement of fish, wildlife and recreation; drainage; and other beneficial purposes. Estimates of water requirements published in State Water Resources Board Bulletin No. 2 have been generally accepted as a measure of requirements, although minor modifications have been made, where such have been indicated by further study.

Concepts of Planning

The formulation of The California Water Plan was predicated upon and guided by certain basic concepts which are expressed herein as the essence of the Plan. These concepts should be clearly borne in mind when evaluating the various facets of the Plan subsequently described in this bulletin.

1. The California Water Plan is conceived as an ultimate plan, one that will meet the requirements for water at some unspecified but distant time in the future when the land and other resources of California have essentially reached a state of complete development.

2. The Plan is designed to be comprehensive. It provides for future beneficial uses of water by individuals and agencies in all parts of the State. Legislative acceptance of the Plan, and firm provision for its progressive project authorization as component projects become feasible, would tend toward elimination of sectional concern as to future availability of necessary water supplies.

3. The California Water Plan is a flexible pattern or framework into which future definite projects may be integrated in an orderly fashion, with due consideration being given to varying interests. As additional data and experience are gained, as technology advances, and as future conditions change in patterns that cannot be foreseen today, The California Water Plan will be substantially altered and improved.

4. The Plan is designed to be susceptible of orderly development by logical, progressive stages as the growing demands and requirements of the State may dictate. Certain of these features should be implemented immediately, while others should be deferred.

5. The many features broadly embraced in The California Water Plan, while believed to be endowed in common with physical feasibility, have widely variant relationships to present concepts of economic and financial feasibility. As an example, extremely costly works would be required to conserve and convey water long distances to irrigate certain lands of very limited present crop adaptability, or to serve lands lying at high elevations, requiring net pump lifts of several thousand feet in some cases, such as the desert area in southern California. Such works are for the indefinite future and their need may never be realized. However, the economics of the distant future cannot be foreseen, and the planning effort is deemed necessary at this time in order that provision may be made for such development if and when the requirement arises.

6. The California Water Plan is designed to include or supplement, rather than to supersede, existing water resource development works. It also incorporates certain of the planned works now proposed or authorized by public and private agencies and individuals. Of special significance in this respect is the Feather River Project, which is proposed as a unit for initial construction under The California Water Plan.

Summarized, the foregoing concepts define The California Water Plan as a comprehensive pattern, with broad flexibility and susceptible of orderly and progressive development as needed, under which the forecast ultimate requirements for water by individuals and agencies for all purposes in all parts of the State can be met. Water is not to be taken away from people who will need it; rather, it is proposed to supply the needs of areas of deficiency by transfer only of excess or surplus water from areas of abundance. Under The California Water Plan, water development by all agencies, federal, state, local, and private, can proceed in a coordinated manner toward common objectives and for maximum ultimate benefit. The Plan is not intended in any way to constitute an inflexible regulation or construction proposal.

The California Water Plan does not purport to include all possible water development projects in the State. Rather, it serves to demonstrate that the full satisfaction of ultimate water requirements in all parts of the State is physically possible of accomplishment. Therefore, the omission herein of any project does not preclude its future construction and integration into the Plan. Further investigation may indicate alternative projects which are more feasible than those discussed herein and which would accomplish the same results.

It is fully acknowledged that The California Water Plan, like any plan for the indefinite future, is based on present forecasts, utilizing data from the short recorded past and accepted technology of today, and, as such, is inherently subject to substantial alteration with the passage of time and the trial of experience. For these reasons, investigation and planning for further water resource development must be a continuing process.

Planning Considerations

In all planning for water resource development, first and prime consideration was given to the requirements, both present and future, for all water uses in areas of origin, before a determination was made of the surplus waters that might be available for exportation to areas of deficient supply. Interference with works of existing entities, or with their operations with respect to use of water, was avoided wherever possible. In fact, most existing facilities would be integrated into the Plan. Present rights and established interests in the use of water have been taken into consideration, although no detailed studies of the status of existing rights have been made specifically for this report. The significance of such studies to state-wide planning is fully recognized but is beyond the scope of this bulletin.

It should be recognized that the planning has necessarily been of a preliminary nature and is appropriate only to the initial definition of projects. In this connection, one controlling factor is dam site foundations, for which, in general, only limited engineering and geologic examination has been possible within the scope of the present investigation. Subsurface geologic conditions have been estimated in most cases only by reconnaissance surface inspection, which is generally not adequate to determine all essential subsurface features.

The need for further surveys involving foundation excavations and borings before projects can be definitely proposed for construction can be best appreciated with knowledge of the importance of foundation characteristics in engineering design. Not only does the foundation constitute one of the major factors in determination of type, height, cost, and feasibility of a dam, but quite often the inadequacy of a foundation leads to abandonment of one site and adoption of another. Similar geologic and engineering information must be developed with respect to availability and quality of construction materials in the vicinity of dam sites. Detailed subsurface investigations will also be needed along conduit routes. It will be imperative to conduct an extensive program of exploratory drilling and excavation under more detailed planning studies, prior to final determination of the feasibility of the features of definite projects. Even more detailed engineering and geologic studies will be required for preparation of construction plans and specifications.

Limitations inherent in the concept of "ultimate," on which are based the pattern of development and the water requirements under The California Water Plan, are of prime significance. This concept pertains to conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized. It must be realized that any forecasts of the nature and extent of such ultimate development and resultant water utilization are inherently subject to appreciable errors. However, such forecasts, based upon best available data and judgment, are necessary in establishing long-range objectives for development of water resources. They are so used herein, with full knowledge that their re-evaluation, after the experience of a period of years, will result in considerable revision.

Possible advancement in certain fields of technology relating to water development may require considera-

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tion at a future time. The field of atomic energy may offer a most promising potentiality in this respect. Utilization and production of electrical energy under The California Water Plan have been based generally on current economic considerations. Future developments in utilization of atomic energy may become instrumental in making economically feasible the conversion of saline water to water of acceptable quality. At the present time, research studies by certain agencies are concerned with the various aspects and processes available for the desalting of sea water. It is reported that certain of these processes show promise for the distant future.

Large-scale availability of low-cost energy might effect future changes in The California Water Plan with respect to feasibility of pumping lifts and economic lengths of conveyance tunnels. In addition, economics of hydroelectric projects would be affected, since the cost of thermal energy production is a factor in evaluating hydroelectric energy. This would probably mean that the power plants proposed under the plan for hydroelectric generation, based upon prevalent concepts of value of power, may be subject to reconsideration under future concepts.

Another potentiality for change in requirement for imported water supplies exists in the possible advancement of technology and economy in treatment and reclamation of sewage. Currently, such waters are substantially wasted, with little consideration being given to their use either because of the cost involved or for esthetic reasons.

The technique of weather modification might advance to the point whereby The California Water Plan could be affected to some degree. It appears unlikely, however, that effects of this modification could be of sufficient proportions as to change materially the over-all plan as presented herein. If such did occur, it could result in a significant increase in water supply in areas of natural surplus of water, a minor increase in areas of deficiency, with both areas needing added flood protection.

One additional aspect of the planning process requires emphasis. It is evident that the development of water in California today deals largely with "leftover" projects, and must utilize dam sites and even entire stream systems which were passed over in the early days as being too difficult of development. Not so evident, however, nor as well recognized, is the fact that in order to effect the greatest benefit at the least cost for any water resource development project today, careful sorting of many alternative plans is required. This involves painstaking study, engineering judgment, and consideration of all possible aspects of the development as related to multiple and often incompatible demands for the water.

Thus, while it is apparent that the fundamental basis of The California Water Plan must rest on presently available economic and technical knowledge, it is recognized that future developments may change this basis. Accordingly, The California Water Plan has been formulated to perform an essential function, in that it forms the engineering basis for guidance and coordination in the planning, construction, and operation of water resource developments which are and will be required in meeting the needs for water throughout the State. It represents an assurance that the waters of the State can be developed in such a manner that the greatest public benefit will be derived, in the light of best available knowledge.

PUBLIC HEARINGS ON PRELIMINARY EDITION OF BULLETIN No. 3

In order to evaluate the adequacy of The California Water Plan, a preliminary draft of Bulletin No. 3, "Report on The California Water Plan," dated May, 1956, was released to responsible agencies and individuals throughout the State for their review and comment. Opportunity for presentation of written or oral comments on the Plan was afforded by a series of public hearings which all agencies and individuals were invited to attend. These hearings, conducted jointly by the Department of Water Resources and the State Water Board, were held as shown in the following tabulation:

San Francisco	August 31, 1956
Eureka	September 6, 1956
Redding	September 7, 1956
Quincy	September 8, 1956
Los Angeles	September 13, 1956
Santa Barbara	September 14, 1956
Fresno	September 24, 1956
Bakersfield	September 25, 1956
Sacramento	October 4, 1956

In addition to providing information to the public, thus facilitating a better understanding of the water problems of California and of plans for their solution, the public hearings were highly beneficial to the Department of Water Resources in the preparation of Bulletin No. 3 for final publication. Nearly 1,500 persons attended the hearings, and some 200 written or oral statements representing a wide diversification of areas and interests throughout the State were presented. These statements, which covered a variety of subjects, have been given careful review and analysis, and the recommendations have been incorporated into The California Water Plan wherever pertinent.

ORGANIZATION OF BULLETIN

Results of the third and final phase of the Statewide Water Resources Investigation, comprising the planning necessary for the solution of California's water problems, are presented in this bulletin in the five ensuing chapters. Chapter II, "Water Problems of California," evaluates the primary water problem of California through a comparison of the water resources and water requirements as determined during the first two phases of the State-wide Water Resources Investigation, and corollary problems. Chapter III, "Water Development Planning," presents a brief historical account of water resource planning and development in California up to the present time, discusses the urgent need for comprehensive coordinated planning and development on a state-wide basis, and outlines the considerations necessary to the formulation of plans to accomplish the solution of California's water problems. Chapter IV, "The California Water Plan," describes the physical features and accomplishments of works, both local and statewide, which would meet the basic objectives heretofore described. Chapter V, "Implementation of The California Water Plan," discusses various considerations, such as legal, economic, financial, and engineering, and others which are vital to the physical implementation of The California Water Plan. Chapter VI, "Summary, Conclusions, and Recommendations," summarizes the bulletin, and presents the conclusions resulting from the State-wide Water Resources Investigation and the recommendations based upon the conclusions.

Appendix A to this bulletin presents a more detailed engineering report on The California Water Plan. It describes both local and interbasin transfer projects on an individual basis, with accompanying tabulations of physical features and capital costs. It also discusses, in some detail, the accomplishments of The California Water Plan and the considerations upon which the operation of the plan will be contingent.

There will be published separately, and at later dates, additional appendixes which will elaborate on certain specific phases of The California Water Plan, and on considerations and premises on which the Plan was based. The basic assumptions, criteria, and procedures employed in formulating the Plan are presented in Appendix B. General geology of the State, geologic conditions affecting the location and design of engineering works, and ground water geology are described in Appendix C. Appendix D outlines the utilization of ground water storage capacity under The California Water Plan, particularly with regard to conjunctive operation of surface and underground reservoirs. Factors involved in maintenance of water quality are treated in Appendix E.

The effects of The California Water Plan on fish and wildlife are presented in Appendix F, as are the potentialities for enhancement of recreational facilities. Flood problems and existing project works are described in Appendix G, and flood control accomplishments of The California Water Plan are discussed. Economic and financial aspects of The California Water Plan are discussed in Appendix H. Water rights and attendant legal considerations and their implications with respect to The California Water Plan are presented in Appendix I.

In the State-wide Water Resources Investigation, due cognizance has been taken of all possibilities for augmenting the State's water supplies. The potentialities of sea-water conversion, waste-water reclamation, artificial increase of precipitation, and watershed management are discussed and evaluated in Appendix J. Future power sources and energy requirements as related to The California Water Plan are considered in Appendix K, which discusses the development of power requirements and future load characteristics, and the adaptability of atomic energy and its influence upon the development of hydroelectric energy.

"The primary water problem of maldistribution of California's water resources . . ."
Klamath River
San Joaquin Valley

CHAPTER II

WATER PROBLEMS OF CALIFORNIA

The past and future growth of California has been and will continue to be dependent upon the development of its water resources. The primary reasons for this are threefold: first, California is endowed by nature with millions of acres of fertile lands of high crop productivity; secondly, due to the semi-arid climatic characteristics, most agricultural lands in the State must be irrigated; and thirdly, California has a great potential for urban and industrial development, resultant in part from the substantial agricultural potential. However, the growth of the State, in itself made possible and stimulated by the development of water, has continually created water problems which have become progressively more and more difficult of solution as local sources of surplus water have been developed.

Why, we might ask, should California have water problems when nature has provided an abundance of water within the State? The answer to this question is simple and clear: the bulk of the waters of the State do not occur *where* they are needed and are not naturally available *when* they are needed. However, this answer—true as it is—grossly oversimplifies the far-reaching and serious basic water problem presently facing us, and becoming magnified and intensified year by year.

The primary water problem of maldistribution of California's water resources and requirements is evaluated in this chapter for each of the major hydrographic areas of the State. This is followed by a discussion of other corollary problems, namely surface water deficiency, ground water overdraft, floods, and impairment of water quality.

WATER RESOURCES

As previously mentioned, the first phase of the State-wide Water Resources Investigation was devoted to evaluation of the water resources of the State and determination of their characteristics, specific nature, occurrence, quantities, and distribution. These data, which have been published in State Water Resources Board Bulletin No. 1, form the basis for the generalizations presented herein.

Precipitation

From a practical standpoint, all water resources stem from precipitation. Its regimen and other characteristics profoundly affect the occurrence of water supplies. California receives most of its precipitation from north Pacific storms. Most of the precipitation occurs in the form of rain at lower elevations and snow in the higher mountain regions. Precipitation varies widely geographically throughout California, due principally to the topography and the Pacific storm pattern. This variation is illustrated by Plate 2, entitled "Geographical Distribution of Precipitation and Runoff." At sea level along the coast, precipitation varies from a seasonal depth of about 50 inches in the north to 10 inches in the south. In the Coast Range and Sierra Nevada, precipitation generally increases with elevation, reaching an average of 110 inches per season in the northwest corner of the State. By way of contrast, the deserts of the southeast, with elevations extending below sea level, average as little as 2 inches of precipitation per season. On the floor of the Central Valley, seasonal precipitation ranges from about 38 inches at Redding to about 6 inches at Bakersfield.

In addition to the wide range of geographical distribution, precipitation in California varies considerably with time, both within the season and from year to year. In general, more than 80 per cent of the total seasonal precipitation occurs during the five months of November through March. To add further to the problem, precipitation frequently departs widely from the mean from year to year, and it is quite common to experience a several-year period of greater than mean precipitation, followed by a period of somewhat similar or even greater length during which the precipitation is considerably less than mean. These two types of periods are commonly referred to as "wet periods" and "drought periods," and their generally alternating occurrence in the past has given rise to the term "cycles." These so-called cycles have varied both in length and intensity. One of the most severe drought periods of record occurred throughout most of the State from 1928 through 1934, with an average precipitation of less than 60 per cent of the mean. The seasons of 1923-24 and 1930-31 were generally the driest in California for the period of record.

Runoff

Runoff is defined as that portion of precipitation which drains from the land through surface channels. The amount of runoff constitutes that portion of the water resources that is available for control, regulation, and distribution to meet requirements for water. Most of the runoff in California originates on mountain and foothill lands, and debouches from these watersheds onto adjoining valley floors. For this reason, estimates of runoff presented herein generally represent that part of precipitation that flows from mountain and foothill areas.

The Sacramento River, which, along with the San Joaquin River, drains the Central Valley, is the largest stream in the State. The main stream originates in the Cascade Range at the northern end of the State and flows almost due south through the Sacramento Valley. It is joined at the Sacramento-San Joaquin Delta by the San Joaquin River, which drains the northern portion of the San Joaquin Valley, and both streams flow westward in a network of channels emptying into San Francisco Bay.

The Klamath-Trinity River system, second only to the Sacramento River, drains a large part of the northern mountain watershed, including lands across the state boundary in Oregon. Other major streams, including the Mad, Eel, and Russian Rivers in the north; Salinas, Santa Maria, and Santa Ynez Rivers in the central part of the State; and Santa Clara, Los Angeles, San Gabriel, Santa Ana, San Dieguito, and San Diego Rivers in the southern sector, convey runoff from the seaward slopes of the Coast Range to the ocean.

The remainder of the State, with the exception of a narrow strip adjoining the Colorado River, has no outlet to the ocean. The eastern slopes of the Sierra Nevada give rise to a number of rivers flowing eastward into Nevada, including the Truckee, Carson, and Walker. The Owens River, also rising along the east slopes of the Sierra, flows southerly along the foothills and terminates in Owens Lake. In the southern part of the State several streams originate on the landward side of the coastal mountains and extend easterly to natural sumps in the desert. Among these are the Mojave River, whose course traverses the Mojave Desert to Soda Lake, although its flow rarely reaches its terminus, and the Whitewater River, which extends to but seldom discharges into the Salton Sea.

Because runoff in California is derived from precipitation, it generally reflects similar monthly and seasonal variations, particularly in those portions of the State where precipitation occurs as rainfall. Moreover, the steep slopes, shallow soil mantle, and relatively sparse vegetative cover in many of the watersheds have little retarding effect on the precipitation as it collects and concentrates in stream channels on its inexorable journey to the ocean. Thus, with the exception of snow-fed streams, runoff in California is generally sporadic in nature, with short, intense floods followed by long periods of little or no flow.

A substantial portion of California's precipitation occurs in the form of snow in the Sierra Nevada and parts of the Cascade and Siskiyou Ranges, which contributes a modifying effect on runoff. This water accumulates during the winter in extensive snow fields at high elevations and is released, as runoff, months later during the late spring and early summer snowmelt period. This flow is far more uniform than runoff resulting directly from rainfall, and its value is greatly enhanced by its more or less predictable nature and the fact that it is sustained well into the growing season when precipitation is negligible. Outstanding examples of the retarding effect of snowpack storage on runoff are found in the flows of the San Joaquin River at Friant and the Kings River at Piedra, where 75 per cent of the runoff occurs during the April-July snowmelt period, during which time average precipitation approximates 15 per cent of the seasonal total.

It is estimated that seasonal natural runoff for the State (not including California's rights in and to the waters of the Colorado River) averaged some 71,000,000 acre-feet per season during the 53-year period 1894-95 through 1946-47. Runoff in individual years has varied from a high of 135,000,000 acre-feet in 1937-38 to a minimum of 18,300,000 acre-feet in 1923-24. The average seasonal runoff during the critical 10 years from 1927-28 through 1936-37 averaged only 69 per cent of the mean for the 53-year period, and in no season did runoff reach the long-time mean.

As previously stated, the bulk of the total seasonal natural runoff in California occurs in the northern portion of the State, with more than 40 per cent from the North Coastal Area and about 32 per cent stemming from the Sacramento Valley. In contrast, only 2 per cent of the total runoff occurs in the South Coastal and Colorado Desert Areas. Estimated mean seasonal natural runoff for the several major hydrographic areas of the State is listed in Table 1 and is graphically illustrated on Plate 2. The major hydro-

TABLE 1

ESTIMATED MEAN SEASONAL FULL NATURAL RUNOFF OF HYDROGRAPHIC AREAS

Area number on Plate 3	Hydrographic area	Runoff[a]	
		In acre-feet	In per cent of total
1	North Coastal	28,890,000	37.9
2	San Francisco Bay	1,245,000	1.6
3	Central Coastal	2,448,000	3.2
4	South Coastal	1,227,000	1.6
	Colorado River[b]	1,212,000	1.6
5A	Sacramento River Basin	22,390,000	29.4
5B, C	San Joaquin-Tulare Lake Basin	11,246,000	14.7
6	Lahontan	3,177,000	4.2
7	Colorado Desert	221,000	0.3
	Colorado River[b]	4,150,000	5.5
	TOTALS	76,212,000	100.0

[a] Values given represent runoff from mountain and foothill areas generally at the base of the foothills. Comparatively little control is possible below that point.
[b] Regulated flows representing California's rights in and to the waters of the Colorado River.

graphic areas are delineated on Plate 3, entitled "Major Hydrographic Areas and Planning Groups."

Ground Water

The extensive ground water basins of California provide natural regulation for runoff from tributary drainage areas and for precipitation directly on overlying lands. Some 250 ground water basins having valley floor areas of about 5 square miles or larger have been identified in California. A large part of the surface runoff from tributary mountain and foothill watersheds that would otherwise waste to the ocean is retained in these basins and conserved for later utilization. In effect, these ground water reservoirs provide a means for natural regulation of stream flow in much the same manner as is accomplished by surface reservoirs.

Sufficient data on the ground water basins of California are available to permit an estimate of gross storage capacity within certain depth limits for 211 valley floor areas. The areas for which such storage capacities were estimated comprise 96 per cent of the total valley floor area of all basins of the State. The depth limits vary from basin to basin, but the average weighted interval is approximately 185 feet, or generally between the depths of about 15 and 200 feet. The gross storage capacity within this depth interval is about 450,000,000 acre-feet. The Central Valley alone contains over 130,000,000 acre-feet of this total in approximately the same depth interval.

Only a portion of the gross storage capacity is usable storage, largely because of the presence of saline water or other waters of deleterious mineral quality. These waters either limit the depth to which ground water levels may be lowered or, in many areas, preclude the use of ground water. Enough information is presently at hand to estimate the usable storage capacity for only 80 ground water basins, comprising 43 per cent of the total valley floor area of the State. In the Central Valley, usable capacity in the depth interval from 15 to 200 feet aggregates about 100,000,000 acre-feet.

More than half the water presently consumptively used in California comes from underground sources. Many of these ground water basins have been intensively developed. In the San Joaquin Valley and parts of southern California particularly, the ready availability of ground water has been primarily responsible for supporting rapid expansion of agriculture and industry far beyond the firm capabilities of water resource developments. This has been accomplished by utilizing the vast reserves of water stored in these underground reservoirs, in many cases at rates greatly exceeding their replenishment. Presently available data concerning ground water are far less comprehensive than for surface water resources. Much more study will be necessary to evaluate reasonably accurately the capability of ground water resources of the State.

WATER REQUIREMENTS

Under the State-wide Water Resources Investigation all lands in the State have been classified as to their suitability for development under probable ultimate conditions. Determinations have also been made of the location, nature, and extent of present water service areas, and appropriate factors for the various types of water use have been evaluated. Estimates of present and probable ultimate water requirements developed from these data, and published in State Water Resources Board Bulletin No. 2, have been generally accepted as a measure of water requirements for the formulation of The California Water Plan. However, modifications have been made where the need for such has been indicated by further study. These estimates, modified where necessary, are summarized in this section.

In 1950, the year adopted as "present" in Bulletin No. 2, a gross area of about 7,300,000 acres was under irrigation in California. The actual area irrigated, or net area, was about 6,900,000 acres. A gross area of about 20,000,000 acres is classified as suitable for irrigated agriculture, of which an estimated 16,200,000 acres could be irrigated in any one season under ultimate conditions of development. In 1950, approximately 1,100,000 acres were devoted to urban, suburban, and industrial types of land use. It is estimated that urban, suburban, and industrial water service areas will ultimately occupy about 3,600,000 acres.

For the most part, the remaining lands of California include only scattered water service areas, largely in mountainous and desert regions and in national forests and monuments, public beaches and parks, private recreational areas, wildfowl refuges, and military reservations. It is expected that even under ultimate development the majority of these lands will be only sparsely settled and will have only very minor requirements for water service. About 180,000 acres of such remaining lands actually receive water service at the present time. It is assumed that all of the approximately 77,300,000 acres of such lands ultimately will be served with water in the minor amounts sufficient for their needs.

Table 2 summarizes data relative to present and ultimate water service areas in the seven major hydrographic areas of California, classified by broad land usage groupings. The potential water service areas under The California Water Plan, consisting of all lands included in the irrigated and urban-suburban-industrial categories, are delineated on Plate 4, entitled "Present and Ultimate Areas of Intensive Water Service."

TABLE 2

PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS

(In acres)

Area number on Plate 3	Hydrographic area	Areas of intensive water service				Miscellaneous water service areas		Totals	
		Irrigated		Urban, surburban, and industrial					
		Present*	Ultimate	Present*	Ultimate	Present*	Ultimate	Present*	Ultimate
1	North Coastal	223,000	1,023,000	19,000	53,000	19,000	11,425,000	261,000	12,501,000
2	San Francisco Bay	163,000	66,000	225,000	1,408,000	50,000	1,222,000	438,000	2,696,000
3	Central Coastal	362,000	1,244,000	52,000	169,000	12,000	5,808,000	426,000	7,221,000
4	South Coastal	652,000	1,156,000	547,000	1,611,000	1,000	4,228,000	1,200,000	6,995,000
5A	Sacramento River Basin	1,130,000	3,603,000	101,000	127,000	28,000	13,380,000	1,259,000	17,110,000
5B, C	San Joaquin-Tulare Lake Basin	3,993,000	7,955,000	90,000	165,000	57,000	12,820,000	4,140,000	20,940,000
6	Lahontan	236,000	3,107,000	10,000	54,000	5,000	17,812,000	251,000	20,973,000
7	Colorado Desert	587,000	1,822,000	14,000	33,000	10,000	10,561,000	611,000	12,416,000
	TOTALS	7,346,000	19,976,000	1,058,000	3,620,000	182,000	77,256,000	8,586,000	100,852,000

* Present service areas determined as of 1950.

TABLE 3

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS

(In acre-feet)

Area number on Plate 3	Hydrographic area	Irrigation		Urban, suburban, and industrial		Miscellaneous		Totals	
		Present*	Ultimate	Present*	Ultimate	Present*	Ultimate	Present*	Ultimate
1	North Coastal	483,000	1,880,000	21,000	85,000	9,000	99,000	513,000	2,064,000
2	San Francisco Bay	294,000	98,000	386,000	3,408,000	30,000	6,000	710,000	3,512,000
3	Central Coastal	572,000	2,010,000	52,000	217,000	6,000	19,000	630,000	2,246,000
4	South Coastal	1,020,000	1,901,000	885,000	3,635,000	2,000	16,000	1,907,000	5,552,000
5A	Sacramento River Basin	3,645,000	6,912,000	104,000	303,000	70,000	212,000	3,819,000	7,427,000
5B, C	San Joaquin-Tulare Lake Basin (Including Sacramento-San Joaquin Delta)	9,057,000	15,605,000	173,000	438,000	143,000	262,000	9,373,000	16,305,000
	Operation of Salinity Control Barrier	0	0	0	0	0	876,000	0	876,000
6	Lahontan	712,000	6,508,000	12,000	108,000	17,000	120,000	741,000	6,736,000
7	Colorado Desert	3,261,000	6,192,000	23,000	107,000	56,000	111,000	3,340,000	6,410,000
	TOTALS	19,044,000	41,106,000	1,656,000	8,301,000	333,000	1,721,000	21,033,000	51,128,000

* Present requirements determined as of 1950.

By far the largest use of water in California is for agriculture, a condition that will prevail even under conditions of complete development. The present consumption of water for irrigation is estimated to be about 90 per cent of the total for all beneficial purposes, and will amount to about 80 per cent ultimately. The actual requirement for water for irrigated agriculture, at present about 19,000,000 acre-feet per season, would more than double under conditions of complete development, to about 41,000,000 acre-feet per season. The total requirement for water in California for all consumptive purposes in 1950 was about 21,000,000 acre-feet per season. It is forecast that this will eventually increase to some 51,000,000 acre-feet per season.

Estimates of present and ultimate mean seasonal water requirements, under the broad land use groupings and by the major hydrographic areas, are presented in Table 3.

CALIFORNIA'S WATER PROBLEMS

From the discussion and data presented in the preceding sections of this chapter, it is apparent that California's water problems result primarily from the maldistribution of its water resources and water requirements, both geographically and with respect to time. The major sources of water are in the northern part of the State where stream flow wastes into the ocean virtually unused. The productive land and major urban areas are located in the central and southern regions, where water supplies are insufficient. Interposed between the major sources of water and the principal areas of deficiency are great distances and formidable ranges of mountains. Well over 70 per cent of the total stream flow in the State occurs north of an east-west line drawn through Sacramento. In contrast, an estimated 77 per cent of the present and 80 per cent of the forecast ultimate water requirements are found south of the same line. This geographic disparity is clearly indicated in Table 4, which shows a comparison of the water supply with the present and ultimate water requirement for each major hydrographic area of the State, expressed as percentages of the respective totals for the State.

In addition to the unequal areal distribution of California's water resources and requirements, its water problems are further intensified by the sporadic nature of the occurrence of runoff, both within the season and from year to year. The greater part of the runoff occurs during the winter and spring months when the demand for water is the least. Fortunately, a considerable portion of the runoff of most major inland mountain streams is detained in snowfields of the Sierra Nevada until the late spring and early summer snowmelt period. However, this natural regulation is not by any means sufficient to provide for the large demands in the summer and fall.

Although seasonal fluctuation of runoff is a serious problem, because its regulation requires a considerable amount of storage, it is the fluctuation of stream flow from year to year that presents the most difficult problem of regulation. California is subject to extended wet and dry periods. As previously stated, the State suffered a severe drought in the late 1920's and early 1930's, one of many in the past, during which the runoff of streams throughout the State for a 10-year period averaged only 69 per cent of the long-time mean. These periodic droughts have superimposed on the need for storage for normal seasonal regulation the need for provision of extremely large amounts of reservoir storage capacity for necessary cyclic regulation of water supply. A severe drought, superimposed upon present deficiencies in water supply development, could create widespread havoc and even economic disaster throughout California. Furthermore, there is no reason to believe that drought conditions in the future may not be more intense and of longer duration than those of the short recorded past.

All other water problems of California basically result from the primary problem of geographical maldistribution and seasonal and cyclic fluctuation of the water resources of the State, and are briefly discussed herein as problems of water deficiency, both surface and underground, floods, and impairment of water quality.

Problem of Water Deficiency

Because of the characteristic semiarid climate, nearly all areas of the State experience a natural surface water deficiency during the summer and fall months when rainfall is negligible and runoff is meager. This seasonal deficiency is often greatly intensified and prolonged by the extremely variable occurrence of California's water resources from year to year, whereby rainfall and resultant runoff is subnormal for varying periods of years. To add to the natural problems of seasonal and cyclic deficiency, the water resources are not geographically distributed in conformity with the requirements. This has necessitated a high degree of development of available resources in the central and southern parts of the State.

Works have been constructed by numerous entities for regulation of stream flow and conveyance to areas of use, and the water thus delivered has allowed extensive agricultural activity on fertile lands which formerly supported only hay, grain, and native grasses. Many fertile areas of potential productivity, however, are not close enough to surface supplies to allow their development within the limited means of some local agencies.

Further, during periods when runoff is deficient over a series of years, those agencies and individuals depending on facilities adequate only for seasonal regulation are faced with the necessity of cutback in their economy. Occasionally, agricultural develop-

TABLE 4

DISTRIBUTION OF WATER RESOURCES AND REQUIREMENTS

Area number on Plate 3	Hydrographic area	Natural stream flow, in per cent of total for State	Requirement for water, in per cent of total for State		Requirement for additionally developed water, in acre-feet	
			Present*	Ultimate	Present*	Ultimate
1	North Coastal	40.8	2.4	4.0	13,000	1,564,000
2	San Francisco Bay	1.7	3.4	6.9	42,000	**2,257,000
3	Central Coastal	3.5	3.0	4.4	65,000	1,681,000
4	South Coastal	1.7	9.1	10.9	370,000	**3,027,000
5A	Sacramento River Basin	31.6	18.1	14.5	124,000	3,732,000
5B, C	San Joaquin-Tulare Lake Basin (including Sacramento-San Joaquin Delta)	15.9	44.5	31.9	1,661,000	9,427,000
	Operation of Salinity Control Barrier	0.0	0.0	1.7	0	876,000
6	Lahontan	4.5	3.6	13.2	279,000	6,148,000
7	Colorado Desert	0.3	15.9	12.5	0	**2,181,000
	TOTALS	100.0	100.0	100.0	2,554,000	30,893,000

* Present requirements determined as of 1950.
** Assumes imports to full extent of claimed water rights.

ments—and urban developments as well—have overextended their economy during wet periods with extremely critical results during following periods of drought.

Surface diversions and interbasin transfers have done much in the past to develop the economy of the State and are the great potential of the future. However, it may be categorically stated that the degree of economic development which is enjoyed today would not have been possible without the utilization of ground water. The availability of what appeared to be an unlimited supply of ground water has been a great boon to this development. It has been necessary only to put down a well and utilize water from a vast underground reservoir at relatively small cost; expensive conservation and transmission systems have been unnecessary and distribution facilities minimized. Extensive areas overlying natural ground water basins have been developed to a high level of productivity. By utilization of a ground water source, many municipalities in the central and southern parts of the State have also experienced expansion which otherwise would have been impossible.

However, the high level of economic development in many areas of the State has been achieved at the expense of overdraft conditions on the underlying ground water basins, wherein the extraction has exceeded the replenishment. In many of these areas the overdraft is continuing—in fact increasing—generally with no active measures being taken to correct the serious problem. How long these conditions of overdraft, or "mining" of ground water resources, can continue without drastic and far-reaching detrimental consequences is a matter of serious concern. If the underground sources of water are allowed to be completely depleted and no other sources of supply are developed in the interim, the economy of the State will not just stand at the current level, but must of necessity regress to one supportable largely by surface developments. Surface water sources are meager in the central and southern areas of the State where the water requirements are the greatest. The calamity of economic depression attendant on the excessive depletion of ground water reservoirs would not be limited to those agricultural areas overlying the reservoirs. Just as the whole State now enjoys the benefits of an expanding economy, so would the whole State—north as well as south—feel the possible catastrophic effects of the destruction of ground water basins by continued overdraft.

Overdraft conditions presently exist in several of the major and in many of the minor ground water basins in the State. The most serious overdraft in terms of magnitude is manifested in the San Joaquin-Tulare Lake Basin where the present (1955) draft exceeds the mean seasonal replenishment by some 2,500,000 acre-feet. Conditions are particularly acute along the west and south sides of the basin. Overdraft conditions are also serious in the Antelope Valley, presently approximating 175,000 acre-feet per season. The overdraft on the coastal plain of Los Angeles, Orange, Santa Barbara, and Ventura Counties is estimated at 400,000 acre-feet per season. In addition to these areas of critical overdraft, substantial overdrafts are being experienced in portions of the Sacramento Valley, in the Santa Clara, Salinas, and Santa Maria Valleys in central California, and the Santa Clara River Valley in southern California. Twenty-four smaller ground water basins are also known to be overdrawn.

The present (1955) deficiency in developed water supply, both surface and underground, aggregates some 4,000,000 acre-feet per season on a state-wide basis, largely representing an overdraft on ground water supplies. It is forecast that, if California is to attain her full economic potential, additional water supplies amounting to some 31,000,000 acre-feet per season must ultimately be developed to meet consumptive requirements plus irrecoverable losses. On certain streams additional water will have to be developed for stream flow maintenance for fish, wildlife, and recreational purposes, and for maintenance of water quality.

Problem of Floods

It is ironical that the very forces which man now attempts to control to prevent flood damage have formed the flat fertile valleys which attracted him originally. Agricultural enterprise, with the resultant urban and industrial economy, has been developed almost entirely upon the fertile natural flood plains and basins and alluvial fans of active streams.

The great Central Valley is itself an evolvement of many centuries of periodic flooding of the Sacramento and San Joaquin Rivers and their tributaries. It also is the major example in California of the results of recent intensive improvements encroaching upon flood plains. During the flood of December, 1955, great havoc was wrought throughout this area, which includes that particular area of disaster in and about Yuba City. Protective works were generally designed for the economy existent prior to World War II. When the levees of the Feather River were breached, 38 lives were lost and some 100,000 acres flooded, including Yuba City. It should be noted that this tragic loss of lives and destruction of property would have been prevented had Oroville Dam and Reservoir been in operation in conjunction with existing downstream flood control works.

The combined effect of flood runoff of Central Valley streams and coincident extremely high tides during the 1955 flood, produced critical conditions in the Sacramento-San Joaquin Delta. Consisting as it does of a maze of reclaimed islands and separating chan-

". . . the State . . . has developed an economy which is largely contained on areas naturally subject to flooding."

Break on Feather River Near Yuba City, December, 1955 nels, the Delta is particularly vulnerable to the combination of flood flows, high tides, and strong winds, as is a great part of the shore of San Francisco Bay. The below-sea-level elevation of most of the islands in the Delta, and the poor bearing properties of the organic soils which limit the height to which levees can be built, constitute a flood problem. This resulted during the 1955 flood in the inundation of two islands and partial flooding of three others.

Flood conditions in the North Coastal Area are particularly acute on the isolated flood terraces along streams such as the Klamath, Trinity, Mad, Eel, and Van Duzen Rivers. During floods these streams discharge tremendous quantities of water with extremely destructive force. Floods have, in fact, removed whole villages and left little evidence to indicate their former existence. The isolated nature and partial development on these flood terraces restrict the amount of protection which could be economically afforded at the present time; but the nature of existing conditions does point up the flood damage potential as development proceeds in this and other comparable areas and the necessity for giving consideration to flood control needs in future water projects.

The critical position of extensive urban encroachment on alluvial fans, with respect to the inherent flood conditions on these fans, is particularly notable in the area along the east shore of San Francisco Bay and in the South Coastal Area, the major examples of this development in California. Constantly shifting channels, high flood velocities, and heavy debris loads are always a threat on active alluvial fans. The resultant danger to human life and concentrated economic developments was early realized, particularly in the South Coastal Area. Basin-wide flood control projects constructed in that area are indicative of the degree of planning which is necessary and which will become necessary in many other natural flood areas as they develop in the future. Although flood conditions still exist in the South Coastal Area, because many projects are not yet completed, the potential damage has been greatly reduced. Likewise, the Sacramento River Flood Control Project, first authorized in 1917, has provided a substantial degree of protection to valley lands, although additional upstream storage is required for full protection.

An important consideration in the matter of flood conditions is that of lack of watershed management. Early-day hydraulic mining contributed substantially to flood problems in the valley lands below areas of mining operations. The debris load of flooding streams was increased many fold over what would have been naturally transported. The debris load is a prime factor in the cause of flooding, because at slower stream velocities on the valley floor the debris settles out and effectively reduces the stream channel capacity.

Today hydraulic mining has virtually ceased in the mountains of California, but there are still causes existent which unnaturally increase the debris load of streams and, also, unnaturally increase the runoff of streams during periods of high flow. Overgrazing by stock, forest fires, and often excessive cutting of timber very seriously reduce the vegetative cover of mountainous watersheds, thereby lessening or destroying completely the natural retentive and retarding qualities of the watershed with regard to the precipitation which falls thereon.

In summary, the present population of the State—some 14,000,000 people—has developed an economy which is largely contained on areas naturally subject to flooding. While noteworthy progress in flood control has been achieved, particularly by the flood control projects constructed and under construction by the Corps of Engineers, U. S. Army, the growth of the State has been so rapid that these efforts still fall far short of providing an adequate degree of protection, even for the present population, in most areas of the State. Future increases in population of the State to an estimated ultimate total of some 40,000,000 will magnify and intensify present flood problems, as the increased development will continue to concentrate generally in the same areas naturally subject to flooding. Additional flood protection must be provided as rapidly as possible.

Problem of Water Quality

Deleterious effects on the quality of water are generally manifested as a consequence of surface and ground water deficiencies, lack of drainage, and improper disposal of wastes. Problems of water quality are common to nearly all other water problems.

In 1949 the State Legislature considered maintenance of the quality of the State's water resources of sufficient importance to warrant the formation of a State Water Pollution Control Board and nine regional water pollution control boards to protect the beneficial uses of the State's waters from adverse and unreasonable detriment due to disposal of sewage and industrial wastes. Responsibility for protection of the public health from hazard due to improper disposal of sewage and industrial wastes was continued in the State and local health departments. By a concurrent action, the Legislature added Sections 229 and 231 to the Water Code, which direct the Department of Water Resources to:

> "229. . . . , either independently or in cooperation with any person or any county, state, federal or other agency, to the extent that funds are allocated therefor, shall investigate conditions of the quality of all waters within the State, including saline waters, coastal and inland, as related to all sources of pollution of whatever nature and shall report thereon to the Legislature and to the appro-

priate regional water pollution control board annually, and may recommend any steps which might be taken to improve or protect the quality of such waters.

"231. . . . , either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through the interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water pollution control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the Legislature from time to time, its recommendations for proper sealing of abandoned wells."

By these actions, it was recognized that the problem of water quality is essentially an unnatural one, caused largely by mismanagement of water resources as well as by inadequate treatment before disposal of utilized waters.

In numerous coastal ground water basins normally containing fresh water, overdraft conditions have resulted in the intrusion of sea water into the aquifers, or the natural underground formations which store and transmit water. This has been caused by reversal of the natural seaward ground water gradient due to excess of pumped extractions over the natural ground water replenishment. As the aquifers of the coastal ground water basins are generally below sea level, saline water has moved in to replace a portion of the extracted water. In some cases—the Salinas Valley, southern Alameda County, and Orange County are notable examples—sea water has intruded into these erstwhile fresh water aquifers for distances of two or more miles. The restitution of areas which have been lost to sea-water degradation or any other type of degradation will be a long process—if possible at all, since the saline water must be physically removed, either by pumping or by maintenance of favorable gradients for an extended period. Meanwhile, overlying users have lost an economical source of water which can be replaced only by the costly process of deepening wells to a lower undegraded aquifer—when existent, or by importing surface supplies.

There also exist potential sources of quality degradation from deep connate brines and adverse salt balance. Connate brines are ocean waters that were trapped in ground water basins which were inundated by the ocean in past geologic periods. Bodies of connate brines underlie large areas of the Sacramento and San Joaquin Valleys at varying depths. In some areas the upper surfaces are relatively close to the land surface, as along the west side of the San Joaquin Valley and in the Delta area, thereby reducing the potential yield of these basins by limiting the extent to which the ground water resources can be developed without infiltration of these brines. In many areas of the Central Valley connate brines have already been encountered in pumping operations where localized overdraft conditions exist. In some of these areas, the overlying fresh waters have become too saline for use.

The extent of adverse salt balance in ground water basins throughout the State is not known at the present time, due to the lack of long-term records of mineral analyses. Salt balance refers to that desirable condition wherein the amount of soluble salts entering a basin is balanced by the amount of salts leaving the basin—either by natural disposal, sewage outflow, or by pumping for export.

All waters contain some salts in solution. Circulation of available water by continued use and re-use in a ground water basin, with a gradual decrease in supply due to evaporation and transpiration while the mineral content of the basin remains relatively constant, will result in an increase in the proportion of salts in solution with respect to the remaining water available. Continued lack of supplementary water supplies in present areas of overdraft points to the fact that eventually the concentrations of soluble salts will reach limiting values beyond which the water will be unfit for beneficial use.

In the process of drilling and altering wells, improper methods are being employed in many instances, resulting in an inadequate seal between strata of usable and unusable waters, thus allowing interchange; and in lack of adequate surface seals, permitting inflow of inferior surface waters with consequent damage to ground water quality. Likewise, failure to seal abandoned wells, or improper sealing when attempted, has resulted in the degradation or pollution of ground water. These problems are rapidly becoming more serious as older well casings deteriorate and are abandoned and the drilling of new wells continues at an unprecedented rate. At the present time the Department of Water Resources is investigating well drilling conditions and methods in the State in order to formulate well drilling and abandonment standards to afford adequate protection to the quality of ground waters.

A quality problem involving surface water is presently manifested in the inherently high mineral content of streams draining the west side of the San Joaquin Valley. The problem is particularly acute during periods of low flow when, in traversing ground water basins on the valley floor, the water percolating into these stream beds contributes to adverse salt balance in those basins, particularly those suffering an overdraft condition.

Surface sea-water encroachment into the Delta region of the Central Valley has occurred in the past due to the seasonal and cyclic fluctuation in stream flow and the depletion by extensive upstream diversions. All irrigation supplies for fertile Delta islands, and for many of the lands along the Sacramento River, are diverted from the intervening streams and sloughs, and the threat to the agricultural economy of this area is serious.

Alleviation of the salt-water intrusion problem was of prime consideration in the planning and construction of the Central Valley Project. Stored winter surplus waters from reservoirs of the project have been used for repulsion of saline water by maintaining a certain minimum fresh-water outflow to Suisun Bay during periods of low natural flow in the summer and fall months. However, ultimate developments requiring greater beneficial use of all available waters will eventually require that repulsion of saline water by fresh-water outflow be substantially reduced. A plan for physical barriers, being considered in the ultimate development of the State's water supply, is discussed in Chapter IV.

So far, this discussion has dealt largely with problems of protection of mineral quality from deterioration due to man's development of the water resources concerned, a matter to which too little attention has been given to date. Better known are the disastrous results caused by disposal of inadequately treated sewage and industrial wastes to streams and to ground water basins. Waste disposal problems may arise not only from liquid-borne wastes but also from disposal of garbage, refuse, and industrial wastes. Notable progress has been made by the State and Regional Water Pollution Control Boards and by the State and local health departments in preventing and abating pollution and contamination due to waste disposal. Every effort must continue to be made in the future to maintain the quality of the State's waters by appropriate planning for and control of the treatment and disposal of wastes, giving consideration to the effect of such waste disposal upon future planned uses as well as the present uses of the receiving waters. In planning for future urban and industrial development, careful consideration must be given to problems of waste disposal to prevent damage to the quality of the State's water resources.

Man's development has characteristically exerted an adverse effect upon the native quality of waters. Most uses of water by man, for irrigation, for instance, as well as for the disposal of sewage and industrial wastes, add pollutants and degradants to the waters with resultant deterioration of the quality. Hence, as these uses increase, the necessity for adequate treatment and disposal of waste waters becomes increasingly imperative if the quality is to be maintained at satisfactory levels for the higher uses. This is particularly true in areas of deficiency, where the quality of imported waters must be maintained at sufficiently high levels to permit necessary re-use.

The removal and final disposal of harmful degradants or pollutants without danger or detriment, whether by means of separate lined conveyance conduits or in natural channels, in may cases is possible only by providing for dilution of the waste waters with waters of higher quality. This may require the use of a portion of developed local supplies or the importation of water specifically for that purpose. The use of water resources for waste disposal is a necessary one and must be considered along with other water requirements for beneficial use. It will be necessary to find and apply the degree of dilution of waste waters needed in order to arrive at the proper and economic balance in the use of water as between waste removal and higher uses. One of the determinants in the use of water for waste removal is the necessity for maintaining a favorable salt balance. These are problems requiring continuing study for proper solution.

In summary, it may be stated unequivocally that unless the quality of the State's water resources is maintained at proper levels, full satisfaction of California's ultimate water requirements will not be possible.

Problem of Production of Hydroelectric Energy

The further extensive development of hydroelectric power as an inseparable part and partner in California's water resource development is a fully recognized requisite. The power potential of the north coastal streams, certain tributaries of the Sacramento River, and remaining undeveloped sites on east side tributaries in the San Joaquin Valley almost equals the total present steam and hydroelectric capacity now available in California. Full future satisfaction of water demands in all parts of California will require mass movement of large volumes of water through long conveyance systems and over high mountain ranges. Considerably more energy will be needed for pumping than is presently developed in California. Moreover, it is estimated that by the year 2000, California's total energy demand will exceed by 10 to 12 times the present power capability; the pumping load will be only a small part of that total demand. Hydroelectric power now finds its greatest value as "peaking" energy, and efficiently and economically complements steam power generated from fossil fuels. Likewise, it will combine equally well with atomic power generation in the years ahead. It seems reasonably certain that the power market will absorb hydroelectric power output as rapidly as it can be made available. The problem then, is to make each hydroelectric power opportunity yield the maximum in terms of energy output and revenue, but in proper balance with the other demands on and for the water resources concerned.

Problems of Recreation, Fish, and Wildlife

The need for more and better opportunities for wholesome outdoor recreation in California is rapidly expanding, due to the impact of a growing population, increased awareness by the people of the joys and benefits of such activity, and increased time and opportunity available to them for such pursuits. Accessible water areas and flowing streams well stocked with fish constitute an important aspect of the public desire for recreational opportunities. Satisfaction of that desire to the maximum feasible extent is a problem inherent in the development of California's water resources. That development will provide several hundred new reservoirs with many thousands of acres of water area, and will make possible releases of water in hundreds of miles of natural streams for improvement of fish and wildlife habitat. Enhancement of fish and wildlife resources and development of the recreational potential will provide important economic assets to many areas in California, particularly in the mountains and foothills. Provisions of facilities and opportunities for such use by the public therefore becomes an important objective in further water development.

Problem of Drainage

An ever-present problem in irrigated agriculture is the necessity of providing adequate drainage. Extensive drainage systems may be necessary to maintain soil productivity. Leaching and drainage have made possible the reclamation and use of large areas formerly considered valueless. Adequate drainage and proper disposal of saline drain waters may be an important factor in maintenance of ground water quality.

At the present time, the most serious unsolved drainage problem in California is in the west side of the San Joaquin Valley. It is considered probable that full solution will require a master drainage channel extending from Buena Vista Lake in Kern County to Suisun Bay.

Drainage must be considered an integral and indispensable part of the development and utilization of water resources. Adequate provision must be made therefor in the total program.

Problem of Full Use of Available Storage Capacity

A highly important problem which must be continually kept in mind in the further development of California's water resources involves the proper use of available storage capacity, both surface and underground. With respect to surface storage development, the most economical dam and reservoir sites have already been developed, leaving the less desirable projects available for future construction. Remaining combinations of good dam sites with surface reservoir sites of adequate capacity are rare, particularly in the areas in which export waters must be developed. With regard to ground water, it has been demonstrated in many areas of the State that the ground water basins, once considered a source of virtually inexhaustible supply, must be carefully managed in order to ensure their continued usability.

Because of the limited remaining surface storage capacity susceptible of development and the many purposes and uses to which the developed water must be put, it is highly important and urgently necessary that the available storage capacity be used wisely and for maximum benefit. This can be accomplished only by achieving the optimum development at each site selected for construction, which necessitates provision for the full development of the water production capabilities of the watershed and, in many instances, operation of the reservoir to meet the needs of several purposes, such as irrigation, urban, and industrial uses; flood control; power generation; recreation; fish and wildlife; and protection of water quality.

Failure to develop a site to its full potential through construction of a single-purpose project where a multipurpose project is necessary and justified initially in the public interest, or initial construction such as to preclude later full development, would result in the extravagant waste of the site.

Of paramount importance among the advantages inherent in multipurpose planning and development are economy and conservation of project sites. With respect to economy, it is generally cheaper to provide for several water uses in a single project than to build several single-purpose projects. Conservation of project sites is necessary because the scarcity of favorable dam sites dictates the fullest practicable development of the potential of each site.

In view of California's continuing growth in population and water demand, practices which result in the wasting of surface storage opportunities by inadequate development, without regard to future requirements for other purposes, should no longer be permitted on any stream in the State. These criteria should apply wherever storage is contemplated by the State or any other agency. In those cases where initial construction to optimum size of reservoir is currently infeasible, then provisions for future raising of the dam to full height should be incorporated in the original construction.

Careful management of California's underground storage capacity will be required not only in areas where increased use of ground water resources is expected, but also for preservation of the present level of use in those basins which are experiencing or are threatened with overdraft and deterioration of water quality. In other words, unless an effective management program is implemented in the near future, involving the maintenance of water quality and the limiting of pumping extractions within safe yield rates, the utility of the State's ground water basins cannot be perpetually maintained.

". . . water is the lifeblood of recreation and fish and wildlife."

CHAPTER III

WATER DEVELOPMENT PLANNING

The discussion and data presented in Chapter II have firmly established the fact that the number one present and future water problem in California centers around the disparities in the occurrence of water supply and requirements—both in terms of *time* and *place*. In brief review, the disparity in time refers to the natural occurrence of runoff principally during the winter and spring months and in highly varying quantities from year to year, while the requirements for water imposed by man's developments are characteristically the greatest during the summer months and are relatively uniform from year to year. The disparity in place refers to the varying distances between the sources of supply and the areas of need, with the bulk of the resources occurring in the north and the major requirements in the central and southern areas of the State. All planning and construction efforts by agencies and individuals have been and will continue to be dedicated mainly to the equalizing of the "time" and "place" factors. However, with a few notable exceptions, these efforts have in the past been limited in scope and objectives to local areas.

This chapter presents a brief historical account of water resource planning and development in California up to the present time, discusses the urgent need for comprehensive coordinated planning on a state-wide basis, and outlines the planning considerations utilized as bases for formulating The California Water Plan.

HISTORY OF WATER RESOURCE DEVELOPMENT

The history of water resource development in California has largely been that of control and regulation of the supply at its source, to insure its availability when needed, and conveyance to the area where needed. Fortunately, the greater portion of the water resources of the State so far developed and utilized have been regulated in ground water storage by nature, thus reducing the need for construction of surface storage reservoirs. Furthermore, the extensive occurrence and ready availability of ground water resources in these areas have greatly reduced the past need for extensive conveyance facilities. However, many areas of the State have been and will continue to be dependent primarily upon the development of surface water supplies. As future water requirements increase throughout the State, development of surface water supplies and transfer to areas of need will become increasingly important.

History of the use of water in California by white settlers began with the Spanish missions in the final third of the eighteenth century. Profiting by their experience in arid Baja California, the padres established most of the Alta California missions at locations where water for irrigation was available. Except for limited cultivation by Indians along the west bank of the Colorado River, it was in the mission gardens of fruits and vegetables, and perhaps in occasional fields of grain, that irrigation in California had its beginnings. Even today, more than a century and a half later, remnants of mission works to supply irrigation and domestic water may be seen, notably at San Diego Mission Dam on San Diego River, at Santa Barbara Mission Dam and Reservoir above Santa Barbara, and at Mission San Antonio de Padua near King City.

Acreage irrigated at the Spanish missions was small, yet it provided an important object lesson for American and European settlers who began arriving in California in the 1830's and 1840's. During the first two decades of American occupation, from 1850 to 1870, settlers in the southern part of California built small ditches diverting from streams of the coastal plain, mainly in the Los Angeles, San Gabriel, and Santa Ana River Basins. In the northern and central parts of the State water was also diverted from streams or obtained from artesian flows, and to a limited extent was lifted from streams with steam-driven pumps. In the foothills of the Sierra Nevada development of irrigated agriculture was accelerated by the expansion in population that accompanied and followed the Gold Rush. Mining ditches were subsequently utilized to convey irrigation supplies to areas of use after mining had ceased.

The first irrigation supplies were diverted from nearby streams, without storage, and lands irrigated were limited to those that could be watered from available low summer flows. In southern California, however, the need for storage reservoirs was soon recognized and several important dams, including Bear Valley, Hemet, Sweetwater, and Cuyamaca, were constructed or begun in the 1880's. In the remainder of the State all major storage reservoirs, primarily for irrigation and flood control, have been constructed since 1900. A number of these, such as Melones, Don Pedro, and Exchequer, were financially assisted by the hydroelectric power developed from the water stored.

Early irrigation following the Spanish and Mexican days was practiced mainly on an uncoordinated, individual basis. By 1856, however, a commercial company had constructed canals to irrigate wheat near Woodland in Yolo County, and about that time groups of settlers were joining together to build ditches in the south. Construction of larger irrigation works by development companies and cooperatives was well under way by the 1870's and 1880's, in both the southern part of the State and the central and southern parts of the San Joaquin Valley.

In 1887, the original Wright Irrigation District Act was passed by the Legislature, partly as a result of prior court decisions regarding water rights which were adverse to irrigation development. These decisions had established the doctrine of riparian rights, which largely limited the use of water to lands bordering natural stream channels. By providing for the organization and government of irrigation districts, declaring use of water for irrigation of district lands a public use, and vesting in the districts the power of eminent domain to acquire necessary water, riparian or otherwise, the Wright Act and subsequent acts which have developed from it have made possible much of the present great agricultural development of California. Activities of many individuals, cooperatives, and water utilities also have contributed to the dominant importance of irrigated agriculture to the economy of the State.

The large metropolitan areas of the State, under pressure of ever-increasing requirements and diminishing sources of undeveloped local water, have exercised initiative and leadership in solving their water supply problems. By their efforts, outstanding achievements in developing remote sources of supply and crossing mountains and deserts with extensive conveyance systems have been accomplished.

Typical of such accomplishments is the history of the City of Los Angeles which, as far back as 1905, had outgrown its local water supplies and had initiated studies to locate additional sources of water. These studies culminated in construction of a 238-mile aqueduct to convey waters developed on the Owens River, on the eastern slopes of the Sierra Nevada, to terminal reservoirs in the San Fernando Valley. This project was completed in 1913, and in 1940 the system was extended northward to develop additional supplies from the Mono Basin watershed. The present average capacity of the Los Angeles Aqueduct is estimated at 320,000 acre-feet per season. The system operates entirely under gravity flow, except that during periods of extreme drought the surface runoff has been augmented by pumping from wells in Owens Valley. Hydroelectric power generating installations are provided to utilize the substantial elevation differentials along the route of the aqueduct.

Ten years after completion of the Los Angeles Aqueduct, the City of Los Angeles and other communities in southern California foresaw the need for additional water supplies. Studies of the possibilities of importing water from the Colorado River were initiated by the Los Angeles Department of Water and Power, but were taken over in 1928 by The Metropolitan Water District of Southern California, then a newly formed organization of 11 southern California cities. The studies culminated in construction by the district of the Colorado River Aqueduct, which diverts water from the Colorado River at Lake Havasu behind Parker Dam. The water is lifted 1,617 feet over mountain barriers by a series of five pumping plants, and conveyed a distance of 242 miles to Lake Mathews, western terminus of the aqueduct proper. A distribution system from Lake Mathews serves lands in Los Angeles, Orange, Riverside, and San Bernardino Counties. The San Diego Aqueduct, a twin-barrelled conduit, conveys water from the Colorado River Aqueduct to San Diego County. The Colorado River Aqueduct, in operation since 1941, is the longest and largest domestic water supply line in the world. It is designed to deliver 1,212,000 acre-feet annually, the total right of the Metropolitan Water District, when completed to full capacity. It is now estimated that this source will furnish ample water for perhaps 10 or 15 years, at which time another and even longer step must inevitably be taken.

Other outstanding examples of initiative and leadership in water supply development in California are manifested by the major reservoirs constructed by communities of the San Francisco Bay Area on the Mokelumne and Tuolumne Rivers on the western slope of the Sierra Nevada, and the aqueducts which convey municipal and industrial water great distances to the Bay area, the South Bay area, and southern portions of Alameda County. The City and County of San Francisco foresaw many years in advance that its locally available water supply would be outgrown, and initiated planning studies as early as 1900 for developing a major system for importing large quantities of water from a distant source. The Tuolumne River system was chosen as the source of San Francisco's future water supply, and by 1934, when needed, Hetch Hetchy Reservoir and Lake Eleanor in the Tuolumne River watershed had been completed and water was delivered to the San Francisco Peninsula by the Hetch Hetchy Aqueduct, extending some 135 miles from the Tuolumne River to Crystal Springs Reservoir on the peninsula.

The Hetch Hetchy Aqueduct features a 25-mile tunnel through the Coast Range, the longest tunnel in the world at the time of completion. The aqueduct will convey not less than 448,000 acre-feet per season to the service area, as now constituted, of the Hetch Hetchy system when that system is developed to its ultimate capacity. This will require additional storage and duplication of present conveyance facilities, including a parallel bore through the Coast Range.

". . . the East Bay area . . . has developed the waters of the Mokelumne River . . ."
Pardee Dam

". . . water pumped from the Delta for use in Contra Costa County."
Contra Costa Canal

The many communities in the East Bay area, through the formation of the East Bay Municipal Utility District, have developed the waters of the Mokelumne River by Pardee Reservoir, and have constructed the Mokelumne Aqueduct to transport the developed waters from Pardee Reservoir to terminal reservoirs in western Contra Costa and Alameda Counties. The aqueduct presently delivers about 125,000 acre-feet per season, and has a conveyance capacity of some 162,000 acre-feet per season. The district contemplates an ultimate yearly delivery of 364,000 acre-feet through the Mokelumne Aqueduct. The district proposes to construct additional storage facilities on the Mokelumne River and additional aqueduct capacity to make this delivery possible.

All the aforementioned water supply projects have been conceived and consummated through local effort. However, especially during the past 20 years, federal agencies have entered the field of water resource development in California. The Corps of Engineers of the United States Army, through its responsibilities for flood control and navigation, as previously mentioned in Chapter II, and the Bureau of Reclamation of the Department of the Interior, in the interests of conservation and reclamation, have both constructed comprehensive projects. The most extensive of these is the Central Valley Project, now being completed in substantial accord with the State Water Plan, as published in Division of Water Resources Bulletin No. 25 and reported to the Legislature in 1931.

The Central Valley Project, constructed and operated by the Bureau of Reclamation, is a multipurpose development designed to supply water for irrigation, municipal, industrial, and other uses, improve navigation on the Sacramento River, provide adequate flows to maintain suitable water quality in the Sacramento-San Joaquin Delta, control floods in the Central Valley, and produce hydroelectric energy. In accomplishing the first-named function, it conserves surplus flows of the Sacramento River for use in the Sacramento Valley and in the Delta and for conveyance to and use in the San Joaquin Valley. Shasta Dam, key structure of the project, stores headwaters of the Sacramento River. Its regulated releases, after passing through hydroelectric power plants at Shasta and Keswick Dams, flow down the stream channel to the Sacramento-San Joaquin Delta. A pumping plant located near Tracy lifts water from sea level in the Delta to an elevation of about 200 feet and discharges it into the Delta-Mendota Canal, which extends 117 miles along the west side of the San Joaquin Valley to Mendota Pool in the San Joaquin River.

The second major element of the Central Valley Project consists of Friant Dam on the San Joaquin River and the Madera and Friant-Kern Canals. This unit supplies lands on the east side of the San Joaquin Valley in Madera, Fresno, Tulare, and Kern Counties. These diversions from the San Joaquin River are partly replaced by Sacramento River waters at Mendota Pool to supply certain former users of San Joaquin River flows under an exchange contract.

These basic elements of the Central Valley Project are augmented by additional associated units. The transfer of Sacramento River water across the Delta to the Tracy Pumping Plant is accomplished by the Delta Cross Channel. The Contra Costa Canal conveys water pumped from the Delta for use in Contra Costa County. A number of lesser conservation, conveyance, and distribution works provide additional water service, and an extensive transmission network has been established to facilitate utilization of energy from the several power features of the project.

Folsom Dam on the American River, now completed, will contribute to the over-all operations of the Central Valley Project. Consideration is now being given to the so-called Folsom South Canal to convey releases from Folsom Reservoir southward to supply lands in Sacramento and San Joaquin Counties. Latest addition to the Central Valley Project is the Trinity Project, incorporated in the original State Water Plan but later eliminated by action of the State Legislature. This unit, the only feature of the project extending beyond the Central Valley watershed, is now under construction. It will develop flows of the upper Trinity River and convey them eastward across the drainage divide to the Sacramento River, utilizing the elevation differential for production of hydroelectric power. It should be noted that Folsom Reservoir and Trinity Diversion Project, although incorporated in the Central Valley Project, as authorized by the Federal Government, and included in The California Water Plan, are not included in the Central Valley Project as defined in the State Water Code.

Several other projects have been completed recently or are under construction in the State by the Federal Government. The Solano Project of the Bureau of Reclamation consists of Monticello Dam and Reservoir on Putah Creek, now completed, and the Putah South Canal extending southerly through Solano County, presently under construction. The Sly Park Project, recently constructed by the Bureau of Reclamation, develops water in the mountain watershed of the Cosumnes River and conveys it to the American River Basin for use on foothill lands.

The Corps of Engineers has completed Pine Flat Reservoir on the Kings River and Isabella Reservoir on the Kern River for flood control and irrigation. The Corps is initiating construction of the Success Project on the Tule River and is preparing plans for construction of the Terminus Project on the Kaweah River, both also for flood control and water conservation.

In the Central Coastal Area the Bureau of Reclamation is constructing Vaquero Reservoir on the

"The Central Valley Project . . . conserves surplus flows of the Sacramento River for use in the Sacramento Valley . . . the Delta . . . and in the San Joaquin Valley."

Shasta Dam

Delta-Mendota Canal

Cuyama River, a tributary of the Santa Maria River. This reservoir will provide water conservation for recharge of ground water and flood control. In coordination with a levee project authorized for construction by the Corps of Engineers on the Santa Maria River, nearly complete flood protection will be provided in the Santa Maria Valley. Cachuma Reservoir, recently completed by the Bureau of Reclamation on the Santa Ynez River, provides supplemental water in Santa Barbara County. The Bureau of Reclamation also is constructing Casitas Reservoir on Coyote Creek, a tributary of the Ventura River, to increase supplemental water supply in Ventura County.

Several reservoir projects are presently under consideration by the Bureau of Reclamation, including Auburn Reservoir on the American River and San Luis Reservoir westerly of Los Banos in the San Joaquin Valley.

The United States Department of Agriculture under the authority of the federal "Watershed Protection and Flood Prevention Act" as amended, is participating to an increasing extent in water resource control and development in California. The federal legislation authorizes the Department of Agriculture in cooperation with the states and their political subdivisions to investigate, to provide financial and other assistance, and to undertake works of improvement for: (1) flood prevention, including structural and land treatment measures; and (2) the conservation, development, utilization, and disposal of water for all purposes and uses. The act provides that initial applications for projects be submitted to the appropriate state agency or the governor, and if not disapproved within 45 days, the Secretary of Agriculture may approve and proceed with the investigation, negotiations for, and construction of the proposed works. Projects are limited to watershed areas not exceeding 250,000 acres, and reservoirs are limited to a capacity not exceeding 2,500 acre-feet, unless specific congressional approval of larger reservoirs is given.

Despite the foregoing limitations on size of projects, this program if undertaken on a large scale may have far-reaching consequences in the development of California's water resources. It is therefore of primary importance that the closest coordination and cooperation be maintained as to these projects during planning and later stages among the state agencies concerned with land and water resource development, the federal agencies, and the local agencies involved. The coordination should be initiated long before official submission of proposals to the State for approval or disapproval, in order that the availability and the best use of the water resources involved may be determined and agreed upon.

Waters of the Colorado River are of vital importance to the developed economy of southern California. In addition to supplying The Metropolitan Water District of Southern California through the Colorado River Aqueduct, these waters are utilized to irrigate lands in Palo Verde, Imperial, and Coachella Valleys. The All-American Canal, built by the Bureau of Reclamation and now operated by the Imperial Irrigation District, originates at Imperial Dam on the Colorado River near Yuma and extends westerly across Imperial Valley along the California side of the Mexican border. The canal has an intake capacity of about 10,000 second-feet. Near the boundary of the Imperial Irrigation District, the Coachella Canal branches northward from the All-American Canal to supply lands along the eastern shore of the Salton Sea and in lower Coachella Valley. It should be noted that the All-American system, in common with the Colorado River Aqueduct, is dependent upon Hoover Dam and its reservoir, Lake Mead, for regulation of the Colorado River.

The foregoing water supply projects by no means represent the entire existing water development picture for California. Projects of lesser magnitude, though not necessarily of secondary significance, transport supplies to areas of use in other drainage basins. Localized conservation developments, many of them incorporating flood control and hydroelectric power features, constitute a large factor in the State's water supply program.

Not to be overlooked in the history of water supply development in California are the ground water reservoirs, which at present furnish more than one-half the water used on irrigated lands and for domestic, municipal, and industrial purposes. Extensive development of ground water is concentrated largely in the Central Valley and southern California, and consists primarily of a multitude of individually owned installations operated on a completely uncoordinated basis. Improvement of pumping equipment, and extension of electric power service generally over most of the important ground water basins since the turn of the century, together with the rapid growth of water requirements, particularly in recent years, have so stimulated development that in many basins the ground waters have been severely overdrawn. Serious losses have already resulted and more will follow until corrective measures are taken. The Raymond Basin area in Los Angeles County provides an example of properly managed ground water resources. This resulted from court action. Similar actions are in process for the West Coast Basin in Los Angeles County and the Tia Juana Basin in San Diego County.

Perennial lowering of ground water levels has been substantially retarded in several ground water basins by artificial recharge with both native and imported waters. About 25 public districts and private entities of various types are presently conducting such programs. Essentially, artificial recharge involves the use of stream channels, spreading basins, or abandoned gravel pits to supplement natural percolation. The recharge capability of these percolation works is commonly increased by detention of excess runoff in upstream reservoirs and the control of releases to rates within the percolation capacity of the works.

Notable achievements in artificial recharge have been accomplished by the Los Angeles County Flood Control District, the Orange County Flood Control District, United Water Conservation District in Ventura County, San Bernardino County Flood Control District, Santa Clara Valley Water Conservation District, and Kern County Land Company, among others.

COMPREHENSIVE COORDINATED PLANNING AT STATE-WIDE LEVEL

A great deal of progress has been made so far in the development of California's water resources. No one can refute the fact that the initiative and resourcefulness of local agencies in planning and constructing water development projects has been largely responsible for the present highly developed level of economy throughout the State. The assistance of the Federal Government has been most helpful. However, the growth of the State, made possible by the progressive development of water supplies, has constantly created new water problems, each of which has become successively more difficult of solution. All too often, limited planning for the future has resulted in construction of works sufficient only to meet the needs of the present, as growth throughout the State has continued at rates exceeding even the most optimistic forecasts.

The great water development projects conceived and constructed in the past, notable as they are and vital to the State's development as they have been, represent comparatively localized planning when considered from the state-wide standpoint. Even the Central Valley Project, a revolutionary plan when conceived and a phenomenal development as it is being constructed, is limited in its scope and benefits to a comparatively small part of the State as a whole, notably portions of the Sacramento Valley, the Sacramento-San Joaquin Delta, and of the San Joaquin Valley. It is but a magnification of what some 100 irrigation and reclamation districts have done on their own initiative with local financing. Without such local projects constructed in the past, however, California for the most part would still be a semiarid wasteland.

Because of the dictates of economics, which governs water development as well as all other engineering projects, the cheapest and easiest-to-develop water projects have always been selected first for construction. Naturally, local water supplies were developed first. Development of water from distant sources and conveyance through lengthy and costly aqueducts have been resorted to only after available local supplies have become insufficient. The same principle of economics has prevailed in the selection of alternative sources of imported water supplies. Thus, we are now faced with the inevitable consequences: future water development in California must involve "leftover" local projects and costly major import projects which are generally beyond the means of all but a very few local agencies.

Today, there is increasingly severe competition between areas and between uses for the remaining available water resources. In some streams there is no remaining unappropriated water available for the further development of areas which should logically be served therefrom. As previously mentioned, several of the major ground water basins are seriously overdrawn.

In view of this and of the previously discussed wide disparity between the occurrence of the State's water resources and needs, both as to time and place, it is apparent that the era of piecemeal water development planning and construction virtually has reached an end. Future development of the State's water resources must rely, to a constantly increasing extent, on coordinated, comprehensive planning on a state-wide level if the needs of all areas and all uses are to be met in the most effective and economical manner. The need for such planning is continually becoming more evident as undeveloped local water resources diminish and development of supplemental supplies becomes more complex, while water requirements increase in unprecedented proportions.

The purpose of such coordinated, state-wide planning must be to establish a framework into which all future water development projects, both local and state-wide, can be integrated, and which will serve as a guide to ensure optimum development and utilization of available water resources, with due consideration to the varying interests and uses involved. This is the objective of The California Water Plan. It will serve as the engineering basis for proper administration in the public interest of the State's water resources by the various agencies involved. It will provide the means for badly-needed coordination in further planning and in the construction and operation of water projects among the manifold entities, federal, state, local, and private, engaged in water control and development in California.

A continuing, coordinated, state-wide, planning program, implemented progressively by the construction of projects as necessary and justified, is the only means by which the logical, orderly, and economic development of California's water resources can be assured to the degree necessary to meet the ultimate requirements for all uses. The construction of projects to accomplish the objectives of the planning program will undoubtedly require the combined efforts of the Federal Government, the State Government, and local entities, but the State logically must take a leading role, since much of the development that will be needed is outside the scope of federal interest and beyond the capabilities of local entities. Further, the magnitude of the job to be done will require the financial support of all agencies involved.

PLANNING FOR DEVELOPMENT OF CALIFORNIA'S WATER

Solution of California's water problems will not be fully accomplished until the water resources are captured and controlled at their source, transported to areas of need, and reregulated to the demand schedules prevailing in the particular areas served in amounts sufficient to meet the ultimate requirements for all beneficial uses. The indicated solution will involve the redistribution of water supplies for use in local areas, and the transfer on a state-wide basis of water from northern areas of abundance to central and southern areas of deficiency. Thus, the planning of projects necessary for achievement of the required degree of water resource development to meet the ultimate requirements involves three primary considerations, each of which presents difficult but not insurmountable obstacles. As presented herein, these considerations concern the development of a solution of ultimate problems, but do not cover the many phases of interim uses and transfers of water that would inevitably occur during the step-by-step implementation of the ultimate plan.

Capture and Control of Water

The first consideration—capture and control of the water at its source—involves the planning of large surface storage reservoirs and substantial ground water storage to regulate the inherent seasonal and cyclic fluctuation of stream flow to a more or less uniform seasonal supply, for conveyance to areas of use both local and distant. Actually it is the variation of runoff from year to year, rather than that within the season, that imposes the large storage requirements, as sufficient storage must be available to capture surplus water during wet periods to carry through subsequent extended drought periods. Were it not for the variable or cyclic occurrence of the water resources, the storage requirement would be greatly reduced. The enormous storage requirement, as subsequently developed in this bulletin, probably could be met by surface storage alone on the north coast streams. However, full cyclic regulation of the flow of the Sacramento Valley streams would necessitate not only full development of all available surface storage opportunities but also conjunctive operation of the large underground reservoirs in the Sacramento and San Joaquin Valleys. Some 30 per cent of the developed runoff of the Sacramento Valley would need to be regulated by underground storage. This in turn would require the provision of conveyance canals adequate in capacity to transport this secondary water, of irregular occurrence and variable flow characteristics, to the areas of recharge of the underground storage basins.

Conveyance to Areas of Need

The second consideration—the conveyance of water over long distances to areas of need—involves large conduits which must pass over or through either or both the Coast Range and Tehachapi Mountains, and which would extend practically from the northern to the southern borders of the State. Economic and geologic considerations dictate the design of such conduits generally for continuous year-round conveyance of a uniform quantity of water, in order to minimize the size of tunnels, pumping plants, canals, siphons, and other conveyance facilities. In certain cases, however, pumping plants and conduits would be designed for larger capacities to enable the use of lower cost off-peak power. Moreover, conveyance of the variable seasonal secondary water from the Sacramento Valley to the San Joaquin Valley would necessitate the design of certain conduits to the maximum rather than the average seasonal flows. Even at their minimum possible size wherever possible, conveyance facilities required for interbasin transfer of water under ultimate conditions would be without precedent in magnitude and scope.

Reregulation in Areas of Use

Finally, the third consideration— the reregulation of delivered water to the monthly demand schedule prevailing in the areas of use—involves the planning of terminal storage reservoirs to regulate the largely uniform deliveries to the varying monthly demands for the various uses in the areas served. Because the bulk of the water would be delivered to most areas on a uniform seasonal basis, the required terminal storage facilities would be relatively small. However, in areas such as the San Joaquin Valley, where a portion of the supplemental water would be delivered on a variable basis from year to year, final regulation would be accomplished by use of ground water storage to a very large extent.

Development and Use of Water

In addition to the foregoing considerations of development, conveyance, and reregulation of water, planning for the ultimate solution of California's water problems also requires the consideration of other physical problems brought about by the development and use of water. Those problems associated with the development of water involve the operation of reservoirs for the several beneficial, although somewhat incompatible, purposes of providing municipal, irrigation, and industrial supplies; flood control; fish and wildlife; recreation; navigation; and power generation. Problems associated with the use of water involve the consideration of protection of water quality and provision for adequate drainage. Means of financing, although involving problems vital to the effectuation of the vast system of works necessary to the solution of California's water problems, are beyond the scope of planning considerations presented herein.

Certain basic legal concepts are inherent in the planning considerations necessary to the solution of California's water problems. Minimum possible interference with vested water rights is a major objective. However, some instances of conflict with vested rights are inevitable in a plan of such magnitude. In those instances of interference and to the extent vested rights might be adversely affected, the interference would have to be adjusted either by agreement, purchase, or condemnation. Exchanges of water, where necessary or desirable, would be accomplished by mutual agreement among the parties affected, including the State and Federal Government where pertinent. With respect to the protection of areas of origin of water and the areas of deficiency for which new water supplies must be made available, it is assumed that the legislation necessary to provide that protection would be enacted prior to its need. Similarly, with regard to ground water operations, it is assumed that necessary legislation would establish the policy and the authority which would enable the operation of ground water basins to the degree required under ultimate conditions, prior to the time such operation becomes necessary. Many other legal problems are certain to arise as the water resources are developed. For the purposes of this report it is assumed that they will be solved as the need arises.

Development of Water. As previously stated, problems associated with the development of water involve the operation of reservoirs for the somewhat incompatible purposes of providing municipal, irrigation, and industrial supplies; flood control; fish and wildlife; recreation; navigation; and power generation. This statement refers to the problem of resolving the inherent conflict in the allocation of limited available reservoir storage to each of those purposes. As an example, operation for flood control sometimes requires the use of storage that might otherwise be used for conservation. Operation for power generation similarly may encroach upon conservation storage, because of the required minimum storage for maintenance of power head. Moreover, the schedule of power releases is not in phase with the schedule of releases for irrigation purposes, although a large portion of the conservation releases also accomplishes the dual purpose of power generation. Operation of reservoirs for water supply, flood control, and power generation is not readily amenable to recreational use of the reservoir area because of the extreme and sometimes rapid fluctuations of water levels. Furthermore, reservoir releases for downstream fishery enhancement may adversely affect the conservation yield for other purposes. Conversely, any major storage structure would affect anadromous fish by blocking their passage to upstream spawning areas, necessitating the provision of adequate facilities for maintaining the fisheries resources. To minimize the effects of these conflicts and thus achieve the maximum degree of conservation consistent with the manifold benefits desired, carefully coordinated operation of multipurpose reservoirs is mandatory.

All of the foregoing purposes of water development are vitally necessary and must be fully considered in planning for the solution of the State's water problems. Such planning involves consideration of certain reservoirs to be operated solely for flood control, other reservoirs to be operated solely for fish and wildlife and recreational purposes, and certain reservoirs to be operated primarily for power generation. However, most major reservoirs would be operated for all of these and other beneficial purposes.

1. *Flood Control.* It should be pointed out that, in addition to planned operation for flood control, a measure of incidental flood protection would be derived from operation of any storage reservoir. However, storage capacity sufficient to contain all flood waters would require extremely large and expensive reservoirs. Generally, it is not feasible to attain complete conservation and flood control by storage alone. Improvement of downstream channels in combination with upstream storage reservoirs will probably provide the most economic solution to the important problem of flood control in California. Flood control has in the past and will continue to be largely a joint endeavor between the United States, the State, and local public interests.

2. *Recreation, Fish, and Wildlife.* Outdoor recreation and fish and wildlife conservation are essential considerations in planning for water resource development. When reservoir storage is contemplated on streams with recreation potential, sufficient reservoir releases must be planned to maintain favorable downstream conditions for recreational pursuits and propagation of fish life. Planning of major dams which would block passage of migratory fishes to their ancestral spawning grounds requires the concurrent planning of fish ladders, substitute fish hatcheries, or spawning ground, or development of other streams solely for fish life as compensatory measures. Planning for recreational purposes also involves the contemplated operation of reservoirs dedicated solely to the improvement of summer stream flow conditions in popular recreational areas where such flows are presently deficient.

"Generally, it is not feasible to attain . . . flood control by storage alone."
Sacramento Weir on Sacramento River

". . . hydroelectric power as an inseparable part and partner in California's water resource development is a fully recognized requisite . . ."
Electra Power Plant on Mokelumne River

At the time of acquisition of lands, easements, and rights of way for reservoirs and other water development works, additional lands should be included for public access and for development and use of recreational opportunities. Likewise, at the time water resource development planning is done, planning by those state, federal and local agencies responsible for associated recreational opportunities should be accomplished.

3. *Power Generation.* The essential role of hydroelectric power production in the further development of California's water resources and economy was discussed in Chapter II. As therein stated, the problem will be to make each hydroelectric power opportunity yield the maximum feasible output in terms of firm capacity, energy, and revenue, consistent with the other demands for the water resources concerned. Major planning considerations include in each case: determination of the most economic combination of height of dam, dead storage, head, and releases for power in balance with releases for other purposes; provision for generation of the most economically favorable peaking power capacity and energy, wherever pertinent, which includes adequate afterbay storage and forebay storage as needed; and utilization of power drops along major aqueduct routes where feasible, particularly on the descending side of mountain crossings. A possible future power opportunity may develop in the form of pumped storage power plants which would use low-cost off-peak power from other sources for pumping to a reservoir at a higher elevation and would generate high-value peaking power on return of the water to an afterbay or to the aqueduct system.

Use of Water. Delivery and use of supplemental water supplies in areas of need will solve the problems of water deficiency and directly resultant problems; but unless precautions are taken, other problems may result as a consequence. Of these corollary problems, water quality is one of the most significant. This is particularly serious in areas overlying ground water basins which are utilized to any appreciable extent in meeting the water requirements. The problems in point concern the protection of mineral quality of the local ground waters by importing waters of good mineral quality, by maintenance of proper salt balance, and by the maintenance of favorable drainage conditions through control of the ground water levels by pumps and drainage systems. Maintenance of proper quality in surface streams is equally important. Another serious problem is that of subsidence of lands, caused by heavy withdrawals of ground water and by application of surface water.

1. *Protection and Maintenance of Water Quality.* The basic objective with regard to quality of water in the State under ultimate development concerns the assurance that the available waters will meet the minimum quality requirements for all beneficial uses thereof. Planning toward this objective involves the evaluation of the native quality of waters in terms of their suitability for such uses, the careful maintenance of quality in areas of use, and protection of the quality of water in source areas in streams and reservoirs and of exported waters from degradation during transfer, at requisite levels to prevent injurious effects.

With respect to the suitability of waters for beneficial uses, certain minimum quality requirements have been set forth, and are generally accepted as standards for classification of waters for the various uses. Probably the most widely accepted standards are those formulated by the United States Public Health Service for drinking water, as shown in Table 5.

TABLE 5

MINERAL STANDARDS FOR DRINKING WATER
U. S. Public Health Service, 1946
(In parts per million)

Constituent	Limit
Mandatory limits	
Fluoride (F)	1.5
Lead (Pb)	0.1
Selenium (Se)	0.05
Hexavalent chromium	0.05
Arsenic (As)	0.05
Nonmandatory but recommended limits	
Iron (Fe) and manganese (Mn) together	0.03
Magnesium (Mg)	125
Chloride (Cl)	250
Sulphate (SO_4)	250
Copper (Cu)	3.0
Zinc (Zn)	15
Phenol	0.001
Dissolved solids	500 (1,000 permitted)

Quality requirements for irrigation water have been proposed by various investigators. Classifications of irrigation water presently in use by the Department of Water Resources are based on studies of the University of California at Davis. One such classification is set forth in Table 6. The classes shown in Table 6

TABLE 6

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

Chemical properties	Class I	Class II	Class III
	Excellent to good	Good to injurious	Injurious to unsatisfactory
Total dissolved solids:			
In ppm*	Less than 700	700-2,000	More than 2,000
In conductance, $Ec \times 10^6$ at 25°C	Less than 1,000	1,000-3,000	More than 3,000
Chlorides, in ppm	Less than 175	175-350	More than 350
Sodium, in per cent of base constituents	Less than 60	60-70	More than 70
Boron, in ppm	Less than 0.5	0.5-2.0	More than 2.0

* ppm—parts per million.

are generally empirical, being based on average soil and crop adaptability.

Recent research has been conducted at the University of California at Davis, taking into account drainage characteristics of the soil and employing revised standards for evaluation of salinity of irrigation waters. These standards, which are coming into more general use, are presented in Table 7. Water quality standards will undoubtedly change in the future as a result of further study. Hence the standards given herein should not be regarded as absolute.

TABLE 7

TENTATIVE CLASSIFICATION FOR EFFECTIVE SALINITY OF IRRIGATION WATER

Soil conditions	Terms used	Class of water		
		I[1]	II	III[2]
Little or no leaching of the soil can be expected.	m.e./l[3] of ions ppm lbs/acre-foot	3 165 450	3-5 165-275 450-750	5 275 750
Some leaching but restricted. Deep percolation or drainage slow.	m.e./l of ions ppm lbs/acre-foot	5 275 750	5-10 275-550 750-1500	10 550 1500
Open soils. Deep percolation of water easily accomplished.	m.e./l of ions ppm lbs/acre-foot	7 385 1050	7-15 385-825 1050-2250	15 825 2250

[1] Upper limit—maximum limit.
[2] Lower limit—minimum limit.
[3] m.e./l—milli-equivalents per liter.

Planning considerations with respect to water quality involve the following: provision for protecting the mineral and sanitary qualities of waters at requisite levels; determination of natural base levels of radioactivity to facilitate the detection of any future increase in radioactive contamination; determination of the waste assimilation capacity of the various waters concerned, or, in other words, the degree to which these waters can be used for waste disposal without adverse and unreasonable detriment to the beneficial uses, considering future as well as present uses thereof; the necessity of providing water to dilute and carry away waste products resulting from man's activities without harmful effects; planning for further urban and industrial development with due regard to the problems of waste disposal; and maintenance of a favorable salt balance in the many basins of the State by provision for exporting from each basin at least as much salt as is brought into it each year by native and imported waters, as well as from other sources.

Because of the widely varying quality requirements for the manifold industrial uses, these requirements are not discussed in this chapter. Such information will be published in Appendix E to this bulletin. In general it may be said that waters meeting the United States Public Health Service drinking water standards and the requirements for irrigation can be made acceptable for even the most exacting industrial requirements by proper treatment at the point of use.

With respect to maintenance and enhancement of fish and wildlife, the maintenance of adequate dissolved oxygen in the water and freedom from toxic concentrations of harmful materials are prime considerations. Also important are low turbidity and freedom from floating oil and grease. Further, high-quality water is necessary for maintaining a suitable habitat, food supply, and spawning areas.

With respect to the quality of water necessary for the full effectuation of The California Water Plan, a Board of Water Quality Consultants, retained to advise on water quality problems under the ultimate pattern of water transfer and use, has submitted a report recommending specific limits of quality for water diverted from the southern boundary of the Sacramento-San Joaquin Delta.

These recommendations, as presented in Table 8, have been adopted by the Department of Water Resources as the quality objectives to be met at the points of diversion for water to be exported to the major areas of deficiency. These objectives have been used in formulation of The California Water Plan, and unless the quality is maintained at or higher than these levels, full implementation of the Plan will not be possible.

TABLE 8

WATER QUALITY LIMITS FOR WATER FOR EXPORT AT POINTS OF DIVERSION AT SOUTHERN BOUNDARY OF SACRAMENTO-SAN JOAQUIN DELTA

RECOMMENDED BY BOARD OF CONSULTANTS ON WATER QUALITY AND ADOPTED BY DEPARTMENT OF WATER RESOURCES

Item	Limit
Total Dissolved Solids	400 ppm
Electrical Conductance (Ec $\times 10^6$ at 25°C)	600
Hardness as $CaCO_3$	160 ppm
Sodium Percentage	50%
Sulphate	100 ppm
Chloride	100 ppm
Fluoride	1.0 ppm
Boron	0.5 ppm
pH Value	7.0-8.5
Color	10 ppm
Other constituents as to which the U. S. Public Health Service has or may establish mandatory or recommended standards for drinking water	USPHS Limits

2. *Maintenance of Drainage.* Drainage of agricultural lands, already a serious problem in many areas of California, will become an increasingly important consideration in planning for the future development and use of California's water resources. The large imports of water and the greatly increased application of water, under ultimate conditions would aggravate present drainage problems, would create new problems by forming swamps or "water-logged" areas in the lower portions of ground water basins, and would increase the probability for salinization of

the soils unless prevented by appropriate measures. The existence of high-water-table areas and increased salinity problems would not only preclude the usefulness of large areas of potential agricultural lands, but would result in excessive, uneconomic consumptive use by swamp-type vegetation of water which otherwise could be salvaged for beneficial purposes.

Solution of drainage problems will involve consideration of drainage ditches and canal networks, and pumps to control the elevation of the water table in areas subject to waterlogging. In addition, studies should be made relative to the permeability of soils, particularly with regard to reclamation of vast acreages of presently saline and sodium saturated lands. Methods employed under ultimate development probably would be similar to present practices in the San Joaquin Valley, but on a broader scale. A further consideration in planning for drainage is the point of disposal of highly saline drainage waters. For the San Joaquin Valley, for instance, this may necessitate a master drain emptying into Suisun Bay.

3. *Subsidence.* Subsidence of the land surface presents unusual and difficult problems which must be considered in planning for the major conduits required for transportation of water to central and southern areas of deficiency. The most serious subsidence now is in the San Joaquin Valley, where sinking of the land surface has changed the gradient of a portion of the Delta-Mendota Canal of the U. S. Bureau of Reclamation enough in places to reduce its capacity. Subsidence also has damaged canals, wells, and pipe lines of numerous irrigation systems, as well as oil and gas pipe lines, electric transmission towers, and numerous buildings. Two separate types of subsidence have been identified in the San Joaquin Valley, namely: (1) regional or deep-seated, subsidence, and (2) local shallow subsidence.

The deep-seated subsidence is believed to be caused by withdrawal of ground water from pressure aquifers, the lowering of the pressure head being accompanied by sinking of the land surface. A related type of subsidence has occurred in the Long Beach area, where subsidence accompanying heavy withdrawals of oil has caused actual or threatened surface advance of the sea into certain areas. The deep-seated subsidence in the San Joaquin Valley is occurring principally on the west side of the valley in an elongated area stretching from north of Mendota to south of Huron, and in the southern part of the valley in an irregularly shaped area centering near Delano. The maximum amount of subsidence in the Mendota-Huron area is actually greater than 16 feet, and the area is presently subsiding at a rate of almost 1 foot per year. It is the effect of this deep-seated subsidence which has changed the gradient of the Delta-Mendota Canal. The maximum subsidence in the Delano area amounts to more than 13 feet. Other areas in the State, such as the Santa Clara Valley, also are affected by subsidence.

Notwithstanding the adverse effects from deep-seated subsidence, the local shallow type of subsidence probably has the potential to cause most damage to man-made structures. This type of subsidence occurs when water is applied in quantity, as by irrigation, on certain low-density soils which occur extensively on the semiarid west side of the San Joaquin Valley. Settlement of this type of land after irrigation is very irregular and causes heavy sinking of irrigation ditches, breaking of concrete-lined ditches and of pipe lines, tilting of high tension towers, and cracking and breaking of foundations of buildings after lawn irrigation which, in places, has caused houses to tilt at strange angles.

The areas affected by shallow subsidence extend around the western and southern borders of the San Joaquin Valley, at the base of the Coast Range. Local subsidence of 10 feet and more has occurred in locations where unlined ditches were attempted in earlier days. The surface of an experimental test plot, kept under water continuously for several months during 1956 and 1957, has subsided 7 feet in 7 months. Although the mechanism of shallow subsidence is not clear, it probably involves rearrangement and compaction of soil particles when wetted, accompanied perhaps by removal of gypsum and other solubles by solution.

Shallow subsidence also has occurred in the peat lands of the Sacramento-San Joaquin Delta, where much of the land is now below sea level, resulting in severe flood control problems. This subsidence may be due to a lowering of the water table, consumption of peat by plant growth, drying and blowing away of the peat by wind, or a combination of these and other factors.

The magnitude of the effect of subsidence on planning the routes and design of major conduits for transportation of water from north to south is evidenced by the large areas subject to subsidence, which must be either crossed or detoured. In addition to subsidence of peat lands in the Delta, which must be crossed by all water transferred to the central and southern portions of the State, there are more than 70 miles of lands along the contemplated conduit routes in the Mendota-Huron area which are subject to both shallow and deep-seated subsidence. Moreover, along these routes, some 50 miles of lands south of Kettleman City and Tulare Lake and 20 miles of lands south of Buena Vista Lake are subject, at least in part, to shallow subsidence.

Faced by these conditions, the Department of Water Resources is actively investigating the causes and mechanisms of land subsidence in cooperation with a number of other state and federal agencies, coordinated by the Inter-Agency Committee on Land Subsidence in the San Joaquin Valley.

CHAPTER IV
THE CALIFORNIA WATER PLAN

The water problems of California and the need for comprehensive planning have been described in the preceding chapters. This chapter presents a summary discussion of the physical features and accomplishments of the works which would fulfill the objectives of The California Water Plan in the solution of those problems. To facilitate a greater appreciation and better understanding of the Plan, its scope and objectives and the concepts basic to the attainment of its objectives should be clearly borne in mind, and are re-emphasized for this purpose in the following paragraphs.

The California Water Plan is a master plan for the control, conservation, protection, and distribution of the waters of California, to meet present and future needs for all beneficial uses and purposes in all areas of the State to the maximum feasible extent. It is a comprehensive plan which would reach from border to border both in its constructed works and in its effects. The Plan is a flexible pattern susceptible of orderly development by logical progressive stages, the choice of each successive incremental project to be made with due consideration to the economic and other pertinent factors governing at the particular time.

The water development works described in this chapter and shown on the plates accompanying this bulletin demonstrate one means believed practicable of accomplishing the objectives of The California Water Plan in each area of the State, based on presently available knowledge. As knowledge increases, as technology improves, as conditions change through the years, and as future patterns of development become more easily discernible, more suitable alternatives to any feature or features herein discussed are likely to be found. It is the intention that as the time approaches for construction in any given area, further studies will be made to determine the most feasible solution in the light of conditions then obtaining. That solution may depart considerably from the Plan as now conceived. In the meantime, the elements of The California Water Plan presented herein will provide a basis of comparison with other alternatives, and furthermore, will serve as a guide for the selection of works for future construction. It is anticipated that continuing study will be given to The California Water Plan and that it will be modified when and as necessary.

The California Water Plan, as now presented and as it may be modified from time to time, is designed to serve as the engineering basis for the administration of the State's water resources by the various agencies concerned, to the end that maximum benefit may ultimately be achieved. It will provide a much needed means of coordination of the efforts of the manifold federal, state, and local public agencies and private entities engaged in the planning, construction, and operation of water projects.

The California Water Plan is an ultimate plan, designed to meet the water requirements of the indefinite future when the land and other resources of the State are essentially fully developed. It is fully acknowledged that certain of the forecast ultimate requirements for water may never be realized, and that the facilities which would provide for those requirements may never be constructed. However, the planning effort is deemed necessary at this time in order that provision may be made for such development if and when such requirements arise. The Plan includes and would fully utilize existing works, as well as those works presently proposed by public and private agencies and individuals. It is designed so that it would interfere with vested water rights to the minimum possible extent. In those instances where such interference would be inevitable, it is contemplated that just compensation would be paid. Likewise, it is anticipated that exchanges of water, where necessary to achieve the most economical solution, would be consummated only after agreements had been reached with the holders of vested rights thereto.

The omission of a project from those described herein does not necessarily preclude the possibility of construction of that project. Nor does the inclusion of a particular project indicate that that specific element is the only one that should be considered. Rather, each project should be judged on its merits when it is proposed, in the light of its prospective accomplishments in meeting the basic objectives of The California Water Plan for the particular water resources concerned.

The California Water Plan consists of two principal categories of water resources developments. The first category embraces the local works designed to meet present and future water needs in each of the major hydrographic areas of the State. Water development projects within this category are hereinafter described under the heading "Development to Meet Local Requirements." The second category comprises a major system of works to conserve and export surplus waters from the North Coastal Area and the Sacramento

River Basin, and to transfer these waters to areas of deficiency elsewhere in the State in sufficient amounts to meet the forecast ultimate requirements. These interbasin transfer facilities are collectively designated the "California Aqueduct System," and are subsequently described under that heading.

The California Water Plan, comprising both the local development works and the California Aqueduct System, gives consideration to water conservation and reclamation, to flood control and flood protection, to the use of water for agricultural, municipal, and industrial purposes, to hydroelectric power generation, to salinity control and protection of the quality of fresh waters, to drainage, to navigation, and to the interests of fish, wildlife, and recreation. It contemplates the conjunctive operation of surface and ground water reservoirs, which operation would be essential to regulation of the large amounts of water ultimately to be involved.

DEVELOPMENT TO MEET LOCAL REQUIREMENTS

In the course of the current investigation, numerous preliminary plans have been made for development of local water resources to meet local needs throughout California. The formulation of these plans was based upon the premises that the water occurring in each hydrographic area would be developed to the maximum reasonable and practicable extent, that exports from areas of surplus would be limited to that water available over and above local needs, and that imports to areas of deficiency would be limited to only that water needed to supplement locally developed supplies.

Although this section is confined to a summary description of local developments insofar as possible, features of the California Aqueduct System necessarily enter into the discussion wherever their effects would supplement the accomplishments of local developments. However, the description of the aqueduct facilities is presented separately in a later section of the chapter.

Local development features of The California Water Plan are presented by the major hydrographic areas of the State, in the following order: North Coastal Area, San Francisco Bay Area, Central Coastal Area, South Coastal Area, Sacramento River Basin, San Joaquin-Tulare Lake Basin, Lahontan Area, and Colorado Desert Area. The location of these areas is shown on Plate 3, and the local development works are delineated on the 26 sheets of Plate 5.

North Coastal Area

The North Coastal Area is by far the most prolific water-producing area in California, with an aggregate mean seasonal unimpaired runoff of nearly 29,000,000 acre-feet. The estimated present and probable ultimate seasonal water requirements of 518,000 acre-feet and 2,160,000 acre-feet, respectively, represent but a fraction of the available supply. In spite of this abundance of water, the North Coastal Area is not without its water problems.

Because of the relatively low elevation of the North Coastal Area and its proximity to the ocean, most of the precipitation occurs as rainfall, and stream discharge into the ocean increases markedly within a short time following a storm. More than 85 per cent of the total seasonal runoff occurs during the 6-month period from November through April, on the average. The need for water is characteristically greatest during the dry summer months from July through October, when less than 10 per cent of the total seasonal runoff occurs. Thus, there is need for seasonal regulation by storage, whereby winter flood flows are stored for use during the following summer months of high demand. In addition to variation within the season, runoff in the North Coastal Area experiences considerable fluctuation in amount from year to year, resulting in so-called "wet" or "dry" periods. This characteristic of the water supply creates a need for cyclic carry-over storage in addition to the need for seasonal regulation.

The greatest water problem facing the North Coastal Area is that of occasional great floods such as occurred in 1907, 1938, 1950, and 1955. The last and worst of these great floods, in December, 1955, sent streams of the area to record heights, and caused loss of life and widespread destruction of communities, farm lands, industry, and utilities, particularly along the Eel, Klamath, Trinity, Mad, Smith, and Russian Rivers, and Redwood Creek. However, because of the large amount of storage required for effective flood control, single-purpose flood control reservoirs are generally not economically justified.

Except for the extensive Klamath Project of the United States Bureau of Reclamation, described hereafter, present development of the ample water resources of the North Coastal Area is very limited. Storage at Lake Pillsbury on the upper Eel River and a diversion into the Russian River Basin are operated primarily for generation of hydroelectric power. A power development is located on the Klamath River near the state line, the water supply for which is regulated in Oregon. Sweasey Dam on the Mad River provides municipal water supplies for the City of Eureka. Dwinnell Dam and Reservoir on the Shasta River furnishes irrigation water to lands in Shasta Valley. Several relatively small irrigation systems serve upland valleys, and minor pumping of ground water for domestic, municipal, and irrigation purposes is scattered throughout the area.

Two major projects are presently under construction in the North Coastal Area by federal agencies. The Coyote Valley Project, under construction by the Corps of Engineers, U. S. Army, on the East Fork of the Russian River, will develop water for municipal. industrial, and irrigation purposes, and will substantially enhance recreational opportunities and fish and wildlife resources in the Russian River Basin. The Trinity Division of the Central Valley Project, being constructed by the United States Bureau of Reclamation, will divert water from the upper Trinity River to the Sacramento Valley, to develop hydroelectric energy and to augment the water resources of the Central Valley. The project will also provide local benefits.

Local development works of The California Water Plan would meet future water requirements in the North Coastal Area. Both the local works and the works of the California Aqueduct System would provide much needed flood control and would enable releases of stored water to enhance summer and fall stream flow in the interests of fish, wildlife, and recreation. It should be emphasized that facilities of the California Aqueduct System, in addition to their primary export function, also would accomplish substantial benefits in the North Coastal Area in terms of flood control, stream flow maintenance, and power generation, and in this respect are difficult of differentiation from the local works.

For planning purposes the North Coastal Area has been subdivided into four units, and the local development works are segregated according to these units for discussion herein. These units are designated the "Klamath-Trinity Group," "Eel-Mad Group," "Russian River Group," and "Pacific Basins Group," and their locations are shown on Plate 3. The physical features and costs of all local works for the North Coastal Area are presented in Table 9 which follows this discussion under the heading "Summary of North Coastal Area."

Klamath-Trinity Group. The Klamath-Trinity Group consists of the California portion of the drainage system of the Klamath River, including the entire Trinity River system. Its area within California approximates 10,000 square miles, most of which is occupied by mountains and foothills. However, the Tule Lake area and Shasta, Scott, Hayfork, and Hoopa Valleys contain substantial areas of agricultural lands.

The Klamath Project, built and operated by the United States Bureau of Reclamation, is by far the largest existing water supply development in the Klamath-Trinity Group. This project utilizes waters of the Klamath River and Lost River system to irrigate nearly 200,000 acres of lands in Oregon and California. The project also controls water levels in Tule Lake, and reregulates the flows of the Klamath River for power generation. The previously mentioned Trinity Diversion of the Central Valley Project will divert 872,000 acre-feet of water annually from the upper Trinity River to the Central Valley, and will generate a substantial block of hydroelectric power.

The Klamath-Trinity Group, although favored with abundant water resources, is confronted with several present and future water problems. First, the group will require the development of an additional 640,000 acre-feet of water per season to meet the full irrigation, urban, and industrial potential. Second, there is an urgent need for the control of floods on the Klamath and Trinity Rivers. Floods threaten the valley lands adjacent to those rivers, and the threat is particularly acute in the urban and agricultural areas on the coastal plain. The community of Klamath near the mouth of the Klamath River, and Klamath Glen a few miles upstream, were virtually demolished by the flood of December, 1955. Third, there is the problem of maintenance of favorable anadromous fishery, which is not so much a problem at the present time, but which will arise after the development of major dams and reservoirs in the area which would block the passage of anadromous fish to their spawning grounds and would inundate spawning areas. Moreover, the streams of the Klamath-Trinity Group have a large hydroelectric power potential which is a prime consideration in future development of the water resources of the group.

The Klamath River Basin Compact, an interstate compact which has as its purpose the promoting of orderly and comprehensive development and the use of the water resources of the Klamath River Basin, has been ratified by the States of California and Oregon and is now awaiting approval of the Congress of the United States. This compact provides for the distribution and use of water within the Upper Klamath River Basin, which is defined as the drainage area of the Klamath River and all its tributaries upstream from the boundary between Oregon and California, including the closed basins of Butte, Red Rock, Swan Lake, and Lost River Valleys, and Crater Lake.

Terms of the Klamath River Basin Compact establish an order of preference of use of water within the Upper Klamath River Basin, with domestic and municipal use first and irrigation use second, followed in turn by recreational use, including use for fish and wildlife, industrial use, and use for hydroelectric power generation. Diversions of water outside the Upper Klamath River Basin are prohibited, with minor exceptions, by the compact, which also makes available to the California portion of the upper basin sufficient water from the Klamath River in Oregon for the future irrigation of 100,000 acres of undeveloped irrigable land which cannot feasibly be served from any other source. There is also established a permanent commission to administer the terms of the compact.

The objectives of The California Water Plan in the Klamath-Trinity Group are threefold: first, the de-

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North Coastal Area—Redwood Grove

velopment of sufficient water supplies to satisfy the present and ultimate requirements for water for irrigation, urban, industrial, recreational, and power generation purposes, and to preserve and enhance fishery and wildlife resources; second, the provision of adequate flood protection; and third, the conservation of some 8,000,000 acre-feet of water per season for export to areas of deficiency elsewhere in the State. These objectives could be met by the planned local developments and the major reservoirs and conduits of the California Aqueduct System.

Local development works in the Klamath-Trinity Group could provide water to meet irrigation, urban, and industrial needs, and could considerably improve existing stream flow conditions in the interests of fishery resources and recreation. In addition, operation of these works could effect some flood control. Major reservoirs of the California Aqueduct System on the Klamath and Trinity Rivers, in developing some 8,000,000 acre-feet of water seasonally for export, could effect a high degree of flood control on those rivers, and generate an abundance of power for enhancement of the local economy. The adverse effect of these major reservoirs on the anadromous fishery could be offset somewhat by compensatory measures, such as improvement of downstream flow conditions and a new lake fishery. Also, the improvement of environmental conditions on other streams could be effected, as will be shown during the ensuing discussion.

Beatty, Boundary, and Chiloquin Narrows Dams, if constructed as parts of the Klamath Project of the Bureau of Reclamation, could augment the yield of that project by developing the waters of the Sprague and Lost Rivers. Boundary dam site is located on Lost River at the upper end of Langell Valley on the California-Oregon line. Beatty and Chiloquin Narrows Dams and Reservoirs would be located on the Sprague River in Oregon. Under terms of the aforementioned Klamath River Basin Compact, the water supply developed by these works would be utilized throughout the Upper Klamath River Basin, including lands in Oregon as well as in California. Water would be served to lands in California by appropriate conveyance facilities, as shown on Sheet 1 of Plate 5.

Iron Gate Dam and Reservoir, located on the Klamath River about 4 miles east of Hornbrook, California, could be constructed primarily to provide urgently needed reregulation of releases from the California Oregon Power Company's hydroelectric power developments on the Klamath River. It could also provide a forebay for pumping irrigation supplies for use in Shasta Valley. Under this plan the water developed in the upper basin would be conveyed to Shasta Valley by the Bogus Conduit, two pumping lifts along the route of the conduit being required.

Montague Dam and Reservoir, located on the Shasta River about 4 miles north of Yreka, if constructed would also provide water for irrigation use in Shasta Valley. In addition, sufficient releases would be made to the Shasta River to maintain a minimum flow of 20 second-feet for recreational purposes.

Grenada Ranch Dam and Reservoir, located on the Shasta River about 3 miles southeast of the town of Grenada, could be constructed to supply municipal water to the City of Yreka, as well as to provide a gravity irrigation supply for portions of Shasta Valley adjacent to the river.

Callahan Dam and Reservoir, located near the town of Callahan, could be constructed to regulate the Scott River and to develop water for irrigable lands in Scott Valley. Callahan Reservoir would also provide flood control for the valley. Releases would be made to maintain and improve the present fishery.

Layman Dam and Reservoir, located on Hayfork Creek just above its confluence with the South Fork of the Trinity River, if constructed would be utilized primarily to supply water for irrigable lands in Hayfork Valley. In addition, sufficient releases to the downstream channel would be made to maintain a minimum flow of 10 second-feet during the summer months, which would enhance fishery conditions below the dam.

The hydroelectric power potential of the Salmon River could be developed by Morehouse Reservoir and its associated power plant, located on the Salmon River just below the mouth of Morehouse Creek. Although Morehouse Reservoir would be utilized primarily for power production, the incidental stream flow regulation provided would materially enhance accomplishments of downstream units of the California Aqueduct System. Moreover, the reservoir would provide a measure of flood control.

Waters of the South Fork of the Trinity River could be regulated by Smoky Creek Reservoir, located about 7 miles upstream from Forest Glen and above Eltapom Reservoir, a feature of the California Aqueduct System. This reservoir would be dedicated solely to maintenance of favorable stream flow conditions throughout the summer months. A minimum flow of 45 second-feet would be maintained, whereas under present conditions the summer flows have upon occasion virtually ceased. Thus, a 22-mile reach of stream between Smoky Creek Dam and Eltapom Reservoir would be considerably improved as a habitat for fish life, particularly for the several trout species, and spawning areas would be available for the lake fishery that would develop in Eltapom Reservoir.

In summary, the 10 reservoirs and associated works constituting the local development works for the Klamath-Trinity Group under The California Water Plan would have an aggregate storage capacity of

1,920,000 acre-feet, and would make available additional water supplies amounting to some 760,000 acre-feet per season. About one-third of this yield would be utilized in Oregon, and the remainder would serve California lands. The described development would not fully satisfy the possible ultimate water requirements of the group, as there are a number of small scattered areas of irrigable land which are too remote to be economically reached by projects of the scope considered herein. However, adequate local water resources are available in the event that requirements for such lands materialize.

Facilities considered for conveyance of the developed water supplies to areas of use include 7 pumping plants and 53 miles of conduits. A yearly total of about 343,000,000 kilowatt-hours of electric energy could be made available by the Morehouse Power Plant. Furthermore, the foregoing local development works, operated in conjunction with facilities of the California Aqueduct System, would considerably enhance the recreational potential of the group by reservoir releases to maintain stream flow throughout the summer months.

Data on the general features and capital costs of the local development works in the Klamath-Trinity Group are presented in Table 9. The location and layout of their component features are delineated on Sheets 1 and 3 of Plate 5.

In addition to local developments, The California Water Plan envisages 10 storage reservoirs in the Klamath-Trinity Group, to be operated primarily as features of the California Aqueduct System. These reservoirs would provide nearly 27,500,000 acre-feet of additional storage capacity in the group. As previously stated, the aqueduct features are difficult of differentiation from local developments with respect to creation of recreational opportunities, protection from flood damage, and power generation. These 10 reservoirs would constitute large bodies of water adaptable for swimming, boating, and other recreational activities. The minimum pools maintained at many of these reservoirs would provide opportunities for development of trout fisheries. Furthermore, a large degree of protection from floods would be afforded by the conservation reservoirs, for both local and export purposes, which would provide about 870,000 acre-feet of surcharge storage in addition to their normal conservation pools. The detention effect of this storage capacity would substantially reduce peak flood flows, even without planned operation of the reservoirs for flood control. Damage caused by the floods of December, 1955, would have been considerably reduced had these units of The California Water Plan been in operation. Complete flood protection could be provided by reservation of storage space specifically for that purpose. However, the degree of flood protection warranted is a matter of economics and a factor for future determination.

Eel-Mad Group. The Eel-Mad Group includes the drainage basins of the Eel and Mad Rivers, and all the remaining coastal drainage between the Mattole River on the south and Redwood Creek on the north. The terrain, typical of most of the North Coastal Area, is predominantly mountainous. Valley and mesa lands comprise only about 5 per cent of the total area of 4,340 square miles, and are mostly located near the mouth of the Eel River and adjacent to Humboldt Bay. Eureka, the largest city in the North Coastal Area, is situated on the shore of Humboldt Bay.

The abundant water resources of the Eel-Mad Group are largely undeveloped at present. The Scott and Van Arsdale Dams on the upper Eel River are operated in conjunction with a diversion from the Eel River Basin to the Russian River Basin for hydroelectric power generation, and Sweasey Dam on the lower Mad River is operated for development of a municipal water supply for the City of Eureka. Small local surface diversions and minor ground water pumping constitute the only remaining water supply developments within the group.

Water problems of the Eel-Mad Group are of the same nature as those of the foregoing Klamath-Trinity Group. The demands for agricultural, domestic, and industrial water supplies are growing and will ultimately require a supplemental water supply of about 366,000 acre-feet per season, most of which will be for irrigated lands. However, the industrial potential for water is considerable, particularly in the processing of timber for pulp production. Although the foregoing estimate of ultimate supplemental water requirements includes provision for future pulp production, it is quite possible the estimated requirements for this purpose may have to be revised upward, with a resultant modification of water development plans. Adequate water could be made available for such possible increases if they materialize.

The pressing need for flood control projects in the Eel-Mad Group was demonstrated by the flood of December, 1955. Record flows in the Eel River caused widespread destruction in areas important to both the present and future economy of the group. Agricultural lands and a number of lumber mills on the alluvial plains near the mouths of streams, particularly those of the Eel and Mad Rivers and Redwood Creek, were severely damaged.

There exists a significant potential for improvement of summer stream flow characteristics in every major waterway of the Eel-Mad Group, not only for enhancement of the fish habitat, but also for the furtherance and development of recreational areas. Such areas are now in increasing demand by visitors from throughout the State. Recreation is bound to be important to the future economic welfare of the North Coastal Area.

The objectives of The California Water Plan in the Eel-Mad Group consist of the development of sufficient water supplies to satisfy the ultimate water requirements for all beneficial purposes, including irrigation, urban, industrial, recreational, fish and wildlife, and power generation; provision of adequate flood control; and the regulation of some 2,600,000 acre-feet of water per season for export to areas of deficiency elsewhere in the State. The ultimate water requirements within the group itself could be met by construction of storage reservoirs on local streams adjacent to the areas of need. Such reservoirs would also enhance the fishery and the recreational opportunity, and would provide some flood control. In addition, the major reservoirs of the California Aqueduct System on the Eel River could serve to generate a large block of hydroelectric power to support local industrial development, and effect a high degree of flood control on the Eel River. In compensation for adverse effects of the major reservoirs on the anadromous fishery, the South Fork of the Eel River and the Bear River could be developed solely for improvement of the fishery and of recreational conditions.

Local developments discussed herein generally fall into two categories. Reservoirs in the first category would be primarily for development of irrigation, municipal, and industrial water supplies, while those of the second category would provide for enhancement of the fishery and the general recreational potential.

Crannell Dam and Reservoir, located on Little River about 1 mile upstream from the community of Crannell, if constructed would provide domestic and industrial water for the Eureka-Arcata area. Water service would also be provided to the northernmost portion of the agricultural and domestic areas lying north of the Mad River.

The Butler Valley dam site is located on the Mad River about 1 mile northwest of the community of Maple Creek. If a dam were constructed at this site, releases from the reservoir would flow down the Mad River, from which water could be diverted at Sweasey Dam or pumped from the lower Mad River and conveyed to service areas lying both north and south of the river. In this connection, a dam and reservoir is contemplated for construction by the Humboldt Bay Municipal Water District on the upper Mad River at the Ruth site near the Humboldt-Trinity county line. Ruth Dam and Reservoir would develop municipal and industrial water for use in the Eureka area. This project has been approved by the Department of Water Resources as an initial local development on the Mad River. However, the development of the upper Mad and Van Duzen Rivers for export purposes, as subsequently described under the California Aqueduct System, would necessitate the eventual replacement of Ruth Dam with a similar development at the Butler site or an alternative downstream site.

Yager Dam and Reservoir, located on Yager Creek about 8 miles east of Fortuna, could serve lands lying north and south of the lower Eel River. Water would be released from the reservoir down Yager Creek and pumped to the service areas. In addition, releases from Yager Reservoir would improve summer stream flow conditions in lower Yager Creek, and in the lower Van Duzen and Eel Rivers into which it discharges, thus enhancing fishing and other recreational pursuits.

The South Fork of the Van Duzen River could be developed by Larabee Valley Dam and Reservoir, located at Larabee Valley about 7 miles east of Bridgeville. Water released from Larabee Valley Reservoir would flow down the Van Duzen River, improving summer flows for fishing and recreation along the lower river, an area of scenic beauty and the present location of a state park. The water could then be routed from a pumped diversion to the delta areas north and south of the Eel and Van Duzen Rivers.

The ultimate requirements for irrigation, urban, and industrial water in the vicinity of Willits in Little Lake Valley could be met by Valley's End Dam and Reservoir on Tomki Creek about 7 miles east of Willits. Under this project water would be diverted from Valley's End Reservoir through a tunnel into Berry Creek in Little Lake Valley, and rediverted from Berry Creek for delivery around the edge of the valley.

Streeter Dam and Reservoir could be constructed on Tenmile Creek, a tributary of the South Fork of the Eel River, about 5 miles northwest of Laytonville. The conserved water could be delivered to irrigable lands in the Laytonville area by means of pump lifts and conduits. In addition, the reservoir would be well suited for recreational development, because of its proximity to U. S. Highway 101.

Plans for provision of supplemental water to Round Valley involve a special situation. Under ultimate conditions the supplemental requirements of Round Valley could be met by water from Etsel Reservoir, a feature of the California Aqueduct System, and by pumpage from the Round Valley ground water basin. However, during the interim period preceding construction of Etsel Reservoir, Franciscan Dam and Reservoir which would be located on a tributary of the Middle Fork of the Eel River about 6 miles northeast of Covelo, could be operated in conjunction with a direct diversion of water from Williams Creek to meet the ultimate requirements of Round Valley. The construction of Etsel Reservoir would require the raising of Franciscan Dam which would then become an auxiliary dam of Etsel Reservoir, as can be seen on Sheet 5 of Plate 5.

Branscomb Dam would be located on the South Fork of the Eel River about 5 miles northwest of the community of Branscomb. If constructed, the reservoir would improve summer flows in that accessible stream as is flows through groves of great redwood trees. The South Fork is world famous as a scenic recreational area. Releases of water from the reservoir would eliminate summer stagnation in pools and temperatures intolerable to fish life. A minimum flow of 100 second-feet in the South Fork of the Eel River below the mouth of Rattlesnake Creek would be provided.

The fishery on the Bear River could be enhanced by construction of Brushy Creek Dam and Reservoir at a point 6 miles south of Scotia. Brushy Creek Reservoir would provide a minimum summer flow of about 14 second-feet in the Bear River for improvement of recreational and fishery conditions.

Caution Dam and Reservoir on the North Fork of the Eel River could similarly improve stream flow conditions in the interest of fish life and recreation. Caution Dam would be located 8 miles north of the Trinity-Mendocino county line. Releases of water would be made from the reservoir to maintain a minimum discharge of 30 second-feet in the downstream channel to the proposed Sequoia Reservoir, a feature of the California Aqueduct System.

In summary, the 10 reservoirs and associated facilities comprising local development works for the Eel-Mad Group under The California Water Plan could meet all local ultimate supplemental water requirements, with the exception of those for certain small scattered parcels of land. The reservoirs would have an aggregate gross storage capacity of about 450,000 acre-feet and could develop about 410,000 acre-feet per season of firm supplemental water, including water to be released from storage for fish and recreation.

The local developments, along with the major reservoirs of the California Aqueduct System in the Eel-Mad Group, could provide a high degree of flood control, particularly on the Eel River. It is estimated that the record peak flow of 500,000 second-feet in the Eel River at Scotia during the flood of December, 1955, would have been reduced to a peak flow of only 315,000 second-feet if all of the works proposed under The California Water Plan had been in operation. A considerable measure of flood control could also be provided on the Mad River by Ranger Station Reservoir, or a substitute therefor, of the California Aqueduct System, and by Butler Valley Reservoir, a local development feature.

Recreational opportunities associated with the local development works and the California Aqueduct System would be abundant for the Eel-Mad Group. In addition to improved stream flow conditions, approximately 73,000 acres of water surface area would be created by the 15 new reservoirs, thus affording expanded opportunities for such recreational pursuits as fishing, boating, picnicking, and swimming.

Russian River Group. The Russian River Group comprises the Russian River Basin and a small area to the south draining into the Pacific Ocean and Tomales Bay. Its area totals about 1,750 square miles, of which some 1,500 square miles comprise mountains and foothills and the remainder is classified as valley and mesa land.

Present water needs in the Russian River Group are met both by diversion of surface flows and pumpage of ground water. The largest existing water supply development is that of the Potter Valley Irrigation District which serves about 4,000 acres of land in Potter Valley, utilizing waters diverted from the Eel River and released into Potter Valley for power generation purposes. The Santa Rosa water works is the largest municipal water service agency, delivering supplies from both surface and underground sources.

Coyote Valley Dam and Reservoir, on the East Fork of the Russian River about 5 miles north of Ukiah, is presently under construction by the Corps of Engineers, U. S. Army, as a water conservation and flood control project. The project will develop irrigation and municipal water supplies for use on lands along the Russian River and in the lower basin extending south to the City of Santa Rosa. It will also enhance recreational opportunities and fish life in the lower Russian River by maintenance of desirable summer stream flow.

Coyote Valley Reservoir, when completed, will have a gross storage capacity of 122,000 acre-feet, including 48,000 acre-feet of flood control storage reservation. Provisions have been made in the planning for future enlargement of the dam and reservoir to an ultimate storage capacity of 199,000 acre-feet. The Corps of Engineers is authorized to construct downstream channel improvements as a part of this project.

The Russian River Group has ample water resources to meet its present and future water requirements. However, because of the large fluctuation in runoff from season to season and within the season, the control and development of the water resources presents a problem. Supplemental water supplies aggregating about 375,000 acre-feet per season would be necessary to fully meet requirements under ultimate conditions.

The requirement for water for fish and recreation is also a major consideration on the Russian River and its tributaries. The lower portion of the Russian River is a famed summer recreational area, with pleasant weather, water for swimming and fishing, pleasing scenery, and proximity to large centers of population. Summer stream flows have, in the past, dropped considerably below the minimum requirements for these purposes. This condition will be corrected by operation of Coyote Valley Reservoir, which will provide release of water in sufficient volume to maintain a minimum flow of 125 second-feet in the lower Russian River near Guerneville, particularly during the summer months.

In common with the rest of the North Coastal Area, the Russian River Group is presently faced with a serious flood control problem. The flood of December, 1955, inundated agricultural lands, commercial structures, and homes along the Russian River. Particularly heavy damage was inflicted on summer homes along the lower river, notably in and around Guerneville.

Under The California Water Plan, 14 new dams and reservoirs are contemplated in the Russian River Group, including the future enlargement of the Coyote Valley Reservoir to its ultimate stage. These reservoirs could supply sufficient water to meet ultimate requirements for irrigation, municipal, and recreational purposes, and provide a substantial measure of flood control as well.

The upper Russian River and tributaries could be developed by 6 reservoirs, in addition to the Coyote Valley Reservoir enlarged to its ultimate stage as proposed by the Corps of Engineers. These reservoirs, on Franz, Maacama, Big Sulphur, Cummisky, Feliz, Robertson, and Saysal Creeks, would be supplementary to and operated in coordination with Coyote Valley Reservoir. Their combined yield could be utilized throughout the Russian River area, the Santa Rosa plains, and the Tomales-Bodega area, and surplus water could be exported to the San Francisco Bay Area.

Knights Valley Reservoir would be unique in that it would involve two separate dams, one on Franz Creek and one on Maacama Creek, constructed to sufficient heights that they would form a common reservoir at higher water stages. Franz and Maacama Dams would be located about 6 miles east of Healdsburg. Knights Valley Reservoir could furnish water to local downstream lands and provide minimum summer and winter stream flows in Maacama Creek of 5 second-feet and 30 second-feet, respectively, for fishery enhancement.

Big Sulphur Dam and Reservoir, located on Big Sulphur Creek about 3 miles east of Cloverdale, could develop water for local downstream use and for conveyance to the Santa Rosa-Sebastopol and the Tomales-Bodega areas. In addition, the reservoir could provide 43,000 acre-feet of flood control storage space, and releases could be made to provide minimum summer and winter flows of 10 second-feet and 50 second-feet, respectively, for improvement of fishery conditions.

In addition to the foregoing, reservoirs could be constructed on four smaller tributaries to the upper Russian River. These include Cummisky Dam and Reservoir on Cummisky Creek, 5 miles north of Cloverdale; Feliz Dam and Reservoir on Feliz Creek, 1 mile west of Hopland; Robertson Dam and Reservoir on Robertson Creek, 4 miles north of Ukiah; and Saysal Dam and Reservoir on Saysal Creek, 6 miles northeast of Healdsburg. Lands downstream from these reservoirs could be served by local distribution works.

As previously stated, the seven reservoirs in the upper Russian River area could develop water for conveyance to the Santa Rosa plains, the Tomales-Bodega area and the San Francisco Bay Area, in addition to providing water for local downstream service areas. The water could be conveyed to all but the downstream service areas by the Sonoma Aqueduct, a feature of the California Aqueduct System, which would also convey water diverted from facilities of the Eel River Division of the California Aqueduct System. These facilities are delineated on Sheets 5 and 7 of Plate 5.

Dry Creek Dam and Reservoir, located on Dry Creek about 5 miles southwest of Cloverdale, could be operated to provide water for downstream service areas, and for fishery enhancement by releases of water to maintain minimum summer and winter flows of 10 second-feet and 75 second-feet, respectively. A minimum reservoir storage of 15,000 acre-feet would create favorable conditions for propagation of warmwater fish species. In addition, Dry Creek Reservoir could provide substantial flood protection by maintaining a flood control reservation of 43,000 acre-feet of storage capacity.

A dam and reservoir on Warm Springs Creek, 6 miles west of Geyserville, and one on Mill Creek, 3 miles east of Healdsburg, could augment the water supply developed by Dry Creek Reservoir. Releases sufficient to maintain minimum summer and winter stream flows of 5 second-feet and 25 second-feet, respectively, could be provided from each reservoir for maintenance of fish life. Furthermore, minimum reservoir pools could be reserved for propagation of warmwater fishes. In addition to providing water to local downstream service areas, water from these reservoirs and Dry Creek Reservoir could be pumped from the Russian River and conveyed to the northerly portion of the Santa Rosa plains.

Bearpen Dam and Reservoir on East Austin Creek about 7 miles above its mouth was planned for fishery and recreational purposes only, and as such would be operated to maintain summer stream flows in that creek below the dam. In addition to maintenance of a desirable stream flow for fishing and swimming, a minimum reservoir storage of 1,000 acre-feet could be provided for propagation of warmwater fish.

Mark West Dam and Reservoir on upper Mark West Creek and Laguna Dam and Reservoir on lower Mark West Creek near its junction with the Russian River could jointly develop sufficient water to meet the remainder of the ultimate requirements of the Santa Rosa plains. Although the primary purpose of these reservoirs would be for conservation, there

North Coastal Area Economic Activities—Recreation and Dairying would be major incidental benefits to the fishery and to recreation. The Laguna reservoir area is already one of the most popular places in the State for duck and pheasant hunting, and enlargement of the existing water area would substantially improve duck hunting. Furthermore, the reservoir would form a highly desirable warmwater fishing lake because of the shallow water and long shore line. Minimum summer and winter flows of 5 second-feet and 25 second-feet, respectively, could be maintained by releases from Mark West Reservoir for fishery enhancement.

Walker Dam and Reservoir on Walker Creek about 2 miles southwest of Tomales, could be constructed, to provide water for the Tomales-Bodega area. The water developed by Walker Reservoir would be used primarily in the Stemple Creek drainage area, which would require a substantial pumping lift.

In summary, the local phase of The California Water Plan for the Russian River Group would comprise 14 reservoirs and associated works. Operated coordinately and as a basin-wide development, these local works could accomplish a threefold purpose: namely, (1) provision of sufficient water to serve all potentially irrigable and urban lands within the Russian River Group, and to export a small supply to the San Francisco Bay Area (2) enhancement of the anadromous, resident trout, and warmwater fishery and of the recreational opportunity, and (3) provision of a substantial measure of flood control. The local development works would have an aggregate gross storage capacity of about 1,100,000 acre-feet and could make available additional water supplies aggregating some 415,000 acre-feet per season. As planned, the Russian River Group would receive about 375,000 acre-feet of this water per season, and about 40,000 acre-feet would be exported to the San Francisco Bay Area. A large portion of the yield made available would be conveyed to the Santa Rosa plains, the Tomales-Bodega area, and the San Francisco Bay Area by the Sonoma Aqueduct, proposed as a feature of the California Aqueduct System primarily for transferring Eel River water to the San Francisco Bay Area.

The importance of the Russian River and its tributaries to sport fishing and recreation is fully recognized in The California Water Plan. Releases of water could be made from the reservoirs on the more important fishing streams to assure conditions satisfactory for fish life and for public recreation.

In addition to the foregoing accomplishments, flood control storage reservations aggregating about 134,000 acre-feet could be maintained in Dry Creek, Big Sulphur, and Coyote Valley Reservoirs. This reserved storage capacity would provide a substantial measure of flood protection. Additional incidental flood control benefits could be derived from the remaining reservoirs and from authorized channel improvements to be constructed by the Corps of Engineers. These works would greatly reduce damage from flooding along the Russian River flood plain. However, complete prevention of damage to property would require appropriate flood zoning in conjunction with the foregoing works.

Pacific Basins Group. The Pacific Basins Group comprises three relatively small non-contiguous segments of the North Coastal Area adjacent to the ocean, which are isolated from each other by the Klamath-Trinity and the Eel-Mad River drainage basins. Its total area of 3,530 square miles is predominantly mountainous. The group includes the Smith River drainage area in the northernmost segment and the Redwood Creek drainage area in the middle portion, while the larger southern section includes the drainage areas of the Mattole, Noyo, Navarro, and Garcia Rivers.

Present water development in the Pacific Basins Group is insignificant compared to the available water resources, and includes only the minor works of a number of small public and private agencies formed to supply water for municipal and domestic use. Agricultural water is presently developed entirely on an individual basis.

The ultimate seasonal water requirement of the entire group is estimated to be only a little more than 180,000 acre-feet, compared to the total mean seasonal runoff of about 12,000,000 acre-feet. However, satisfaction of those requirements would require the construction of water storage facilities. Moreover, since the streams flow largely in deep narrow canyons, substantial pumping lifts and conduits with rather tortuous alignments would be required to deliver the conserved water to service areas which are located mainly on hills and ridge tops.

The streams of the Pacific Basins Group are a natural habitat for anadromous fish such as steelhead trout and silver salmon, as well as resident trout. However, under present conditions extremely low summer flows cause the loss of a large percentage of the young fish, while erratic flows during early winter and spring frequently severely reduce the success of the spawning runs. Because of the importance of recreation and the fishery to the present and future economy of the group, a number of reservoirs contemplated under The California Water Plan would be dedicated to the improvement of stream flow conditions by planned releases for that purpose.

In certain areas, notably on the Smith River Plain, on lands near the mouth of Redwood Creek, and along the lower Mattole River, large winter flows create a significant flood problem, causing considerable damage to utilities and low-lying farm lands.

The ultimate water requirements of the Pacific Basins Group could be met by local surface water development works and increased use of ground water. Summer stream flow conditions could be improved by releases of water from reservoirs in the interests of fish life and recreation.

The ultimate supplemental water requirement of about 55,000 acre-feet per season on the Smith River plain could probably be met by operation of the underlying ground water basin, without surface storage development. It appears that an adequate supply is available in the ground water basin if operated in conjunction with direct diversions from the Smith River. However, in the event that the yield of ground water should prove inadequate, Rowdy Creek Dam could be constructed on Rowdy Creek for development of the required additional yield.

Green Point Reservoir, which would be located on Redwood Creek a short distance upstream from Highway 299, could be operated for maintenance of favorable flow conditions in the downstream channel during the summer months. Releases of water from the reservoir amounting to 15 second-feet would supplement the natural flow below the dam, thus improving 42 miles of stream channel for fishery and recreational purposes.

Thorn Dam and Reservoir on the headwaters of the Mattole River could similarly be operated to improve downstream flow conditions by releases of water at the rate of 55 second-feet, resulting in improved conditions for fish on a 55-mile reach of the river.

Water to meet the requirements of the area along the Mendocino coast from Rockport south to Fort Bragg could be developed by dams and reservoirs on Pudding, Campbell, and Hayworth Creeks, and on the South Fork of Tenmile River. Glenblair Dam and Reservoir would be located on Pudding Creek about 4 miles east of Fort Bragg. Yesmar Dam and Reservoir would be located a short distance downstream from the confluence of Campbell Creek and the South Fork of Tenmile River. These two dams would create a common reservoir in Little Valley which normally drains into Pudding Creek. The yield of Glenblair-Yesmar Reservoirs could be used in the northern portion of the Mendocino coast, including Fort Bragg.

Hayworth Dam and Reservoir, located on Hayworth Creek about 3 miles north of its confluence with the Noyo River, could meet the remaining water requirements of the northern portion of the Mendocino coast. Although the primary purpose of Hayworth Reservoir would be water conservation to meet the foregoing requirements and not stream flow maintenance, its operation would provide a minimum release of 10 second-feet, which would improve stream flow conditions in the 26-mile reach between the dam and a downstream diversion point near the ocean.

The water developed by Caspar Dam and Reservoir, which would be located on Caspar Creek about 4 miles upstream from the town of Caspar, could be utilized in the southern portion of the Medocino coastal area.

Summer stream flow conditions in the Big River Basin could be improved by construction of Hellgate Reservoir on the South Fork of Big River about 5 miles above the main stem. Releases of water from Hellgate Reservoir could increase the natural summer flow in a 33-mile reach of the stream below the dam by 15 second-feet.

McDonald Dam and Reservoir, which would be located on the Albion River approximately 6 miles east of Albion, could develop water for use on lands lying on both sides of the Albion River.

The ultimate water requirements of Anderson Valley and other service areas of the Navarro River Valley could be met by Lone Tree, Big Foot, and Castle Garden Dams and Reservoirs. In addition, releases of water from the reservoirs could be made for improvement of the fishery and the recreational opportunity in the area.

Lone Tree Dam and Reservoir would be located on Indian Creek about 6 miles upstream of Philo. A portion of the water yielded from the reservoir could supply irrigable lands located along the Navarro River between Booneville and Philo. In addition, water released from the reservoir for the service area from Philo downstream to Navarro would utilize the natural stream channel, thus improving the fishery and the recreational conditions.

Big Foot Dam and Reservoir on Rancheria Creek about 4 miles south of Yorkville Post Office, could be operated for the maintenance of summer stream flow. Castle Garden Dam and Reservoir, located on the North Fork of the Navarro River, could also be operated for this purpose. Releases from Big Foot and Castle Garden Reservoirs could be made on a schedule designed to enhance the fishery and recreational opportunity, with minimum summer flows of 16 second-feet and 10 second-feet, respectively, provided below the dams. Thus, fish life on the main stem of the Navarro, as well as on two of its principal tributaries, would be considerably improved. Moreover, the attractiveness of the stream for recreational purposes, such as swimming, boating, camping, and picnicking in the redwood groves along the lower reaches would be enhanced.

Tin Can Dam and Reservoir, which would be located on Alder Creek about 5 miles northeast of Manchester, could serve lands lying along the coast from the mouth of the Navarro River southerly to the Gualala River at the Mendocino-Sonoma county line, including the relatively extensive irrigable area in the vicinity of Point Arena.

A headwater reservoir could be created in the Garcia River Basin by the construction of Garcia Dam and Reservoir just below the joining of Pardaloe and Mill Creeks. A minimum summer stream flow of 25 second-feet for recreational purposes and fishery enhancement could be assured by operation of Garcia Reservoir.

Three reservoirs in the Gualala River Basin could be operated for improvement of summer stream flow conditions. Billings Dam would be located on the North Fork just below the junction of Billings and Bear Creeks, and could provide a summer release of 20 second-feet into the downstream channel. Neese Ridge Dam and Reservoir, which would be located on the Wheatfield Fork just above Wolf Creek, could also release 20 second-feet in the downstream channel during the summer months. Houser Bridge Dam and Reservoir would be located on the South Fork of the Gualala River about 6 miles southeast of Stewarts Point. It could provide summer releases of 35 second-feet into the downstream channel to supplement natural flows. These three reservoirs in the Gualala River Basin would collectively improve the fishery and recreational conditions in 60 miles of stream channel, as well as maintain an open channel for the Gualala River all the way to the ocean.

In summary, the 16 reservoirs constituting the local development works for the Pacific Basins Group under The California Water Plan would have an aggregate gross storage capacity of 314,000 acre-feet. They could make available additional water supplies amounting to some 156,000 acre-feet per season, consisting of 84,000 acre-feet of conservation yield and 72,000 acre-feet of yield assigned to stream flow maintenance. An additional yield of approximately 55,000 acre-feet per season probably could be obtained from ground water storage underlying the Smith River plain.

Including the foregoing yield from the ground water basin in the vicinity of Crescent City, the prospective local development works could meet all estimated future water requirements of the Pacific Basins Group, with the exception of certain widely scattered small parcels of agricultural lands which are too remote to be economically reached by projects of the scope considered herein. However, sufficient water supplies are available in the event that those lands should ever require service.

In addition to meeting the agricultural, municipal, and industrial water requirements of the Pacific Basins Group, the local development works could substantially improve more than 310 miles of stream channels for sport fishing and for general recreational purposes, including camping, boating, swimming, and picnicking. The future development of further recreational facilities has been considered so significant in the North Coastal Area that, wherever possible, stream flow maintenance works have been planned on the smaller streams of this group to minimize impairment on the more important streams elsewhere in the area.

Summary of North Coastal Area. The California Water Plan in the North Coastal Area envisages a total of 50 new reservoirs for local water development purposes. Included are 25 reservoirs planned primarily for development of water supplies to meet increased consumptive use, 15 reservoirs planned primarily for stream flow maintenance, and 10 reservoirs that would provide water for both purposes. In addition, 15 major dams and reservoirs with associated power plants, pumping plants, and tunnels, would be constructed in the area as features of the California Aqueduct System. These facilities, which are described in a subsequent section of this chapter, would conserve surplus flows of stream systems of the North Coastal Area for export to areas of deficiency elsewhere in the State. The prospective reservoirs to meet local water requirements would have an aggregate storage capacity of about 3,280,000 acre-feet and could provide an estimated yield of some 1,310,000 acre-feet per season for this purpose, plus an additional yield of about 250,000 acre-feet per season for stream flow maintenance.

In addition to the yield of the foregoing reservoirs, an estimated 100,000 acre-feet per season of the ultimate local water requirement could be met by further development of ground water resources. The remainder of this requirement in the North Coastal Area, not satisfied from contemplated local works of The California Water Plan, would occur primarily in connection with irrigable lands lying in isolated small scattered tracts which, as previously stated, are considered too remote to be economically reached by projects of the scope considered in this bulletin. However, water resources are available for such lands for development by individuals or appropriate local agencies when and if the demand develops.

Planned and incidental releases of water to downstream channels from the local reservoirs and the incidental water releases from major reservoirs of the California Aqueduct System would increase the fish population and improve facilities for camping, boating, swimming, and other recreational activities. These improved conditions would attract many additional vacationists to the area, which is already famous for such attractions.

Features of the California Aqueduct System, in addition to enhancing the recreational potential of the North Coastal Area by provision of large water surface areas and improved stream flow would also result in a substantial measure of flood protection. This would be especially effective in the Eel River Basin. Studies indicate that the initial upstream features of the Eel River Division of the California Aqueduct System, consisting of Willis Ridge and Etsel Reservoirs, could have almost completely regulated the flow of the Eel River below Dos Rios during the flood of December, 1955.

Data on the general features and capital costs of the local development works of The California Water Plan in the North Coastal Area are presented in Table 9. The locations and layouts of these facilities,

TABLE 9

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN NORTH COASTAL AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use	Capital cost [a]
Klamath-Trinity Group											
Beatty	Sprague River	Sec. 17 & 20, T36S, R13E WB&M Oregon	E	55	4,350	150,000	140,000	110,000	I	Klamath-Tule-Butte Basins	$4,687,000
Boundary	Lost River	Sec. 18, T48N, R7E & Sec. 20, T41S, R14W, WB&M 2	E	125	4,250	100,000	100,000	41,000	I	Klamath-Tule-Butte Basins	3,925,000
Chiloquin Narrows	Sprague River	Sec. 10, T35S, R7E, WB&M Oregon	E	135	4,300	440,000	430,000	180,000	I,P	Klamath-Tule-Butte Basins	7,086,000
Iron Gate	Klamath River	Sec. 9, T47N, R5W 1	CG	137	2,300	35,400	16,700	122,000	I,R,F	Shasta Valley	3,963,000
Montague	Shasta River	Sec. 7, T45N, R6W 1	E	108	2,500	87,000	75,300	84,000	I,R,F	Shasta Valley	5,293,000
Grenada Ranch	Shasta River	Sec. 36, T44N, R6W 1	E	62	2,580	22,800	20,800	20,000	I,U	Shasta Valley and Yreka	735,000
Callahan	Scott River	Sec. 17, T40N, R8W 1	E	271	3,355	133,000	126,000	61,700	I	Scott Valley	10,714,000
Layman	Hayfork Creek	Sec. 15, T31N, R11W 3	E	160	2,638	21,500	20,500	20,600	I,F,R	Hayfork Valley	3,345,000
Morehouse	Salmon River	Sec. 28, T11N, R7E, HB&M 1	R	575	1,530	910,000	540,000	550,000	P		45,656,000
Smoky Creek	South Fork Trinity River	Sec. 5, T28N, R12W 3	E	190	2,635	16,800	16,500	16,500	R,F		2,616,000
Eel-Mad Group											
Crannell	Little River	Sec. 9, T7N, R11E, HB&M 1	E	180	246	36,000	28,000	35,000	I,U	Eureka Plains	2,354,000
Butler Valley	Mad River	Sec. 6, T4N, R3E, HB&M 3	E	160	476	55,000	50,000	60,000	I,U	Eureka Plains	5,977,000
Yager	Yager Creek	Sec. 6, T2N, R2E, HB&M 3	E	221	646	124,000	117,000	105,000	I,U	Eel Delta	4,272,000
Larabee Valley	South Fork Van Duzen River	Sec. 19, T1N, R5E, HB&M 3	E	220	2,480	49,000	47,000	62,400	I,U,F	Eel Delta	5,134,000
Valley's End	Tomki Creek	Sec. 17, T18N, R12W 5	E	160	1,735	57,000	29,000	22,000	I,U	Little Lake Valley	1,843,000
Streeter	Ten Mile Creek	Sec. 21, T22N, R15E 5	E	83	1,520	16,000	13,000	13,400	I,U	Laytonville Valley	959,000
Franciscan	Short Creek	Sec. 28, T23N, R12W 5	E	155	1,548	33.000	29,000	14,000	I,U	Round Valley	1,991,000
Etsel	Middle Fork Eel River	(Franciscan Reservoir ultimately part of Etsel Reservoir. Additional yield allocated to 12,000 acre-feet for local development and 497,000 acre-feet for export. See Table 19.)									
Branscomb	South Fork Eel River	Sec. 29, T22N, R16W 5	E	176	1,517	46,000	44,000	40,000	F,R,FC		6,000,000
Brushy Creek	Bear River	Sec. 7, T1S, R1E, HB&M 3	E	150	1,300	5,000	5,000	5,000	F,R		1,730,000
Caution	North Fork Eel River	Sec. 31, T4S, R8E, HB&M 3	E	185	1,740	12,000	11,000	9,000	F,R		2,250,000
Russian River Group											
Enlarged Coyote Valley	East Fork Russian River	Sec. 34, T16N, R12W 5	E	189	806	[b]77,000	[b]77,000	75,000	I,FC,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	12,969,000
Knights Valley	Franz Creek	Sec. 22, T9N, R8W 7	E	223	436	285,000	285,000	50,000	I,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	9,064,000
	Maacama Creek	Sec. 9, T9N, R8W 7	E	258	436						
Big Sulphur	Big Sulphur Creek	Sec. 10, T11N, R10W 7	E	320	808	92,000	87,000	43,800	I,FC,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	14,429,000
Cummisky	Cummisky Creek	Sec. 10, T11N, R10W 7	E	153	660	13,000	12,000	8,400	I	Russian River Basin, Tomales-Bodega area, North Bay area	1,538,000
Feliz	Feliz Creek	Sec. 24, T13N, R12W 7	E	137	640	49,000	47,000	23,000	I	Russian River Basin, Tomales-Bodega area, North Bay area	5,563,000
Robertson	Robertson Creek	Sec. 7, T14N, R12W 5	E	170	765	26,000	26,000	13,400	I	Russian River Basin, Tomales-Bodega area, North Bay area	4,133,000
Saysal	Saysal Creek	Sec. 25, T10N, R9W 7	E	180	450	11,000	10,000	6,200	I	Russian River Basin, Tomales-Bodega area, North Bay area	2,295,000
Dry Creek	Dry Creek	Sec. 5, T10N, R11W 7	E	252	545	203,000	188,000	42,700	I,FC,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	9,921,000
Mill	Mill Creek	Sec. 25, T9N, R10W 7	E	180	425	48,000	45,000	12,000	I,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	5,006,000
Warm Springs	Warm Springs Creek	Sec. 24, T10N, R11W 7	E	190	460	39,000	37,000	12,000	I,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	4,209,000
Bear Pen	Big Austin Creek	Sec. 5, T8N, R11W 7	E	180	383	10,000	9,000	8,000	R,F	Russian River Basin, Tomales-Bodega area, North Bay area	3,011,000
Laguna	Laguna de Santa Rosa	Sec. 34, T8N, R9W 7	CG	24	65	28,000	26,000	19,000	I,U,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	407,000
Mark West	Mark West Creek	Sec. 14, T8N, R8W 7	E	154	553	38,000	35,000	10,200	I,R,F	Russian River Basin, Tomales-Bodega area, North Bay area	3,045,000
Walker	Walker Creek	Sec. 9, T4N, R9W 7	E	145	193	75,000	74,000	23,000	I	Russian River Basin, Tomales-Bodega area, North Bay area	2,271,000

Pacific Basins Group												
Rowdy Creek	Rowdy Creek	Sec. 33, T18N, R1E, HB&M	1	(No detailed study made at this site)						I,U	Smith River Plain	
Green Point	Redwood Creek	Sec. 14 & 15, T6N, R3E, HB&M	3	E	130	965	5,000	5,000	5,100	F,R		2,945,000
Thorn	Mattole River	Sec. 22, T5S, R2E, HB&M	3	E	160	1,165	35,000	33,000	33,000	F,R		6,711,000
Glenblair	Pudding Creek	Sec. 3, T18N, R17W	5	E	160	152	75,000	61,000	24,000	I	Fort Bragg area	4,847,000
Yesmar	South Fork Tenmile River	Sec. 14, T19N, R17W	5	E	160	152						
Hayworth	Hayworth Creek	Sec. 33, T19N, R15W	5	E	160	600	9,000	8,000	7,000	U,R,F	Fort Bragg area	2,256,000
Caspar	Caspar Creek	Sec. 9, T17N, R17W	5	E	155	238	9,000	8,000	3,900	I	Fort Bragg area	1,876,000
MacDonald	Albion River	Sec. 17, T16N, R16W	5	E	155	185	27,000	25,000	15,000	I	Adjacent coastal plateau	2,511,000
Lone Tree	Indian Creek	Sec. 14, T14N, R14W	5	E	230	864	16,000	16,000	12,000	I,R,F	Navarro and Anderson Valleys	3,376,000
Big Foot	Rancheria Creek	Sec. 30, T12N, R12W	7	E	115	1,042	13,000	10,000	6,000	F,R		1,252,000
Castle Garden	South Branch, North Fork Navarro River	Sec. 19, T15N, R14W	5	E	140	520	5,000	4,000	3,600	F,R		2,204,000
Tin Can	Alder Creek	Sec. 11, T13N, R16W	7	E	250	744	67,000	67,000	22,600	I	Pint Arena area	3,732,000
Garcia	Garcia River	Sec. 12, T12N, R14W	7	E	180	1,065	15,000	14,000	9,200	F,R		2,986,000
Billings	North Fork Gualala River	Sec. 34, T12N, R14W	7	E	155	690	9,000	9,000	7,600	F,R		1,581,000
Neese Ridge	Gualala River	Sec. 31, T10N, R12W	7	E	130	450	9,000	9,000	8,100	F,R		1,234,000
Houser Bridge	Gualala River	Sec. 22, T9N, R13W	7	E	135	445	15,000	14,000	12,800	F,R		1,285,000
Totals							3,652,000	3,099,800				237,187,000

Power plant	Location, MDB&M, and sheet of Plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours	Capital cost[a]
Klamath-Trinity Group						
Morehouse	Sec. 22, T11N, R7E, HB&M	1	470	90,000	343,500,000	$8,849,000

Associated features	Length of conduit, in miles: Canal	Tunnel	Pipe	Total	Pumping plants: Total number	Installed capacity, in kilowatts	Seasonal power consumption, in kilowatt-hours	Capital cost[a]
Klamath-Trinity Group	44.8	0.9	11.9	57.6	10	88,200	147,600,000	$25,411,000
Eel-Mad Group		2.0		2.0				1,697,000
Russian River Group	2.0		0.8	2.8	2	3,700	10,000,000	1,281,000
Pacific Basins Group								
Totals	46.8	2.9	12.7	62.4	12	91,900	157,600,000	$28,389,000

Symbols of Type of Dam
E—Earthfill
R—Rockfill
CG—Concrete gravity

Symbols of Purpose
I—Irrigation
U—Urban (domestic, municipal, industrial)
R—Recreation
F—Enhancement of fish environment
P—Power generation
FC—Flood control

[a] At 1955 price levels.
[b] In addition to existing storage capacity of 122,000 acre-feet.

which have been described in all the foregoing sections, are delineated on Sheets 1, 3, 5, and 7 of Plate 5.

San Francisco Bay Area

Because of its mild and equable climate, its strategic location, its waterways and outstanding natural harbor, and its fertile agricultural lands, the San Francisco Bay Area has become one of the most highly developed regions of California. However, this high degree of development has imposed water demands far in excess of the yield of local water resources throughout most of the area. Had it not been for far-sighted planning and progressive water resource development, wherein water is imported on a large scale from distant watersheds, the population growth could never have reached its present stage. Yet, in spite of the notable steps taken to obtain water supplies to meet the ever increasing needs, severe water problems exist in several portions of the San Francisco Bay Area.

The great need for water, coupled with the paucity of available water resources, has forced the people of the San Francisco Bay Area into a more advanced stage of water resource development than in many other areas of California. Opportunity for further development of local water resources is and has for some time been very limited, and has fostered the development of foreign watersheds and the importation of water through aqueducts many miles in length.

In efforts to solve water supply problems a number of public and private agencies have been formed, and by their initiative several outstanding water supply projects have been constructed. One of the most widely known of such projects, the Hetch Hetchy Project, was constructed by the City of San Francisco, and began delivery of water from Hetch Hetchy Reservoir and Lake Eleanor in Yosemite National Park to the San Francisco Peninsula in 1934. The Hetch Hetchy Aqueduct is about 150 miles in length and features a 25-mile tunnel through the Coast Range, the longest tunnel in the world at the time of completion. The East Bay Municipal Utility District likewise has constructed an outstanding water supply project, involving the importation of water from Pardee Reservoir on the Mokelumne River to the East Bay area, a distance of some 95 miles, through the Mokelumne Aqueduct.

Present water problems in the San Francisco Bay Area are manifested by serious overdrafts on the ground water resources of Santa Clara Valley, Livermore Valley, and the southern portion of Alameda County. Although these ground water basins are physically meeting the demands, their usefulness is threatened by the intrusion of sea water or of other waters of undesirable quality. The draft on these basins presently (1955) exceeds their mean annual replenishment by an estimated 41,000 acre-feet. The developed water surface supplies in Marin County are presently (1955) adequate to meet the requirements; however, the potential for further local development is limited, and water deficiency problems are imminent in the near future. Nearly all areas in the San Francisco Peninsula and the East Bay are dependent upon imported water supplies.

It is estimated that satisfaction of water requirements in the San Francisco Bay Area will ultimately involve the use of nearly 7 per cent of the total developed water supplies in the State. With less than 2 per cent of the water resources of the State, it is obvious that the area will be a major area of ultimate water deficiency. The requirements for supplemental water, in addition to the import of water through present facilities to the full extent of existing or claimed rights, are forecast to reach some 2,110,000 acre-feet per season under ultimate conditions. Nearly all of this water would of necessity be supplied by imports from areas of water surplus in other regions of California.

Flood problems in the San Francisco Bay Area are largely local in nature, and occur primarily on the highly developed urban areas immediately adjacent to stream channels and along the bay shore. The flood of December, 1955, exemplified this type of damage. Throughout the entire bay area that flood sent streams to record heights and caused considerable damage in upstream areas as well as along the bay shore. The Napa River overflowed its banks through most of its length in Napa Valley. Large areas of agricultural lands in the Livermore and Amador Valleys were inundated by overflow of tributaries of Alameda Creek, and industrial developments in Livermore Valley and the highway and railroads in Niles Canyon suffered heavy damage. Heavy damage was also inflicted upon southern Alameda County. The recently completed Lexington Dam and Reservoir on Los Gatos Creek averted a disaster of major proportions in Los Gatos and a portion of the City of San Jose.

The objectives of The California Water Plan in the San Francisco Bay Area are twofold: first, the development of local water resources to the maximum practicable extent to satisfy increasing needs for irrigation, urban, industrial, and recreational purposes, and a measure of flood control; and second, the importation of water through facilities of the California Aqueduct System to meet the ultimate requirements of all lands considered susceptible of water service. Because of the limited potential for further development of local water resources, elimination of present water problems and provision of water to meet future increased requirements in the area will necessitate substantial importation of water from areas of surplus in other regions of the State. In this regard, additional imports proposed by certain water service

San Francisco Bay Area

agencies, notably the City of San Francisco and the East Bay Municipal Utility District, by extension and enlargement of their existing facilities, have been taken into consideration in the formulation of plans for ultimate water supply in the area.

For convenience of presentation herein, the San Francisco Bay Area has been divided into three major subareas. These are designated and are hereinafter referred to as the "North Bay Group," "Southeast Bay Group," and "Peninsula Group," and their locations are shown on Plate 3. The layout of the water development works in the San Francisco Bay Area is delineated on Sheets 7, 8, and 10 of Plate 5. Data on the physical features and costs of the local works considered are presented in Table 10 which follows this discussion under the heading "Summary of San Francisco Bay Area."

North Bay Group. The North Bay Group embraces those portions of Marin, Sonoma, Napa, and Solano Counties draining into San Francisco, Bodega, Tomales, San Pablo, and Suisun Bays. It reaches from the Pacific Ocean on the west to the Sacramento-San Joaquin Delta on the east, and extends north to the drainage divides defining the Sacramento Valley and the Russian River Basin. The area is drained by the Napa River and Suisun, Sonoma, and San Antonio Creeks, which flow into San Francisco Bay, and Lagunitas Creek, which empties into Bodega Bay.

The meager water resources of the North Bay Group have been rather intensively developed. Lagunitas Creek, the principal stream in Marin County, has been almost fully developed by the Marin Municipal Water District. Present development on that creek includes Kent Lake, formed by the recently completed Peters Dam, Lagunitas Reservoir, and several smaller reservoirs. Surface water storage works in Napa Valley include, among others, Lake Henessey on Conn Creek, owned and operated by the City of Napa, and Rector Creek Dam, constructed by the State Department of Public Works to develop a water supply for the State Game Farm and the Veterans Home near Yountville.

The City of Vallejo operates several reservoirs in Solano County for development of water supplies. In addition, the city has recently constructed an import water supply project involving a pumped diversion of water from Cache Slough in the Sacramento-San Joaquin Delta and its conveyance to the city by pipe line. The capacity of this project is about 23,000 acre-feet per season, although present (1955) delivery is less than 10,000 acre-feet.

In addition to the foregoing surface water facilities, ground water is developed in Petaluma, Sonoma and Napa Valleys, and the Fairfield area of Solano County. It is estimated that these ground water basins have an aggregate yield equivalent to the present (1950) draft therefrom, or about 18,000 acre-feet per season. The potential for additional development of ground water in these basins is limited. In localized areas in each of the basins excessive pumping has lowered ground water elevations below sea level, so that sea-water intrusion has become an active threat.

Because of the paucity of suitable dam and reservoir sites on the greater water-producing streams, and prior development of the more feasible sites, opportunity for further development of the water resources of the North Bay Group is very limited. Marin and southern Sonoma Counties are faced with an imminent water shortage, and certain water service agencies there are looking to the Coyote Valley Project on the East Fork of the Russian River near Ukiah as an early available source of supplemental water. Solano County is similarly faced with the need of an imported water supply for future growth, although the problem in that area is not as urgent as in Marin and Sonoma Counties. The entire North Bay Group will be in need of an imported water supply in the near future, and will ultimately require an import of more than 1,200,000 acre-feet of supplemental water per year.

Flood problems exist along all the principal streams of the North Bay Group. Most of the lands subject to inundation lie in the lower reaches of the streams, being in large part reclaimed tidal marshes. However, flooding also occurs along the upper reaches, where agricultural lands and residences on lower-lying lands are inundated. Expansion of existing urban areas is intensifying this problem. Local public agencies and private land owners have built levees, cleared channels, and placed revetments to halt bank erosion. However, no coordinated plans have been followed, and in general works are inadequate to contain floods of any appreciable magnitude.

Local water development works contemplated as features of The California Water Plan in the North Bay Group comprise reservoirs on Sonoma and Nicasio Creeks, and on the Napa River and its tributaries. Operation of these reservoirs would provide water to meet irrigation, urban, and industrial uses, and improve existing stream flow conditions in the interests of the fishery and the recreational opportunity. In addition, these works could effect some flood control.

Municipal and industrial water supplies could be made available to service areas in Marin County from Nicasio Reservoir, located on Nicasio Creek about 3 miles east of the community of Nicasio. This reservoir and associated conveyance facilities are presently scheduled for construction by the Marin Municipal Water District to supplement its presently developed water supplies. Water would be conveyed from the reservoir to the service areas by means of a pipe line and booster pumping plants.

Bear Creek Dam and Reservoir, located on Sonoma Creek about 2 miles north of Kenwood, if constructed could provide domestic water for communities in the vicinity immediately downstream from the dam. Operation of Bear Creek Reservoir could also provide some flood control and enhance summer stream flows for recreational purposes.

Further conservation of the water resources of Napa Valley could be accomplished by dams and reservoirs on Dry and Sulphur Creeks, tributaries to the Napa River, and a pumped diversion of water from the Napa River to an off-stream storage reservoir near St. Helena. The reservoir formed by Wing Canyon Dam would be located on Dry Creek about 3 miles southeast of Yountville, and could serve downstream urban areas. Sulphur Springs Dam, located on Sulphur Creek about 1.5 miles southwest of St. Helena, could similarly serve urban lands in Napa Valley. The Spring Valley Project would involve a diversion of excess winter flows from the Napa River to a point about 2 miles west of St. Helena, and pumping of this water through an average lift of 75 feet into Spring Valley Reservoir, an off-stream storage unit, located about 1,000 feet east of the diversion point. The water stored during the winter months would be regulated to an irrigation demand schedule for release into the Napa River for downstream diversions.

The five reservoirs and associated facilities comprising the local development work of The California Water Plan in the North Bay Group would provide 29,000 acre-feet of new water per year, which would serve an estimated 8,400 acres of irrigated and urban lands in the group. The reservoirs would have an aggregate gross storage capacity of some 53,000 acre-feet, and would enhance the recreational and sport fishing potential of the area by creating new bodies of water and by improving summer flows in downstream channels.

It is apparent that the additional seasonal yield of 29,000 acre-feet to be obtained from further development of local water resources is insignificant compared to the estimated total ultimate supplemental water requirement of nearly 1,250,000 acre-feet per season in the North Bay Group. Even with full development of the local yield, there would remain an ultimate seasonal supplemental water requirement of 1,217,000 acre-feet. Provision of this water would be made by facilities of the California Aqueduct System, the Putah South Canal of the Solano Project, the North Bay Aqueduct, the Eel River Diversion, the Cedar Roughs Tunnel, and Montezuma Reservoir. These works are summarized herein and are described in more detail subsequently under the heading "California Aqueduct System."

The Solano Project, presently under construction by the United States Bureau of Reclamation, will serve water developed in Monticello Reservoir, on Putah Creek, to lands in Solano County through the Putah South Canal. Studies made by the Department of Water Resources in connection with the Salinity Control Barrier Investigation have indicated that 55,000 acre-feet per season of this water will be utilized in the portion of Solano County within the San Francisco Bay Area.

The North Bay Aqueduct would serve large areas of low lying lands to the north of Suisun and San Pablo Bays. It is contemplated that eventually the water would be diverted from Montezuma Reservoir on the Sacramento West Side Canal of the California Aqueduct System, located near Fairfield. However, initially the water would be diverted from Lindsay Slough in the Sacramento-San Joaquin Delta. From Lindsay Slough the water would be conveyed in a westerly and southwesterly direction past Fairfield and Cordelia, to a small terminal reservoir about 2 miles northeast of Novato. An ultimate seasonal delivery of about 308,000 acre-feet of water to the North Bay Group is contemplated, distributed as follows: Marin and Sonoma Counties, 156,000 acre-feet; Napa Valley, 28,000 acre-feet; and Solano County, 124,000 acre-feet. Delivery of this water would be accomplished by releases along the route of the aqueduct.

The Eel River Diversion contemplates a delivery of about 422,000 acre-feet of water per season to Marin and southern Sonoma Counties to meet the remaining ultimate supplemental water requirements in that area. The water would be conveyed from the Eel River by means of a tunnel from Willis Ridge Reservoir into Potter Valley, thence down the Russian River to a rediversion near Geyserville. From this point the water would be conveyed southerly about 40 miles by canal and pipe line to Stemple Reservoir, located on Stemple Creek about 3 miles southwest of Cotati. Stemple Reservoir would regulate the continuous diversion to the variable monthly demand schedule in the service area.

In Napa Valley, there would still remain a supplemental water requirement of about 224,000 acre-feet per season under ultimate conditions, in addition to the contemplated delivery of 28,000 acre-feet per season by the North Bay Aqueduct. This requirement could be met by a diversion of Eel River water, as described later in this chapter under the California Aqueduct System, from Monticello Reservoir on Putah Creek, and its conveyance westerly by a tunnel through Cedar Roughs Ridge, where it would be released into Conn Creek for regulation in Lake Hennessey.

Water to meet the remainder of the ultimate supplemental requirements in Solano County, over and above deliveries by the Putah South Canal and the North Bay Aqueduct, would be provided by diversion from Montezuma Reservoir at the terminus of the Sacramento West Side Canal near Fairfield. Although diversions could be made from any desired point along the Sacramento West Side Canal, which

San Francisco Bay Area—Napa Valley Grape Harvest would pass through Solano County, such diversions would have to be made at a constant rate so as not to sacrifice the delivery potential of the canal, and local storage would be required to regulate the constant diversions to the varying monthly demands in the service area.

In summary, facilities of the California Aqueduct System would ultimately deliver some 1,220,000 acre-feet of water per season to service areas in the North Bay Group, distributed as follows: Solano Project, 55,000 acre-feet; North Bay Aqueduct, 308,000 acre-feet; Eel River Diversion, 422,000 acre-feet; Cedar Roughs Tunnel, 224,000 acre-feet; and Montezuma Reservoir, 208,000 acre-feet. These deliveries, with the 28,000 acre-feet of water per season secured by further local development, would fully satisfy the ultimate water requirements of all lands considered susceptible of water service in the North Bay Group.

Southeast Bay Group. The Southeast Bay Group comprises the portions of Contra Costa, Alameda, and Santa Clara Counties within the San Francisco Bay drainage, being bounded by San Pablo and Suisun Bays on the north, the San Joaquin Valley drainage divide on the east, San Francisco Bay and San Mateo county line on the west, and the Santa Cruz Mountains and Morgan Hill Divide on the south. The group is occupied by a highly developed urban and industrial economy. Irrigated agriculture also plays a significant role in the economy, particularly in Santa Clara Valley.

The high degree of development attained in the Southeast Bay Group has been made possible, in large part, by exploitation of the extensive ground water storage in alluvial fill areas, notably the Santa Clara and Livermore Valleys, and southern Alameda County along the east shore of the bay. More than 100,000 acres of irrigated lands in north Santa Clara Valley are presently (1955) served from wells. The principal surface water development works consist of Calaveras Reservoir on Calaveras Creek, and installations on Alameda Creek at and above Sunol, operated by the City of San Francisco for local water service and export to the Peninsula; the Upper and Lower San Leandro, San Pablo, and Lafayette Reservoirs operated by the East Bay Municipal Utility District both for conservation of local water resources and for terminal storage for the Mokelumne Aqueduct; and reservoirs on Coyote, Arroyo Calero, Alamitos, Guadalupe, and Los Gatos Creeks, operated conjunctively with ground water storage by the Santa Clara Valley Water Conservation District.

Artificial recharge of ground water basins is practiced both in Alameda and Santa Clara Counties. The Alameda County Water District is utilizing abandoned gravel pits for spreading surplus flows in Alameda Creek, thus supplementing natural stream channel percolation in the Niles Cone area. The Santa Clara Valley Water Conservation District operates percolation ponds and natural stream channels in conjunction with surface reservoirs which control releases to rates within the percolation capacity of these works.

Water is presently imported to the Southeast Bay Group through the Contra Costa Canal, constructed by the United States Bureau of Reclamation; the Mokelumne Aqueduct of the East Bay Municipal Utility District; and the Hetch Hetchy Aqueduct of the City of San Francisco, which now serves supplemental water to the City of Hayward, the Alameda County Water District, other areas in southern Alameda County, and the portion of northern Santa Clara County included in the Milpitas-Sunnyvale-Palo Alto area.

The Contra Costa Canal diverts water from Rock Slough in the Sacramento-San Joaquin Delta, and serves lands along the northern portion of Contra Costa County extending generally from Oakley on the east to Martinez on the west. The present capacity of the system is estimated to be about 85,000 acre-feet per season to the Bay area. It is estimated that this delivery could be increased ultimately to 146,000 acre-feet per season.

The East Bay Municipal Utility District serves lands in western Contra Costa and northwestern Alameda Counties. The Mokelumne Aqueduct furnishes the principal water supply for the service area of the district. Although the present capacity of the system is limited to 162,500 acre-feet of water per season, the district has secured permits, and plans to ultimately import some 364,000 acre-feet per season, which quantity will meet the ultimate requirements of its service area. Construction of additional local reservoir storage is contemplated by the district, for the joint purposes of providing terminal storage for the Mokelumne Aqueduct, and developing local water resources. These planned local works comprise Pinole Reservoir on Pinole Creek, Briones Reservoir on Bear Creek, both in western Contra Costa County, and enlargement of the existing Upper San Leandro Reservoir.

As a result of heavy long sustained drafts on ground water resources in the Southeast Bay Group, and the continuing trend toward increasing municipal, industrial and irrigation demands, the ground water basins of Livermore Valley, Santa Clara Valley, and southern Alameda County are seriously overdrawn at the present time. Ground water pumping levels in the vicinity of San Francisco Bay are substantially below sea level in the latter two areas, with the resultant threat of destruction of the ground water resources by intrusion of sea water from beneath the bay. In fact, sea water has already intruded into the upper aquifer in southern Alameda County, rendering the water unsuitable for use, and has entered the lower aquifer, largely through abandoned or defective wells. Overdrafts on ground water in these areas presently (1955) aggregate an estimated 41,000 acre-feet per season.

In addition to ground water overdrafts, the surface water supplies of the Southeast Bay Group are inherently deficient, and the group depends primarily on imported water supplies to meet present requirements. Under ultimate conditions, some 825,000 acre-feet per season of supplemental water will be required, in addition to the delivery of water through present import facilities to the full extent of existing or claimed rights.

The Southeast Bay Group is presently faced with a two-fold flood problem: tidal flooding of lands adjacent of San Francisco Bay, and storm water flooding by streams flowing across the coastal plain. Lands adjacent to the bay have been reclaimed by dikes, with tidal gates across stream outlets which hold back the tides but limit outflow to the bay and cause ponding of surface runoff on the valley floor behind them. A number of streams have thus been completely cut off from direct access to the bay. Flood problems other than those directly related to tidal influence occur principally in the Walnut Creek watershed in Contra Costa County, along Alameda and San Lorenzo Creeks in Alameda County, and on the flood plains of streams tributary to San Francisco Bay in Santa Clara County. These streams flow through some of the most rapidly developing urban areas in the San Francisco Bay Area, the problem being intensified in recent years by encroachment of urban and industrial development on the flood plains.

The principal flood problems of the Southeast Bay Group are within the boundaries of the three county flood control districts in the group. These districts are actively engaged in planning and constructing works for the alleviation of flood conditions, taking cognizance of the probable urban nature of development under ultimate conditions in their respective areas. When completed, these flood control works should provide adequate flood protection.

Opportunity for further development of local water resources toward meeting ultimate water requirements in the Southeast Bay Group is very limited. In fact, full practicable development could not meet the present supplemental water requirement, assuming existing imports were continued in their present quantities. The objectives of The California Water Plan in the group are, therefore, development of the remaining local water resources within the limits of feasibility, and importation of water through facilities of the California Aqueduct System in amounts sufficient to meet the ultimate water requirements of all lands considered susceptible of water service. The utility of the ground water resources would be preserved by maintaining a proper balance between ground water replenishment and the pumping draft from the basins.

Local water development works contemplated as features of The California Water Plan in the Southeast Bay Group consist of reservoirs on the Alameda Creek system in Alameda County; and a reservoir on San Francisquito Creek, a well field, and a percolation canal to augment ground water replenishment, all in the Santa Clara Valley.

Sanatorium Dam and Reservoir, located on Arroyo del Valle about 5 miles south of Livermore, and Mocho Dam and Reservoir on Arroyo Mocho, 5 miles southeast of Livermore, could, if operated in conjunction with downstream ground water storage in Livermore Valley, develop a new seasonal yield of about 9,300 acre-feet for use in the valley. In order to develop this yield, the use of considerable cyclic ground water storage capacity would be required. Such operation would involve the detention of runoff in surface storage only for the time required for regulation of releases to rates which could be absorbed in downstream channels for replenishment of ground water storage.

In addition to its local function in developing the waters of Arroyo del Valle, Sanatorium Reservoir could provide regulation for water imported to Alameda County through the South Bay Aqueduct, described subsequently. A portion of the available storage could be allocated to development of local runoff, and the remainder could serve to regulate the imported waters.

La Costa Dam and Reservoir on San Antonio Creek about 3 miles above its confluence with Alameda Creek, when constructed would control the waters of La Costa, Indian, and San Antonio Creeks. This reservoir could be operated effectively in conjunction with ground water storage capacity in the Niles Cone area, and the conserved water could provide a portion of the present supplemental requirements in that area. However, the City of San Francisco proposes to construct La Costa Dam and Reservoir, under claim of water rights on Alameda Creek and tributaries, as an integral portion of the water supply operated by San Francisco; and, under such circumstances, the reservoir would not be operated conjunctively with the Niles Cone ground water basin.

Prospective local water resource developments in the Santa Clara Valley consist of a dam and reservoir on San Francisquito Creek, a well field for the salvage of ground water adjacent to Coyote Creek, and a diversion canal from Calero Reservoir to Los Gatos Creek to augment ground water replenishment.

Little Francis Dam and Reservoir would be located on San Francisquito Creek about 5 miles upstream from U. S. Highway 101 in San Mateo County. The Coyote Valley well field would be located near the north end of Coyote Valley, and could provide an urban water supply for the City of San Jose by sal-

Calaveras Reservoir on Calaveras Creek Provides Water for San Francisco Metropolitan Area vaging ground water which presently wastes to San Francisco Bay because of existing high ground water levels. The well field would consist of a series of deep wells spaced about a quarter of a mile apart in a line adjacent and parallel to Coyote Creek.

The Calero Diversion would extend northwesterly from the existing Calero Reservoir on Arroyo Calero, to Los Gatos Creek, intercepting flows from Alamitos and Guadalupe Creeks, and conveying these waters in open canal for a distance of about 9 miles to Guadalupe Creek and then in pipe line an additional 6 miles to Los Gatos Creek. The waters would be discharged into Los Gatos Creek for percolation in the channel of that creek.

The total seasonal new yield developed by the foregoing works in the Santa Clara Valley would aggregate about 12,900 acre-feet. However, it should be mentioned that the Santa Clara Valley Water Conservation District is presently proposing a program, including recharge of ground water basins, to improve and expand its existing system for conservation of water that would otherwise waste to San Francisco Bay. This program includes enlargement and extension of the present distribution system, and construction of dams and reservoirs on Penitencia, Guadalupe, Silver, and Calabazas Creeks. The district estimates that these four reservoirs, with a combined storage capacity of 17,500 acre-feet, would develop a new yield of about 10,000 acre-feet per season when operated in conjunction with ground water storage.

The seasonal yield of the new local water development works in the Southeast Bay Group contemplated under The California Water Plan would aggregate only 34,000 acre-feet, including the proposed developments of the East Bay Municipal Utility District on Pinole, Bear, and San Leandro Creeks. These works could only partially offset the present supplemental water requirements in the group, even though they represent essentially the full practicable development of local water resources. This fact points up the real necessity for the early development of an imported water supply.

In addition to the yield from the foregoing local developments, there would remain a total ultimate supplemental water requirement of some 1,148,000 acre-feet per season in the Southeast Bay Group. Of this total, the following supplies could be made available by existing agencies: (1) an additional 201,000 acre-feet per season could be imported by the East Bay Municipal Utility District for service within the district, (2) an additional 61,000 acre-feet per season could be delivered to Contra Costa County by the Contra Costa Canal of the Central Valley Project, and (3) the City of San Francisco states that an additional 109,000 acre-feet per season could be delivered to the Santa Clara Valley and an additional 125,000 acre-feet to the southern Alameda County and Livermore units by the Hetch Hetchy Aqueduct of the City of San Francisco. The remainder necessary would be provided by the Kirker Pass Aqueduct and the South Bay Aqueduct, both features of the California Aqueduct System.

The Kirker Pass Aqueduct contemplates the delivery of 164,000 acre-feet per season to lands in Contra Costa County not considered susceptible to service by facilities of the Contra Costa Canal and the East Bay Municipal Utility District. The aqueduct would convey water from the Antioch Crossing of the Delta Division of the California Aqueduct System in a general southwesterly direction about 21 miles to Lime Ridge Reservoir, about 2 miles west of Clayton. The Kirker Pass Aqueduct would provide the balance of the ultimate supplemental water requirement in Contra Costa County.

The South Bay Aqueduct would provide water in amounts sufficient to meet the remainder of the supplemental water requirements of Alameda County and Santa Clara Valley under ultimate conditions. As contemplated, the aqueduct would be constructed in two stages. The initial stage would comprise the Alameda-Contra Costa-Santa Clara-San Benito Counties Branch of the authorized Feather River Project Aqueduct, presently under intensive study by the Department of Water Resources for possible early construction. Deliveries of water by the Alameda-Contra Costa-Santa Clara-San Benito Counties Branch would be supplemented at a future time by construction of additional diversion and conveyance works which would parallel the facilities of the initial stage. The total contemplated deliveries under ultimate conditions would be about 627,000 acre-feet per season, distributed as follows: Livermore Valley, 187,000 acre-feet; southern Alameda County coastal plain, 198,000 acre-feet; and Santa Clara Valley, 242,000 acre-feet.

Regulation of water delivered by the initial stage of the South Bay Aqueduct would be provided in Airpoint Reservoir, about 2 miles east of Mission San Jose, and Evergreen Reservoir located about 6 miles southeast of San Jose, or alternatives thereto. These reservoirs would regulate the constant or uniform delivery to the variable monthly demands in the Southeast Bay Group. In this connection, available data indicate that the use of Airpoint Reservoir might be questionable from the geologic standpoint, due to possible excessive leakage.

Construction of the South Bay Aqueduct to the ultimate stage contemplates the use of a portion of the storage space in Sanatorium Reservoir on Arroyo del Valle. However, it is now apparent that the ridges on either side of the reservoir are capped with gravels which are probably permeable. Thus, storage in the reservoir would probably be limited due to the possibility of leakage at higher water stages.

Delivery of water to southern Contra Costa County and the northern portion of Livermore Valley could be accomplished by an alternative route of the South Bay Aqueduct. This alternative would consist of a diversion of water at the outlet portal of Brushy Peak Tunnel, and the conveyance along the northerly edge of Livermore Valley to a regulatory storage reservoir in Doolan Canyon, as shown on Sheet 10 of Plate 5. A reservoir at this site would be strategically located with respect to serving lands in Contra Costa County not within feasible reach of any existing water service agency. Studies of this alternative route have been of only a preliminary nature.

In summary, the objectives of The California Water Plan in the Southeast Bay Group would be met by local water developments which would provide 34,000 acre-feet per season; an increase in delivery capacity of existing import facilities, amounting to 357,000 acre-feet per season, and imports through facilities of the California Aqueduct System, in the amount of 791,000 acre-feet per season, distributed as follows: Kirker Pass Aqueduct, 164,000 acre-feet; and South Bay Aqueduct, 627,000 acre-feet. Together, the foregoing deliveries would fully satisfy the ultimate water requirements of all land considered susceptible of water service in the Southeast Bay Group.

Sanatorium, La Costa, and Little Francis Reservoirs would provide a measure of incidental flood control. However, the bulk of the required flood control works in the Southeast Bay Group are planned for construction by the three county flood control agencies in the area. Benefits to recreation and fish life would probably be slight because of operation primarily for water conservation.

Peninsula Group. The Peninsula Group comprises the City and County of San Francisco and nearly all of San Mateo County. San Francisco County occupies only the northern tip of the peninsula, forming an approximate square about 7 miles on each side. A major topographic feature of the peninsula is a mountain range lying north and south, forming its backbone. The City of San Francisco and adjacent communities in the northern portion of the bay side of San Mateo County constitute one of the most highly developed urban areas in the United States. The major segment of the economy is based upon industrial development, primarily manufacturing and food processing.

The Peninsula Group is drained principally by streams on the western slope which discharge into the Pacific Ocean. There are no undeveloped streams of any significance draining the eastern slope into the bay, with the exception of San Francisquito Creek, which forms the southerly boundary of the group.

The high degree of urban development attained in the Peninsula Group has been made possible, for the most part, by water supplies imported from foreign watersheds. Development of local water resources had been virtually completed prior to 1900, with the construction of Pilarcitos, San Andreas, and Upper and Lower Crystal Springs Reservoirs by the Spring Valley Water Company, predecessor to the San Francisco Water Department. Alameda Creek in the Southeast Bay Group was first developed for a water supply for San Francisco and the peninsula around 1900, and was fully developed and outgrown by the early 1930's.

The need for imports of water from distant sources on a large scale was foreseen by the City of San Francisco sufficiently in advance that Lake Eleanor and Hetch Hetchy Reservoir on the Tuolumne River watershed and the Hetch Hetchy Aqueduct were completed by the time the peninsula and Alameda Creek systems became insufficient to meet the water requirements. Water was first delivered from Hetch Hetchy Reservoir and Lake Eleanor in Yosemite National Park to Crystal Springs Reservoir on the peninsula through the Hetch Hetchy Aqueduct in 1934.

Other than possible minor localized water problems along the coast in San Mateo County, there are no water shortage problems in the Peninsula Group. Moreover, the City and County of San Francisco plan to import sufficient water through the Hetch Hetchy Aqueduct to meet the ultimate water requirements of San Francisco, the bay side of San Mateo County, and the coastal side of the county south nearly to Half Moon Bay.

Present flood problems in the Peninsula Group occur principally on the bay side of the peninsula, and are of a localized nature due to the comparatively small drainage areas of the uncontrolled streams. However, during intense storms these streams present serious flood threats to the highly developed urban areas which are rapidly extending along the bay shore over the entire length of the peninsula. Encroachment of these developments on the channels and flood plains has restricted channel capacities and has made maintenance difficult, as well as subjecting high-value property to possible inundation. Flood plains of streams on the coastal side of the peninsula are utilized mainly for agricultural pursuits, and flood damage has not been great. However, predictions of future land use patterns indicate a predominantly urban culture under conditions of ultimate development, and future flood problems will become greatly magnified.

The objectives of The California Water Plan in the Peninsula Group would be met by local development works on Pescadero and Butano Creeks to serve the coastal portion of San Mateo County south of Half Moon Bay, and by increased imports by the City and County of San Francisco to serve the remainder of the group.

Waters of the Pescadero Creek system would be developed by two dams, one on Pescadero Creek, about

1.5 miles east of Pescadero, and another on Butano Creek about 1 mile southeast of Pescadero and just above the confluence of Butano and Pescadero Creeks. Pescadero Dam would be limited in height to avoid inundation of any portion of Memorial Park with its beautiful grove of virgin redwoods. Water conserved by Butano Point Reservoir would be augmented by a gravity diversion through a pipe line from Pescadero Reservoir. The water supply made available by these reservoirs could be conveyed in a pressure pipe from Butano Point Dam northerly along the coast to the vicinity of Half Moon Bay. A pumping plant located at the downstream toe of the dam would lift the water to an elevation of about 400 feet at a summit about 6 miles north of the dam. From this point the water would flow by gravity to the vicinity of Half Moon Bay. Releases would be made to service areas along the conduit route.

The Pescadero Creek development would make available a seasonal supply of 40,000 acre-feet, which quantity could meet the ultimate water requirements of the forecast exclusively urban-type land use in the areas south of the service area of the San Francisco Water Department. In addition, considerable incidental flood control would be accomplished, and warmwater fishery could be enhanced. The balance of 196,000 acre-feet of ultimate supplemental water requirements in the Peninsula Group would be met by service of water imported through the Hetch Hetchy Aqueduct by the City and County of San Francisco.

Summary of San Francisco Bay Area. Objectives of The California Water Plan in the San Francisco Bay Area would be met by further development of local water resources, by increases in deliveries of existing import projects operated by local water service areas, and by imports through facilities of the California Aqueduct System. Further development of the meager and presently highly developed local water resources is limited. Of the total ultimate supplemental water requirements of 2,111,000 acre-feet per season, only 103,000 acre-feet would be provided by increased development of local water resources, and the remaining 2,008,000 acre-feet would be delivered by the facilities of the California Aqueduct System indicated in the following tabulation:

Solano Project	55,000 acre-feet
North Bay Aqueduct	308,000 acre-feet
Eel River Diversion	422,000 acre-feet
Cedar Roughs Tunnel	224,000 acre-feet
Montezuma Reservoir	208,000 acre-feet
Kirker Pass Aqueduct	164,000 acre-feet
South Bay Aqueduct	627,000 acre-feet

The foregoing developments would make available sufficient water to meet the ultimate requirements of the highly developed urban economy of the San Francisco Bay Area. The prospective local developments would include 10 storage reservoirs with an aggregate capacity of 227,500 acre-feet, of which 199,000 acre-feet would be devoted to local water conservation. These works could provide a measure of incidental flood control, although there would be no primary flood control operation. Maintenance of minimum pools in proposed reservoirs, although small, would create conditions favorable to the warmwater fishery. Moreover, recreational opportunities could be increased by construction and operation of these reservoirs.

Data on the general features and capital costs of the local development works contemplated as features of The California Water Plan in the San Francisco Bay Area are presented in Table 10. The locations and layouts of all of these facilities are delineated on Sheets 7, 8, and 10 of Plate 5.

Central Coastal Area

The Central Coastal Area is primarily an agricultural region, situated between the heavily populated San Francisco Bay and Los Angeles metropolitan areas. While agricultural, industrial, and population growth in the area, in general, has not been as rapid or extensive as that which has occurred in these adjoining regions, certain localized portions have achieved a high degree of development where adequate water supplies are available.

Irrigated agriculture and associated industries for the processing of agricultural products comprise the major economic activity in the Central Coastal Area, particularly in the fertile valleys, such as the Pajaro and Salinas Valleys, where underlying ground water is readily available. Other industries of lesser importance consist of oil refineries, lumber mills, and fishing.

Water supplies in the Central Coastal Area are presently obtained principally from ground water sources. Although these water supplies are physically meeting present requirements, most of the ground water basins are highly developed, and in some cases are overdrawn. Such conditions have developed in the Pajaro and southern Santa Clara Valleys, the Hollister area, and the Salinas, Santa Maria, and Cuyama River Valleys. As a result of these overdraft conditions, degradation of quality of ground water supplies, resulting from sea-water intrusion, has occurred in the Monterey coastal area of the Salinas and Pajaro Valleys, and perennial lowering of ground water levels is manifested in the San Benito, Pajaro, and lower Salinas Valleys. The overdraft on the ground water resources in the Central Coastal Area is presently (1955) estimated to aggregate some 65,000 acre-feet per season.

There are at the present time eight surface storage developments in the Central Coastal Area, with an aggregate capacity of about 626,000 acre-feet and an estimated safe seasonal yield of about 115,000 acre-feet. The largest of these developments is Nacimiento

TABLE 10

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN FRANCISCO BAY AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, (Shown on sheets 7 and 10 of Plate 5)	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Net	Seasonal yield, in acre-feet	Purpose	Place of water use	Capital cost [a]
North Bay Group											
Bear Creek	Sonoma Creek	Sec. 21, T7N, R6W	E	200	730	4,900	4,800	2,700	U	Upper Sonoma Valley	$2,933,000
Nicasio	Nicasio Creek	Sec. 28, T3N, R8W	E	175	160	22,800	22,700	12,000	U	Marin Municipal Water District	3,418,000
Spring Valley	Unnamed stream	Sec. 32, T8N, R5W	E	86	267	7,000	7,000	5,400	I	Napa Valley	1,329,000
Sulphur Springs	Sulphur Creek	Sec. 1, T7N, R6W	E	110	395	6,200	6,100	2,900	U	Napa Valley	2,168,000
Wing Canyon	Dry Creek	Sec. 14, T6N, R5W	E	171	400	12,300	12,000	6,400	U	Napa Valley	3,645,000
Southeast Bay Group											
Mocho	Arroyo Mocho	Sec. 1, T4S, R2E	E	65	840	2,000	2,000	[c]0	I,U	Livermore Valley	731,000
Sanatorium [b]	Arroyo del Valle	Sec. 3, T4S, R2E	E	175	708	44,000	[d]44,000	[c]3,000	I,U,S	Livermore Valley	----------
LaCosta	San Antonio Creek	Sec. 22, T4S, R1E	E	131	431	20,000	[e]20,000	[e]5,000	I,U	Niles Cone	2,290,000
Little Francis	San Francisquito Creek	Sec. 17, T6S, R3W	E	91	290	7,300	7,200	3,000	U	Palo Alto	2,203,000
Peninsula Group											
Butano Point	Butano Creek	Sec. 15, T8S, R5W	E	178	168	77,000	75,000	40,000	U	San Mateo coast	4,645,000
Pescadero	Pescadero Creek	Sec. 12, T8S, R5W	E	140	168	31,000	30,000				2,357,000
Totals						234,500	230,800				$25,719,000

Associated features	Length of conduit, in miles: Canal	Length of conduit, in miles: Pipe	Length of conduit, in miles: Total	Pumping plants: Total number	Pumping plants: Installed capacity, in kilowatts	Pumping plants: Seasonal power consumption, in kilowatt-hours	Capital cost [a]
North Bay Group		8.7	8.7	2	680	1,800,000	$2,031,000
Southeast Bay Group	10.3	17.6	27.9	[f]7	270	2,000,000	2,222,000
Peninsula Group		16.8	16.8	1	3,590	19,700,000	4,092,000
Totals	10.3	43.1	53.4	10	4,540	23,500,000	$8,345,000

Symbol of Type of Dam
E—Earthfill

Symbols of Purpose
I—Irrigation
U—Urban (Domestic, municipal, industrial)
S—Reregulation of imported waters to local demand schedules

[a] At 1955 price levels, with exception of Spring Valley Reservoir which is 1956.
[b] Possibility of excessive leakage. See comment on page 60.
[c] Mocho and Sanatorium Reservoirs would be operated in conjunction with Livermore Valley ground water storage to develop a total yield of 9,300 acre-feet per season.
[d] 17,000 acre-feet of storage allocated to local development, and 27,000 acre-feet to regulation of deliveries by South Bay Aqueduct.
[e] LaCosta Reservoir would be operated in conjunction with southern Alameda bayside ground water storage to develop a total yield of 6,700 acre-feet per season.
[f] Coyote Valley well field, see page 60.

Reservoir on the Nacimiento River, constructed to a storage capacity of 350,000 acre-feet by the Monterey County Flood Control and Water Conservation District. It is planned that this reservoir will be operated in conjunction with ground water storage in the Salinas Valley. Among other significant developments in the Central Coastal Area are Cachuma Reservoir on the Santa Ynez River, recently constructed by the United States Bureau of Reclamation, and Vaquero Reservoir on the Cuyama River, presently under construction by the same agency. Vaquero Reservoir will be operated in conjunction with ground water storage in the Santa Maria Valley.

The present (1955) water requirement in the Central Coastal Area, amounting to about 630,000 acre-feet per season, will ultimately increase to about 2,246,000 acre-feet per season. The present requirement for supplemental water will ultimately be increased from the present (1955) total of 65,000 acre-feet per season to about 1,681,000 acre-feet per season. Ground water resources of the area could meet little more than the present supplemental water requirements, even if developed to their full potential. It is evident, therefore, that the future development to meet ultimate requirements must rely upon local surface storage works, and upon imports through facilities of the California Aqueduct System.

In addition to the serious water supply problems in the Central Coastal Area, there exists a problem of the opposite nature—the periodic occurrence of major floods which have caused extensive damage to agricultural lands and urban development. Flood damage has been experienced along the lower reaches of the San Benito, Salinas, San Lorenzo, and Pajaro Rivers; Soquel Creek; the Santa Maria and Santa Ynez Rivers; and Arroyo Grande Creek.

The channels of the streams in the area have generally steep gradients and storms produce relatively high precipitation intensities. Resultant flood flows in these streams are characterized by very high intensities of relatively short duration. On San Lorenzo River and Soquel Creek, the recent flood of December, 1955, is considered to be the most damaging flood that ever occurred. Continuing development of urban and suburban areas will increase the flood damage potential adjacent to all the foregoing streams.

The objectives of The California Water Plan in the Central Coastal Area are twofold: first, the control and development of local water resources to the maximum practicable extent to satisfy increasing needs for irrigation, urban, industrial, and recreational purposes, to provide flood control, and to enhance the fishery wherever feasible; and second, the importation of water through facilities of the California Aqueduct System to satisfy fully the ultimate requirements of all lands considered susceptible of water service.

Local development works contemplated as features of The California Water Plan in the Central Coastal Area are considered under nine geographical subdivisions. These are designated and are hereinafter referred to as the "Santa Cruz-Pajaro Group," "San Benito Group," "Monterey-Carmel Group," "Salinas River Group," "Carrizo Plain," "San Luis Obispo Group," "Santa Maria Valley," "Cuyama Valley," and "Santa Barbara Group"; and their locations are shown on Plate 3. Suggested plans for local water supply development are presented individually for each of these divisions. Possible methods for importation of supplemental water will be described in the ensuing section entitled "California Aqueduct System."

The layout of the projected water development works in the Central Coastal Area is delineated on Sheets 10, 13, 16, 17, and 20 of Plate 5. Physical features and costs of all the local works are presented in Table 11, which follows this discussion under the heading "Summary of Central Coastal Area."

Santa Cruz-Pajaro Group. The Santa Cruz-Pajaro Group embraces nearly all of Santa Cruz County, the southerly tip of San Mateo County adjacent to the Pacific Ocean, and the Pajaro Valley, portions of which lie in Monterey and San Benito Counties. The area totals some 500 square miles, of which 425 square miles comprise mountains and foothills. The mountains are generally well covered with timber, including extensive growths of redwood.

About three-fourths of all the water developed in the Santa Cruz-Pajaro Group is presently supplied by water pumped from underlying ground water basins. Lands utilizing ground water are generally served by individually owned wells and pumps. Surface diversions are made from numerous streams rising in the Santa Cruz Mountains, principally for urban and recreational uses. The largest surface diversions are made by the Cities of Santa Cruz and Watsonville. The City of Santa Cruz diverts water from Liddell, Laguna, and Majors Creeks, and from the San Lorenzo River; while the City of Watsonville diverts from Corralitos Creek and Brown Valley Creek in the Pajaro Valley.

Although the Santa Cruz-Pajaro Group has ample water resources to meet present and probable ultimate water requirements, except in Pajaro Valley, the area is presently faced with serious water problems. Heavy irrigation season pumping draft from the confined ground water aquifers in the Pajaro Valley has resulted in the intrusion of sea water into the lower portion of the aquifers near Monterey Bay. The overdraft is estimated (1953) to be about 4,000 acre-feet per season. The City of Santa Cruz, which depends almost entirely upon surface diversions, is faced with the threat of a deficiency of available supplies during the late summer months of low runoff, because

Central Coastal Area—Point Lobos

of the lack of adequate storage facilities. Recurrence of a very dry year, such as 1931, would undoubtedly force late summer water rationing throughout the Santa Cruz area.

Another major water problem in the Santa Cruz-Pajaro Group is manifested in periodic floods, resulting from high rainfall intensities, particularly on the Santa Cruz Mountains. The recurring threat of flooding along the lower reaches of San Lorenzo and Pajaro Rivers and Soquel and Branciforte Creeks is great, as was demonstrated by the flood of December, 1955. As an example, the San Lorenzo River at Big Trees reached a peak discharge of 30,000 second-feet during that flood. The previous high for this stream was 24,000 second-feet in February of 1940.

With the exception of Pajaro Valley, the ultimate water requirements in the Santa Cruz-Pajaro Group could be met by development of local water resources. Fulfillment of the objectives of The California Water Plan in the Pajaro Valley would require an import of water through the facilities of the California Aqueduct System.

Agricultural and urban water requirements of lands along the coastal strip north of the City of Santa Cruz could be met by development of Scott Creek. Water of Scott Creek would be conserved in Archibald Reservoir, located about 3 miles north of the town of Davenport.

The probable ultimate supplemental water requirements of the area tributary to Monterey Bay between Meder Creek, immediately west of the City of Santa Cruz, and the Pajaro drainage area, could be provided by storage reservoirs on Bear, Zayante, Soquel, and Aptos Creeks, on the upper reaches of the San Lorenzo River and Soquel drainage basins, and a pumped diversion from the San Lorenzo River near the City of Santa Cruz to an off-stream storage reservoir on Doyle Gulch.

Bear Creek Dam and Reservoir would be located on Bear Creek 4 miles west of the town of Boulder Creek. The reservoir would provide water for urban and recreational uses along the upper reaches of the San Lorenzo River drainage area. Zayante Creek Dam and Reservoir on Zayante Creek, about 4 miles east of the town of Felton, would develop water for use along Zayante Creek and the San Lorenzo River between Zayante Dam and the City of Santa Cruz.

The City of Santa Cruz and surrounding areas near Soquel and Capitola could be served by a pumped diversion of winter runoff of the San Lorenzo River at Santa Cruz, and conveyance of the water by pumping facilities and pipe line to an off-stream storage reservoir on Doyle Gulch about 3 miles east of Santa Cruz. Water could be delivered to the service areas directly from the diversion works during the winter months, and by releases from Doyle Gulch Reservoir through the conveyance facilities by gravity during the summer months.

Glenwood Dam and Reservoir would be located on the West Branch of Soquel Creek, about 6 miles north of the town of Soquel. The reservoir would develop water for use along the down stream channel, and along the coast generally east of Capitola. A similar development on Soquel Creek, about 6 miles northwest of the town of Soquel, would provide water for use along Soquel Creek and on the coastal area in the vicinity of Soquel and Capitola.

Aptos Creek Dam and Reservoir would be located on Aptos Creek about 1 mile north of the town of Aptos. The reservoir could provide urban and agricultural water supplies in the vicinity of the town of Aptos.

The foregoing works could meet the ultimate supplemental water requirements in all of Santa Cruz County, with exception of Pajaro Valley. In addition, operation of these reservoirs would sustain summer flows in the upper reaches of the San Lorenzo River and Soquel Creek, thus enhancing stream fishing and recreation. Although a measure of flood protection would be provided by these developments, such protection would be inadequate for the lower reaches of the San Lorenzo River and Soquel Creeks because of insufficient storage for full control. In this connection, flood control on the San Lorenzo River by means of reservoir storage is not feasible of accomplishment because of the lack of storage sites anywhere on the river. However, the Corps of Engineers, U. S. Army, is preparing to construct an authorized project for levee and channel improvement on the lower San Lorenzo River, which will relieve the present flood threat in the City of Santa Cruz and vicinity.

The ultimate supplemental water requirement in the Pajaro Valley could be met by a diversion of surplus winter flows from the Pajaro River and conveyance of the diverted water to an off-stream storage reservoir in Corn Cob Canyon, and by import through the South Bay Aqueduct of the California Aqueduct System. Surplus flows in the Pajaro River would be diverted during the winter months and conveyed by canal to the vicinity of Watsonville Reservoir, in Corn Cob Canyon, about 1 mile southeast of Watsonville Junction. The water would be pumped into the reservoir and would be released through the same facilities during the irrigation season for use along the lower Pajaro River, in the area where the present ground water overdraft exists.

In addition to the new yield developed by the Pajaro diversion, an additional amount of about 15,000 acre-feet of water per season would be required to satisfy fully the ultimate supplemental requirements in Pajaro Valley. This quantity of water would be conveyed to Pacheco Creek by facilities of the South Bay Aqueduct and released into that creek, where it would flow by gravity down the Pajaro River to be available for rediversion in the Pajaro Valley.

With respect to flooding along the lower Pajaro River, there are no storage sites on the main stream, and no upstream storage development offers sufficient protection. As in the case of the San Lorenzo River, channel improvement and levee construction affords the most satisfactory solution to flood problems. The Corps of Engineers, U. S. Army, has improved the lower Pajaro River, and has plans for further channel improvement.

In summary, prospective local development works by which the objectives of The California Water Plan in the Santa Cruz-Pajaro Group would be accomplished comprise eight dams and reservoirs and two diversion features. Together these works would develop a seasonal new yield of 48,000 acre-feet which would provide for the ultimate water needs in all but the Pajaro Valley, where an additional amount of about 15,000 acre-feet per season would be imported by facilities of the California Aqueduct System. Thus, about 63,000 acre-feet per season would be developed for use in the Santa Cruz-Pajaro Group, which amount would fully meet the ultimate requirements of all the lands considered susceptible of water service. In addition to the conservation accomplishments, the prospective local developments in conjunction with downstream channel improvement would provide flood control on the San Lorenzo River and Soquel Creek, and would enhance recreation and stream fishing in those streams by maintenance of improved summer flows.

San Benito Group. The San Benito Group generally comprises those lands lying in Santa Clara and San Benito Counties which make up the drainage basin of the Pajaro River above Chittenden. Its area totals about 1,190 square miles, of which some 950 square miles comprise mountain and foothills and the remainder is classified as valley and mesa lands.

The present (1954) irrigated acreage in the San Benito Group approximates 70,000 acres, of which about 40,000 acres are located in the Hollister area and the remainder is found in south Santa Clara Valley. The relatively high degree of development has been achieved by exploitation of the extensive ground water storage in alluvial fill areas, notably the south Santa Clara Valley and the Hollister area. The development of the ground water basins has been aided by the facilities operated by local water service agencies for ground water recharge by controlled releases from surface storage reservoirs.

The principal storage works in the San Benito Group consist of the recently completed Chesbro Dam on Llagas Creek and Uvas Creek Dam on Uvas Creek, both projects developed by the South Santa Clara Valley Water Conservation District; Paicines Reservoir, an off-stream storage site for water diverted from the San Benito River, constructed by the Hollister Irrigation District to serve irrigated lands during winter and spring months when water is available; and the North Fork Reservoir on the North Fork of Pacheco Creek, owned and operated by the Pacheco Pass Water District for controlled percolation in Pacheco Creek. The combined storage capacity of these reservoirs is about 28,000 acre-feet, and their yield, obtained by operation in conjunction with ground water storage, is about 22,000 acre-feet per year.

As a result of the sustained drafts on ground water resources in the San Benito Group and the continually increasing irrigation demands, the ground water basin underlying the Hollister area is overdrawn at the present time. The present (1954) seasonal overdraft in this area is estimated to be about 8,000 acre-feet. To meet fully the ultimate requirements of the group, supplemental water supplies totaling 132,000 acre-feet per season would be required in addition to the presently developed supplies. The quality of the ground water underlying about 5,000 acres skirting the foothills easterly of Hollister is somewhat adversely affected by a relatively high boron content.

Recurrent flooding is a threat to the intensively cultivated lands along the Pajaro River where the flood plains of Llagas and Carnadero Creeks merge with the bottom land lake area, extending westward from San Felipe Lake to the vicinity of Sargent. This area is flooded by discharge of tributaries to Tequisquito Slough, as well as Llagas and Carnadero Creeks. In additiou, the banks of the San Benito River are subject to severe erosion during periods of high runoff such as that which occurred during the December, 1955, flood.

The opportunity for further development of local water resources of the San Benito Group is very limited. Therefore, accomplishment of the objectives of The California Water Plan in that group must rely primarily on the importation of supplemental water from areas of surplus elsewhere in the State. However, further development of local water resources could provide sufficient water to meet the ultimate water requirement in the south Santa Clara Valley and to overcome the present deficiency in the Hollister area.

Enlargement of the existing Uvas Creek Reservoir from its present capacity of 10,000 acre-feet to a capacity of 34,000 acre-feet could, if operated in conjunction with the downstream ground water basin in south Santa Clara Valley, provide sufficient water to meet the ultimate supplemental water requirement of the valley. Diversion facilities have been provided so that when releases from this reservoir exceed percolation capacity of the downstream channel in Uvas Creek, excess flows would be diverted into the absorptive Llagas Creek channel.

Water supplies for the Hollister area could be made available by four dams and reservoirs on tributaries to the Pajaro River, consisting of a reservoir on Pacheco Creek, two reservoirs on the San Benito River, and a diversion dam from Tres Pinos Creek.

Harper Canyon Dam and Reservoir would be located on Pacheco Creek about 11 miles northeast of Hollister. Initially, the reservoir could be operated entirely for conservation, with releases being made for augmenting stream channel percolation in Pacheco Creek. However, under ultimate operation, the reservoir could be enlarged to provide sufficient additional storage for regulation of deliveries through the South Bay Aqueduct to the variable monthly demands in the Hollister area.

San Benito Dam and Reservoir, located on the San Benito River about 6 miles downstream from the town of San Benito, would develop an irrigation supply for lands along the river between the dam and the town of Paicines. Cienega Dam and Reservoir, located about 1 mile east of the town of Paicines, would augment the ground water supplies in the Hollister area by releases to the downstream channels. Yield developed by Cienega Reservoir could be augmented by a diversion from Tres Pinos Creek of surplus flows in excess of the percolation capacity of that creek. The diversion dam on Tres Pinos Creek would be located about 2 miles southeast of the town of Paicines, and the water would be conveyed about 1 mile by canal to Cienega Reservoir.

In summary, the prospective local development works in the San Benito Group would provide a total seasonal new yield of 20,700 acre-feet, of which 6,400 acre-feet would be provided in south Santa Clara Valley and 14,300 acre-feet in the Hollister area. A measure of flood control would be provided by operation of these works, although no planned operation for that purpose is contemplated. The Corps of Engineers is investigating the control of floods in the area by channel improvement and/or reservoir control. Water supplies in the amount of 113,000 acre-feet per season would be delivered through facilities of the California Aqueduct System in order to satisfy fully the ultimate water requirements of lands in the San Benito Group.

Monterey-Carmel Group. The Monterey-Carmel Group embraces the Carmel River Basin and the area tributary to the Pacific Ocean immediately to the south, extending to the Monterey-San Luis Obispo county line. Its area totals about 610 square miles, of which nearly 600 square miles comprise mountains and foothills. The Carmel River Basin contains the majority of the irrigable lands, most of which are in the Carmel Valley, and the Monterey Peninsula, a widely known resort area.

Irrigated lands in the Carmel Valley and the urban and suburban areas on the Monterey Peninsula make up the total present (1950) water requirement of about 10,400 acre-feet per year in the Monterey-Carmel Group. The only existing major surface water supply developments in the group consist of Los Padres and San Clemente Reservoirs on the Carmel River, owned and operated by the California Water and Telephone Company. The remainder of the water service is generally supplied by individuals who utilize ground water or who divert directly from the many small streams emanating from the Santa Lucia Range.

The Monterey-Carmel Group has ample water resources to meet present and probable ultimate requirements, water now wasting to the ocean substantially exceeding the latter requirement. The ultimate supplemental water requirement of the group is estimated to be about 37,500 acre-feet per season. As contemplated under The California Water Plan, this requirement would be furnished by increasing the present yield of the ground water basin in Carmel Valley by greater ground water utilization, and by a surface storage development on the Carmel River, which would also have some recreational values.

Development of the Carmel River could be completed by construction of a dam at the Klondike site about 15 miles upstream from Carmel Bay. Klondike Reservoir would inundate the present San Clemente Dam and the filtration plant below the dam. The reservoir would be operated in conjunction with the present Los Padres Reservoir and filter plant, releasing water into existing facilities for urban and industrial distribution on the Monterey Peninsula. In addition, 2,200 acre-feet of water per season would be released directly to the Carmel River for agricultural use along the river below the dam.

The present ground water yield of 2,300 acre-feet per season in the Carmel Valley ground water basin could be increased to 4,600 acre-feet as the acreage of overlying irrigated lands increases in the future. The increased yield would be developed by greater extraction from the ground water basin, thus providing a greater seasonal and cyclic storage depletion during dry periods, which would create additional storage for conservation of water supplies which would otherwise waste to the ocean during ensuing wet periods.

The ultimate supplemental water requirements of about 8,000 acre-feet per season in the coastal portion of the Monterey-Carmel Group south of the Carmel River could be provided by direct diversions from the high-producing streams of the area. Available data indicate that the minimum summer flows in the streams of that area, particularly the Sur and Little Sur Rivers, would always be adequate to meet the peak monthly demands for water in their immediate areas, including sufficient flow for maintenance of fish life. Thus, the diversion of water under ultimate conditions should not impair the present high recreational, fishery, and wildlife value of the area. Should the necessity occur, small headwater reservoirs could be constructed for maintenance of stream flow

The 8,000 acre-feet of water per season available from direct diversion from the coastal streams, along with the 27,200 acre-feet developed by Klondike Reservoir and 2,300 acre-feet secured by greater utilization of ground water in the Carmel Valley, would meet the ultimate supplemental water requirement of 37,500 acre-feet in the Monterey-Carmel Group.

Salinas River Group. The Salinas River Group embraces the total area of some 4,330 square miles drained by the Salinas River and its tributaries. From the southern coastal portion of Monterey Bay, just north of the Monterey Peninsula, this group extends generally southeasterly for a distance of 150 miles through major portions of Monterey and San Luis Obispo Counties and a small part of San Benito County. The topography is generally mountainous and hilly, but is split longitudinally for a distance of nearly 100 miles along its major axis from Monterey Bay to Wunpost by the floor of the Salinas Valley and the meander of the Salinas River.

Described by early visitors as the "Salinas Desert," the Salinas Valley has developed to the point where 80 per cent of the lands susceptible of irrigation are presently irrigated from underlying ground water resources. The major economy of the valley is based upon its agricultural development and allied industries which process and package agricultural products.

Development of agriculture in the Salinas Valley has been possible due to the availability of water in large quantities and of excellent quality. Underlying almost the entire valley floor is an extensive ground water basin which, until recently, has economically yielded sufficient water to satisfy all agricultural, industrial, and domestic water requirements.

Present (1954) water requirements in the Salinas River Group are estimated to be about 267,000 acre-feet per season, nearly all of which are supplied by pumping from underlying ground water storage, particularly in the Salinas Valley north of San Lucas. Net seasonal pumping draft from the extensive ground water basin underlying that valley presently averages 225,000 acre-feet.

Nacimiento Dam and Reservoir, recently constructed by the Monterey County Flood Control and Water Conservation District, and Salinas Reservoir are the only major existing surface water developments in the Salinas River Group. Nacimiento Reservoir, located on the Nacimiento River about 12 miles upstream from its confluence with the Salinas River, has a storage capacity of 350,000 acre-feet, of which 150,000 acre-feet is to be reserved for control of floods on the Nacimiento and Salinas Rivers. The district plans to operate the conservation storage to retain winter flood flows for release during the ensuing months to recharge ground water basins underlying the Salinas River. Salinas Reservoir, with a capacity of 26,000 acre-feet, was built by the Corps of Engineers, U. S. Army, in 1942 for water supply for Camp San Luis Obispo. It is now used for the municipal supply of the City of San Luis Obispo.

Although the safe yield of the ground water resources of the Salinas River Group exceeds the total pumping extraction on an over-all basis, serious overdrafts prevail in the vicinity of Monterey Bay and along the easterly fringe of the valley floor from Salinas southeast to the vicinity of Gonzales. The problem of overdraft in the vicinity of Monterey Bay is typical of many coastal basins where ground water occurs in confined aquifers, or water-bearing zones, which are open to the ocean at their lower end. The present (1954) overdraft on the confined aquifer in the vicinity of Monterey Bay is estimated to be 20,000 acre-feet per season. Sea water has already intruded for a distance of about 3 miles and has necessitated the abandonment of pumping from the intruded aquifer in an area of some 5,000 acres. The deficiency along the eastern fringe of Salinas Valley is due to the inherent deficiency in natural water supplies in that area, and presently (1954) amounts to 8,000 acre-feet per season. The probable ultimate supplemental water requirements of the potential service areas in the Salinas River Group are estimated at 483,000 acre-feet per season, which substantially exceeds the developable local water resources.

In addition to the water conservation problem in the Salinas River Group, the periodic occurrence of floods causes damage to agricultural lands and utilities on the Salinas River flood plain below Wunpost. Operation of the 150,000 acre-feet of flood control storage space in Nacimiento Reservoir will greatly reduce flood hazards and flood damages. However, attainment of the required degree of flood protection for the highly developed economy of the lower Salinas Valley will ultimately necessitate a control structure and channel improvements on the main stem of the Salinas River below its major tributaries.

Objectives of The California Water Plan in the Salinas River Group could be accomplished by both local development works and by imports through facilities of the California Aqueduct System. The local development phase would consist of eight storage reservoirs and three conveyance conduits. The reservoirs would be operated coordinately and in conjunction with downstream ground water storage to attain the optimum degree of local water resource development, and to correct the present problem of sea-water intrusion into the confined aquifer in the vicinity of Monterey Bay. Such operation would necessitate the limiting of draft in the confined aquifers to the safe yield rate, and the delivery of a supplemental surface supply to meet the balance of the water requirements of overlying areas. It would also require the rearrangement of the present pattern of pumping draft in the forebay area, or zone of unconfined ground water, and the increased utilization of underground storage, thus creating greater space for recharge by water which would otherwise waste to the ocean. It is estimated that the safe ground water yield could be so increased by some 50,000 acre-feet per season under ultimate development, in addition to the yield of surface storage facilities.

The contemplated local development works in the Salinas River Group would provide surface water service to the lower and a portion of the upper Salinas Basin by releases and direct conveyance to service areas. Reservoir releases would also be made for control of downstream ground water levels to effect their efficient operation. The prospective surface storage reservoirs include single units on Santa Rita and Jack Creeks, the Arroyo Seco, and the Salinas River, and two units each on the Nacimiento and San Antonio Rivers.

Santa Rita Dam and Reservoir would be located on Santa Rita Creek about 3 miles upstream from its confluence with Paso Robles Creek. Water developed by the reservoir could be released into Santa Rita Creek for diversion downstream to supply urban and irrigation demands in and around the communities of Atascadero and Templeton along the upper Salinas River. Jack Creek Reservoir on Jack Creek, about 2 miles upstream from its confluence with Paso Robles Creek, would supplement the yield developed in Santa Rita Reservoir by similar downstream releases.

Development of the Nacimiento River would be completed by San Miguelito and Jarrett Shut-in Reservoirs. San Miguelito Reservoir would be formed by a dam about 34 miles upstream from the existing Nacimiento Dam. Jarrett Shut-in Reservoir would be located about 8 miles downstream from the San Miguelito site. Both reservoirs would be operated coordinately to conserve the flows of Nacimiento River in excess of the amounts controlled by Nacimiento Reservoir. The yields developed by these reservoirs would be released downstream through Nacimiento Reservoir, and diverted from the Nacimiento River and conveyed to areas of use in the Nacimiento-Shandon Conduit.

This Nacimiento-Shandon Conduit would convey the water easterly from the Nacimiento River, in pressure conduit, to a wye east of San Miguel. The main conduit would continue easterly to Shandon Terminal Reservoir about 1 mile southeast of the town of Shandon. Water would be pumped into the reservoir at an elevation of about 1,190 feet.

The Creston Lateral would extend from the wye near San Miguel in a general southeasterly direction, terminating in the Creston Terminal Reservoir about a mile south of Creston. The foregoing facilities would deliver new urban and irrigation water to valley and foothill lands along the east side of the upper Salinas Valley and to the City of Paso Robles.

Two storage developments on the San Antonio River would complete development of its water resources. Milpitas Dam and Reservoir would be located about 40 miles upstream from the confluence of San Antonio and Salinas Rivers. Pleyto Dam and Reservoir would be located at the lower end of Lockwood Valley, about 10 miles upstream from the confluence of San Antonio and Salinas Rivers. Water from these reservoirs would serve Lockwood and Hames Valleys.

Runoff of the Arroyo Seco would be controlled by Greenfield Dam and Reservoir about 5 miles southwest of Greenfield. A portion of the yield of Greenfield Reservoir would be released into the stream channel to support pumping withdrawals from ground water storage underlying the Arroyo Seco and Salinas River channel. However, the major portion of the new water yield would be diverted and delivered through the Greenfield-Monterey conduit to areas along the west side of Salinas Valley, particularly the area between Salinas and Monterey Bay.

The runoff in the main stem of the Salinas River could be controlled by San Lucas Dam and Reservoir, located about 3 miles downstream from San Lucas and 4 miles upstream from King City. San Lucas Reservoir, which has been authorized and adopted by the Legislature, would be operated both for conservation and flood control, with 150,000 acre-feet of storage reserved for control of flood flows on the Salinas River and its tributaries.

With San Lucas Reservoir in operation, the total new seasonal yield of the surface storage developments contemplated on the Salinas River system would approximate 102,000 acre-feet. An additional yield of 18,000 acre-feet per season could be obtained by transferring the 150,000 acre-feet of flood control storage space in Nacimiento Reservoir downstream to San Lucas Reservoir, at such time as the latter reservoir would become operational, and by operating the additional storage space in Nacimiento Reservoir for conservation. Transfer of the flood control space from Nacimiento to San Lucas Reservoir would be a logical move because of the high degree of control of the drainage area of the basin at the San Lucas site. In addition to its efficacy in the control of floods, San Lucas Reservoir would be necessary for capture and reregulation of the substantial return flows which would result from irrigation of large areas of land in the upper Salinas Basin under ultimate conditions.

The waters conserved by San Lucas Reservoir, and portions of the yields of the future reservoirs on the Nacimiento and San Antonio Rivers would be utilized to eliminate present overdraft conditions and to meet future increases in water requirements in the Salinas Valley. Water would be made available to the lower portion of the valley north of Gonzales, where overdraft conditions prevail, by a surface diversion from the Salinas River and conveyance in the San Lucas-East Side Conduit. This conduit would originate a ie San Lucas Dam and be constructed along the west ide of the Salinas River, crossing the river in a iphon near Soledad, and continuing along the east ide of the river to a terminus about 3 miles north of ie City of Salinas. The conduit would also provide ater service for foothill lands on the east side of the alley by means of takeouts and pump lifts along the onduit route.

In summary, the local development works contemlated in the Salinas River Group would make availble 120,000 acre-feet of supplemental water per eason by operation of eight conservation reservoirs ith a total storage capacity of 1,130,000 acre-feet. hese reservoirs would be operated coordinately and 1 conjunction with downstream ground water basins facilitate the development of an additional seanal yield of 50,000 acre-feet from increased utiliation of ground water storage. Thus, a total yield of dditional water in the aggregate amount of 170,000 cre-feet per season would be made available to meet portion of the estimated ultimate water requireients of lands in the Salinas River Group. However, s previously stated, the ultimate supplemental water equirements within the group are estimated to be 83,000 acre-feet per season. Therefore, additional ater in the net amount of 313,000 acre-feet per eason, requiring a gross delivery of 335,000 acreeet, would be supplied from the Central Coastal queduct, a feature of the California Aqueduct ystem.

In addition to the foregoing water conservation ccomplishments of the contemplated local developient works, a large measure of flood control would e provided by operation of flood control storage in an Lucas Reservoir, and by incidental flood flow reuction from operation of 755,000 acre-feet of conervation storage in the seven other reservoirs.

Carrizo Plain. The Carrizo Plain is a large arid alley of internal drainage, located between the Temlor and Caliente Ranges adjacent to the upper Salinas nd Cuyama Valleys. The valley floor lies at an elevaion of about 2,000 feet above sea level. Mean seasonal recipitation varies from about 8 inches on the valley oor to 10 inches in the surrounding mountains. unoff in streams tributary to the Carrizo Plain is isignificant in amount and is largely disposed of aturally through evaporation from Soda Lake, a atural sump located near the center of the plain.

At the present time a dry-farmed economy exists hich probably will continue for many years in the uture. A large portion of the potentially irrigable ands is utilized for dry-farm production of a highuality Baart wheat for which the flour milling indusry pays premium prices. The remainder of the area devoted to cattle grazing, with small acreage of rigated pasture to supplement the natural forage.

Small amounts of water are presently pumped from ground water storage underlying the Carrizo Plain; but the supplies are very meager, and no opportunity exists for further development of local water supplies. If irrigation in this area were to expand, water to satisfy the needs therefor would have to be imported from outside sources. The cost of such water would be high. The possible ultimate seasonal water requirements, amounting to 245,000 acre-feet, could be provided through facilities of the Carrizo-Cuyama Aqueduct, a feature of the California Aqueduct System.

San Luis Obispo Group. The San Luis Obispo Group consists generally of that portion of San Luis Obispo County lying on the western slopes of the Santa Lucia Range. A small portion of the group extends northward along the coast into Monterey County. The area consists of mountain and foothill lands interlain by numerous small stream valleys and the more extensive valley and coastal plain area of Arroyo Grande Creek.

Present (1953) developed water supply in the San Luis Obispo Group totals about 16,000 acre-feet per season, the majority of which is obtained by pumping from underlying ground water storage. Water supplies for the City of San Luis Obispo, however, are presently obtained largely by importation from Salinas Reservoir on the upper Salinas River near Santa Margarita, as described in the foregoing section dealing with the Salinas River Group. There are no local surface storage developments in the San Luis Obispo Group.

The present net draft on ground water in the San Luis Obispo Group, amounting to nearly 14,000 acrefeet per season, is obtained without any overdraft problem. It is estimated that pumping draft could be increased to some 28,000 acre-feet per season without exceeding the safe yield of local ground water resources. The largest ground water basin in the group underlies the lower valley and coastal plain of Arroyo Grande Creek. Numerous small ground water basins underlie or are adjacent to the lower reaches of the coastal streams.

The objectives of The California Water Plan in the San Luis Obispo Group would be met mainly by further development of local water resources. However, full satisfaction of ultimate water requirements, amounting to an estimated 156,000 acre-feet per season, would necessitate a delivery of some imported water through facilities of the California Aqueduct System.

Most of the favorable local water development sites are located on the streams in the northern portion of the group, whereas the majority of potential water service areas are located in the southern portion, particularly in the vicinity of Arroyo Grande, the coastal plain, and the City of San Luis Obispo. Con-

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Nacimiento Reservoir on Nacimiento River Provides Water for Agricultural Uses in the Salinas Valley templated water development works would consist of an integrated system of reservoirs, comprising two dams on San Carporforo Creek; single dams on Arroyo de la Cruz, San Simeon Creek, Santa Rosa Creek, and Old Creek, all connected by a coastal conduit conveying the developed water supply southward to areas of use; and a reservoir on Arroyo Grande Creek.

Waters of San Carporforo Creek would be controlled by dams and reservoirs at the Bald Top and Ragged Point sites, located about 5 miles and 2 miles, respectively, above the mouth of that creek. Bald Top Reservoir would be operated coordinately with the downstream Ragged Point Reservoir, both facilities releasing water for conveyance in the coastal conduit.

Yellow Hill Reservoir, located on Arroyo de la Cruz about 1.6 miles upstream from its mouth, San Simeon Reservoir on San Simeon Creek about 3 miles north of the town of Cambria, and Santa Rosa Reservoir on Santa Rosa Creek about 5 miles east of Cambria would augment the southward delivery of water in the coastal conduit.

Water to supply future needs of the City of San Luis Obispo and vicinity could be provided by construction of Whale Rock Dam and Reservoir on Old Creek about a mile east of the town of Cayucos. This project was recommended in October, 1955, for construction in the immediate future, under a program of staged development. The Whale Rock Project is contemplated as a joint venture of the State and the City of San Luis Obispo. The Legislature is presently considering an appropriation of funds to finance the State's interest in the project as a water supply for the California Polytechnic Institute and the California Men's Colony. The City of San Luis Obispo has recently authorized the issue of bonds to finance the local cost of the project.

In order to deliver the water to the areas of need, the Cambria Conduit would be constructed from San Carporforo Creek on the north to a terminal point in the vicinity of the City of San Luis Obispo. The Cambria Conduit would proceed along the coast, intercepting waters released from the reservoirs on San Carporforo Creek, Arroyo de la Cruz, and San Simeon, Santa Rosa, and Old Creeks. It would leave the coast near the mouth of Morro Creek, proceeding up Las Osos Valley where the water would be lifted over the low divide into San Lans Valley, and the conduit would finally terminate at Indian Knob Terminal Reservoir on a small tributary of San Luis Obispo Creek about 5 miles south of San Luis Obispo.

Water requirements of the service areas along Arroyo Grande Creek could be met by Lopez Reservoir, on Arroyo Grande Creek about 7 miles upstream from the City of Arroyo Grande. Water would be provided by gravity releases from the reservoir. Lopez Reservoir would be operated to provide water for additional development in the Arroyo Grande area, both by conjunctive operation with downstream ground water storage and by diversion of controlled reservoir releases either from the stream or from a conveyance conduit. Moreover, Lopez Reservoir would provide a substantial degree of incidental downstream flood control, although it would not entirely eliminate the problem.

In summary, the local development phase of The California Water Plan for the San Luis Obispo Group would comprise seven dams and reservoirs and a conduit for conveying portions of the yields of these reservoirs to the areas of use. These reservoirs, with aggregate capacity of 315,000 acre-feet, would, together with increased ground water utilization, provide a safe seasonal yield of 111,500 acre-feet, which would meet a substantial portion of the ultimate water requirements of the group. However, in order to satisfy fully the ultimate requirements, an additional net amount of some 26,000 acre-feet of water per season, requiring a gross delivery of 30,000 acre-feet, would have to be imported through the Central Coastal Aqueduct of the California Aqueduct System.

Santa Maria Valley. The Santa Maria Valley comprises the drainage area of the Santa Maria River, excluding the drainage area of the Cuyama River above Vaquero Dam, and embraces portions of San Luis Obispo and Santa Barbara Counties. The valley includes the intensively developed agricultural area on the coastal plain, centered around the City of Santa Maria; the adjoining Nipomo Mesa; and tributary mountain and hill areas.

Essentially all developed water in the Santa Maria Valley is now obtained from the ground water basin underlying the coastal plain. Water is used principally for agricultural purposes on the floor of Santa Maria Valley and the adjacent Nipomo Mesa. Until recently there have been no major surface storage developments on the Santa Maria River or its tributaries. However, the Santa Maria Project, comprising a 214,000 acre-foot reservoir at the Vaquero site on the Cuyama River, and channel improvements along the Santa Maria River and Bradley Canyon, are now under construction by the Bureau of Reclamation and the Corps of Engineers, respectively. Proposed operation of Vaquero Reservoir contemplates the reservation of 89,000 acre-feet of storage for control of floods, and the balance of the reservoir storage capacity for water conservation. Water retained in the conservation storage pool will be released to the Santa Maria River at rates within the percolation capacity of the channel.

It has been estimated by the Bureau of Reclamation that recharge to ground water by operation of Vaquero Reservoir will be increased by an average amount of 18,500 acre-feet per season. In addition, the flood control accomplishments of the reservoir will be augmented by the construction of levees along Bradley Canyon and along Santa Maria River downstream therefrom to confine large flood flows within the leveed channel.

For many years, pumping extraction from the ground water resources of Santa Maria Valley has exceeded replenishment, resulting in perennial overdraft. Although the large amount of ground water storage capacity has so far made possible the maintenance of overdraft without lowering of water levels below sea level, continuation of overdraft conditions would inevitably result in such lowering, with the resultant threat of sea-water intrusion. It is estimated that the present (1950) seasonal net draft on the ground water basin is about 91,000 acre-feet and that the safe seasonal yield of the basin is only 54,000 acre-feet. It should be noted that the new yield developed by Vaquero Reservoir will not entirely eliminate the present ground water overdraft in Santa Maria Valley.

The water requirements of Santa Maria Valley are forecast to be about 227,000 acre-feet per season under ultimate development. Taking credit for the new yield of the ground water basin operated in conjunction with Vaquero Reservoir, there will ultimately be a demand for supplemental water in the amount of about 154,000 acre-feet per season.

It is estimated that waste of water to the ocean after completion of Vaquero Reservoir will be about 15,000 acre-feet per season on the average. There exists a possibility of saving part of this wasted water by construction of Round Corral Reservoir on the Sisquoc River. However, it is considered that the yield developed at this site would be extremely costly, and, in addition, it is questionable whether sufficient ground water storage would be available for operation in conjunction with storage at the Round Corral site. Therefore, no further local water supply developments in the Santa Maria Valley are considered to be practicable.

It is concluded that the accomplishment of the objectives of The California Water Plan in the Santa Maria Valley will be contingent on ultimate gross import of about 180,000 acre-feet per season from the Central Coastal and Carrizo-Cuyama Aqueducts of the California Aqueduct System. This would provide a net seasonal supply of about 154,000 acre-feet. Provision of supplemental water in this amount would fully satisfy the ultimate water requirements of all lands considered susceptible of water service in the Santa Maria Valley.

Cuyama Valley. The Cuyama Valley consists of the drainage area of the Cuyama River above Vaquero Dam, and embraces portions of San Luis Obispo, Santa Barbara, Ventura, and Kern Counties. The floor of Cuyama Valley lies at an elevation of about 2,000 to 2,500 feet above sea level along the upper reaches of the Cuyama River. Below the lower end of the valley the river flows in a relatively narrow canyon through a rugged mountain area.

Mean seasonal natural runoff from the entire Cuyama Valley drainage area is estimated to be only 22,500 acre-feet, most of which originates in the mountainous area at the lower end of the valley. Runoff is directly responsive to precipitation, and the greatest portion occurs immediately after rain during the winter months. Runoff varies greatly from season to season, there being essentially no flow during some years.

Irrigated lands are located principally on the floor of the Cuyama Valley. In addition, there are small irrigable areas lying along the Cuyama River and its major tributaries. At the present time water is used almost entirely for agricultural purposes, and it is believed that this will still be true under ultimate conditions of development.

Essentially all water utilized within the Cuyama Valley is obtained by pumping from the ground water basin underlying the valley floor. Available data indicate that present net draft on the ground water basin exceeds replenishment, and that ground water levels are experiencing a perennial lowering. No existing service storage developments are in the valley.

As has been indicated, water resources of the Cuyama Valley are relatively meager. With the exception of infrequent peak flood flows, essentially all of the stream flow originating in the mountain area of the upper end of the valley percolates to the ground water basin underlying the valley. The relatively large amount of ground water storage capacity in this basin is adequate to conserve this percolating water for pumped withdrawals by overlying landowners. It is therefore not considered practicable to give consideration to plans for further local water supply developments in the upper valley. Moreover, the runoff originating in the mountain areas at the lower end of the valley passes down the canyon of the Cuyama River and will be almost entirely controlled by conjunctive operation of Vaquero Reservoir and the Santa Maria ground water basin, as previously described.

As is the case with the Santa Maria Valley, it is concluded that accomplishment of the objectives of The California Water Plan in the Cuyama Valley would be contingent upon an import from areas of surplus elsewhere in the State. The cost of such water would be high. Provision of supplemental water supplies in the amount of 53,000 acre-feet per season would satisfy fully the requirements of all lands considered susceptible of water service in the Cuyama Valley. However, because of the very limited opportunity for re-use of applied water in the valley, a gross seasonal delivery of 80,000 acre-feet would be required. This delivery would be provided through facilities of the Carrizo-Cuyama Aqueduct. The excess water, amounting to 27,000 acre-feet per season, would be available for re-use in the downstream Santa Maria Valley.

Santa Barbara Group. The Santa Barbara Group consists of the area lying south of the southerly boundary of the Santa Maria River watershed and westerly of the boundary of the South Coastal Area. Included are the watersheds of San Antonio Creek and the Santa Ynez River, as well as many minor streams. The group is situated almost entirely within Santa Barbara County with the exception of a small area of Ventura County along the easterly edge.

Presently developed irrigated areas in the Santa Barbara Group are located near the City of Santa Barbara, on the Lompoc Plain at the mouth of the Santa Ynez River, and in the narrow valley along the Santa Ynez River inland from the Lompoc Plain. The principal urban areas are the City of Santa Barbara and the City of Lompoc and suburban areas adjacent thereto. The City of Santa Barbara receives its water supply principally from surface storage facilities. However, surrounding areas obtain water from small local ground water basins.

The present (1950) seasonal water requirement of lands in the Santa Barbara Group is estimated to be about 93,000 acre-feet. Of this total requirement, about 62,000 acre-feet is developed from underlying ground water resources and the remainder is supplied by surface storage developments. Although the ground water basins are physically meeting the present draft thereon, certain small local ground water basins in the vicinity of Santa Barbara are presently experiencing an aggregate overdraft of about 2,300 acre-feet per season.

The principal ground water basins in the Santa Barbara Group are located on the coastal plain at the mouth of San Antonio Creek, and in the rolling hill area inland from the Lompoc Plain and north of the Santa Ynez River. Smaller ground water basins are situated along the Santa Ynez River and on the Lompoc Plain. The presently developed ground water yield aggregates about 60,000 acre-feet per season.

At the present time, there are three surface storage developments of significant size on the upper reaches of the Santa Ynez River, namely: Jameson Lake, with a storage capacity of 6,700 acre-feet; Gibraltar Reservoir, with a capacity of 14,500 acre-feet; and Cachuma Reservoir, a United States Bureau of Reclamation project, with a capacity of 210,000 acre-feet. Water conserved by these reservoirs is conveyed by tunnels through the Santa Ynez Mountains for use in and adjacent to Santa Barbara.

The probable ultimate mean seasonal water requirement of lands in the Santa Barbara Group is estimated to be about 343,000 acre-feet. Considering the developed yield of ground water and existing surface storage works, the requirement for supplemental water may ultimately amount to about 229,000 acre-feet per season.

Plans for further development of local water resources of the Santa Barbara Group are limited to the further control of the Santa Ynez River. Because of the relatively small amount of water available for further development, the objectives of The California Water Plan in the group would necessarily be accomplished by an import of water from areas of surplus in other parts of the State.

Camuesa Dam and Reservoir on the Santa Ynez River upstream from Gibraltar Dam, and Salsipuedes Dam and Reservoir on Salsipuedes Creek about 2.5 miles upstream from the confluence with the Santa Ynez River would jointly develop about 11,200 acre-feet per season of additional local water supplies. Water conserved by Camuesa Reservoir would be released into the channel of the Santa Ynez River, passing through the existing Cachuma Reservoir, for diversion to lands adjacent to the river downstream therefrom. Water from Salsipuedes Reservoir would be released into the stream channel to recharge the ground water basin underlying the Lompoc Plain, to be pumped therefrom; or it could be conveyed directly from the dam to the Lompoc area by pipe line.

It should be noted that all or a portion of the yield developed by Camuesa Reservoir could be conveyed through existing tunnels to the area south of the Santa Ynez Mountains. On the other hand, it would be possible to use all or a portion of the yield of the presently constructed reservoirs in the Santa Ynez watershed. However, the changes in the distribution of the local waters would not affect the total quantity of imported water required within the Santa Barbara Group, but would merely redistribute this import requirement between the various areas of the group.

As an alternative to Camuesa Reservoir, consideration was also given to possible developments on the Santa Ynez River at the Hot Springs site and at the Santa Rosa site. However, it was found that a development at either site would be much more costly than at the Camuesa site, and that a development at the Santa Rosa site would flood the majority of the irrigable lands on the floor of Santa Ynez Valley.

The foregoing local water development works would control the runoff of the Santa Ynez River to the maximum degree considered practicable, developing 11,200 acre-feet per season of new yield for use in the area. The remainder of the supplemental water requirements under ultimate conditions, amounting to about 240,000 acre-feet per season, would be imported through facilities of the Central Coastal Aqueduct, a feature of the California Aqueduct System. A gross seasonal delivery of 255,000 acre-feet would be necessary to meet this requirement.

Although no consideration was given to possible improvement of channels or reservation of reservoir storage for the purpose of flood control, operation of Camuesa and Salsipuedes Reservoirs, with total capacities of 156,000 acre-feet, could provide some reduction of peak flows in the Santa Ynez River as a result of temporary surcharge storage above the spillway lip, and by the probable availability of some unused storage space during most years because of the large reservoir capacity on that stream. Operation of the foregoing reservoirs would also provide a measure of enhancement of fishery resources and recreational opportunities.

Summary of Central Coastal Area. The Central Coastal Area is an area of inherent water deficiency, because the yield obtainable from local water resources developed to their maximum practicable extent would be substantially less than the probable ultimate water requirements of the area. Objectives of The California Water Plan in the Central Coastal Area would be accomplished by further development of local water resources and by imports through facilities of the California Aqueduct System. Of the total ultimate supplemental water requirement of some 1,680,000 acre-feet per season, only 468,000 acre-feet would be provided by increased development of local water resources.

The prospective local developments in the Central Coastal Area would consist of 30 storage reservoirs with an aggregate active capacity of 1,800,000 acre-feet, of which 1,650,000 acre-feet would be devoted to water conservation, and 150,000 acre-feet of storage would be reserved in San Lucas Reservoir for control of floods. In addition, surface reservoirs would be operated in conjunction with downstream ground water storage, to develop the optimum yield from local water resources wherever available. Certain of these reservoirs could be operated for flood control in addition to conservation, while the others would provide a measure of incidental flood control. Operation of these reservoirs would considerably enhance the recreational potential and warmwater fishery.

Supplemental water in the net seasonal amount of about 1,160,000 acre-feet to meet the ultimate requirements of all lands considered susceptible of water service in the Central Coastal Area would be provided through facilities of the California Aqueduct System. This would require an aggregate gross delivery of 1,213,000 acre-feet per season, as shown in the following tabulation:

Aqueduct facility	*Group*	*Delivery, in acre-feet*
South Bay Aqueduct	Santa Cruz-Monterey	15,000
	San Benito	113,000
Central Coastal Aqueduct	Salinas River	335,000
	San Luis Obispo	30,000
	Santa Maria Valley	140,000 *
	Santa Barbara	255,000
Carrizo-Cuyama Aqueduct	Carrizo Plain	245,000
	Cuyama Valley	80,000
Total		1,213,000

* An additional 27,000 acre-feet would be available from return flow from Cuyama Valley.

Data on the general features and costs of the local development works investigated as features of The California Water Plan in the Central Coastal Area are presented in Table 11. The locations and layouts of all of these facilities are delineated on Sheets 10, 13, 16, 17, and 20 of Plate 5.

South Coastal Area

The South Coastal Area comprises the drainage areas of those streams discharging into the Pacific Ocean between the southeastern boundary of the Rincon Creek watershed near the Santa Barbara-Ventura county line on the north, and the Mexican border on the south. All of Orange County, major portions of the Counties of Los Angeles, Riverside, San Bernardino, San Diego, and Ventura, and small areas in the Counties of Kern and Santa Barbara are included within the boundaries of the area.

The South Coastal Area contains over one-half of the State's population, with about seven per cent of its area, but receives less than two per cent of the total runoff of the State. Because of its desirable climate, and other factors such as strategic location for military and industrial installations, this area has experienced a growth in population and industry during the past half century which is unparalleled in the history of the United States. This rapid growth has accelerated during the past decade and as yet has shown no indication of levelling off. The population of the entire area in 1955 was about 7,000,000. It is estimated that within the next century the State will attain a population of over 40,000,000, of which about 45 per cent will be located within the South Coastal Area.

The principal population centers in the South Coastal Area are the Cities of Los Angeles and San Diego, both surrounded by densely populated metropolitan areas. These cities owe their phenomenal growth and present large population not only to the influx of retired folks and tourists attracted by the climate, but to the migration of large numbers of workers attracted by the industrial and commercial growth which the area has experienced. It has been estimated that the Los Angeles and Orange Counties area ranks third among the industrial areas in the

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN CENTRAL COASTAL AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Net	Seasonal yield, in acre-feet[a]	Purpose	Place of water use	Capital cost[b]
Santa Cruz-Pajaro Group											
Archibald	Scott Creek	Sec. 18, T10S, R3W 10	E	134	152	20,000	19,800	10,000	I,U	Coastal area north of Santa Cruz	$2,011,000
Bear Creek	Bear Creek	Sec. 10, T9S, R2W 10	E	185	861	8,500	8,200	4,900	U,R	San Lorenzo Basin	2,469,000
Zayante	Zayante Creek	Sec. 36, T9S, R2W 10	E,R	140	603	6,900	6,800	3,900	U,R	San Lorenzo Basin	1,299,000
Doyle Gulch	Rodeo Gulch	Sec. 4, T11S, R1W 13	E	210	314	14,500	14,300	13,200	U	Santa Cruz-Soquel	2,497,000
Glenwood	West Branch Soquel Creek	Sec. 10, T10S, R1W 10	E,R	111	500	2,500	2,400	2,000	I,U	Soquel Creek Basin	632,000
Upper Soquel	Soquel Creek	Sec. 12, T10S, R1W 10	E,R	109	555	1,700	1,600	2,100	I,U	Soquel Creek Basin	709,000
Aptos Creek	Aptos Creek	Sec. 7, T11S, R1E 13	E	132	164	4,100	4,000	2,300	I,U	Aptos area	1,406,000
Watsonville	Corn Cob Canyon	Sec. 14, T12S, R2E 13	E	158	205	21,000	20,400	9,700	I,U	Pajaro River area	3,256,000
San Benito Group											
Enlarged Uvas	Uvas Creek	Sec. 18, T10S, R3E 10	E	158	534	[c]24,000	[c]24,000	6,400	I	South Santa Clara Valley	2,597,000
San Benito	San Benito River	Sec. 5, T16S, R8E 13	E	190	1,317	50,000	43,700	7,000	I	San Benito River area	3,214,000
Cienega	San Benito River	Sec. 10, T14S, R6E 13	E	113	663	40,000	34,000	5,300	I	Hollister area	2,978,000
Harper Canyon	Pacheco Creek	12,000 acre-feet of storage allocated to local development, 53,000 acre-feet to the South Bay Aqueduct. See Table 23.						2,000	I,S	Pacheco Creek area	Table 24
Monterey-Carmel Group											
Klondike	Carmel River	Sec. 11, T17S, R2E 13	E,R	216	525	56,100	55,100	27,300	U,I	Monterey Peninsula	10,753,000
Salinas River Group											
Santa Rita	Santa Rita Creek	Sec. 4, T28S, R11E 16	E	153	1,143	15,000	14,500	3,200	I,U	Atascadero-Templeton area	1,404,000
Lower Jack	Jack Creek	Sec. 18, T27S, R11E 16	E	160	1,130	25,000	24,500	4,600	I,U	Atascadero-Templeton area	1,751,000
San Miguelito	Nacimiento River	Sec. 19, T23S, R7E 16	E	175	1,268	130,000	130,000	13,000	I,U	Salinas Valley and Paso Robles	3,017,000
Jarrett Shut-in	Nacimiento River	Sec. 19, T24S, R8E 16	CA	233	1,114	110,000	110,000	11,000	I,U	Salinas Valley and Paso Robles	4,691,000
Milpitas "B"	San Antonio River	Sec. 11, T22S, R6E 13	E	225	1,288	175,000	174,000	18,500	I	Salinas and Lockwood Valleys	8,139,000
Pleyto "B"	San Antonio River	Sec. 34, T24S, R10E 16	E	168	753	200,000	197,000	21,000	I	Salinas and Lockwood Valleys	4,667,000
San Lucas	Salinas River	Sec. 26, T20S, R8E 13	E	103	405	375,000	361,000	14,600	I,FC	Salinas Valley	22,476,000
Greenfield	Arroyo Seco	Sec. 16, T19S, R6E 13	E	225	555	100,000	96,000	24,100	I	Salinas Valley	8,296,000
Carrizo Plain (no local works)											
San Luis Obispo Group											
Bald Top	San Carporforo Creek	Sec. 2, T25S, R6E 16	E	190	845	20,000	19,500			San Luis Obispo area	2,249,000
Ragged Point	San Carporforo Creek	Sec. 15, T25S, R6E 16	E	250	300	30,000	29,500	22,500	I,U	San Luis Obispo area	5,420,000
Yellow Hill	Arroyo de la Cruz	Sec. 35, T25S, R6E 16	E	204	220	80,000	79,000	79,300	I,U	San Luis Obispo area	6,401,000
San Simeon	San Simeon Creek	Sec. 10, T27S, R8E 16	E	182	224	60,000	59,500	18,200	I,U	San Luis Obispo area	6,944,000
Santa Rosa	Santa Rosa Creek	Sec. 16, T27S, R9E 16	E	210	438	35,000	34,500	11,100	I,U	San Luis Obispo area	4,121,000
Whale Rock	Old Creek	Sec. 34, T28S, R10E 16	E	175	203	40,000	39,500	8,900	I,U	San Luis Obispo area	2,884,000
Lopez	Arroyo Grande	Sec. 32, T31S, R14E 16	E	159	518	50,000	49,000	6,500	I,U	Arroyo Grande area	4,228,000
Santa Maria Valley	(no local works)										
Cuyama Valley	(no local works)										
Santa Barbara Group											
Camuesa	Santa Ynez River	Sec. 7, T5N, R26W SBB&M 20	E	202	1,555	110,000	103,000	5,800	I	Santa Ynez River Basin	7,419,000
Salsipuedes	Salsipuedes Creek	Sec. 13, T6N, R34W SBB&M 20	E	180	332	46,000	45,000	5,400	I	Lompoc Plain	3,686,000
Totals						1,850,300	1,799,800				131,614,000

TABLE 11—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN CENTRAL COASTAL AREA

(These works show future development possibilities. They are not project proposals.)

Associated features	Length of conduit, in miles			Pumping plants			Capital cost[b]
	Canal	Pipe	Total	Total number	Installed capacity, in kilowatts	Seasonal power consumption, in kilowatt-hours	
Santa Cruz-Pajaro Group	1.0	5.0	6.0	3	5,740	7,300,000	$1,745,000
San Benito Group	1.3		1.3				663,000
Monterey-Carmel Group							
Salinas River Group	117.0	31.0	148.0				17,493,000
Carrizo Plain							
San Luis Obispo Group		59.0	59.0				21,369,000
Santa Maria Valley							
Cuyama Valley Group							
Santa Barbara Group							
Totals	119.3	95.0	214.3	3	5,740	7,300,000	$41,270,000

Symbols of Type of Dam
E—Earthfill
R—Rockfill
CA—Concrete arch

Symbols of Purpose
I—Irrigation
U—Urban (domestic, municipal. industrial)
R—Recreation
S—Reregulation of imported waters to local demand schedules
FC—Flood control

[a] Reservoirs of the Salinas River Group would be operated in conjunction with ground water storage to develop an additional yield of 50,000 acre-feet per season
[b] At 1955 price levels.
[c] Enlarged to 34,000 acre-feet from its present capacity of 10,000 acre-feet.

nation, and that nearly one-third of the two million persons employed in the two counties are engaged in manufacturing enterprises.

There are many military reservations in the South Coastal Area, the largest of which are under the jurisdiction of the Department of the Navy. The headquarters of the Eleventh Naval District with training, air, and repair facilities, is located at San Diego, and is a very important element in the economy of that area. Other Department of Navy facilities in the South Coastal Area include several Marine bases, the largest of which is Camp Pendleton, and two major bases in Ventura County. Army and Air Force establishments are distributed throughout the area, the principal base being March Air Force Base in Riverside County.

Concurrently with, but not always paralleling, the population expansion in the South Coastal Area has been the growth of irrigated agriculture. The mild climate allows the production of citrus, avocados, fruits, and nuts, all of which are high-value crops. The phenomenal expansion of population, agriculture, and industry has created ever increasing demands for water. Local water supplies have been obtained to a great extent through exploitation of the large ground water reservoirs. However, these local water supplies are limited and are far from sufficient to support the existing development. In 1950, about one-fourth of the total water used represented overdraft on ground water storage, and one-fourth was water imported from sources outside the area.

The South Coastal Area has a long history of irrigated agriculture dating back to the days of the missions in the eighteenth century. Intensive development of irrigated agriculture began in the late nineteenth century and has progressed rapidly to recent times. In 1950, it was estimated that the net irrigated area totaled some 617,000 acres, nearly one-half being devoted to the production of citrus, avocados, and other specialty crops.

During the past half century, there has been an increasing expansion in the area occupied by urban and industrial developments, with the gross urban area estimated to have been 548,000 acres in 1950. Urbanization has been greatly accelerated in the past few years. This development has taken place largely on agricultural lands immediately adjacent to existing urban areas, and it is considered probable that future urbanization will generally be at the expense of present agricultural areas. The area that will be ultimately occupied by urban and industrial development is estimated to be 1,611,000 acres.

Increase in the area of irrigated lands probably will be dependent in large part upon the availability of an imported water supply, and will occur both by application of water to presently dry-farmed areas and by bringing under cultivation lands not presently farmed due to lack of adequate water supplies. It is estimated in State Water Resources Board Bulletin No. 2 that a gross area of 1,156,000 acres will be devoted to irrigated agriculture under conditions of ultimate development.

The climate of the South Coastal Area is characterized by relatively mild temperatures and light precipitation in the coastal areas, and by somewhat wider temperature variation and heavier precipitation in the inland areas. Precipitation on the area generally varies from as little as 10 inches along the coast to over 40 inches in some of the higher mountain areas.

At present, water supplies in the South Coastal Area are obtained principally by pumping from underlying ground water basins, by storage in and diversion from surface reservoirs, and by importation from the Colorado River and from the Owens River and Mono Basin. Although a large quantity of water is obtained by individual pumping, most of the lands requiring water are served by a multitude of water companies or public agencies, with service areas varying from a few acres to many square miles in extent.

The Metropolitan Water District of Southern California has a right, presently under litigation, to 1,212,000 acre-feet of Colorado River water annually, of which amount about 400,000 acre-feet was delivered in fiscal year 1956. Operating at full capacity, the Owens-Mono Aqueduct of the City of Los Angeles presently delivers about 320,000 acre-feet annually into the area. Water requirements in the South Coastal Area under probable ultimate conditions of development are estimated to total 5,552,000 acre-feet per season. With the Colorado River and Los Angeles Aqueducts operating at full capacity, there will remain about 3,000,000 acre-feet of water per season which must be obtained from further development of local water resources, or from importation through facilities of the California Aqueduct System. Plans for further development of local water supplies subsequently presented herein would increase the safe seasonal local yield by only about 149,000 acre-feet, which appears to be the maximum practicable amount of additional conservation, leaving in excess of 2,800,000 acre-feet of water per season which must be imported from northern California.

Although the South Coastal Area is classified as an arid region, the tributary watersheds occasionally receive precipitation in torrential amounts which produce extremely high intensities of flood runoff in the streams draining the area. These floods have resulted in large financial losses in property damage due to inundation, erosion, and deposition of debris, as well as loss of life. Intensive development of urban areas adjacent to the flood channels has greatly increased the flood damage hazard in most of the area.

The most comprehensive system of flood control works in the area is that of the Los Angeles and San

South Coastal Area—Los Angeles River

Gabriel Rivers and Ballona Creek project now under construction by the Corps of Engineers, U. S. Army, in cooperation with the Los Angeles County Flood Control District, with financial participation by the State of California. Flood control works of lesser magnitude have been constructed on streams throughout the remainder of the area, and additional small flood control works will probably become necessary in the future as a result of intensive urbanization of the area. However, these works would consist mainly of channel improvement measures which are not considered to be within the scope of The California Water Plan. The additional reservoir developments described hereinafter, with the exception of the enlarged Hodges Reservoir on San Dieguito River, include no specific storage reserves for flood control purposes.

Plans for accomplishment of the objectives of The California Water Plan for the South Coastal Area envision the development of additional yield from local water resources to the maximum practicable degree by capture of waters presently wasting to the ocean, and construction of works adequate to convey and regulate sufficient additional imported water to provide fully for water requirements which will exist under probable ultimate conditions of development. In the formulation of plans, consideration was given to coordination of their construction and operation with existing water supply developments in the area, both surface and underground, to the maximum practicable extent.

Inasmuch as a high degree of conservation of runoff from most streams in the South Coastal Area has already been effected by surface storage developments and by artificially recharged underground storage, further conservation of the infrequent waste to the ocean by means of surface reservoirs will necessitate very large storage capacities with respect to the magnitude of the conserved supplies, with attendant long carry-over periods. Developments will be quite costly, and the additional yield quite small with respect to ultimate water requirements. The desirability of constructing a local conservation development at a given time, or the question of whether such developments should be undertaken at all, will be matters for local decision, and will be based upon many factors, including the financial capacity of the constructing agency, the amount of water required at the time construction is contemplated, the availability of a firm supply of imported water at that time, and the unit cost of imported water as compared to the unit cost of yield from a local water resource development. However, because of the small quantities of water involved, future deviation in the plans for local water resource development considered herein would have little material effect upon the over-all plan.

It must be realized that there are numerous factors which, under constant change, tend to alter ground water recharge and the safe yield of ground water basins. Urbanization, with accompanying increase in impervious areas, produces two opposite phenomena. On the one hand consumptive use of precipitation is greatly reduced, increasing the water supply available for conservation, while on the other hand runoff is increased, which, with increased storm drain facilities, may reduce recharge opportunity. Impervious channel lining for flood control purposes decreases the opportunity for recharge of underground basins from flood waters, while construction of spreading grounds tends to compensate for this effect. The effect of operation of flood control reservoirs on the regimen of stream flow can generally increase the opportunity for percolation of flood flows.

Artificial recharge of ground water basins in conjunction with the operation of both flood control and conservation reservoirs is presently accomplished or is planned where practicable. For purposes of this bulletin it is assumed that this practice will result in the maintenance of the present safe yields of the ground water basins. Because, as stated, waste to the ocean now occurs infrequently, the amounts by which the present safe yields might be increased through artificial recharge will be relatively small.

For purposes of analysis, the South Coastal Area has been subdivided into three groups; namely the Ventura Group, the Los Angeles-Santa Ana Group, and the San Diego Group. The location of these groups is shown on Plate 3. In the following sections, plans are presented for the development of local water supplies in each of these groups.

Ventura Group. The Ventura Group consists of the drainage areas of streams flowing into the ocean between the northerly boundary of the South Coastal Area and Topanga Creek, including the Ventura and Santa Clara Rivers, Calleguas Creek, and several smaller creeks. The largest part of the area comprising the group is occupied by mountains and hills. The mountains northerly of the Santa Clara River are quite rugged and reach elevations in excess of 8,000 feet. The majority of the valley lands are on the coastal plain near the mouths of the Santa Clara River and Calleguas Creek, with smaller valley areas located inland along these streams and the Ventura River.

The 1950 federal census reported the population of Ventura County to be 114,647, and by January, 1957, the population had increased to an estimated 159,300. In 1950, the populations of major cities in the county included: Oxnard, 21567; Ventura, 16534; and Santa Paula, 11,049. The oil industry is the leading industry in the county. Other principal industries include agriculture and the associated processing and packing of vegetables and citrus fruits and the processing of sugar beets.

At the present time the Santa Clara River Valley, the coastal plain, and portions of the Ventura River and Calleguas Creek drainage areas are extensively developed to irrigated agriculture. Land use surveys conducted in Ventura County during 1949-50 showed that there were in excess of 109,000 acres of irrigated land. Principal crops were citrus with about 43,000 acres, beans with about 33,000 acres, and walnuts with slightly less than 18,000 acres.

The mild climate typical of the South Coastal Area prevails in the Ventura Group, with proximity to the ocean providing a moderating effect throughout most of the developed area. In excess of 80 per cent of the mean seasonal precipitation occurs during the months of December through March. Killing frosts in the Ventura County area are extremely rare, and consequently, portions of this region are producing as many as three crops per year.

With the exception of small amounts of direct surface diversion, the presently utilized water supplies in the Ventura Group are obtained by pumping from several major ground water basins which underlie most of the developed area. It is estimated that the total usable ground water storage capacity in these basins is over 1,000,000 acre-feet, of which about 400,000 acre-feet has been utilized to date. Off-stream spreading works have been operated by the Santa Clara Water Conservation District and its successor, the United Water Conservation District, since about 1927. During the wet year 1951-52 about 11,800 acre-feet of water was diverted from Piru Creek and percolated in the Piru spreading grounds. During the same year about 25,400 acre-feet of water diverted from the Santa Clara River was spread in the Saticoy grounds. Diversion capacities were 75 second-feet and 145 second-feet, respectively. During 1955, the capacity of the conduit leading to the Saticoy spreading grounds was increased to 375 second-feet, and a 42-inch diameter conduit with a capacity of about 150 second-feet was extended to the El Rio spreading ground a short distance downstream. Presently developed safe yield from ground water and from relatively small diversions of unregulated surface flow is estimated to be about 126,000 acre-feet per season.

There are presently only two major surface storage reservoirs in the area. Matilija Reservoir on Matilija Creek, a tributary of the Ventura River, is owned and operated by the Ventura County Flood Control District. It has a storage capacity of about 7,000 acre-feet, and an estimated safe yield of about 1,400 acre-feet per season. Santa Felicia Reservoir on Piru Creek, a tributary of the Santa Clara River, was recently completed by the United Water Conservation District. Storage capacity is about 100,000 acre-feet, and it is estimated that the reservoir will increase the safe yield available from the Santa Clara River system by about 15,000 acre-feet per season if conveyance facilities, hereinafter described, are constructed to carry water from the reservoir to the coastal plain to alleviate present ground water overdraft therein.

Work was recently started on construction of the Ventura River Project by the United States Bureau of Reclamation. This project will provide a new yield of about 27,000 acre-feet per season, which is more than sufficient to provide for the present supplemental water requirement of 4,000 acre-feet per season in the area included within the Ventura River Municipal Water District, the local contracting agency, and would satisfy all but about 3,000 acre-feet of the probable ultimate seasonal water requirements therein. The project includes a reservoir of 250,000 acre-foot capacity at the Casitas site on Coyote Creek, a tributary of the Ventura River. In addition to storage of flows of Coyote Creek, the reservoir would store flows diverted from the main stem of the Ventura River by means of Robles Diversion Dam and a 500 second-foot conduit to Casitas Reservoir.

It was estimated in State Water Resources Board Bulletin No. 12 that draft on ground water in the coastal plain of Ventura County in 1951 exceeded the safe yield by 59,000 acre-feet per season. It is estimated that, with full realization of the safe yield of the recently completed Santa Felicia Reservoir, this overdraft would be reduced to about 44,000 acre-feet per season. This overdraft may be attributed to two factors: inadequate cyclic carry-over storage capacity in the ground water forebay area, and a lack of sufficient carrying capacity in the pressure aquifers underlying the coastal plain to transmit enough water to prevent the pressure surface elevations from dropping below sea level during periods of heavy pumping draft, thus creating conditions conducive to the intrusion of sea water.

In the uppermost reaches of the Santa Clara River in Los Angeles County, there is a substantial area of irrigable land partly underlain by ground water basins. These basins are presently being pumped but show no evidence of overdraft. However, irrigation of all the lands in the valley will require importation of water, as natural recharge to the basin is limited.

In the Piru, Fillmore, and Santa Paula Basins, lying along the Santa Clara River between the Los Angeles County boundary and the coastal plain of Ventura County, there is no present overdraft, nor is it anticipated that there will be one under ultimate conditions of development.

In the inland portion of the Calleguas Creek watershed, it is estimated that usable ground water storage capacity totals about 200,000 acre-feet. However, due to the generally light precipitation and limited flow in tributary streams, mean seasonal recharge is quite limited, and there is virtually no opportunity for further conservation of local supplies. In State Water Resources Board Bulletin No. 12 it was estimated that, in 1951, there was a ground water overdraft of about 9,000 acre-feet per season in this area. Temporary relief could be obtained by importation of water from Santa Clara River if water rights problems involved in diversion of water from that stream were resolved. Ultimate solution of the water problems in the Calleguas Creek area will, in any event, necessitate importation of large quantities of water through facilities of the California Aqueduct System.

The area southerly of Calleguas Creek is, in large part, mountainous, and is drained by several creeks discharging directly into the ocean, the largest of which is Malibu Creek. Water is obtained primarily by pumping from numerous small ground water basins. Although there are some localized water shortages, it is believed that the present over-all safe yield is just about in balance with present water requirements. However, further increase in water requirements will necessitate importation of water from outside sources.

Present and probable ultimate seasonal water requirements in the Ventura Group are summarized in the following tabulation, wherein the safe yield of local water supplies for ultimate conditions includes the yields of the additional water supply developments hereinafter described.

	Acre-feet per season
Present conditions (1950)	
Water requirement	199,000
Safe yield of local water supplies	142,000
Supplemental water requirement	57,000
Probable ultimate conditions	
Water requirement	512,000
Safe yield of local water supplies	229,000
Requirement for imported water	283,000

Further conservation of runoff in the Santa Clara River could be effected by construction of surface storage on major tributaries thereof. Possible storage developments include a 50,000 acre-foot reservoir at the Blue Point site on Piru Creek, a 100,000 acre-foot reservoir at the Topatopa site on Sespe Creek, and a 100,000 acre-foot reservoir at the Cold Spring site on Sespe Creek. The Santa Clara River Conduit, with a maximum capacity of 120 second-feet, could be constructed from the existing Santa Felicia Reservoir to a distribution system serving the pressure area of the coastal plain. Water released from the reservoirs on Sespe Creek would be diverted from the stream channel downstream from Topatopa Dam, and conveyed into the Santa Clara River Conduit at its crossing of Sespe Creek for delivery to the coastal plain. The locations of the foregoing facilities are shown on Sheet 21 of Plate 5.

Conveyance of waters from the reservoirs in a conduit would increase the amount of water available to the coastal plain. If the stream channel were used for conveyance, a large portion of the water released from the reservoirs would percolate before reaching the coastal plain during extended periods of drought, and would not be available for use thereon. Solution of the problem of sea-water intrusion would require construction of a surface distribution system on the coastal plain area so that, by delivery of surface water supplies, ground water withdrawals could be reduced to amounts within the limits of transmissibility of the underlying aquifers without drawing the pressure gradients down below sea level. Such a system covering a portion of this area is presently under construction by the United Water Conservation District. Solution of the problem would also require the pumping of water from the coastal plain forebay and its operation in conjunction with upstream surface and ground water reservoirs.

In addition to the new yield made available to the coastal plain from the foregoing surface developments, it is estimated that an ultimate net increase in ground water yield in the amount of 26,000 acre-feet per season could be developed by increased extractions of water from ground water basins along the Santa Clara River upstream from the coastal plain. Under ultimate conditions of development, and after construction of further local developments as previously discussed, an estimated 238,000 acre-feet per season of imported water would be needed in the coastal plain, in the portion of the Santa Clara River watershed in Los Angeles County, in the upper Calleguas Creek watershed, in the Malibu Creek drainage area, and along the coastal strip southerly from Calleguas Creek. The California Water Plan envisions conjunctive operation of underground and surface storage in the Ventura Group.

Los Angeles-Santa Ana Group. The Los Angeles-Santa Ana Group includes the San Fernando, San Gabriel, upper Santa Ana, and San Jacinto Valleys; the coastal plain of Los Angeles and Orange Counties; and tributary mountain and hill areas. Included are the drainage areas of the Los Angeles, San Gabriel, and Santa Ana Rivers, as well as several minor streams discharging into the Pacific Ocean between Santa Monica and Newport Beach. About one-half of the total area is occupied by valley and mesa lands. The tributary mountain area separating this group from the Lahontan and Colorado Desert Areas is quite rugged and reaches elevations in excess of 10,000 feet. A range of hills of lower relief separates the inland valleys from the coastal plain.

The Los Angeles-Santa Ana Group contains one of the most populous urban regions in the nation. Population within the group in 1955 was about 6,000,000, or approximately 45 percent of the total for the State. In excess of 2,000,000 people now reside within the City of Los Angeles. In addition, there is extensive agricultural development. In 1950, nearly 70 percent of the irrigated lands in the South Coastal Area were located within the Los Angeles-Santa Ana Group.

Water supplies required by the foregoing urban and agricultural development were first obtained by direct surface diversions and some small surface storage developments. Continuation of the development resulted in intensive utilization of the large ground water basins underlying the valley and coastal plain lands. Of the total underground storage capacity, about 7,000,000 acre-feet of capacity is considered usable, on the basis of those factors of basin configuration, economic pumping lift, and others, as described in the appendix on ground water. The utilization of about 4,500,000 acre-feet of this storage historically has resulted in the development of a safe yield from the local water supplies of 780,000 acre-feet per season.

In the light of the great importance of ground water basins to the economy of the Los Angeles-Santa Ana Group, many steps have been undertaken to assure the fullest practicable utilization of these basins. Percolation in natural stream channels is augmented by spreading operations during periods of flood. At the present time there are 70 artificial recharge projects in the Los Angeles-Santa Ana Group, with a capacity sufficient to spread a continuous flow of about 17,000 second-feet. An additional 55 artificial recharge projects, with capacity of about 4,000 second-feet, are proposed for construction by various local agencies in the group. It is estimated that over 1,000,000 acre-feet of water have been spread since 1900 in the upper Santa Ana Valley alone. The Los Angeles County Flood Control District is constructing spreading works throughout pervious areas of the county to enhance natural percolation, and to attempt, insofar as possible, to replace losses in percolation capacity resulting from lining of stream channels for flood control purposes. The district is also presently engaged in injecting Colorado River water into confined aquifers in the Manhattan Beach area of the West Coast Basin to create a pressure ridge along a portion of the coast line, in an effort to repel sea water. Additional Colorado River water is spread in the forebay areas of the Los Angeles and Orange Counties coastal plains.

In addition to providing the equalizing storage capacity necessary to regulate the erratic natural inflow, the ground water basins provide a natural distribution system. A considerable part of the water used for agricultural lands is obtained from ground water by individual effort, and the use of ground water basins eliminates much of the cost which would otherwise be incurred in the construction of necessary distribution facilities.

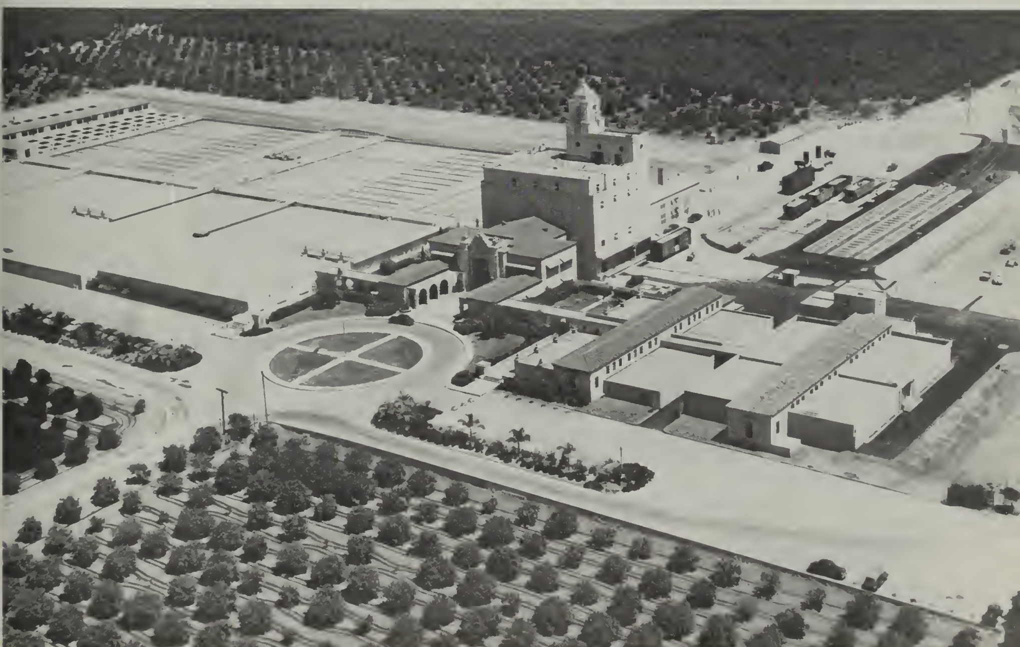
Urbanized areas in the Los Angeles-Santa Ana Group are served water by surface distribution systems of a number of agencies, the largest of which is the Department of Water and Power of the City of Los Angeles. However, even in some of these urbanized areas supplied in part from ground water storage, ground water basins function as a means of conveyance of water to convenient points of delivery to the numerous water service agencies.

Water has been imported to the South Coastal Area from the Owens River and Mono Basin via the Los Angeles Aqueduct by the City of Los Angeles since 1916, and from the Colorado River via the Colorado River Aqueduct by The Metropolitan Water District of Southern California since 1941. The Department of Water and Power of the City of Los Angeles reports that about 319,000 acre-feet per season can be imported from the Owens River and Mono Basin through the Los Angeles Aqueduct and that the full capacity of this facility is presently being utilized.

The Metropolitan Water District of Southern California has rights to the waters of the Colorado River for service in both the Los Angeles-Santa Ana and San Diego Groups in the amount of 1,212,000 acre-feet per season, although this is presently under litigation. It is estimated that due to conveyance and regulation losses, only 1,140,000 acre-feet would be actually available to meet requirements in the South Coastal Area. During 1956, the capacity of the Colorado River Aqueduct was increased to 1,000 second-feet, or about 700,000 acre-feet per season. Plans are under way to complete the aqueduct to its full capacity of about 1,600 second-feet by the year 1960. Representatives of The Metropolitan Water District of Southern California estimate that the full conveyance capacity of this facility will be utilized by the year 1975.

In 1950, draft upon ground water storage in the Los Angeles-Santa Ana Group exceeded replenishment by an estimated average amount of 307,000 acre-feet per season. The most serious manifestations of this overdraft are exhibited in the coastal plain area where, in addition to an actual insufficiency of recharge, the confined aquifers which underlie a large portion of the coastal plain are of inadequate capacity to convey required water supplies from areas of recharge to points of extraction without creation of conditions conducive to the intrusion of sea water. Montebello Forebay, the free ground water area which supplies a large part of the coastal plain pressure area, was essentially full in the early 1940's, while ground water levels coastward thereof were below sea level. At the present time, water levels over the major part of the coastal plain are below sea level, and as a result, sea water has invaded actively pumped aquifers along much of the coast line.

In addition to the foregoing, there are also overdrafts in certain of the interior groundwater basins. Increased use of water in the interior valleys, although not necessarily causing overdraft therein, will tend to diminish the natural supply to the coastal basins,



South Coastal Area—Garvey Terminal Reservoir (top) and F. E. Weymouth Softening and Filtration Plant in the Los Angeles Metropolitan Area thereby tending to increase overdraft in the coastal areas.

As a result of these overdraft conditions, ground water rights have been adjudicated in the Raymond Basin Area in San Gabriel Valley and are in process of adjudication in the West Coast Basin, which occupies the westerly portion of the coastal plain. Extractions from ground water of the Raymond Basin Area were limited to the safe yield thereof by terms of the judgment rendered by the Trial Court in 1944, confirmed by the Supreme Court in 1949. The Superior Court has retained jurisdiction in each of these cases. In the West Coast Basin, most of the parties to litigation have by agreement limited their ground water extractions pending final settlement. In both areas the court appointed the Department of Water Resources as Watermaster to administer provisions of the court decree in the case of Raymond Basin Area and provisions of the current stipulated agreement in the West Coast Basin. In each instance, use of imported water has substantially increased since commencement of watermaster service. Further litigation, such as that now pending in other portions of the group, and subsequent adjudication of rights to extract ground water would save these basins from possible eventual exhaustion and, in some cases, destruction. As a consequence, the use of imported water would be greatly accelerated.

Serious consideration must be given to the problem of salt balance in the underground reservoirs which are so extremely important to the Los Angeles-Santa Ana Group if they are to be preserved for the regulation, distribution, and re-use of native and imported waters. The problems of salt balance have been previously discussed in Chapter II.

Although there are indications of possible present adverse salt balances in several basins in the group, it is believed that, except for certain localized conditions, serious problems will not result under the present level of development. In the future, anticipated large exportations of sewage directly to the ocean should prevent occurrence of adverse salt balance in the San Gabriel and San Fernando Valleys. Similarly, the coastal plain area is provided with necessary outflow in the form of the relatively large extractions from the confined aquifers, the unconsumed residuum of which is largely prevented from returning to the pumped zone. However, in the upper Santa Ana Valley, a very serious situation could develop if careful attention is not given to the problem of salt balance in operation of the ground water basins and in the disposal of waters. As hereinafter discussed, salt balance considerations also influenced the planning of importation facilities with respect to the effect on water quality of imported water supplies from various sources considered.

Present and probable ultimate water requirements, safe local yield, and requirements for imported water in the Los Angeles-Santa Ana Group are summarized in the following tabulation. In 1949-50, a total of about 400,000 acre-feet of water was imported, and about 307,000 acre-feet represented ground water overdraft.

Present conditions (1950)	*Acre-feet per season*
Water requirement	1,483,000
Safe yield of local supplies	776,000
Requirement for imported water	707,000
Probable ultimate conditions	
Water requirement	3,535,000
Safe yield of local supplies	776,000
Requirement for imported water (including importation from Owens-Mono and Colorado River Basins)	2,759,000

It is considered that the present degree of conservation of local surface runoff in the Los Angeles-Santa Ana Group is very near to the maximum that is practicable. Therefore, no plans for additional local water supply developments are hereinafter presented. However, a future recreational development at Lake Elsinore is contemplated by stabilizing and maintaining adequate lake levels.

It is possible that a small amount of additional water could and will be developed from local water supplies by construction of additional artificial ground water recharge works and improved methods of ground water storage operation. However, the amounts of water that could be so obtained are relatively insignificant as compared with the probable ultimate water requirements of the area.

In recent years there have been increasing discussion and study of methods of reclaiming water of suitable quality for irrigation and other uses from the sewage flows presently being discharged into the ocean from the Los Angeles and San Diego metropolitan areas. In connection with statutory responsibilities of the Department of Water Resources, the possibility of reclamation of water from sewage has been studied. The objective of this study was to determine the quantities of water that could be reclaimed, the costs thereof, and potential markets for the reclaimed supply. In certain areas, particularly the upper Santa Ana Valley, involuntary reclamation is occurring by land disposal of sewage treatment plant effluent from interior communities and from cesspools of suburban dwellings. The trend, however, is toward construction of large-scale sewerage systems with ocean disposal because of aesthetic and public health considerations.

Conclusions of the sewage reclamation studies to date are generally that: (1) in the order of 500,000 acre-feet of sewage is discharged annually to the ocean from the Los Angeles metropolitan area and this quantity will increase substantially with continued urban growth; (2) the total quantity of sewage should not be all classed as "waste," since it is serving a beneficial urpose in providing necessary outflow of ground ater extracted for municipal and industrial purposes, thereby removing undesirable salts from the nderlying ground water basin; (3) the mineral ickup inherent in urban and industrial use of water akes the use of reclaimed water for ground water echarge limited in scope because of the possibility f producing an unfavorable salt balance in the round water basin; (4) by its very nature sewage r water reclaimed therefrom accumulates in greatest uantity at the coast at an elevation very near sea vel, requiring expensive conveyance and pumping acilities to make it available for use for ground ater recharge or for industrial uses in the Los ngeles area or farther inland; (5) the effect upon ublic health of use of water reclaimed from sewage or agricultural or urban purposes cannot be fully valuated at this time and, because of aesthetic and ublic health considerations, the market for reclaimed ewage waters may be limited to comparatively small uantities for certain industrial purposes, at least in he near future; and (6) continuing study and periodic evaluation should be given to the feasibility of se of this possible source of water supply, with regard o changes in technological methods and varying conditions by land use and water supply development hat the future may bring. At the present time it does ot appear that reclamation of water from sewage ill affect to a significant degree the demand of the os Angeles-Santa Ana Group for imported water.

San Diego Group. The San Diego Group includes he drainage areas of those streams flowing into the acific Ocean between Newport Beach and the Mexian border. Included are the Santa Margarita, San uis Rey, San Dieguito, San Diego, Sweetwater, Otay, nd Tia Juana Rivers, as well as many minor streams. bout 85 per cent of the area is classified as mounains and foothills. However, much of the hill area ear the coast is gently rolling and suitable for agriultural or urban developments. With the exception f the Temecula-Murrieta area in the upper Santa Margarita River watershed, valley lands are found in cattered small coastal and inland valleys along the major streams, and on coastal mesas near San Diego ay.

Included in the San Diego Group are the densely opulated San Diego metropolitan area surrounding an Diego and Mission Bays and the less populous ut rapidly growing communities of Escondido, Oceanside, Carlsbad, Fallbrook, and Rainbow. It is stimated that the population of San Diego County ncreased from about 550,000 in 1950 to more than 50,000 in January, 1957. About 700,000 of these eople reside in the San Diego metropolitan area.

Aircraft manufacture and fishing are major inustries in the area. The capital investment in plant nd equipment for these industries has almost doubled since 1950. In addition, the headquarters of the Eleventh Naval District including training, repair, air, supply, and radio facilities, are located in the San Diego metropolitan area, and Camp Pendleton, the largest Marine Corps base in the nation, is located near Oceanside.

Agriculture, principally the raising of subtropical fruits, has expanded rapidly in San Diego County during recent years. Although the citrus industry in the South Coastal Area has declined in importance in recent years, the raising of avocados and specialty crops has expanded rapidly. These latter crops have a very high monetary return.

The climate in the San Diego Group is generally mild near the coast, with relatively light precipitation. Proceeding inland, temperature variations become wider and precipitation becomes heavier as elevation increases. Mean seasonal precipitation is approximately 10 inches near the coast and in excess of 40 inches at the highest inland elevations of the tributary watersheds.

Water supplies in the San Diego Group are obtained from numerous small ground water basins, from 12 major and several lesser surface storage developments, and from importations through the two-barreled San Diego Aqueduct. The ground water basins in the area have relatively small capacity and limited recharge. Ground water rights in the Tia Juana Basin are under adjudication, and the basin has been under watermaster service since 1947. Court proceedings have been instituted to adjudicate ground water rights in the San Luis Rey River Basin.

In the years 1941, 1942 and 1943 the United States acquired most of the Rancho Santa Margarita by condemnation and purchase. To these acquisitions it added, by executive order, some public domain lands and established thereupon the United States Naval Ammunition Depot at Fallbrook, the United States Naval Hospital, and Camp Joseph H. Pendleton. Since that time a controversy has arisen between the United States and other water users with regard to the respective right of each to make use of the waters of the Santa Margarita River, which flows through and empties into the ocean on this land held by the United States.

Congress in 1954 undertook to resolve the controversy through legislation. The solution decided upon was the authorization of $22,636,000 for the De Luz Dam on the Santa Margarita River, to be constructed and operated by the Secretary of the Interior acting pursuant to federal reclamation law. The act apparently contemplates a solution of the controversy only as between the Department of the Navy and the Fallbrook Public Utility District. The district must agree, under the terms of the act, that it will not assert against the United States any prior appropriative right it may have to water in excess of the quantity which may be delivered to it under the terms of the act. Sixty per cent of the water impounded by De Luz Dam is allotted by the act to the Secretary of the Navy and forty per cent to the Fallbrook Public Utility District. Storage may not begin, however, until Camp Pendleton and the adjoining naval installations have received all the water to which the United States would be entitled under the laws of California had the dam not been built. The Secretary of the Navy is required to comply with water right acquisition procedures under the laws of California when he is satisfied, with the advice of the United States Attorney General, that such action will not adversely affect rights of the United States under California law. The act provides that water rights are to be determined by the laws of California.

The Executive Branch of the Federal Government sought to resolve the controversy through the prosecution of judicial proceedings. In January, 1951, the United States brought an action against some three thousand defendants to quiet title to water rights claimed to be appurtenant to the lands acquired by the United States. After granting the motion of the State of California to intervene in the proceedings, *United States* v. *Fallbrook Public Utility District*, 101 Fed. Supp. 298 (1951), defining issues affecting Fallbrook, Santa Margarita Mutual Water Company and the State, *United States* v. *Fallbrook Public Utility District*, et al., 108 Fed. Supp. 72 (1952), and ordering a separate trial as against the State and Santa Margarita Mutual Water Company, with their acquiescence, at the same time rendering a decision later described as superfluous and in the nature of proposed findings, *United States* v. *Fallbrook Public Utility District* et al., 109 Fed. Supp. 28 (1952), the United States District Court adjudged, that the Santa Margarita Mutual Water Company and the State of California and each of them "are forever barred from any and all claim of right, title, or interest in and to those rights to the use of water" which the court found vested in the United States. Declaration of Judgment No. 16, *United States* v. *Fallbrook Public Utility District*, et al., 110 Fed. Supp. 767, 788 (1953). The Court of Appeals for the Ninth Circuit reversed the judgment of the District Court, finding error in the breadth of the judgment entered against the State and the Santa Margarita Mutual Water Company. *People of the State of California* v. *United States*, 235 Fed. 2d. 647. The Court of Appeals declared that many of the declarations, findings and conclusions contained in the judgment of the District Court were premature and not well founded in the record before it. The action, which includes the entire Santa Margarita River watershed, was described as being in the nature of a plenary suit to settle the correlative rights of everyone interested in the water. The standard procedure in such a case, the Court declared, is to enter a decree setting up all the rights as of the same date. The case has been remanded to the District Court with a direction that no judgment be entered until the entire suit can be disposed of at the same time.

Due to the limited storage capacity of ground water basins in the San Diego Group, surface development plays a much more important role than in other portions of the South Coastal Area. Of the 148,000 acre-feet per season of presently developed net safe yield, an amount of 73,000 acre-feet, or about one-half, is obtained from surface reservoirs with an aggregate storage capacity of over 700,000 acre-feet. The remaining yield of 75,000 acre-feet is obtained by pumping from ground water or by diversion of unregulated stream flow.

The foregoing safe yield of local surface water supplies is obtained from surface storage reservoirs constructed on all of the major streams in southern San Diego County, including: Morena and Barrett Reservoirs on Cottonwood Creek and Lower Otay Reservoir on Otay River; Loveland and Sweetwater Reservoirs on Sweetwater River; San Vicente, Cuyamaca, and El Capitan Reservoirs on the San Diego River system; Lake Hodges and Sutherland Reservoir on the San Dieguito River; and in the northern part of the county, Lake Henshaw on San Luis Rey River and Vail Reservoir on Temecula Creek, a tributary of Santa Margarita River.

The San Diego Group has been supplied with imported Colorado River water through the existing San Diego Aqueduct since November, 1947. During the season of 1955-56, the flow in this aqueduct averaged about 195 second-feet and totaled about 140,000 acre-feet which is estimated to be equal to its maximum conveyance capacity. It is noted that this amount of imported water is substantially in excess of the annual amount of Colorado River water which the San Diego County Water Authority estimates as its entitlement.

The Department of Water Resources recently completed an investigation of alternative routes for an additional aqueduct to San Diego County, and recommended construction of conveyance facilities to be located generally parallel to the existing line but passing generally from immediately adjacent to 7 miles west of it. The recommended facility would comprise about 30 miles of canal with a capacity of 1,000 second-feet, estimated to be necessary to provide for future water requirements in the service area until about the year 2000, and 73 miles of pipe line with a capacity varying from 432 to 98 second-feet. This pipe line capacity would supply the additional imported water requirements forecast for the year 1980 and represents one-half the capacity estimated to be required in the year 2000. It is contemplated that this aqueduct would convey Colorado River water until Feather River Project water becomes available.

The Metropolitan Water District of Southern Cali-ornia and the San Diego County Water Authority ave announced that they intend to undertake financ-ig and construction of an aqueduct along the align-ent recommended by the Department of Water Re-ources. The district has stated that the upper portion f the aqueduct will be constructed to a capacity of 00 second-feet, or one-half that recommended by the epartment. The capacity of the portion of the pipe ne section to be constructed by the authority has not et been decided.

The sum of the potential safe yield of the existing ocal water supply developments and the conveyance apacity of the existing San Diego Aqueduct exceeds ie present water requirement in the San Diego roup. However, because the full capacity of the ex-ting San Diego Aqueduct was not available or was ot utilized at all times during the current and recent ries of years of low runoff, storage reserves in local ater supply developments have been overdrawn and ie nominal safe yields of these developments cannot ow be realized prior to the occurrence of flood years. he area is now experiencing a rapid growth with at-endant increase in use of water, and additional im-orted water will be needed as soon as construction f the proposed new aqueduct facilities can be com-leted.

The opportunity exists for development of some ad-itional local water supplies but the amounts of these upplies are small when compared to the estimated uture water requirements of the San Diego Group, that it will be necessary to import large quantities f water in the future through facilities of the Cali-ornia Aqueduct System. The following tabulation resents the present and probable ultimate need for nported water in the group, giving consideration to ie eventual development of local water supplies to ie maximum extent practicable:

Present conditions (1950)	*Acre-feet per season*
Water requirement	225,000
Safe yield of local water supplies	148,000
Requirement for imported water	77,000
Probable ultimate conditions	
Water requirement	1,505,000
Safe yield of local water supplies	210,000
Requirement for imported water	1,295,000

Conservation of the waters of the streams in the an Diego Group to the maximum practicable extent ould be accomplished by construction of a 143,000 re-foot reservoir at the De Luz site and a 65,000 re-foot reservoir at the Fallbrook site, both on Santa largarita River; a 145,000 acre-foot reservoir at the lonserate site on San Luis Rey River; a reservoir f 310,000 acre-foot capacity at the Hodges site in eu of the existing 34,000 acre-foot reservoir; a reser-oir of 174,000 acre-foot capacity at the San Vicente site in lieu of the existing 90,000 acre-foot reservoir; and a 100,000 acre-foot reservoir at the Daley site on Jamul Creek, a tributary of Otay River, including enlargement of the existing Dulzura Conduit to bring additional spill waters to the Otay River Basin from Cottonwood Creek, along with controlled releases from the existing storage reservoirs there.

By construction of the foregoing facilities, it would be possible to increase the safe yield of local water supplies of the San Diego Group by about 62,000 acre-feet per season. However, as previously shown, there would still be a demand for imported water of almost 1,300,000 acre-feet under ultimate conditions of development. This supplemental water could be supplied from the Southern California Division of the California Aqueduct System, discussed later in this chapter.

It should be noted that alternative reservoir developments might be selected in lieu of these reservoir projects just enumerated. These alternative projects include: construction of a 188,000 acre-foot reservoir at the De Luz site on Santa Margarita River with no development at the Fallbrook site; construction of a 163,000 acre-foot reservoir at the Pamo site on the San Dieguito River, rather than enlarging Hodges Reservoir; and construction of a 163,000 acre-foot reservoir at the Bonsall site on San Luis Rey River in place of Monserate Reservoir. These alternative possibilities would produce safe yields essentially equal to those that could be obtained from the previously stated projects, but their capital and annual costs, on the basis of preliminary estimates, are close enough to those for the projects shown in Table 12, that further studies should be conducted prior to construction of any of the developments involved. The Department of Water Resources, in cooperation with the City of San Diego, is currently conducting an investigation of the San Dieguito River for the purpose of selecting the best project for further storage on that stream.

Summary of South Coastal Area. The South Coastal Area is extremely deficient in native water resources, being dependent to a major extent upon imported water supplies. Under ultimate conditions nearly 80 per cent of the forecast total water requirements in the area will have to be imported from other regions through existing works and through facilities of the California Aqueduct System. With import of water through the Los Angeles and Colorado River Aqueducts to the full extent of existing and claimed rights, amounting to some 1,530,000 acre-feet per season, there would remain a supplemental requirement of 3,027,000 acre-feet per season in the South Coastal Area under ultimate development.

Under The California Water Plan, local water resources in the South Coastal Area would be developed to their fullest practicable extent. However, the yield

South Coastal Area—Morris Dam on San Gabriel River (top), and Sepulveda Flood Control Reservoir on Los Angeles River hich could be secured by such development would ggregate only 149,000 acre-feet per season, or 5 per ent of the total ultimate supplemental water requireients of the area. The balance of the supplemental equirements, amounting to 2,878,000 acre-feet per eason, would be provided by importation through acilities of the Southern California Division of the alifornia Aqueduct System.

Increased yield of local water resources would be ccomplished by construction of nine reservoirs with ggregate active storage capacity of 1,020,000 acre-feet. hese reservoirs would be operated in conjunction ith ground water storage, wherever practicable, to ecure optimum development of both surface and nderground resources. Artificial ground water reharge, presently practiced quite extensively, would e substantially increased, not only for spreading of ocal runoff and reservoir releases, but for recharge ith imported water supplies as well.

Adequate flood protection would be provided under he California Water Plan in the South Coastal Area y existing and planned flood control works of the everal flood control agencies in the area, and by the ine new local reservoirs hereinbefore described. In ddition, the recreation potential would be developed the maximum feasible extent at existing and future eservoirs. Because of the scarcity and value of water this area, little or no opportunity is expected for e release of water in stream channels for fishery evelopment. However, the reservoirs would provide pportunities to develop a warmwater fishery.

Data on the general features and costs of the local evelopment works contemplated as features of The alifornia Water Plan in the South Coastal Area are resented in Table 12. The locations and layouts of ll of these facilities are delineated on Sheets 20, 21, 4, and 26 of Plate 5.

entral Valley Area—Sacramento River Basin

The Sacramento River Basin is second only to the orth Coastal Area as a region endowed with water upplies far in excess of its ultimate requirements. recipitation occurs principally in the late fall, inter, and early spring months, but melt from the nowpack in the high Sierra Nevada tends to extend e runoff period of the major streams. Some of the reams in the northern part of the basin have their ource in perennial springs of considerable magniude, and flow at a fairly constant rate the year ound. The runoff of others draining from the Coast ange and from the lower elevations of the Sierra evada closely follows the precipitation. Like the orth Coastal Area, a considerable variation occurs the amount of runoff from year to year, and long rought periods have been experienced. Warm winter ains sometimes extend to the higher elevations of the Sierra Nevada and, as exemplified by the disaster of December, 1955, can result in record floods in the Sacramento Valley, especially if snow is present in the mountains.

The present water resource development of the Sacramento River Basin is considerable and varied, but by no means approaches the feasible potential. With the recent completion of Monticello Dam on Putah Creek, the basin now has about 10,000,000 acre-feet of reservoir storage capacity, including 1,600,000 acre-feet in Monticello Reservoir, 1,000,000 acre-feet in Folsom Reservoir, 4,500,000 acre-feet in Shasta Reservoir, 1,308,000 acre-feet in Lake Almanor, and 319,000 acre-feet in the normal operating range of Clear Lake.

While much of the present water development in the Sacramento River Basin has been accomplished by private interests and public utilities, the major developments are those of the Federal Government. The most important and comprehensive of these is the Central Valley Project of the United States Bureau of Reclamation which closely follows original plans of the State of California. The project develops surplus waters in the Sacramento River Basin for local use and export to the San Joaquin Valley. Principal completed features of the project pertinent to the Sacramento River Basin are the large multipurpose Shasta and Folsom Reservoirs, and the Sly Park Unit serving lands on the divide between the American and Cosumnes Rivers. Work has been partially completed on the Sacramento Canals Unit of the project diverting from the Sacramento River at Red Bluff to serve lands on the west side of the valley. More recently, work has been initiated on the Trinity River Division of the project, involving the interbasin diversion of some 872,000 acre-feet of regulated water per year from the North Coastal Area to the Sacramento Valley for local use and export, with attendant generation of large amounts of hydroelectric power.

Irrigation in the Sacramento River Basin is centered largely on the Sacramento Valley floor and along the Pit River, but is also practiced to some extent in the mountain areas, generally in places where old mining ditches are available for diversion and distribution. The vast ground water resources of the basin have been used extensively only in the Sacramento Valley, where the present pumpage is about 1,000,000 acre-feet per season. Upon the completion of licensed works on the North Fork of the Feather River by the Pacific Gas and Electric Company, hydroelectric power will be generated at 44 utility-owned and public power plants with an aggregate installed capacity of about 2,000,000 kilowatts. However, only parts of the Pit River, the Bear and Yuba Rivers, and the North Fork of the Feather River have been intensively de-

TABLE 12

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SOUTH COASTAL AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, SBB&M, and sheet of Plate 5 on which shown		Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Net	Seasonal yield, in acre-feet	Purpose	Place of water use	Capital cost[a]
Ventura Group												
Blue Point	Piru Creek	Sec. 10, T5N, R18W	21	E	240	1,280	50,000	38,000	34,000	I	Ventura County	$8,171,000
Topatopa	Sespe Creek	Sec. 36, T6N, R20W	21	CA	370	2,455	100,000	95,000				15,544,000
Cold Springs	Sespe Creek	Sec. 6, T5N, R22W	21	E	272	3,452	100,000	97,000				8,571,000
Los Angeles-Santa Ana Group	(no local works)											
San Diego Group												
De Luz	Santa Margarita River	Sec. 32, T9S, R4W	24	E	210	307	143,000	129,000	15,500	I,U,FC	Downstream basin	9,609,000
Fallbrook (Lippincott)	Santa Margarita River	Sec. 12, T9S, R4W	24	E	210	497	65,000	56,000				4,823,000
Monserate	San Luis Rey River	Sec. 6, T10S, R2W	24	E	160	407	145,000	145,000	9,000	I,U	Downstream basin	8,634,000
Enlarged Lake Hodges	San Dieguito River	Sec. 18, T13S, R2W	24	CG	210	395	[b]276,000	[b]276,000	17,000	I,U	San Diego coast	21,388,000
Enlarged San Vicente	San Vicente Creek	Sec. 31, T14S, R1E	26	CG	270	714	[c]84,000	[c]84,000	9,000	I,U	San Diego coast	6,719,000
Daley	Jamul Creek	Sec. 22, T17S, R1E	26	E	200	878	100,000	100,000	9,000	I,U	San Diego coast	[d]5,028,000
Totals							1,063,000	1,020,000				$88,487,000

Associated features	Conduit: Maximum capacity, in second-feet	Conduit: Total length, in miles		Capital cost[a]
Ventura Group	120	32.0	Santa Clara River Conduit from Santa Felicia Reservoir to Oxnard Plain	[e]$4,899,000
Los Angeles-Santa Ana Group				
San Diego Group				

Symbols of Type of Dam
E—Earthfill
CA—Concrete arch
CG—Concrete gravity

Symbols of Purpose
I—Irrigation
U—Urban (domestic, municipal, industrial)
FC—Flood control

[a] At 1955 price levels.
[b] In addition to existing storage capacity of 34,000 acre-feet.
[c] In addition to existing storage capacity of 90,000 acre-feet.
[d] Cost includes $800,000 to extend Dulzura Conduit to Daley Reservoir.
[e] Includes cost of Sespe feeder conduit.

eloped for power to date. Large power plants are ocated at the bases of Shasta and Folsom Dams with maller plants located below their afterbays. In addi- on to irrigation facilities, works on the valley floor nclude the Sacramento River Flood Control Project, n extensive system of river levees and by-passes to rotect agricultural and urban areas against damag- ng floods. Also, storage for flood control is specifically eserved in Shasta and Folsom Reservoirs, and is rovided to some extent in other reservoirs of the asin. However, additional works are required, par- icularly reserved storage space in reservoirs, to pro- ide well balanced flood protection to all areas of the alley.

Shallow-draft navigation is maintained on the Sac- mento River as far upstream as Colusa by releases rom Shasta Reservoir, but the official head of naviga- on is at Red Bluff. A separate deep-water ship hannel to Sacramento has been authorized for con- ruction, with some work under way and completed. epulsion of sea water from the channels of the Sac- mento-San Joaquin Delta by release of water from orage is another highly important aspect of pres- nt water resource development in the Sacramento iver Basin.

The runoff of the Sacramento River Basin under atural conditions has been estimated to average ome 22,400,000 acre-feet per year. This is exclusive f a presently indeterminate but probably substantial uantity of water which is known to flow from the asin into the Sacramento-San Joaquin Delta through he alluvium of the Sacramento Valley. It is antici- ated that at least a portion of this underflow will ventually be recovered through more intensive utili- ation of ground water in the Sacramento Valley and y construction of a salinity control barrier at the elta. In addition, change in land use from natural o ultimate conditions will decrease the consumptive se of precipitation by native vegetation and will herefore tend to increase the runoff substantially. With these factors taken into account, it is estimated hat the future runoff of the Sacramento River Basin may be in the order of 24,000,000 acre-feet per year.

The present gross water requirements of the Sacra- mento River Basin are estimated to aggregate about ,670,000 acre-feet per season. These requirements are met principally by direct stream flow diversions, sup- plemented by releases from storage and by pumping rom ground water. About 30,000 acre-feet of the re- uirement is met by imports from the Truckee and osumnes River Basins. Additional imports for local se and for export will become available in the near uture from the Trinity River Division of the Central Valley Project.

Taking into account the availability of return flow rom the upland service areas for downstream use, nd based on the consideration that certain mountain lands classified as irrigable in State Water Resources Board Bulletin No. 2 are now considered to be better suited to forest use, the ultimate water requirement in the Sacramento River Basin has been estimated to be 7,430,000 acre-feet per year. Of this total, it is esti- mated that approximately 6,290,000 acre-feet will be consumed in plant growth and by urban and indus- trial users; 470,000 acre-feet will be recoverable as return flow at the Delta; and the remainder, 670,000 acre-feet, represents irrecoverable losses, including poor-quality waters and sewage and industrial wastes that would be disposed of by a separate waste conduit entering the Delta waste-way channels below a future barrier pool.

In addition to the major problem of floods in the Sacramento Valley and to some extent in the uplands, the Sacramento River Basin contains several local areas of limited water supply. These are located at fairly high altitudes, principally around Goose Lake, in the vicinity of Alturas, and in Sierra Valley. In other mountain areas, notably in the Sierra Nevada, the irrigable lands are often situated on the broad ridges separating the main watercourses, and despite the abundant flow of these streams, cannot be served except by pumping from great canyon depths or through long and difficult gravity conduit routes. The diversion of water to serve these lands often conflicts with otherwise desirable hydroelectric power develop- ments. Seepage from the Sacramento River and rising saline waters in the Peach Bowl area of Sutter County have caused considerable damage on the valley floor. Not the least of the water problems of the Sacra- mento River Basin is the need to preserve and in some instances enhance its recreational potential and its highly important recreational and anadromous fishery.

Objectives of The California Water Plan in the Sacramento River Basin are fourfold: first, the de- velopment of sufficient water supplies to satisfy ulti- mate water requirements for all beneficial local pur- poses, including irrigation, urban, industrial, fish and wildlife, recreational, and navigation; second, protection of urban and agricultural areas from dam- aging floods; third, the development of the hydro- electric power potential of the basin to its feasible maximum; and, fourth, the development of about 10,000,000 acre-feet of surplus water per season for export to water-deficient areas elsewhere in the State. Corollary with these objectives is the need to preserve the quality of the water to a degree consistent with its anticipated use.

Although this section is concerned primarily with developments to meet local requirements, it is pointed out that, like Shasta and Folsom Reservoirs, certain prospective works of the basin would have important export as well as local functions, and, as such, would be extremely difficult of classification as either solely local or solely export facilities. In general, these dual-function works would consist of large multipurpose reservoirs at the foothills of the major streams, and certain smaller irrigation or flood control reservoirs at the foothill line on the less important streams. Although these works are designated and grouped together later as features of the Sacramento Division of the California Aqueduct System, they are described in this section along with those which would primarily serve local purposes. All works of the basin, existing and prospective, are conceived as an integrated system designed to conserve and regulate the native and imported water supplies to an optimum degree, to develop the hydroelectric, recreational, and fishery potential of these waters, and to provide flood protection.

The works of the Sacramento River Basin are considered under 10 separate geographical subdivisions, as follows: the Goose Lake Unit in the extreme northeastern part of the basin; the Pit River Unit northeast of Redding; the Mt. Shasta Stream Group north of Redding; the Redding Stream Group between Red Bluff and Shasta Dam; the West Side Stream Group, comprising the mountain and foothill area on the west side of the basin south of Red Bluff; the Antelope-Butte Stream Group, comprising the mountain and foothill area on the east side of the basin between Red Bluff and the Feather River drainage divide; the Feather River Unit; the Yuba-Bear River Unit; the American River Unit; and the Sacramento Valley Floor. Following the discussion of works in each of these subdivisions, there is a summary statement with tables showing principal characteristics of the various suggested works and their estimated cost.

Goose Lake Unit. The Goose Lake Unit comprises the California portion of the Goose Lake Basin. This basin has an area of about 1,100 square miles, of which 688 square miles are in Oregon and 412 square miles are in California. The streams of the basin drain into Goose Lake, a large shallow body of water situated in both states at an elevation of about 4,800 feet. The lake occupies a shallow depression separated from its outlet to the North Fork of the Pit River by a low divide. Evaporation from the lake surface and consumptive use of water from influent streams tend to balance the inflow to the extent that there has been virtually no outflow during historic times. The lake is important as a wild fowl refuge. Its waters are brackish and not suited to domestic or agricultural use. About 97 square miles of the Goose Lake Unit are mountainous and 315 square miles have been classified as valley and mesa land, but this includes about 120 square miles of water area when the lake is at its highest level.

Precipitation in the Goose Lake Unit ranges from less than 15 inches per season on the flat lands to about 24 inches in the Warner Mountains east of the lake. The principal streams of the unit drain from these mountains, and are, from north to south, Pine, Cottonwood, Willow, Lassen, and Davis Creeks. None of these streams is more than 15 miles long, but several flow perennially. These and the minor streams of the unit have an aggregate natural runoff of only about 68,000 acre-feet per year on the average.

The water problems of the Goose Lake Unit relate entirely to the limited supplies available for development for consumptive purposes. There are no present or future flood problems to deal with and, insofar as the streams are concerned, no quality problems. Although the unique scenic, wildlife, and historical attractions of the area are not widely known, they may become more important in the future, but no special water problems are foreseen in their development.

The Goose Lake Unit is sparsely settled, with virtually no industries except a few small sawmills. Present water development is limited to direct diversion of natural stream flow, augmented by releases from a few small reservoirs aggregating less than 4,000 acre-feet of storage capacity. About 24,000 acre-feet of water per season is developed in this manner to irrigate about 8,500 acres of land along the east shore of the lake, in Fandango Valley, and at the mouths of small streams draining into the lake from the west.

Under ultimate conditions it is anticipated that the Goose Lake Unit will continue to be sparsely settled with only nominal water requirements for urban use and industry. The water service areas, however, may expand to as much as 30,000 acres if satisfactory supplemental water supplies for irrigation can be developed at reasonable cost. Based on prevailing irrigation practices in the unit, this would require a total of about 80,000 acre-feet of water per season—an amount 12,000 acre-feet in excess of the natural runoff.

Plans to drain Goose Lake to obtain additional water supplies for local use and export to the Pit River Unit have been considered but were found to be impracticable in view of the desirability of preserving the lake as a natural wild fowl refuge. Further complications are added by its interstate location. Plans to import water from the Oregon tributaries of the lake are likewise considered to be impracticable because of future requirements in that state. For these reasons and because of the limited local water supply, full irrigation development of the land resources of the Goose Lake Unit may never be realized.

Under The California Water Plan it is anticipated that some further development of the remaining water resources of the Goose Lake Unit may be obtained through the construction of additional small reservoirs by individual owners, as at present; but any substantial increase in the developed water supply would depend on possibilities for ground water utilization. Although little is known concerning the subsurface geology of the unit, existing and prospective

Sacramento River Basin—Bear River Canal in the Sierra Nevada, Constructed in 1850 water service areas are believed to be underlain with alluvial deposits which may contain water of a quality suitable for irrigation. If such ground water basins can be delimited and developed for use, including recharge through spreading works and deep percolation of applied water, it is believed that all of the potentially irrigable lands of the unit could be irrigated without import. Under these circumstances much of the return flow could be recovered for re-use, and a supplemental water supply of only about 26,000 acre-feet per season would be required as compared with 56,000 acre-feet without such re-use.

Another way of bringing additional land under irrigation would be through the use of sprinkler methods of water application. With these methods there would be very little return flow wasted and supplemental water requirements would be nominal. General acceptance of these methods would depend on the economic conditions prevailing in the future.

Pit River Unit. The Pit River Unit comprises all of the 5,350 square-mile drainage basin of the Pit River. About 3,080 square miles of the basin area are mountainous, and 2,270 square miles have been classified as valley and mesa land. The Pit River forms near Alturas with the junction of its North and South Forks, and flows westwardly for a distance of about 170 miles to join the Sacramento River in Shasta Reservoir.

Precipitation in the Pit River Unit averages about 24 inches at the headwaters in the Warner Mountains, 15 inches in the middle reaches, and as much as 80 inches in the Cascade Range, which forms the westerly part of the watershed. The mean natural runoff from the headwater area above Canby is about 260,000 acre-feet per year and, for the basin as a whole, 3,430,000 acre-feet. Stream flow in the upper and middle reaches of the basin is sporadic; but, in the lower reaches it is remarkably uniform due to the fact that the principal tributaries in this area have their source in perennial springs of considerable magnitude. An average of about 11,000 acre-feet of water per season is exported from tributaries of the South Fork of the Pit River into Madeline Plains in the Lahontan Basin. There are no present imports.

Present water development of the headwater area of the Pit River Unit is quite extensive, with most of the 50 or more reservoirs of the unit concentrated in this area. These have been constructed by both individuals and organized water districts, and range in size from a few acre-feet to 77,000 acre-feet for Big Sage Reservoir on Rattlesnake Creek near Alturas. Together they have an aggregate capacity of about 150,000 acre-feet. Releases from these reservoirs are combined with natural stream flow to irrigate an average of about 82,000 acres of land each year in the upper and middle reaches of the basin. Another 23,000 acres are irrigated by direct stream flow diversion in the lower basin area, principally along Fall River and in the vicinity of McArthur and Pittville. The hydroelectric power potential of the lower basin area is partially developed by the Pacific Gas and Electric Company. The company has six large plants on Hat Creek and on the Pit River below Fall River, with application pending before the Federal Power Commission to complete the chain by constructing three additional units on the Pit River and involving a diversion from the McCloud River. Conflicting proposals for development of the latter stream are discussed under the Mt. Shasta Stream Group. A small locally owned plant develops power on Pine Creek near Alturas.

Despite an abundant water supply for the Pit River Unit as a whole, the upper and middle sectors, where most of the irrigable land is situated, are areas of limited supply. Furthermore, these areas are 1,000 to 1,500 feet higher than possible major sources of import from Fall River and other productive tributaries of the unit. Except for some flooding in the vicinity of Alturas, there are no present flood problems of consequence in the unit, and, with the possible exception of Big Valley, none are foreseen for the future. Swampy conditions in the highly developed main valley of the South Fork and in the vicinity of McArthur are alleviated to some extent by drainage ditches and pumping. These conditions probably account for considerable uneconomic consumption of water. The unit is widely used for fishing and hunting and, in some areas, for general outdoor recreation. Lakes and reservoirs are used by wild fowl as nesting places. The preservation and possible enhancement of these resources is a prime consideration in The California Water Plan.

Under ultimate conditions it is anticipated tha present water service areas in the Pit River Unit wil expand to about 324,000 acres, supporting a popula tion of about 38,000 people. Taking into account th possibilities for re-use of return flow, it is estimate that the ultimate water requirements of the uni for consumptive use would be about 478,000 acre-fee per season, as compared with a present requiremen of 244,000 acre-feet.

Objectives of The California Water Plan in th Pit River Unit would be met insofar as possible b the construction of local works. Plans for water de velopment in the Alturas area, comprising lands i the valleys of the North and South Forks and in Ho Springs Valley on the main stem of the Pit Rive contemplate the eventual construction of small reser voirs on Parker Creek near its month, on South For at Jess Valley, on Stony Canyon Creek at Sears Fla and on Crooks Canyon Creek by enlargement o Bayley Reservoir. Flood protection for Alturas woul probably be accomplished by construction of a by pass channel on the North Fork, together with cha l improvements on the North and South Forks and e main stem of Pit River to relieve unsatisfactory ainage conditions. None of these small works has en considered in detail for this report, nor have eir costs and accomplishments been firmly estabhed. They are simply suggested for future considation. In general, due to the very limited water pply of the Alturas area, any considerable expanon of irrigation would be dependent mainly on water pplies obtained from downstream areas. The posilities for obtaining such supplies are intimately lated to and entirely contingent upon the feasibility ground water development in Big Valley, which situated on the Pit River below Hot Springs Valley. though little is now known about the ground water sources of Big Valley, further investigations are heduled to begin in fiscal year 1957-58.

Plans for water development for Big Valley contemate the construction of Allen Camp Reservoir at e head of the valley on the Pit River, and Round alley Reservoir on Ash Creek with feeder canal from illow Creek, its principal tributary. Ash Creek enrs Big Valley from the south. It is anticipated that e combined yield of Allen Camp and Round Valley servoirs would be in the order of 120,000 acre-feet r season. However, should it be found feasible in e future to operate these reservoirs in conjunction th possible, but not assured, ground water storage pacity in Big Valley, the combined yield might exd 200,000 acre-feet per season. In this event, it uld be possible not only to meet the full ultimate ter requirements of Big Valley, but to allow mped diversions, in the amount of about 50,000 re-feet per season, to be made from Allen Camp servoir into Hot Spring Valley. Due to the relatively v cost of storage in Allen Camp Reservoir, it is lieved that it may be feasible in the future to reve about 40,000 acre-feet of its capacity for flood ntrol.

Supplemental water supplies for Dixie Valley, ich is located on the upper reaches of Horse Creek, uld be obtained by pumping from Little Valley servoir to be located downstream. Horse Creek ens the Pit River from the south below Big Valley.

Lands in the Fall River, McArthur, and Pittville eas could obtain their supplemental water supplies diversions from Fall River and/or pumping from ll River Mills Reservoir, which would be formed a dam on the Pit River below Fall River near the vn of Fall River Mills. Although it is believed that afe dam could be constructed at this site, blanketof the reservoir area in some places might be reired to avoid large loss of conserved water. The servoir would be at the same level as the present cific Gas and Electric Company diversion dam on ll River, and would replace that facility as well as prove the output of an associated power plant by oviding forebay capacity not now available. Because of its narrow operating range, the reservoir would afford exceptional opportunity for recreational development, especially including an ideal lake fishery.

Lands in the Burney area and in Goose Valley would continue to be served as at present by pumping from ground water and by direct stream flow diversion. Most of the land in these areas is considered better suited to continued forest use and recreation rather than to future irrigated agriculture. No storage works are now contemplated except possibly a small reservoir on Burney Creek in the general vicinity of Dry Lake, but there is some question concerning the ability of a reservoir in this porous lava area to retain water.

The remaining hydroelectric power resources of the Pit River Basin would be developed by the construction of Pit River Power Plants Nos. 2, 6, and 7 as has been proposed by the Pacific Gas and Electric Company, with the water supply for Plants Nos. 6 and 7 possibly augmented by diversion from the McCloud River, if approved by the Federal Power Commission. For purposes of this report, however, it was assumed that the McCloud River would not be diverted into the Pit River. With the existing plants, these plants would develop the full power potential of the Pit River between Fall River and Shasta Reservoir, involving a total head of about 2,000 feet. A small development on Hat Creek at Sugar Loaf Mountain is also contemplated. This development would utilize the natural spring-fed flow of Hat Creek through a drop of about 600 feet.

In summary, prospective works in the Pit River Unit would consist of major reservoirs at Allen Camp, Round Valley, and Fall River Mills; several minor reservoirs at various locations; channel improvement works in the vicinity of Alturas; and four hydroelectric power plants. The reservoirs would add more than 500,000 acre-feet of capacity to the present storage system of the basin, including 40,000 acre-feet that would be reserved in Allen Camp Reservoir for future flood control. Depending on the feasibility of conjunctive operation with ground water, the reservoirs would make supplemental water supplies of from 160,000 to 240,000 acre-feet per season available for local use. The new power plants would have a combined installed capacity of about 183,000 kilowatts and would generate an average of about 886,000,000 kilowatt-hours per year. In addition to the probably excellent recreational and fishery potential of Fall River Mills Reservoir, it is anticipated that the other reservoirs may afford opportunities for recreational development, and there will be some incidental enhancement of stream flow for these purposes.

Mt. Shasta Stream Group. The Mt. Shasta Stream Group comprises the drainage basin of the McCloud River and the area tributary to the main stem of the Sacramento River above Shasta Dam. The combined

1,300 square-mile drainage area of these streams is essentially mountainous and heavily forested.

Precipitation in the Mt. Shasta Stream Group is the heaviest in the entire Sacramento River Basin, varying from about 34 inches per season at the City of Mt. Shasta to more than 80 inches on the higher peaks and ridges. The runoff averages about 2,300,000 acre-feet per year, of which the McCloud River contributes 1,400,000 acre-feet from 685 square miles of watershed area and the Sacramento River provides 900,000 acre-feet from 618 square miles.

Except for Shasta Reservoir, which regulates the water of the Pit River as well as the streams considered herein, there is no present significant development of the water resources of the Mt. Shasta Stream Group. Towns, industries, and individuals obtain their water supplies from springs and wells. Minor diversion of natural stream flow is made for irrigation on the gentle lower slopes of Mt. Shasta in the vicinity of the towns of Mt. Shasta and McCloud. Shasta Reservoir, a feature of the Central Valley Project, develops water for power and irrigation and provides flood protection to downstream areas. Releases are coordinated with downstream accretions to provide for navigation on the Sacramento River below Red Bluff and to repulse sea water at the Delta, as well as for diversion from the Sacramento River for local use and from the Delta for export. Because of its export function, Shasta Reservoir is considered to be a feature of the California Aqueduct System and is further discussed subsequently in that section.

There are no present water problems of consequence in the Mt. Shasta Stream Group. Consumptive water requirements are and will continue to be relatively small. With the exception of some minor flooding of low-lying areas at Dunsmuir, there are no present flood problems, nor is there any indication that floods will constitute a hazard in the future. Maintenance of stream flow for fish, wildlife, and recreation is considered to be a fundamental requirement for all water development planning in this area.

The basic plan for development of the water resources of the Mt. Shasta Stream Group under The California Water Plan, as outlined herein, contemplates that the headwater runoff, not required for irrigation and stream flow maintenance, would be conveyed to and regulated in an off-stream storage reservoir on Squaw Valley Creek, principal tributary of the McCloud River, and then released through a system of works to develop the power head to Shasta Reservoir.

Supplemental water supplies for irrigation of lands in the vicinity of the City of Mt. Shasta could be obtained by pumped diversions from Wagon Valley Reservoir. This reservoir would be located on the Sacramento River near Mt. Shasta and would also conserve water for stream flow maintenance on the Sacramento River. After fulfilling these requirements surplus water would be diverted from Wagon Valle Reservoir and conveyed eastward by canal and tun nel into Willow Reservoir on Squaw Valley Creel with return flow from the Mt. Shasta area and the sur plus flow of Soda Creek, a tributary of the Sacra mento River, intercepted enroute. Water from th McCloud River, in excess of stream flow maintenanc requirements, would be diverted at a point about miles southeast of the town of McCloud, and conveye by tunnel to Willow Reservoir, with the surplus flo of Elk Creek, a minor tributary, intercepted enrout Willow Reservoir would be created by constructing dam at the lower end of Squaw Valley, about 7 mile south of the town of McCloud.

From Willow Reservoir the water would be con veyed southward by tunnel to the Willow Powe Plant, discharging into the McCloud River arm c Chonton Tubas Reservoir. This reservoir would b formed by constructing a dam on the McCloud Rive immediately below the mouth of Squaw Valley Creel also known as North Fork of McCloud River. Fror Chonton Tubas Reservoir the water would be con veyed by tunnel to the Chonton Tubas Power Plan discharging into the McCloud River arm of Shast Reservoir. Releases for stream flow maintenanc would be made from both reservoirs.

Under an arrangement proposed by the Pacific Ga and Electric Company in its application to the Fed eral Power Commission for a license to develop th power resources of the McCloud River, the water fro Willow Reservoir would be conveyed eastward by tun nel to a power drop at the head of a McCloud Dive sion Reservoir on the McCloud River north c Hawkins Creek. From this reservoir the water woul then be conveyed southeastward by tunnel, intercep ing the flow of Hawkins Creek enroute to an Iro Canyon Reservoir on Iron Canyon Creek, a tributar of the Pit River. From Iron Canyon Reservoir th water would be conveyed southward by tunnel to power drop on the Pit River opposite Pit No. 5 Pow Plant of the Pacific Gas and Electric Company. Th remaining head to Shasta Reservoir would then b developed through the proposed additional pow plants of the Pit River power system, discussed in th foregoing section dealing with the Pit River Un Although the application for license shows no impo from the Sacramento River, this feature could easi be added.

An application for power license by the Californ Oregon Power Company proposes to develop the pow potential of the McCloud River in six plants betwe Bartle and Shasta Reservoir in a stepped arrang ment, each step consisting of a small diversion regulating reservoir on the McCloud River, a condu and a power drop returning the water to the rive This is essentially a "run-of-river" type of develo ent, dependent upon the natural spring-fed regulaon of the river for its feasibility. Under this plan, Willow Reservoir would not be constructed, nor would ater be imported from the Sacramento River for ower development, as in the basic plan.

The Department of Water Resources is currently 1957) giving further study to the proposals of the acific Gas and Electric Company and the California regon Power Company as to the accomplishments of ese proposals in relation to The California Water lan. The department has filed a petition to intervene any future hearings of the Federal Power Commison concerning pending applications for license.

In summary, the basic plan of the Mt. Shasta tream Group would comprise three reservoirs and vo power plants with associated conduits and diveron facilities. The reservoirs would have a gross orage capacity of about 324,000 acre-feet, of which),000 acre-feet would be inactive and 305,000 acreet would conserve water for local consumptive use, ream flow maintenance, and power. Because of their latively small capacities, the reservoirs would contribte little to the safe yield of Shasta Reservoir. The Willow and Chonton Tubas Power Plants would have combined installed capacity of 208,000 kilowatts and ould generate an average of about 1.1 billion lowatt-hours per year.

Redding Stream Group. The Redding Stream roup is situated directly north of the Sacramento alley and includes the stream basins tributary to the acramento River between Red Bluff and Shasta Dam. hese tributary streams are Clear Creek and Cottonood Creek, entering the Sacramento River from the est, and Cow Creek with its many tributaries, and ear, Battle, and Paynes Creeks flowing from the east. he stream group encompasses a total area of about 610 square miles, comprising rich farm land on the alley floor, rolling grass-covered foothills, a gently oping volcanic plain in the middle sector of the asterly watershed, and rugged mountains at the eastn and western boundaries. About 1,830 square miles f the stream group area are mountainous and 780 uare miles have been classified as valley and mesa nd.

Precipitation in the Redding Stream Group varies om about 25 inches per season on the valley floor to) inches in the high mountains, generally as a direct unction of the elevation. The mean natural runoff of e stream group is about 2,740,000 acre-feet per year.

Present water requirements for agriculture are met ubstantially by direct stream flow diversions, principally from the Sacramento River to serve lands in the nderson-Cottonwood Irrigation District, and from ow Creek and its tributaries to serve contiguous nds. Water supplies for Happy Valley are obtained v long canal diversions from tributaries of Clear Creek and the North Fork of Cottonwood Creek, augmented by releases from Musselbeck (Rainbow Lake) Reservoir on the latter stream. The City of Redding pumps it water supply from the Sacramento River. Other communities obtain their water supplies principally from wells. Hydroelectric power is developed on Cow and Battle Creeks at six small plants of the Pacific Gas and Electric Company, utilizing the natural spring-fed headwater runoff of these streams, with some minor storage regulation. A large block of power is developed at the federally owned Keswick Power Plant, situated at the Keswick Afterbay Dam on the Sacramento River below Shasta Dam.

Mandatory controlled releases from Shasta Reservoir sometimes cause flooding of urban developments which, in recent years and notwithstanding posted warnings, have encroached upon the flood plain of the Sacramento River in the vicinity of Redding. Otherwise, there are no present water problems of consequence in the Redding Stream Group. Abundant water supplies are available for local development to meet all future supplemental requirements. The main objectives of The California Water Plan in the group are to conserve and regulate the runoff of the tributary streams to an optimum degree for local and downstream use for irrigation, power, fishery, and recreation purposes; and to provide flood protection for local and downstream areas.

Plans for development of the water resources of the Redding Stream Group contemplate the eventual construction of eight main foothill reservoirs on tributary streams, together with certain related minor storage and diversion works, conduits, and one hydroelectric power plant. All of these works would be in addition to, and, in certain respects, complementary to the storage, conduit, and hydroelectric power facilities of the California Aqueduct System in the area.

Storage features of the California Aqueduct System in the Redding Stream Group would consist, principally, of Kanaka, Saeltzer, and Girvan Reservoirs on Clear Creek, and Iron Canyon Reservoir or suitable alternative thereto on the Sacramento River. The capacity of the latter reservoir under The California Water Plan would be about 950,000 acre-feet; whereas the authorized Iron Canyon Project of the Corps of Engineers, U. S. Army, contemplates a reservoir with a capacity of about 500,000 acre-feet. However, the difference in normal pool elevations would be only about 20 feet. These reservoirs, together with associated conduits and power plants, are described later in this chapter as features of the Klamath-Trinity and Sacramento Divisions of the California Aqueduct System.

Local works on Cottonwood Creek would consist of Dippingvat Reservoir on the South Fork; Rosewood Reservoir on Dry Creek, a tributary of the South Fork, with diversion from Cold Fork, also a tributary of the South Fork; Fiddlers Reservoir with power plant and afterbay on the Middle Fork; and Hulen Reservoir on the North Fork. These reservoirs would provide water for local use in Cottonwood Valley and in the Reeds Creek area west of Red Bluff. They would also provide flood protection for the Sacramento Valley as well as local areas, and improve and enhance stream flow to encourage the development of anadromous fishery in Cottonwood Creek in conjunction with fish ladder provisions at Iron Canyon Reservoir. In addition to a small block of power that would be developed by the Fiddlers Power Plant, the water developed by these reservoirs, and not required for local use, would contribute to the supply available for use through the Iron Canyon Power Plant of the California Aqueduct System.

As previously stated, the developments on Clear Creek are considered to be features of the California Aqueduct System in connection with import from the North Coastal Area. However, these features, particularly Kanaka Reservoir, would be effective in conserving and regulating the runoff of Clear Creek. In this regard it is anticipated that Kanaka Reservoir would eventually assume the conservation and flood control functions of Whiskeytown Reservoir, which is authorized for federal construction as a feature of the Trinity River Division of the Central Valley Project. The transfer of these functions would be required because Whiskeytown Reservoir, located farther upstream, would be at too high an elevation and of too small a capacity to regulate the future imports of the Klamath-Trinity Division. Studies indicate that it would not be economic at the present time to construct the larger Kanaka Reservoir rather than Whiskeytown Reservoir. As contemplated under The California Water Plan, small quantities of the conserved waters of Clear Creek would be used locally in Happy Valley and other places as required, but the bulk of the water supply would flow through the aqueduct features for downstream use, including the generation of hydroelectric power.

Developments contemplated on tributaries of Cow Creek would consist of: Bella Vista Reservoir on Little Cow Creek, with natural water supply augmented by the diversion of Clover Creek into a small Oak Flat Reservoir on Oak Run, with further conveyance by large tunnel into Norton Gulch which drains into Little Cow Creek; and Millville Reservoir on South Cow Creek, which would be connected by a short equalizing tunnel with a small reservoir on Old Cow Creek. The inflow to the Millville-Old Cow Creek Reservoir combination would be augmented by the diversion of the winter flow of Bear Creek through a natural saddle into South Cow Creek. Part of the conserved and regulated waters of Cow Creek would be used locally as required, and the remainder would flow into Iron Canyon Reservoir for further disposition. Flood protection for the Sacramento Valley well as local areas would be provided by the reservoi and they would improve and enhance stream flo for the maintenance of fish life in Cow Creek.

The regulation of Battle and Paynes Creeks f conservation and flood control could be accomplish by partial conservation of Battle Creek in Batt Creek Reservoir, supplemented by off-stream stora in a large Wing Reservoir on Inks Creek. Spills fro Battle Creek as well as the winter runoff of Payn Creek would be diverted into Wing Reservoir throu large-capacity flood channels. There would be local use of the developed water supplies, except f stream flow maintenance for fish life on the low reaches of Battle and Paynes Creeks, and all releas would flow into Iron Canyon Reservoir for furth downstream regulation and use, including power ge eration.

In summary, the local works of the Redding Strea Group would provide 1,325,000 acre-feet of reserv storage capacity, of which about 100,000 acre-fe would be inactive and 260,000 acre-feet would be served for flood control. Fiddlers Power Plant, local development, would have an installed capac of about 8,000 kilowatts. Specifically, the local res voirs would provide about 600,000 acre-feet of fi water per season from the tributary stream runoff local and downstream use. When considered in co junction with Kanaka and Iron Canyon Reservoi and after taking into account future local consum tive requirements within the Redding Stream Gro the reservoirs would regulate for downstream use average of about 2,150,000 acre-feet of local run per season, of which about 800,000 acre-feet wo be a firm supply. The local reservoirs, together w Kanaka and Iron Canyon, would contain about 57- 000 acre-feet of storage space specifically reserved flood control. This space operated in conjunction w reserved storage space in Shasta Reservoir would highly effective in reducing flood flows in the Sac mento River at Redding and Red Bluff, and at same time would afford local flood protection e where within the Redding Stream Group. The fl control storage space would be utilized to regul the flood flows in such a manner as to yield subst tial quantities of secondary water for power gen tion, ground water recharge, and export. Fidd Power Plant could generate an average of about 000,000 kilowatt-hours per year.

West Side Stream Group. The West Side Stre Group comprises all streams of the Sacramento Ri Basin draining from the easterly slopes of the Co Range south of Cottonwood Creek. The east boundary of the area between Red Bluff and Arbu is defined approximately by the projected locatio f the Corning and Tehama-Colusa Canals of the reau of Reclamation. These canals comprise featu

Sacramento Valley—Agriculture and Navigation of the Sacramento Canals Unit of the Central Valley Project. South of Arbuckle the boundary is more clearly defined by the natural topography. Capay Valley on Cache Creek is considered to be part of the Sacramento Valley floor area. The combined drainage area to the base of the foothills is about 4,000 square miles, of which 3,000 square miles are mountainous and 1,000 square miles have been classified as valley and mesa land. The principal streams of the group are, from north to south, Redbank, Elder, Thomes, Stony, Cache, and Putah Creeks.

Precipitation in the West Side Stream Group occurs largely as rainfall and varies from about 20 inches per season at the eastern foothill boundary to more than 80 inches in some places at the summit of the Coast Range. The aggregate natural runoff of the streams averages about 1,900,000 acre-feet per year.

East Park and Stony Gorge Reservoirs on Stony Creek, Clear Lake on Cache Creek, and Monticello Reservoir on Putah Creek, comprise the present major water storage facilities within the West Side Stream Group. All other reservoirs have an aggregate capacity of less than 3,700 acre-feet, of which about 1,700 acre-feet are contained in Detert Reservoir near Middletown on Bucksnort Creek, a tributary of Putah Creek. Water conserved in reservoirs on Stony Creek and in Clear Lake is used in Sacramento Valley floor areas. Water conserved in Monticello Reservoir is also used in Sacramento Valley floor areas, but a large quantity will shortly be exported to parts of Solano County located south and west of the Sacrament River drainage divide boundaries. Because of its large capacity, Monticello Reservoir effectively controls and regulates the flood flows of Putah Creek. Clear Lake on Cache Creek and the reservoirs on Stony Creek provide only limited regulation of the flood flows of their respective streams. Operation of Clear Lake for irrigation and flood control is governed by court decree to a considerable extent.

There are at present about 13,000 acres of land under irrigation within the West Side Stream Group. This land is irrigated principally by pumping from ground water, with some direct diversion of natural stream flow and releases from storage. Irrigable lands of the stream group aggregate about 270,000 acres, with an ultimate water requirement of about 635,000 acre-feet per season when land that would be inundated by reservoirs is taken into account. The irrigable lands occur in parcels of varying size throughout the middle and lower reaches of the stream group area, with principal concentrations located in the vicinity of Middletown and Pope Valley in the Putah Creek Basin; around Clear Lake and in Bear Valley in the Cache Creek Basin; around East Park Reservoir in the Stony Creek Basin; and in the foothill area between Red Bluff and Arbuckle. It is estimated that the future population of the stream group may be about 26,000 people.

There is no present water deficiency in the West Side Stream Group and no flood problems of consequence except around Clear Lake, caused principally by the limited capacity of the outlet channel. The quality of the water supplies is generally good, but somewhat inferior to the supplies of other parts of the Sacramento River Basin. In the Cache Creek Basin below Clear Lake some of the minor tributaries have an especially high boron content.

The objectives of The California Water Plan in the West Side Stream Group are to conserve the water for local and downstream use, and to provide flood protection for local and downstream areas. Maintenance of stream flow for recreation is generally not of importance in this area, but the major reservoirs themselves may develop important recreational opportunities. In addition, small reservoir impoundments designed specifically for recreation and fishing may be desirable in some localities. There is little concern with hydroelectric power, except insofar as local water supplies may be combined with imported supplies from the Eel River under the California Aqueduct System and used for this purpose.

Under The California Water Plan it is contemplated that the waters of Redbank Creek, together with spill from Dippingvat Reservoir on the South Fork of Cottonwood Creek, would be conserved for irrigation and regulated for flood control in Schoenfield Reservoir on Redbank Creek; and the waters of Elder Creek would be conserved for irrigation and regulated for flood control in Galatin Reservoir on Elder Creek. These reservoirs would serve lands as far south as Thomes Creek and would provide partial protection for downstream areas against damaging floods.

The waters of Thomes Creek would be partially conserved in Paskenta Reservoir on Thomes Creek with spill diverted through a saddle into Newville Reservoir on the North Fork of Stony Creek for further conservation and regulation for flood control. Newville Reservoir would also conserve surplus water diverted from Stony Creek below East Park Reservoir and from Grindstone Creek, principal tributary of Stony Creek. A small power plant would be installed at the base of Newville Dam. The remaining waters of Stony Creek would be conserved for irrigation and regulated for flood control in Black Butte Reservoir on the main stem of the stream near the foothill line. This reservoir has been authorized for construction by the Corps of Engineers, U. S. Army, and is classified as a feature of the Sacramento Division of the California Aqueduct System. New water supplies developed by Paskenta, Newville, and Black Butte Reservoirs would be used along and between Thomes and Stony Creeks and in the foothill area of the stream group as far south as Arbuckle. Secondary water supplies, comprising regulated flood release from Black Butte Reservoir, would be used for ground water recharge and export.

The runoff from some of the minor foothill streams between the drainage divides of Stony and Cache Creeks could be partially conserved for recreation by constructing small reservoirs at Clark Valley on the South Fork of Willow Creek, Squaw Flat on Logan Creek, High Peak on Hunters Creek, and Golden Gate on Funks and Stone Corral Creeks. These small reservoirs could possibly also be used for flood control and for terminal storage of pumped diversions from the Tehama-Colusa Canal to serve contiguous lands.

Irrigation developments in the Clear Lake area of Cache Creek would consist of Excelsior Reservoir on Copsey Creek with feeder canal from Seigler Canyon Creek, both tributary to the outlet channel of Clear Lake, to serve lands near the lake outlet; Boggs and Kelseyville Reservoirs on Kelsey Creek, with feeder canal from Cold Creek into the latter reservoir, to serve Big Valley and other lands south of the lake; and Pitney Ridge Reservoir on Middle Creek and Lakeport Reservoir on Scott Creek, a tributary of Middle Creek, to serve lands on the north and west sides of the lake.

Flood control in the Clear Lake area could be provided by conducting spills from Kelseyville and Lakeport Reservoirs into Clear Lake through separate floodway channels; by improving and leveeing the channel of Middle Creek; and by enlarging the outlet channel of Clear Lake with downstream flood control storage space provided in Guinda Reservoir at the head of Capay Valley, or in alternative reservoirs at Blue Ridge or Wilson Valley. These alternative sites are presently (1957) under detailed investigation. Present court decrees governing the operation of Clear Lake for flood control would have to be rescinded and/or modified before the outlet channel could be enlarged.

Firm water supplies developed in Guinda or suitable alternative reservoir would be used in Capay Valley and other downstream areas. Secondary supplies, comprising regulated flood releases, would be used for ground water recharge and export. Because of the latter function, Guinda Reservoir, or suitable alternative, would be classified as a feature of the Sacramento Division of the California Aqueduct System.

Other local developments in the Cache Creek Basin would consist of Indian Valley Reservoir on the North Fork of Cache Creek for conservation and flood control, and pumped diversions from East Park Reservoir on Stony Creek to serve irrigable lands in Bear Valley. A small reservoir could be constructed on Bear Creek at the lower end of Bear Valley to impound water for recreational purposes.

Local works in the drainage basin of Putah Creek would consist of Middletown Reservoir on Putah Creek to serve lands in the vicinity of Middletown, and Goodings Reservoir on Maxwell Creek, a tributary of Pope Creek which flows into Putah Creek, to serve lands in Pope Valley by pumped diversions. Local inflow to Goodings Reservoir would be augmented by importations of surplus water from Middletown Reservoir and Pope Creek.

The principal feature of the California Aqueduct System on Putah Creek would be Monticello Reservoir of the Eel River Division. No increase in capacity of Monticello Reservoir is contemplated under The California Water Plan, but considerable revision in its planned operation may be desirable. In its local function this reservoir would serve downstream areas and provide flood protection thereto. It would also afford opportunities for recreational development. With respect to future local development it is pertinent to note that recent permits issued by the State Water Rights Board to the United States Bureau of Reclamation in furtherance of the Solano Project, contain a condition subjecting the permits to depletion of stream flow above Monticello Reservoir in an amount not to exceed 33,000 acre-feet annually by future appropriations of water for reasonable beneficial use within the watershed of Putah Creek above said reservoir; provided such future appropriations shall be initiated and consummated prior to full beneficial use of water within the Solano Project service area. This permit term may make it necessary that any developments constructed in the area upstream from Monticello Reservoir for conservation of local water resources subsequent to the time that full beneficial use has been made under the Solano Project be based on an exchange of water imported from the Eel River or other sources under The California Water Plan.

In summary, the local works of the West Side Stream Group would consist of 17 reservoirs together with associated diversion dams and a power plant; feeder and service conduits, including pump lifts where required; and leveed stream channel improvements and floodway channels. The reservoirs would have a combined gross storage capacity of 1,920,000 acre-feet, of which only 154,000 acre-feet would be inactive. Operated in conjunction with ground water storage in local areas, these reservoirs would insure virtually full irrigation development of the land resources of the stream group and would provide opportunities for recreational development. In conjunction with features of the California Aqueduct System, these reservoirs would regulate water for downstream use, including ground water recharge and export. Together with Monticello Reservoir and Clear Lake, the reservoirs would contain about 400,000 acre-feet of storage space specifically reserved for flood control and strategically disposed throughout the stream group to protect downstream areas. Flood protection for the Clear Lake area would be accomplished by

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enlarging the lake outlet and other appropriate measures. The Newville Power Plant at the base of Newville Dam would have an installed capacity of about 8,500 kilowatts and would generate an average of about 33,000,000 kilowatt-hours per year.

Antelope-Butte Stream Group. The Antelope-Butte Stream Group comprises the small stream basins of the Sierra Nevada located between the Feather River and the Battle and Paynes Creek drainage divides. The principal streams of the group, from north to south, are Antelope, Mill, Deer, Big Chico, and Butte Creeks. These streams, together with the smaller streams of the group, drain a mountainous area of about 1,140 square miles. They are distinguished from most other streams of the Sierra by their parallel courses and steep descent from the headwaters or headwater valleys to the Sacramento Valley floor, with few tributaries and little opportunity for storage enroute.

Precipitation varies from about 25 inches per season at the western foothills to more than 70 inches at the eastern mountain boundary. Much of this precipitation falls as snow which, along with the porous character of the upper watersheds, tends to equalize the runoff to some extent. The mean natural runoff of the stream group is about 1,180,000 acre-feet per season, of which the minor foothill streams contribute about 210,000 acre-feet.

The irrigable lands of the Antelope-Butte Stream Group are situated mainly on the Paradise Ridge between the West Branch of the Feather River and Butte Creek. Smaller parcels are located on the broad ridges on both sides of Big Chico Creek. A fairly large parcel at the headwaters of Antelope Creek is considered now as being better suited to continued forest use rather than for irrigated agriculture. Lands of the Paradise Irrigation District are served from Magalia and recently completed Mosquito Junction Reservoirs on Little Butte Creek. Mountain meadows and downstream areas are irrigated by direct diversion of stream flow without benefit of storage. Hydroelectric power is generated on Butte Creek at the De Sabla and Centerville plants of the Pacific Gas and Electric Company. These plants utilize the natural stream flow of Butte Creek, supplemented by a diversion from the West Branch of the Feather River. There are no other present water developments of consequence in the Antelope-Butte Stream Group. All of the major streams of the group and several of the minor streams provide spawning ground for anadromous fish.

There are no serious present water problems within the area of the Antelope-Butte Stream Group, but the streams often cause damage on contiguous areas of the Sacramento Valley floor. Flood problems are sometimes aggravated by the abrupt dislodgment of logs and debris.

Under The California Water Plan it is contemplated that the waters of Antelope Creek, together with Salt and Little Antelope Creeks on the immediate north and south, respectively, would be conserved through spreading and ground water recharge and regulated for flood control in Antelope Basin Reservoir. This reservoir would be created in an exceedingly permeable area on the valley floor at the base of the foothills east of Red Bluff by constructing a long earthen dike across the several stream channels to form a closed basin. The lands which would be occupied by the reservoir are not classified as irrigable and could be used for grazing most of the time, as at present.

The waters of Mill and Deer Creeks would be developed for power and conserved and regulated, together with several adjacent minor foothill streams, for irrigation and flood control. The power features would consist of Morgan Springs Reservoir at the headwaters of Mill Creek, with releases diverted by canal to Deer Creek Meadows Reservoir on Deer Creek, whence the head would be developed by canal, tunnel, and pipe line in a series of four power drops to the base of the foothills. Flow from the intermediate reaches of Mill Creek below Morgan Springs Dam would be diverted into the power system by tunnel entering Deer Creek below the first power drop. Except for the headwater reservoirs on Mill and Deer Creeks, no structures are planned that, with adequate fish ladders, could not be negotiated by anadromous fish.

The power releases from the terminal plant of the system on Brush Creek would be reregulated in Brush Basin Reservoir, a feature of the California Aqueduct System located east of Vina. Like Antelope Basin, this reservoir would also be formed on the valley floor at the base of the foothills by constructing a long earthen dike to create a closed basin. In this case the inundated lands, though not classified as irrigable, are not permeable and very little direct ground water recharge could be anticipated. The reservoir itself would intercept the direct flow of a number of minor foothill streams besides Brush Creek; but the flood flows of Mill, Toomes, Deer, and Rock Creeks would be conveyed to the reservoir for storage and regulation through large-capacity floodway channels. Low diversion dams on these streams would permit the passage of anadromous fish; and normal stream flow would not be diverted.

Irrigation supplies for lands on Keefer Ridge, north of Big Chico Creek, would be conserved in Butte Creek House Reservoir at the headwaters of Butte Creek. Water released from this reservoir would be diverted downstream at Butte Meadows into Big Chico Creek and from Chico Meadows on that stream to Keefer Ridge. Supplemental water supplies for the Paradise Ridge area and for the area between Big Chico and Butte Creeks would be developed in

Grizzly Gulch Reservoir on Butte Creek and diverted downstream at Carpenter to both areas. Grizzly Gulch Reservoir would also be used to maintain stream flow for subsequent downstream diversion for power through the De Sabla and Centerville plants of the Pacific Gas and Electric Company, as at present. Additional water supplies for the Paradise Ridge area would also be developed by enlargement of Magalia Reservoir and by construction of a large Forks of Butte Reservoir on Butte Creek.

Foothill development of Big Chico and Butte Creeks would consist of a small conservation reservoir on Big Chico Creek, which would be used during the flood season to divert flood flows through a large tunnel into Butte Creek for storage and regulation in Castle Rock Reservoir, a feature of the California Aqueduct System. While no insurmountable interference with the anadromous fishery of these streams would result from construction of the upstream reservoirs, the foothill dams definitely would present serious barriers to migration. Remedial measures would include fish hatcheries, development of downstream spawning grounds, and possibly fish ladders—at least at Big Chico Dam.

In summary, prospective works of the Antelope-Butte Stream Group would consist of 10 new and enlarged reservoirs; 4 power plants; a number of small diversion and afterbay dams; and necessary conveyance and service conduits, comprising tunnels, pipe lines, and canals. The reservoirs would add about 550,000 acre-feet of storage capacity to the stream group system, of which about 48,000 acre-feet would be inactive and 125,000 acre-feet would be reserved in Antelope Basin, Brush Basin, and Castle Rock Reservoirs for flood control. The new power plants would have a combined installed capacity of 97,000 kilowatts and would generate an average of about 456,000,000 kilowatt-hours per year. Releases would be made for stream flow maintenance from all reservoirs in the interest of fish, wildlife, and recreation. In combination with parallel levees, where needed, floods on Antelope, Mill, Deer, Big Chico, and Butte Creeks could be reduced to future leveed channel capacities.

Feather River Unit. The Feather River Unit comprises the entire drainage basin of the Feather River above Oroville and the adjoining foothill area drained by Little Dry Creek on the north and Honcut Creek on the south. The unit has an area of about 3,740 square miles, of which about 3,000 square miles are mountainous and the remainder comprises valley and mesa lands. The Feather River has three principal tributaries which, in order of size and importance, are the North, Middle, and South Forks. The North Fork has two main tributaries, namely West Branch and East Branch. Irrigable lands of the Feather River Unit are located principally in the large headwater valleys of the Feather River Basin and in the foothill area south of Oroville.

Precipitation over the Feather River Unit ranges from about 25 inches per season at the western foothill boundary to as much as 90 inches at the summit of Mt. Lassen, but only about 15 inches in Sierra Valley. The estimated mean natural runoff of the Feather River at Oroville is 4,600,000 acre-feet per year. The combined mean natural runoff of Little Dry Creek and Honcut Creek amounts to about 80,000 acre-feet per year.

The main stem of the North Fork of the Feather River has been extensively developed for power by the Pacific Gas and Electric Company with storage provided principally in Mtn. Meadows, Lake Almanor, Butt Valley, and Bucks Lake Reservoirs. The main power system, when completed, will comprise nine plants with a combined installed capacity of about 686,000 kilowatts, exclusive of Big Bend Plant which eventually will be abandoned due to submergence by Oroville Reservoir. Separate diversions for power are also made by the company from the West Branch of the North Fork to serve the small De Sabla and Centerville plants on Butte Creek, as described in the Antelope-Butte Unit, and to serve the small Lime Saddle and Coal Canyon plants of the Feather River Unit.

The mountain valleys of the Feather River are irrigated by direct stream flow diversion, supplemented, in the case of Sierra Valley, by a small import of partially regulated water from the Truckee River Basin. Water supplies for the Oroville-Wyandotte Irrigation District, comprising lands in the foothill area of the unit south of Oroville, are diverted from the South Fork of the Feather River through the Palermo Canal; from Lost Creek Reservoir on Lost Creek, a tributary of the South Fork, through the Forbestown Ditch; and directly from North Honcut Creek with minor storage in Lake Wyandotte. Foothill lands northwest of Oroville are served from the Lime Saddle-Coal Canyon Power Canal. Valley floor lands are served by direct diversions from the Feather River. Communities of the unit obtain their water supplies from wells, springs, and streams.

Present water requirements of the Feather River Unit amount to about 189,000 acre-feet per season for water service areas aggregating about 92,000 acres. In the future, it is estimated that the water service areas will expand to about 218,000 acres with an ultimate water requirement of about 547,000 acre-feet per season when opportunities for re-use of developed water are taken into account.

Except for Sierra Valley and the community of Portola, there are no present major problems of water deficiency within the Feather River Unit. Floods on the Feather River do not constitute a major problem in upstream areas, but in the Sacramento Valley floor they are the main concern and, in the past, have caused great damage and loss of life.

The objectives of The California Water Plan within the Feather River Unit are to develop and regulate the water supplies to an optimum degree for local use and export, flood control, power, recreation, and stream flow maintenance for fish and wildlife. Recreation and stream flow maintenance for the enhancement of fish is considered especially important to the economy of the basin, with particular values attached to the streams of the upper Indian Creek area, the Middle Fork Canyon system, and the Lake Almanor area.

Under the California Water Plan it is assumed that the present undeveloped power potential of the North Fork of the Feather River between Lake Almanor and Belden will be developed in the near future by tunneling for three drops, as planned by the Pacific Gas and Electric Company. The remaining undeveloped water resources of the North Fork, comprising principally the East Branch of the North Fork, would be developed by projects on Indian and Spanish Creeks, main tributaries of the East Branch. The waters of Indian Creek would be conserved and regulated for irrigation, power, recreation, and stream flow maintenance for fish and wildlife, in five headwater reservoirs above Indian Valley, namely, Genesee and Antelope Valley on Indian Creek; Squaw Queen and Dixie Refuge on Last Chance Creek, an important tributary of Indian Creek; and Abbey Bridge on Red Clover Creek, also an important tributary of Indian Creek. The plan also contemplates that Dixie Creek, a tributary of Red Clover Creek, would be diverted by canal into Squaw Queen Creek, a tributary of Last Chance Creek, for storage and regulation in Squaw Queen Reservoir.

Water released from Antelope Valley and Abbey Bridge Reservoirs for stream flow maintenance would flow into Genesee Reservoir for further disposition. Water released from Dixie Refuge Reservoir for stream flow maintenance, together with water diverted from Dixie Creek, would enter Squaw Queen Reservoir, whence the flow would be diverted by tunnel to develop the power head to Genesee Reservoir. Releases from Genesee Reservoir would be used for irrigation in Indian Valley, for stream flow maintenance in Indian Creek and in the main stem of the East Branch, and for power. The power head below Genesee Reservoir would be developed by tunnel in a single drop between a forebay above Indian Falls on Indian Creek and an afterbay on the East Branch below the mouth of Indian Creek.

The works on Spanish Creek would consist of a large Meadow Valley Reservoir with feeder tunnels from Bear Creek, a tributary of the Middle Fork of the Feather River, and from Nelson Point Reservoir on the Middle Fork of the Feather River. Water released from Meadow Valley Reservoir would be used for irrigation and urban purposes in American Valley, for stream flow maintenance on Spanish Creek, and for power with the head between the reservoir and Rich Bar on the North Fork of the Feather River developed by tunnel in a single drop.

On the Middle Fork of the Feather River, water supplies for Sierra Valley would be conserved in three reservoirs on separate headwater tributaries, namely Grizzly Valley on Big Grizzly Creek, Frenchman on Little Last Chance Creek, and Sheep Camp on Craycroft Creek, with minor streams intercepted by feeder canal and pumped into the latter reservoir. These reservoirs could also be used to a limited extent for stream flow maintenance on the Middle Fork. Additional supplies, if needed, could be obtained by gravity diversion from Squaw Queen Reservoir to Abbey Bridge Reservoir, and thence by pumping from Abbey Bridge Reservoir through a tunnel into Grizzly Valley Reservoir, in which event development of the power head to the floor of Sierra Valley might be warranted. The head could be developed by pipe line with an afterbay below the power plant on Big Grizzly Creek to reregulate the power releases to an irrigation and stream flow maintenance demand schedule. Other less favorable opportunities for reservoir development of additional water supplies for Sierra Valley exist at Clover Valley on Smithneck Creek near Loyalton, and at Randolph on Cold Stream near Sierraville. Finally, additional supplies might be obtained from ground water sources if well development should prove to be feasible.

Supplemental water supplies for Portola and other communities along the main stem of the upper Middle Fork could be made available from the improved stream flow of Middle Fork but the local development of minor spring-fed streams would probably be more desirable.

Development on the Middle Fork of the Feather River below Sierra Valley would consist of Nelson Point Reservoir to conserve water for stream flow maintenance and for power by diversion to Meadow Valley Reservoir, as previously noted. Below Nelson Point Dam at Hartman Bar the remaining flow of the Middle Fork, in excess of stream flow maintenance requirements, could be diverted by tunnel to Swayne Reservoir on French Creek, a tributary of the North Fork, with the flow of Little North Fork, a tributary of the Middle Fork, intercepted enroute. From Swayne Reservoir the water would be released through penstocks to a power plant on the North Fork arm of Oroville Reservoir.

Under an alternative arrangement proposed by the Richvale Irrigation District, the headwaters of the Middle Fork would be conserved and regulated in Frenchman and Grizzly Valley Reservoirs above Sierra Valley, in Gold Lake Reservoir on Frazier Creek, in Clio Reservoir on the Middle Fork above

Genesee Valley in Feather River Basin

Sacramento Valley—Foothill Hay Production

Blairsden, and in Nelson Point Reservoir, for power development along the Middle Fork and for irrigation of district lands on the Sacramento Valley floor. Water conserved in the upstream reservoirs would flow down the stream channel of the Middle Fork into Nelson Point Reservoir, whence the power head to the Middle Fork arm of Oroville Reservoir would be developed by tunnel in a series of five drops with regulatory and diversion facilities provided enroute on the Middle Fork, as required. The feasibility of this proposal may depend upon utilizing for power virtually all of the present water supply in critical years without further impairment by additional upstream use in Sierra Valley. The district has been granted a preliminary permit by the Federal Power Commission. The Department of Water Resources is currently (1957) giving further study to this proposal, as well as to the other developments discussed herein for the Middle Fork.

Other developments on the Middle Fork of the Feather River would probably consist of small reservoirs on downstream tributaries to maintain stream flow for fish, wildlife, and recreation. Typical but not necessarily desirable sites are Mt. Ararat on Willow Creek, Whiskey Hill on South Branch, and Quartz Hill on Fall River.

Water supplies for areas dependent on the South Fork of the Feather River would be made available under The California Water Plan by a combination power and water supply development involving the utilization of surplus flows from Canyon and Slate Creeks, tributaries of the North Yuba River, as well as from the South Fork itself. Under the plan the waters of the South Fork would be conserved in Little Grass Valley Reservoir and released to the stream channel of the South Fork for subsequent diversion by tunnel into an enlarged Lost Creek Reservoir on Lost Creek, a tributary of the South Fork. Water from Canyon and Slate Creeks would also be diverted by tunnel and conserved in the enlarged Lost Creek Reservoir.

Part of the water released from Lost Creek Reservoir would serve lands along the Forbestown Ditch, as at present, and new lands in the Dobbins-Oregon House area west of the North Yuba River. The remainder would be conveyed by tunnel to a power drop on the South Fork at the mouth of Lost Creek and thence again by tunnel to another power drop on the South Fork near Forbestown. From this point, the water would be diverted from the river and conveyed by canal and tunnel to serve the foothill lands of the unit south of Oroville.

A number of other plans for development of the water and power resources of the South Fork of the Feather River, both with and without imports from the North Yuba River, have been proposed by various agencies from time to time. Among these are plans by the Pacific Gas and Electric Company, the Oroville-Wyandotte Irrigation District, and Yuba County and the Yuba County Water District. In an effort to resolve differences between the plans of the Oroville-Wyandotte Irrigation District and the Yuba County interests, the State Engineer on October 7, 1955, pursuant to Water Right Decision No. 838, suggested a compromise plan wherein the capacity of Little Grass Valley Reservoir would be made much larger than contemplated in the plan first described above, and the South Fork diversion to Lost Creek Reservoir would include unregulated water imported by tunnel from Fall River, a tributary of the Middle Fork of the Feather River. The existing Lost Creek Reservoir would not be enlarged, and water supplies imported by tunnel from Canyon and Slate Creeks would be conserved in a Sly Creek Reservoir immediately upstream. Regulated water supplies made available by this alternative plan would be released from existing Lost Creek Reservoir and utilized for irrigation and power in much the same manner as first described above.

The various proposals for development of the South Fork of the Feather River are currently (May, 1957) under consideration by the State Water Rights Board in acting upon the conflicting application of Oroville-Wyandotte Irrigation District and Yuba County and Yuba County Water District.

Additional small local developments in the foothill area of the Feather River Unit south of Oroville would consist of South Honcut Reservoir on South Honcut Creek for irrigation and flood control, and Bangor Reservoir on North Honcut Creek for recreation and stream flow maintenance. Wicks Corner Reservoir on Cottonwood Creek, a tributary of Dry Creek which drains the foothill area north of Oroville, would provide recreation and stream flow maintenance on that stream.

Features of the California Aqueduct System within the Feather River Unit would consist of Oroville Dam and Reservoir, Oroville Power Plant, a diversion dam below the power plant, and canal serving another power plant enroute to an off-stream afterbay. In their local function these features would protect Sacramento Valley floor areas against damaging floods, conserve and regulate water for use on the valley floor, enhance and improve stream flow in the Feather River, and afford opportunities for recreational development. Oroville Reservoir will have a capacity of 3,500,000 acre-feet with 500,000 acre-feet tentatively reserved for flood control. Oroville Reservoir and related facilities have already been authorized as a part of the Feather River Project, the initial unit of The California Water Plan, and work thereon is currently under way.

In summary, local works of the Feather River Unit would consist of at least 21 new and enlarged reservoirs; six new power plants, exclusive of those existing or proposed for the Pacific Gas and Electric Company North Fork System; and associated conveyance, feeder, and service conduits, with diversion structures, afterbays, and other auxiliary features as required. The local reservoirs would have a combined gross storage capacity of about 2,100,000 acre-feet, of which about 77,000 acre-feet would be inactive. They would provide water for local use in the upland and foothill areas of the unit, while Oroville Reservoir would serve dependent areas on the Sacramento Valley floor and would provide flood protection thereto. Releases would be made from the local reservoirs for stream flow maintenance in the interests of fish and wildlife, and many of the reservoirs themselves would afford opportunity for recreational development. The new local power plants would add about 331,000 kilowatts of installed capacity to the basin power system, and would generate an average of about 1.3 billion kilowatt-hours of new energy per year.

Yuba-Bear River Unit. The Yuba-Bear River Unit is located on the western slope of the Sierra Nevada between the Feather and American River Units. It consists of the drainage basins of the Yuba and Bear Rivers, and the minor drainage areas of Auburn Ravine, Doty Ravine, and Coon Creek south of the Bear River; Dry Creek between the Bear and Yuba Rivers; and French Dry Creek and the southern drainage of South Honcut Creek north of the Yuba River. Included within the unit are approximately 1,720 square miles of land area ranging from rugged mountains to rolling foothills. Only about 75 square miles of the area have been classified as valley and mesa land.

Precipitation in the Yuba-Bear River Unit varies from about 25 inches per season at the western foothill boundary to as much as 70 inches in the high mountains. The mean natural runoff of the Yuba River is about 2,420,000 acre-feet per year. The Bear River has a mean natural runoff of about 360,000 acre-feet per year, and the minor foothill streams together have a mean natural runoff of about 144,000 acre-feet per year.

Most of the presently irrigated area as well as potentially irrigable land lies within the boundaries of the Browns Valley and Nevada Irrrigation Districts and the Yuba County Water District. Some of the reservoirs and canals presently employed to serve these areas date back to the days of hydraulic mining. The Browns Valley Irrigation District obtains its water supply principally from the North Yuba River by diversion from the Colgate power tunnel. Existing works of the Nevada Irrigation District include about a dozen large and small reservoirs which are used to regulate the headwater runoff of the Middle and South Yuba Rivers, Bear River, and Deer Creek which enters the Yuba River from the south below Englebright Dam. Except for releases from Scotts Flat Reservoir on Deer Creek and from Van Geisen (Combie) Reservoir on the Bear River, the water developed by these reservoirs flows through local power facilities of the Pacific Gas and Electric Company, after which it is distributed to the lands of the district.

The Camp Far West Irrigation District, located west of the Yuba-Bear River Unit boundary, develops its water supply in Camp Far West Reservoir on the Bear River to serve downstream areas on both sides of the river. The Pacific Gas and Electric Company owns and operates 12 power plants within the unit. In addition to utilizing the water developed by the works of the Nevada Irrigation District as previously noted, the company operates approximately 20 of its own dams and reservoirs, ranging in size from small diversion structures to the 74,500 acre-foot capacity Lake Spaulding Reservoir on the South Yuba River.

The water problems of the Yuba-Bear River Unit relate mainly to the conflicting uses of developed water for power, irrigation, and stream flow maintenance for fish and wildlife. Although some local flood problems exist within the unit, much of the runoff of the streams is uncontrolled and heavy damage is inflicted upon the Sacramento Valley floor during major floods.

Development of the Yuba-Bear River Unit under The California Water Plan contemplates that part of the remaining undeveloped headwaters of the Yuba River would be concentrated by further diversion of tributaries into Lake Spaulding, whence the developed water would be released for power and irrigation. Under this plan, the waters of the South Fork of the North Yuba River would be diverted below the mouth of Haypress Creek and conveyed by tunnel to Jackson Meadows Reservoir on the Middle Yuba River. Releases from Jackson Meadows Reservoir would flow into the existing Milton-Bowman-Spaulding diversion facilities of the Nevada Irrigation District and into Lake Spaulding through an enlarged Spaulding No. 3 Power Plant. Water from Fordyce Lake on Fordyce Creek, now draining into Lake Spaulding, would be conveyed by canal, together with the intercepted water of Rattlesnake Creek and the South Yuba River, into an enlarged Lake Valley Reservoir on the North Fork of the North Fork of the American River. After satisfying nominal stream flow maintenance requirements for fish on that stream, releases from Lake Valley Reservoir would be returned to the South Yuba River by pipe line with a power drop into Lake Spaulding. From Lake Spaulding the developed and regulated waters of the upper Yuba River Basin would be released through two separate existing conduit systems; namely, the Drum System of the Pacific Gas and Electric Company and the South Yuba Canal.

Water conveyed by the Drum System would enter the Bear River through the Dutch Flat Power Plant as at present. Here the water would be diverted and would flow in a canal into a proposed Rollins Reservoir on the Bear River through a new power drop. Releases from Rollins Reservoir would flow through a power plant at the base of the dam, and, after reregulation in an afterbay, would again be diverted into the Drum System as at present, where it would be available for irrigation on the divide between the Bear and American Rivers and for power generation at enlarged Halsey and Wise Power Plants. The winter power releases from the latter plant would be conveyed by tunnel to Auburn Reservoir on the North Fork of the American River, and stored for subsequent summer release to Auburn Ravine for irrigation of the foothill lands north of Folsom Reservoir.

The South Yuba Canal would continue to serve lands in the Nevada City-Grass Valley area as at present, but with an increased supply made available in part by additional releases from Lake Spaulding and in part by enlarging Scotts Flat Reservoir on Deer Creek to store the winter power releases from Deer Creek Power Plant. Both this plant at the terminal and the Spaulding No. 2 Power Plant at the head of the South Yuba Canal would be enlarged to utilize the additional water supplies made available by new upstream storage works.

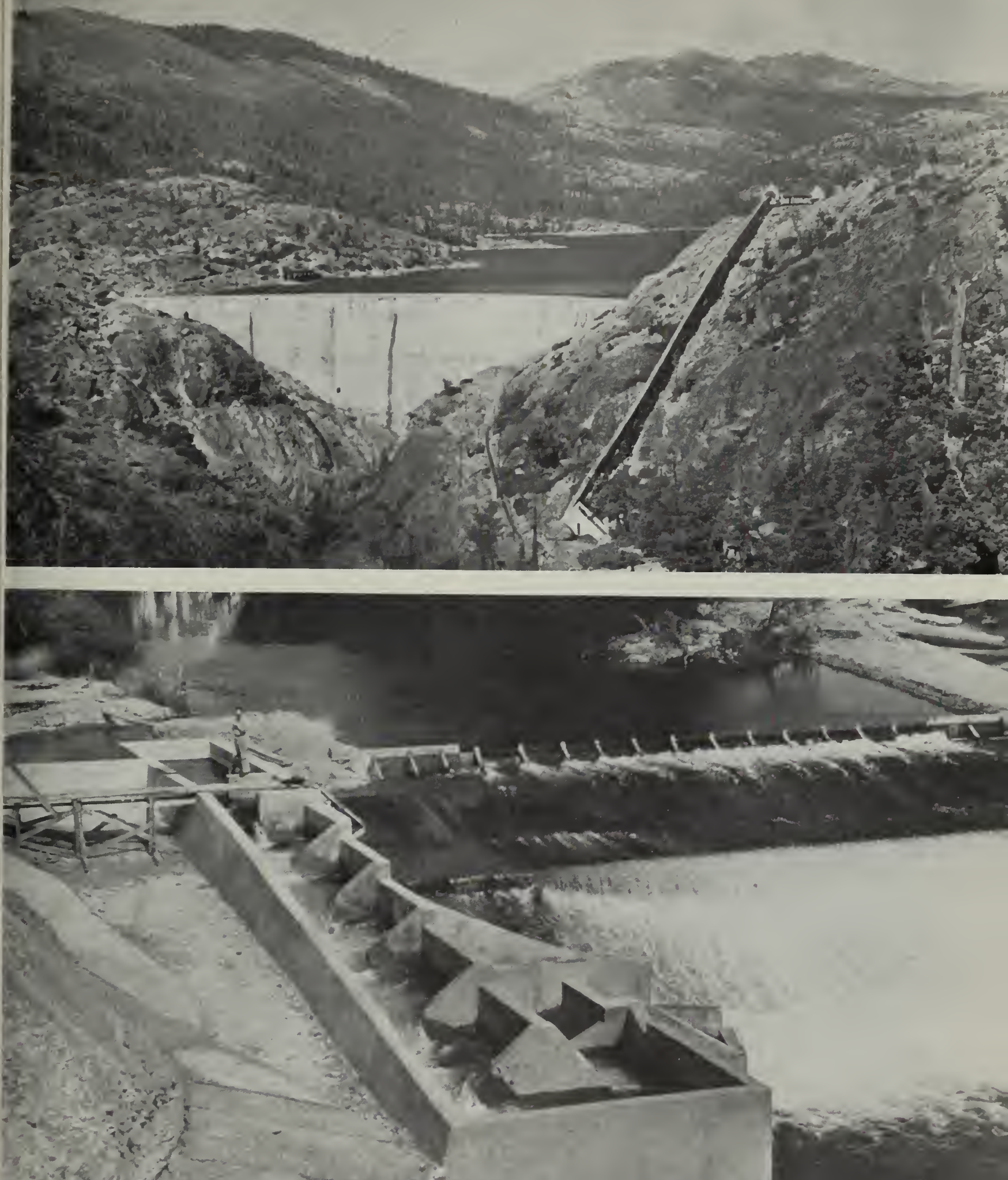
Additional water supplies for the Nevada City-Grass Valley area and new water supplies for the North San Juan area would be made available by a combination power and water supply development that would concentrate the runoff from the middle sectors of the Middle and South Yuba Rivers in a large storage reservoir near Washington on the South Yuba River. In this project the waters of the Middle Yuba River would be diverted at a point near Allegheny and would flow through a tunnel into Washington Reservoir. Releases from Washington Reservoir would then be conveyed by tunnel to a forebay near Nevada City, whence diversions for irrigation and power would be made. A main irrigation canal would divert southward into the Nevada City-Grass Valley area. A smaller irrigation conduit would cross the South Yuba River by inverted siphon to serve lands in the North San Juan area. Releases for power would flow through a penstock to the Devils Slide Power Plant on the South Yuba River. Part of the power releases from this plant would be diverted from an afterbay on the South Yuba River through the existing Excelsior Ditch into a proposed Anthony House Reservoir on Deer Creek, where it would be stored for subsequent irrigation use. The remaining power releases would be diverted from the same afterbay and conveyed by tunnel to a Jones Bar Power Plant on the South Yuba River near the head of Englebright Reservoir.

Except for the diversion of the South Fork of the North Yuba River into Jackson Meadows Reservoir, the only other headwater development contemplated for the North Yuba River would be the diversion of Canyon and Slate Creeks, tributary thereto, into Lost Creek Reservoir in the drainage basin of the South Fork of the Feather River. These latter works would comprise a part of the South Fork Feather River Development and have been previously discussed under the heading "Feather River Unit."

The Department of Fish and Game considers that the main stem of the North Yuba River has certain unique and desirable natural flow characteristics for angling that should be preserved in perpetuity for future generations to enjoy. Furthermore, the stream flows through an area rich in historical background. For these reasons no developments are now considered for the accessible reaches of the river above the mouth of Canyon Creek; but in future, more detailed investigation, careful consideration should be given to the relative advantage of adhering to this principle or of further water development, if the need arises for additional water. Historic Downieville, in this area, sometimes suffers damage from floods, but it is improbable that corrective measures, other than the possible relocation of some buildings to a safe level, could ever be justified under presently accepted methods of evaluating flood control benefits.

Prospective works on the North Yuba River below the mouth of Canyon Creek would consist of Wambo Dam and Reservoir, with a short tunnel to develop about 400 feet of power head into an enlarged Bullards Bar Reservoir on the North Yuba River. This latter reservoir would be connected by a short equalizing tunnel with a large Freemans Reservoir on Middle Yuba River. The two connected reservoirs would thus, in effect, constitute a single large multipurpose reservoir, with the power head to Englebright Reservoir then developed by tunnel. About 160,000 acre-feet of the combined storage space would be reserved in the reservoirs for flood control.

Foothill development of the Yuba River would consist of Parks Bar Reservoir below Englebright Dam for flood control, and Waldo Reservoir, on Dry Creek, a tributary of Bear River, to provide off-stream storage for surplus Yuba River water. Water supplies for Waldo Reservoir would be diverted by tunnel from Englebright Reservoir into Deer Creek, combining therewith for further diversion to a small distributing reservoir south of Parks Bar Dam. From this point the surplus water would be further conveyed by canal to Waldo Reservoir for storage and regulation. The head available between the distributing reservoir and the main stem of the Yuba River below Parks Bar Dam would be developed for power, utilizing firm water supplies developed by upstream storage works and conveyed to this point by the foregoing described diversion facilities. A low afterbay dam on the Yuba River below the power plant would reregulate the power releases. All of the prospective foothill works of the Yuba River would have important export as



Sacramento River Basin—Spaulding Dam on South Fork of Yuba River and Fish Ladder at Deguerre Point Diversion Dam on Yuba River well as local functions, and have therefore been designated as features of the California Aqueduct System.

Major foothill storage regulation of the remaining water resources of the Bear River below Rollins Reservoir would be accomplished by enlarging the present Camp Far West Reservoir east of Wheatland. This reservoir would be used for both conservation and flood control, and has also been designated as a feature of the California Aqueduct System.

The waters of French Dry Creek, principal downstream tributary of the Yuba River entering from the north, would be conserved for local use in Virginia Ranch Reservoir located about 7 miles above Browns Valley. Waters of Coon Creek would be conserved for local use by construction of a small Coon Creek Reservoir on the middle reaches of Coon Creek. Other possibilities for storage development on the minor foothill streams of the unit would be a small Auburn Ravine Reservoir on Auburn Ravine below the town of Auburn and a Doty Ravine Reservoir on Doty Ravine northeast of Lincoln.

In summary, prospective works of the Yuba-Bear River Unit under The California Water Plan would consist of about 16 new and enlarged reservoirs; a number of diversion works at various locations; necessary conveyance and service conduits; and 15 new and enlarged hydroelectric power plants. The new reservoirs would add about 2,000,000 acre-feet of capacity to the present storage system of the unit. Of this, about 400,000 acre-feet would be reserved for flood control. The reservoirs would provide supplemental water supplies for all dependent areas and would regulate substantial quantities of water for export. They would provide a measure of flood control for local areas and would afford substantial flood protection to downstream areas. Releases would be made from the reservoirs to maintain and in some instances enhance the stream flow in the interests of fish, wildlife, and recreation. The power plants would provide about 325,000 kilowatts of new capacity and would generate an average of about 1.2 billion kilowatt-hours of new energy each year. Of this, about 40,000 kilowatts and 83,000,000 kilowatt-hours are considered to be creditable to the Parks Bar Power Plant, a feature of the California Aqueduct System. This takes into account the loss of power at the upstream Narrows Power Plant, which eventually would be abandoned due to submergence by Parks Bar Reservoir.

American River Unit. The American River Unit comprises the drainage basin of the American River above the Fair Oaks gaging station and the adjoining foothill area north to the southern drainage boundary of Auburn Ravine. The total area, measured to the base of the foothills, is 2,050 square miles, of which the American River Basin itself contains 1,920 square miles. About 1,900 square miles of the American River Basin are considered to be mountainous. Elevations range from about 150 feet at the western foothill boundary to about 10,000 feet along the crest of the Sierra.

The main stem of the American River is formed by the junction of its North and South Forks in Folsom Reservoir. The North Fork has no important tributaries except the Middle Fork which joins it near Auburn. The Middle Fork has one important tributary, the Rubicon River. The South Fork has two main tributaries, namely Silver Creek and Silver Fork. The forks of the American River and their principal tributaries flow from the headwaters through deeply incised canyons separated from each other and from adjoining streams by comparatively broad east-west trending ridges. The irrigable lands of the unit are located on the main ridges and on the rolling foothills.

Precipitation in the American River Unit ranges from about 25 inches per season at the base of the foothills to more than 70 inches in the high mountains. The estimated full natural runoff of the American River amounts to about 2,770,000 acre-feet per year at the Fair Oaks gage. The runoff of the minor streams of the unit north of Folsom Reservoir amounts to only about 79,000 acre-feet per year. Under ultimate conditions of development it is anticipated that exchanges of water with neighboring basins will result in a small increase in the water supply of the unit.

The economy of the American River Unit is based mainly on activities relating to agriculture, lumbering, mining, and recreation. Because of its proximity to large centers of population in northern California and because of an excellent road network, including two transcontinental highways, the recreational opportunities, in particular, are being rapidly developed. These include skiing resorts, summer home and camp sites, trout fishing, etc. Indicative of the interest in recreation is the almost unprecedented attraction of the recently completed Folsom Reservoir and Lake Natoma to boating, fishing, and water sports enthusiasts. Development of the lake shore at both of these reservoirs has been authorized as part of the State Park System.

Present water development in the American River Unit consists of: about 67,000 acre-feet of headwater storage located principally in Lake Valley, Loon Lake, Medley Lakes, Twin Lakes, and Silver and Webber Reservoirs for power, irrigation, and stream flow maintenance; 14,600 acre-feet of debris control storage in North Fork Debris Storage Reservoir near Auburn; and 1,000,000 acre-feet of multipurpose storage in Folsom Reservoir. Folsom Afterbay at Nimbus, called Lake Natoma, contains about 9,000 acre-feet of storage capacity. The El Dorado Irrigation District in the vicinity of Placerville obtains water from the El Dorado Forebay and Webber Reservoir in the watershed of the South Fork of the American River and from Diamond Ditch and Sly Park Reservoir in the

Cosumnes River Basin. The Georgetown Divide Public Utility District, serving lands on the divide between the Middle and South Forks, obtains its water supply principally from Loon Lake on Gerle Creek through a long and inefficient conduit system dating back to the mining days.

The foothill area north of Folsom Reservoir is served from the Drum Power System of the Pacific Gas and Electric Company with water originating principally in the Bear and Yuba Rivers, but including a modest supply diverted from the North Fork of the North Fork of the American River at Lake Valley Reservoir. There is no important water development at present on the Foresthill Divide between the North and Middle Forks other than for municipal and industrial requirements of the town of Foresthill. Downstream areas are served from Folsom Reservoir and by pumping from the American River. There are four existing hydroelectric power installations in the American River Basin, namely, the El Dorado and American River plants of the Pacific Gas and Electric Company and the Folsom and Nimbus plants of the Federal Government.

The present water requirements of the American River Unit, for consumptive purposes, amount to some 63,000 acre-feet per season for water service areas aggregating about 31,000 acres. These requirements are met, without deficiency, by releases from some of the foregoing works, together with importations of developed water from adjoining basins. Future demands on the American River for agriculture and urban purposes may amount to about 217,000 acre-feet per season when dependent lands in the Cosumnes River Basin, as well as those within the unit, are taken into account. The problem of floods is not a major concern in the upper American River Basin; and Folsom Reservoir, in conjunction with river levees, provides a high degree of protection for downstream areas. The preservation of fish and wildlife in the basin does not constitute a problem except as regards conflicting uses of developed water for other purposes. The former anadromous fishery of the upper basin has been blocked by the construction of Folsom Dam, but the provision of a salmon and steelhead fish hatchery below Lake Natoma is proving to be remarkably effective as a remedial measure.

Main objectives of The California Water Plan in the American River Unit are the development of its land, water, power, fish, wildlife, and recreational resources to the highest practicable degree.

Plans for development of the water resources of the American River Unit, in accordance with the principles of The California Water Plan, were first published in preliminary draft form in State Water Resources Board Bulletin No. 21, entitled ''American River Basin Investigation, Report on Development Proposed for The California Water Plan''. Following release of the preliminary draft report in June, 1955, the Board held public hearings which culminated in the adoption of a somewhat modified plan of basin development proposed by the Sacramento Municipal Utility District as an acceptable alternative to the basic plan presented in Bulletin No. 21. The Board directed that both plans be presented in the final edition of Bulletin No. 21 and in this bulletin. Accordingly, both plans are discussed herein under the general headings of ''Basic Plan'' and ''Modified Plan''.

1. *Basic Plan.* Prospective works in the watershed of the North Fork would consist of the enlargement of Lake Valley Reservoir on the North Fork of the North Fork for off-stream storage of water from the South Yuba River as discussed in the Yuba-Bear River Unit; a small reservoir on the headwaters of the North Fork at The Cedars, or suitable alternative site, to conserve water for stream flow maintenance in the interests of fish, wildlife, and recreation; a group of three small reservoirs on the Foresthill Divide, namely, Sugar Pine on North Shirttail Canyon, and Forbes and Big on Forbes Creek, with feeder canal or possible future tunnel from Secret Canyon and other tributaries of Middle Fork, for irrigation of the divide area and possibly for fish, wildlife, and recreational purposes; and a large Auburn Reservoir and Power Plant at the head of the North Fork arm of Folsom Reservoir, to conserve and regulate water for local use and export. Because of its export function, Auburn Reservoir is classified as a feature of the California Aqueduct System. The other works on the North Fork have strictly local functions.

Water developed and/or regulated for export in Auburn Reservoir would enter Folsom Reservoir for further disposition through the Auburn Power Plant at the base of the dam. In its local function, Auburn Reservoir, in addition to fishing and recreation, would store the winter power releases of Wise Power Plant for subsequent release for use on the foothill lands of the American River Unit north of Folsom Reservoir during the irrigation season. This would involve a tunnel between Auburn Reservoir and Auburn Ravine with connecting shaft to the afterbay of the Wise Power Plant. The tunnel would be gated at each end to control flow in either direction. Irrigation diversions would be made downstream from Auburn Ravine, as required, with possible additional regulatory storage provided in Whitney Ranch Reservoir on Pleasant Grove Creek. This small reservoir would also be used to conserve the local runoff of Pleasant Grove Creek.

Plans for the Middle Fork contemplate that water supplies for the Georgetown Divide area between the Middle and South Forks would be conserved in a large Stumpy Meadows Reservoir on Pilot Creek, a tributary of the Rubicon River. The water would be conveyed to the service area through a renovated and enlarged Georgetown Ditch, comprising a portion of the present conveyance system from Loon Lake Reservoir. Upper portions of this conveyance system would likewise be enlarged and improved by tunneling to convey surplus water from Gerle Creek and the South Fork of the Rubicon River to Stumpy Meadows Reservoir to augment natural inflow from Pilot Creek. A small feeder canal from Onion Creek, a tributary of Silver Creek, would be provided. In addition to its irrigation function, Stumpy Meadows Reservoir would afford opportunities for fishing and recreation, including stream flow releases to Pilot Creek for these purposes.

The excellent power potential of the Middle Fork of the American River and its headwater tributaries would be developed by a separate system of works comprising: four headwater reservoirs with associated conduits and power plants above a regulating and diversion reservoir at Parsley Bar on the Rubicon River; a main power conduit, consisting of a tunnel to Long Canyon and a canal along Ralston Ridge to a forebay at the end of the ridge; a high head Ralston Power Plant, served by pressure tunnel from Ralston Forebay and discharging into the Rubicon River arm of an American Bar Reservoir on the Middle Fork; and a low head American Bar Power Plant, developing the remaining head to the Middle Fork arm of Auburn Reservoir by tunnel. The headwater reservoirs would consist of French Meadows on the Middle Fork with feeder tunnel from Duncan Creek; Lower Hellhole on the Rubicon River; enlarged Loon Lake on Gerle Creek with feeder conduits from the South Fork of the Rubicon River and from upper Rubicon River by way of Rockbound and Buck Island Lakes; and Gerle below Loon Lake on Gerle Creek. Releases from all of the foregoing reservoirs would be made for stream flow and fishery maintenance purposes prior to diversion for power. The power head between these reservoirs would be developed by tunnel as follows: French Meadows to Lower Hellhole to Parsley Bar and Loon Lake to Gerle to Parsley Bar.

Plans for development of Silver Creek in the watershed of the South Fork of the American River contemplate that its headwater runoff would be conserved for power and for irrigation of the Placerville Divide area in a large Junction Reservoir, with dam located below the forks of Silver Creek and with a feeder canal diverting from the South Fork of the American River in lieu of far more costly on-stream storage. The regulated water from Junction Reservoir would be conveyed southward by tunnel to a power plant on a small tributary of the South Fork, and thence, after reregulation in an afterbay, by canal and tunnel to the existing Sly Park Reservoir in the Cosumnes River Basin, crossing the South Fork of the American River by inverted siphon. Sly Park Reservoir, under the basic plan, would continue to regulate Cosumnes River water as at present, functioning primarily as a conduit for the water imported from Junction Reservoir. From Sly Park Reservoir the water would be conveyed to an enlarged Webber Reservoir on Webber Creek, a tributary of the South Fork of the American River, with power drops enroute below Sly Park Dam and into Webber Reservoir. The latter reservoir would also receive additional inflow by feeder canal from the South Fork of Webber Creek. Stream flow maintenance releases for fish and recreation would be made from all of the above-mentioned reservoirs and diversions prior to any diversions for power or irrigation.

From Webber Reservoir the water would be conveyed to a small distributing reservoir on Hangtown Creek south of Placerville, with power drops enroute below the dam and into the distributing reservoir. From this reservoir a main irrigation conduit would extend westward along the ridge between the American and Cosumnes Rivers, while another conduit would return unused water to the South Fork of the American River with a power drop at Gold Hill, discharging into Salmon Falls Reservoir, which is subsequently described.

A variation of the basic plan for Silver Creek would route the water from Junction Reservoir by tunnel through two successive power drops, namely Jaybird on Silver Creek, and Camino on the South Fork of the American River at a point opposite the existing El Dorado Power Plant of the Pacific Gas and Electric Company. Releases from the Camino Power Plant would be reregulated in a Slab Creek Reservoir on the South Fork of the American River. From Slab Creek Reservoir the water would be diverted by tunnel to Webber Creek, whence it would be further diverted for irrigation on the Placerville Divide and returned to the South Fork for power as in the basic plan. Another variation would substitute three small reservoirs for the single large Junction Reservoir of the basic plan. The substitute reservoirs would consist of Lower Ice House on the South Fork of Silver Creek, with feeder canals from the South Fork of the American River and the Jones Fork of Silver Creek; Union Valley Reservoir on the main stem of Silver Creek, also receiving inflow from a Lower Ice House Power Plant; and a small Junction Diversion Reservoir, regulating the discharge from a Union Valley Power Plant. The works below the latter reservoir would follow either of the two foregoing suggested alignments.

Under the basic plan, additional water supplies would be made available for the Placerville Divide area through development of Silver Fork, with the surplus waters of that stream diverted by canal and tunnel for off-stream storage and regulation in a large Alder Creek Reservoir on Alder Creek. Water released from this reservoir in excess of stream flow maintenance for recreation and fishing would flow through a power plant on Alder Creek and would then enter the El Dorado Ditch of the Pacific Gas and Electric Company, whence it would flow to the El Dorado Forebay for further disposition. Part of the developed water would then be conveyed through an enlarged El Dorado Irrigation Ditch to serve lands in the eastern part of the Placerville Divide area, while the remainder would flow through and improve the output of the existing El Dorado and American River Power Plants.

The basic plan also contemplates that major conservation of the waters of the South Fork would be accomplished in a large Salmon Falls Reservoir, a feature of the California Aqueduct System, with dam and power plant located at the head of the South Fork arm of Folsom Reservoir. In its local function, Salmon Falls Reservoir would afford excellent opportunity for fishing and recreational development as well as increase the degree of flood protection made available to downstream areas. However, this important reservoir would, unfortunately, inundate the site of gold discovery in California; and as a consequence thereof the Legislature has directed that "In no event shall a permit to appropriate water be issued by the State for the purpose of a project which would flood any portion of the Gold Discovery Site State Park at Coloma unless such issuance is specifically authorized by law." Studies indicate that there are no feasible alternative storage sites for a large reservoir on the South Fork. The best alternative would be to divert the flow of the South Fork into the Cosumnes River for storage in Nashville Reservoir. This would require a diversion dam at Slab Creek on the South Fork and a tunnel to Webber Creek and then to Nashville Reservoir. This plan, however, would be virtually ineffective in regulating the heavy flood runoff of the South Fork to any considerable degree.

2. *Modified Plan.* Under the modified plan of complete basin development, as proposed by the Sacramento Municipal Utility District and adopted by the State Water Resources Board as an acceptable alternative to the basic plan, many features would remain the same or substantially the same as in the basic plan. For this reason and in order to avoid repetition, discussion of the modified plan is presented essentially on the basis of differences between it and the basic plan, wherever such differences exist.

Under the modified plan the water stored in Loon Lake Reservoir and the natural flow of Gerle Creek would be diverted to Union Valley Reservoir on Silver Creek for power development. The effect of this diversion would be to reduce the water supply available for power development on the Middle Fork and for diversion to Stumpy Meadows Reservoir on the Georgetown Divide. As a consequence, the basic plan for the Middle Fork power development would necessarily be revised to exclude the power drops from Loon Lake into Gerle Reservoir and from that reservoir into Parsley Bar Reservoir. Gerle Reservoir would be eliminated. Below Parsley Bar to Ralston the power head of the Middle Fork would be developed in two drops instead of the single large Ralston drop. Below Ralston Power Plant to the head of Auburn Reservoir the power head would likewise be developed in two drops with reservoirs at American Bar and Volcano, instead of the single larger American Bar power development described above in the basic plan. The modified plan also proposes the conveyance of water in tunnels instead of open canals. Preliminary estimates indicate that, even with the reduced water supply and the increased cost occasioned by the substitution of tunnels for open canals, the altered Middle Fork power development would still be sufficiently attractive to warrant early development.

Irrigation supplies for the Georgetown Divide would be developed in a smaller Stumpy Meadows Reservoir on Pilot Creek with feeder canal from Onion Creek, and in four other small reservoirs situated on streams draining from the divide area, namely, Tipton Hill on Rock Creek, and Traverse, Canyon, and Greenwood on streams of like name. Water developed in Canyon Creek Reservoir would be diverted by tunnel to Greenwood Reservoir for further disposition. This system of small reservoirs would afford about the same degree of development for the Georgetown Divide area as the single large Stumpy Meadows Reservoir described in the basic plan. An added advantage would be that additional increments of water could be obtained more readily by the construction of the small reservoirs than by successively raising Stumpy Meadows Reservoir as would be required in the basic plan. Except as discussed above, the remaining features of the North and Middle Fork developments of the American River would remain substantially the same as in the basic plan.

The diversion of Middle Fork water to Silver Creek under the modified plan contemplates the eventual full utilization for power of some 1,600 feet of head between Loon Lake Reservoir and Union Valley Reservoir. This would be accomplished by the construction of two small power plants enroute to the point of diversion at Sawmill on Gerle Creek, and by a small terminal power plant at the end of a Robbs Peak tunnel diverting into Union Valley Reservoir. Other works on Silver Creek, under the modified plan, would consist of Ice House Reservoir on the South Fork of Silver Creek at a site upstream from the one discussed in the basic plan; a tunnel diversion from Ice House Reservoir with a power plant discharging into Union Valley Reservoir; and a small Junction Diversion Reservoir regulating the discharge from

Union Valley Power Plant. There would be no feeder canal diverting from the South Fork of the American River as in the basic plan, since the Sacramento Municipal Utility District determined that diversion from the Middle Fork of the American River to Silver Creek for water development is more economical than diversion from the South Fork of the American River.

From Junction Diversion Reservoir the water would flow by tunnel to Jaybird Power Plant on Silver Creek, and then again by tunnel to Camino Power Plant at the head of a Slab Creek diversion and regulating reservoir on the South Fork of the American River. From Slab Creek Reservoir the water would be diverted by tunnel and flow through a White Rock Power Plant with the remaining head to Folsom Reservoir, then developed in three drops comprising, successively, a small Kelsey Reservoir and Power Plant, a large Coloma Reservoir and Power Plant, and a very small Salmon Falls Reservoir and Power Plant.

The waters of Silver Fork, under the modified plan, would be developed in the same manner as in the basic plan, except that releases from the Alder Creek Power Plant would flow down the stream channel of Alder Creek for subsequent diversion from the South Fork of the American River into an enlarged Sly Park Reservoir, whence the water would be conveyed to an enlarged Webber Reservoir with power drops en route as in the basic plan. From the enlarged Webber Reservoir the water would be conveyed with a terminal power drop into a small distributing reservoir on Hangtown Creek near Placerville, whence diversions would be made for irrigation as in the basic plan, but with no further power development by return of water to the South Fork of the American River. Additional water supplies for the area would be obtained as required by pumping from Folsom Reservoir, combined with terminal storage for the pumped water in a small Malby Reservoir on Carson Creek near White Rock.

In summary, two alternative plans have been described for development of the water resources of the American River Unit in accordance with the objectives of The California Water Plan. The first of these, designated as the basic plan, contemplates the eventual construction of 17 new and enlarged reservoirs; a number of diversion works at various locations; necessary conveyance and service conduits; and 15 new power plants. The new reservoirs would add almost 2,300,000 acre-feet of capacity to the present storage system of the unit. None of this storage capacity would be specifically reserved for flood control, but incidental flood control benefits would result from the large amount of surcharge storage available in the reservoirs. The reservoirs would provide supplemental water supplies for all dependent areas and would regulate substantial quantities of water for export. Releases would be made from the reservoirs to maintain, and, in some instances, enhance the stream flow in the interests of fish, wildlife, and recreation. The power plants would provide 565,000 kilowatts of new capacity and would generate an average of about 2.5 billion kilowatt-hours of new energy each year. Variations of the basic plan might increase the number of reservoirs and reduce the number of power plants. Of the foregoing estimates, about 1,500,000 acre-feet of the new storage capacity and 153,000 kilowatts of installed power capacity would be developed by features of the California Aqueduct System.

The second plan was suggested by the Sacramento Municipal Utility District and has been designated as the modified plan. It would utilize about 25 reservoirs to provide about the same storage as in the basic plan and would develop the power potential at 22 new plants. The basic plan is superior to the modified plan from the standpoint of over-all costs and ultimate accomplishments; but parts of the modified plan are more adaptable to staged construction and it is therefore considered to be an acceptable alternative to the basic plan. The Sacramento Municipal Utility District has recently (March, 1957) been issued water right permits by the State Water Rights Board to begin its development.

Sacramento Valley Floor. The Sacramento Valley Floor embraces an area of about 4,300 square miles south of Red Bluff between the foothills of the Sierra Nevada and the Coast Range. Except for Sutter Buttes, which rise precipitously from the valley floor near Yuba City, the land is relatively flat or gently rolling in most areas. The stream system includes the Sacramento River, flowing in the trough of the valley, and the various tributary streams flowing into the river from the surrounding mountains.

Economic development of the Sacramento Valley Floor is based primarily on agriculture and its allied food-processing industries. In addition, major industries are engaged in the extraction or mining and the production of natural gas, clay, limestone, sand and gravel, and gold. The Sacramento River and the valley floor portions of its tributaries are important spawning streams for salmon, on which the salmon fishing industry depends in large measure, and also as spawning areas for steelhead, shad, and striped bass. All of these are of vital concern to sport fishing, which is of major economic importance to the area and to the State. Likewise, the Sacramento Valley Floor area is regarded as a major hunting area, as it contains excellent shooting grounds for waterfowl, pheasant, quail, and dove.

Precipitation on the Sacramento Valley Floor averages about 22 inches per season, decreasing slightly from north to south. Much of the precipitation not consumed by plant growth probably penetrates to the ground water, since the estimated mean seasonal natural surface runoff from the valley floor amounts to only about 321,000 acre-feet as compared with a mean seasonal precipitation of about 5,000,000 acre-feet.

Present (1949) water service areas of the Sacramento Valley Floor aggregate about 900,000 acres, supporting a population of about 400,000 people according to the 1950 census. Present gross urban and agricultural water requirements, amounting to some 3,810,000 acre-feet per season, are substantially met in most areas of the valley by direct stream flow diversions from the Sacramento River and its several tributaries, supplemented by releases from upstream storage and by pumping from ground water. According to a land use survey conducted in 1949, there is a present supplemental requirement of about 124,000 acre-feet per season for the Tehama, Arbuckle, Yuba, Marysville-Sheridan, and Carmichael areas.

Present flood protection on the Sacramento Valley Floor, though grossly inadequate in some areas, comprises a vast system of river levees and by-pass channels, as part of the Sacramento River Flood Control Project, supplemented by reserved storage space in Shasta and Folsom Reservoirs. Some reduction in flood peaks is also afforded by unfilled reservoir space and surcharge storage available above the spillway lip in all other reservoirs of the Sacramento River Basin.

In addition to flood control and water development and distribution works on the Sacramento Valley Floor, a large salmon and steelhead fish hatchery is located on the American River below Lake Natoma; and a 30-foot depth ship channel is being constructed from Collinsville to Sacramento, via the Sacramento River and Yolo By-Pass on the west side of the river.

Protection against damaging floods is the most important, and in some areas the most urgent, of the water problems of the Sacramento Valley Floor. Other problems relate to adverse seepage from the Sacramento River; rising connate saline waters in the Peach Bowl area of Sutter County; the disposal of sewage, industrial wastes, and drainage waters; and the protection and enhancement of the fishery resources and recreational values of the Sacramento River and its tributaries. No particular problems are foreseen in providing adequate water service for the rapidly growing urban, agricultural, and industrial areas. Under ultimate conditions it is anticipated that the water service areas of the Sacramento Valley Floor may expand to about 2,400,000 acres, supporting a future population of about 1,400,000 people, and requiring a supplemental water supply of about 2,460,000 acre-feet per year.

Under The California Water Plan it is contemplated that flood protection for the Sacramento Valley Floor would be substantially increased by assigning and specifically reserving about 1,850,000 acre-feet of storage space in prospective reservoirs of the Sacramento River Basin for that purpose. This storage space would be strategically disposed on the tributary streams; and, in addition, the new reservoirs would contain a large volume of surcharge storage space effective in reducing peak rates of flow. On the valley floor, stream channels would be improved and leveed, wherever necessary, to protect adjoining developed areas to the extent warranted.

Methods to alleviate damage from seepage in specific local areas will require further detailed study; but, in general, it is believed that the full coordinated use of the ground water basins in the alluvium of the Sacramento Valley, under conditions of ultimate development, could limit the deleterious effects of seepage to small areas immediately adjacent to the river levees. Further study may indicate the necessity and feasibility of additional measures. Coordinated use of ground water is further discussed in this chapter under the heading of "Utilization of Ground Water Storage."

Insofar as disposal of sewage, and industrial wastes and drainage waters are concerned, The California Water Plan envisages a trunk line waste conduit into which such waters could be pumped for disposal. The conduit would be built only if experience should indicate that the water resources would otherwise be seriously impaired. It would begin at Redding with a capacity of about 50 second-feet, and would flow through that area in a buried conduit to a pumping station south of Cottonwood Creek. Here, the water would be lifted to the divide between Cottonwood and Dibble Creeks, whence it would flow by gravity in both open and closed conduit along the west side of the Sacramento Valley into the Sacramento River Deep Water Ship Channel, or by separate conveyance conduit to the Delta below any future barrier. It is anticipated that the terminal capacity of the waste conduit would not exceed 500 second-feet, and its cost would be in the order of $20,000,000.

Supplemental water supplies to meet present deficiencies and near future requirements on the west side of the valley and in the vicinity of Chico would be obtained from the Corning and Tehama-Colusa Canals, diverting from the Sacramento River at Red Bluff, and from the Chico Canal diverting near Chico. Water supplies for these canals will be made available from the authorized Trinity River Division of the Central Valley Project of the Federal Government. Folsom Reservoir will relieve the present deficiency in the Carmichael area and may, with full upstream development, supply all of the future needs of the Sacramento metropolitan area. Remaining present and future supplemental requirements on the Sacramento Valley Floor would be obtained from developments on the tributary streams, as described in preceding sections, and by increased pumping from ground water.

Under The California Water Plan, the anadromous and other fishery resources of the Sacramento River and its tributaries would be enhanced to the maximum feasible extent. The recreational potential would likewise be developed.

In summary, The California Water Plan for the Sacramento Valley Floor would satisfy present and future supplemental water requirements, provide substantial increased flood protection, maintain high-quality water and improve the quality where necessary, and enhance the fishery and recreational potential.

Summary of Sacramento River Basin. The California Water Plan for the Sacramento River Basin contemplates the gradual addition of about 17,500,000 acre-feet of storage capacity to the present basin reservoir system. This capacity would be contained in about 130 strategically disposed storage, diversion, and regulatory reservoirs, ranging in size from small impoundments for recreation to about 3,500,000 acre-feet in Oroville Reservoir on the Feather River. Twenty-four of the new reservoirs, with a combined capacity of about 9,000,000 acre-feet, are classified as features of the Klamath-Trinity, Eel, and Sacramento Divisions of the California Aqueduct System, but many of these would have important local as well as export functions. The new reservoirs would contain about 1,850,000 acre-feet of storage space specifically reserved for flood control, to augment about the same amount of such storage space now reserved in Shasta and Folsom Reservoirs and made available in other existing reservoirs of the basin.

Under The California Water Plan, the present and future reservoirs of the Sacramento River Basin would yield an average of about 17,700,000 acre-feet of water per year for local use and export, of which about 12,500,000 acre-feet would be a firm supply. Of this, about 6,000,000 acre-feet may be regarded as new water. Assuming that all local demands would be met from firm water supplies and taking into account the availability of return flow, there would be an average of about 10,000,000 acre-feet per year of regulated water available to meet present and future export demands on the water supplies of the Sacramento River Basin.

Based upon conventional concepts of reservoir operation, and considering the probable incidental safe ground water yield of the Sacramento Valley, about 6,000,000 acre-feet of the export supply would be on a firm basis. The remainder would be a variable supply, ranging from zero in dry years to about 6,000,000 acre-feet in wet years, and averaging about 4,000,000 acre-feet per year over a long-time period. Conventional reservoir operation is defined herein as the achievement of optimum safe surface reservoir yield, as distinguished from conjunctive operation wherein optimum combined safe surface and ground water yield is the objective.

Under full conjunctive operation of surface and ground water storage in the Sacramento River Basin, with the foothill reservoirs of the basin operated substantially to regulate seasonal flows and the ground water reservoirs operated for cyclic storage, about 8,000,000 acre-feet per year of the export supply would be on a firm basis. The corresponding variable supply would then average only about 2,000,000 acre-feet per year, ranging from zero in dry years to about 3,000,000 acre-feet in wet years. For purposes of this report it was assumed that there would be a gradual transition from conventional to conjunctive reservoir operation as the need to utilize ground water storage to a greater extent develops. Further discussion of the general subject of conjunctive operation is presented in greater detail later in this chapter.

Specifically, the reservoirs of the Sacramento River Basin which have been classified as local works would have an aggregate capacity of about 8,700,000 acre-feet. These reservoirs would contain a total of about 550,000 acre-feet of storage space specifically reserved for flood control. In the aggregate their combined safe yield in terms of new water would be about 3,000,000 acre-feet per year. Their cost, including feeder conduits where pertinent, would be in the order of $600,000,000.

There would be about 45 new and enlarged hydroelectric power plants associated with the local reservoirs. These plants would have a combined installed power capacity of about 1,600,000 kilowatts and would generate an average of about 7.2 billion kilowatt-hours per year. Including related diversion works, conduits, penstocks, forebays, afterbays, etc., their cost would be in the order of $375,000,000.

Other local works would consist of main conveyance and service canals for irrigation, wells for irrigation and urban purposes in some areas, additional levees and floodway channels where needed, distribution and drainage systems, and possibly a main waste conduit extending southward from Redding the full length of the Sacramento Valley. The cost of this conduit and the main conveyance and irrigation conduits in the upland areas of the basin would be in the order of $70,000,000. No estimates of cost were made for the various drainage and distribution systems and other local works on the Sacramento Valley Floor that would be required for complete development of the land and water resources of the Sacramento River Basin.

In summary, the local works of The California Water Plan would provide sufficient regulated water to meet the local needs, develop the hydroelectric power potential to the maximum economic limit, substantially increase the flood protection in the local areas, maintain the high-quality water and improve it where necessary, and maintain and enhance the sh, wildlife, and recreational potential to the maxi-num feasible extent.

The general features and costs of the principal local evelopment works contemplated in the Sacramento liver Basin are presented in Table 13. Similar in-ormation for the aqueduct features of the basin evelopment is presented later in this chapter in ables 17 through 22, under appropriate divisions of he California Aqueduct System.

entral Valley Area—
an Joaquin-Tulare Lake Basin

California's greatest present and future water defi-iencies are in the San Joaquin and Tulare Lake asins. These two great basins, which are separable s to their drainage characteristics, contain 40 per ent of the irrigable lands of the State but share only 6 per cent of the State's total water resources. ogether they comprise the greatest and most produc-ve single agricultural area of the State and are rossly deficient in native water supply.

The San Joaquin-Tulare Lake Basin is approxi-ately 300 miles long and 130 miles wide, and em-races an area of 33,000 square miles, or about one-fth of the area of the State. In the central portion f the basin, surrounded by mountains on three sides nd by the San Joaquin Delta at its northerly end, es the San Joaquin Valley, a region of 13,500 square iles of gently sloping plains, with predominantly rtile soils well adapted to agriculture. The highest eaks of the Sierra Nevada rise above the valley along s entire eastern length. In these rugged scenic ountains lie the southern portion of the historic other Lode region, a large area of national forest, ree national parks, and many state parks, all of hich afford excellent opportunities for recreation.

Because of favorable soil and climatic conditions, e San Joaquin-Tulare Lake Basin has pioneered irri-ation development in California. About 3,700,000 res of a total irrigable area of about 8,000,000 acres ave been placed under irrigation. More than 50 irri-ation districts have been formed, as well as other pes of public districts and private companies, and their initiative many notable water works have en constructed to furnish water and other services irrigators.

Precipitation in the San Joaquin-Tulare Lake Basin nges from less than 5 inches per season at the uthern end of the San Joaquin Valley to 60 to 70 ches on higher ranges of the Sierra Nevada. About) per cent of the precipitation falls during the onths of November through April, with little or no infall on the valley floor during the growing season hen the moisture demands of the crops are at their eak. Runoff of streams tributary to the basin comes rgely from snow which provides a beneficial natural gulation.

The major portion of the San Joaquin-Tulare Lake Basin is drained by the San Joaquin River and its many tributaries which comprise one of the largest stream systems in California. Principal tributaries of the San Joaquin River include the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, and Fresno Rivers. The Tulare Lake Basin, a closed basin, constitutes the southern portion of the area, and the Kings, Kaweah, Tule, and Kern Rivers, as well as numerous minor streams, are tributary to it.

The present water requirements in the San Joaquin-Tulare Lake Basin are being met in several ways. At the north end of the basin there are diversions from Delta channels. Along the east side of the trough of the San Joaquin Valley there are substantial diversions from the major streams, some of which have been virtually completely developed for use. In addition, water from the Sacramento-San Joaquin Delta is imported in the Delta-Mendota Canal which began operation in 1951. There is also considerable pumping from ground water throughout the basin, particularly in the southern Tulare Lake Basin where development of ground water, combined with surface storage, has resulted in virtually complete conservation of the surface runoff.

During 1954 approximately 8,250,000 acre-feet of water were withdrawn from underlying ground water storage in the San Joaquin-Tulare Lake Basin, representing over two-thirds of the ground water utilized in the entire State. Two of the major rivers of the basin, the Mokelumne and the Tuolumne, furnish water which is conveyed westerly across the valley in pipe line aqueducts for use in the San Francisco Bay Area. Substantial hydroelectric power development has taken place on the Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings and Kern Rivers.

Objectives of The California Water Plan in the San Joaquin-Tulare Lake Basin are: first, to develop fully and distribute local water supplies for all beneficial purposes, including irrigation, municipal, industrial, fish and wildlife, recreation, and power generation; second, to protect urban and agricultural areas from damaging floods; third, to convey and distribute the imported water supplies necessary to satisfy fully the ultimate water requirements for all beneficial purposes; and fourth, to protect the quality of water by adequate drainage and removal of unsuitable waters. The necessity for protection and enhancement of fish and wildlife resources and for development of the recreational potential are important considerations that must be borne in mind in further development of the surface water resources of the basin.

Virtually all portions of the San Joaquin-Tulare Lake Basin are now experiencing or are threatened with serious water problems of one kind or another. The most serious and widespread problem is the in-

TABLE 13

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SACRAMENTO RIVER BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet[a]	Purpose	Place of water use	Capital cost[b]
Goose Lake Unit	(Ground water development	if feasible)									
Pit River Unit											
Parker	Parker Creek	Sec. 33, T43N, R13E 2									
Jess Valley	South Fork Pit River	Sec. 10, T39N, R14E 2							I	Alturas area	
Sears Flat	Stony Canyon	Sec. 32, T39N, R12E 2									
Bayley (enlarged)	Crooks Canyon	Sec. 32, T40N, R12E 2									
Allen Camp	Pit River	Sec. 35, T41N, R7E 2	E	138	4,285	195,600	185,000	85,000	I,FC	Big Valley	$4,871,000
Round Valley	Ash Creek	Sec. 21, T39N, R9E 2	E	85	4,281	85,000	83,000	52,000	I	Big Valley	3,057,000
Little Valley	Horse Creek	Sec. 3, T35N, R7E 4	E	70	4,216	25,000	20,000	8,000	I	Dixie Valley	731,000
Fall River Mills	Pit River	Sec. 31, T37N, R5E 4	CG	113	3,324	175,000	20,000	80,000	I,P,R	Fall River-McArthur-Pittville area	4,614,000
Burney	Burney Creek	Sec. 11, T34N, R2E 4	E	100	3,986	5,000	5,000	5,000	I	Burney area	581,000
Pit No. 1 Afterbay	Pit River	Sec. 15, T36N, R4E 4	CG		2,835				P	Pit River	(Included with power plants, Pit Nos. 2, 6, 7)
Pit No. 5 Afterbay	Pit River	Sec. 5, T35N, R1W 4	CG	150	1,410	12,000	7,800		P	Pit River	
Pit No. 6 Afterbay	Pit River	Sec. 31, T35N, R1W 4	CG	230	1,270	34,000	16,500		P	Pit River	
Mt. Shasta Stream Group											
Wagon Valley	Sacramento River	Sec. 29, T40N, R4W 1	CA	185	3,175	22,300	17,500	60,000	I,F	Mt. Shasta City area	2,000,000
Willow	Squaw Valley Creek	Sec. 11, T38N, R3W 1	E or R	291	2,894	250,000	246,000	460,000	P,F	McCloud River	23,670,000
Chonton Tubas	McCloud River	Sec. 28, T37N, R3W 1	R	258	1,730	52,000	42,000	720,000	P,F	McCloud River	10,400,000
Redding Stream Group											
Dippingvat	South Fork Cottonwood Creek	Sec. 36, T27N, R7W 3	E	205	1,150	55,000	51,300	47,000	I	Redding area and Sacramento Valley	3,220,000
Cold Fork	Cold Fork Cottonwood Creek	Sec. 17, T27N, R7W 3	E	100	1,340			76,000	D	Divert to Rosewood Reservoir	580,000
Rosewood	Dry Creek	Sec. 16, 21, T28N, R6W 3	E	200	783	200,000	196,000		I,FC	Redding area and Sacramento Valley	11,858,000
Fiddlers	Middle Fork Cottonwood Creek	Sec. 28, 33, T29N, R7W 3	R & E	310	1,050	310,000	270,000	126,000	I,P,FC,F	Redding area and Sacramento Valley	18,900,000
Fiddlers Afterbay	Middle Fork Cottonwood Creek	Sec. 23, T29N, R7W 3	E	73	750	5,400	1,000		P		Included with Fiddlers Power Plant
Hulen	North Fork Cottonwood Creek	Sec. 16, T30N, R6W 3	E	205	850	96,400	93,400	42,000	I,FC	Redding area and Sacramento Valley	3,700,000
Bella Vista	Little Cow Creek	Sec. 20, T32N, R3W 4	E	110	600	146,000	138,000	90,000	I,FC	Redding area and Sacramento Valley	9,194,000
Oak Flat	Oak Run	Sec. 25, T33N, R2W 4	E	80	1,490	5,300	5,000		I,D	Oak Run Creek and divert to Bella Vista Reservoir	1,137,000

TABLE 13—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SACRAMENTO RIVER BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet [a]	Purpose	Place of water use	Capital cost [b]
Redding Stream Group—Continued											
Old Cow Creek	Old Cow Creek	Sec. 9, T31N, R2W 4	E	145	815	18,000	10,000		D	Old Cow Creek and divert to Millville Reservoir	$2,130,000
Millville	South Cow Creek	Sec. 17, T31N, R2W 4	E	215	800	206,000	200,000	140,000	I,FC,F	Redding area and Sacramento Valley	9,320,000
Bear Creek	Bear Creek	Sec. 25, T31N, R2W 4	R	140	1,180				D	Divert to Millville Reservoir	3,280,000
Battle	Battle Creek	Sec. 25, T30N, R2W 4	E	230	890	40,000	36,000	10,500	D,F	Divert to Wing Reservoir	2,140,000
Wing	Inks Creek	Sec. 25, T29N, R3W 4	E	185	500	243,000	222,000	74,500	I,FC	Sacramento Valley	7,150,000
Paynes	Paynes Creek	Sec. 3, T28N, R2W 4	E	100	650				D	Divert to Wing Reservoir	1,590,000
Iron Canyon	Sacramento River	(Aqueduct feature—see Table 21)									
West Side Stream Group											
Schoenfield	Redbank Creek	Sec. 16, T26N, R6W 3	R	280	990	174,000	170,000	32,400	I,FC	Area southwest of Red Bluff	7,560,000
Galatin	Elder Creek	Sec. 14, T25N, R6W 3	E	215	923	183,000	176,000	33,000	I,FC	Area southwest of Red Bluff	4,700,000
Paskenta	Thomes Creek	Sec. 6, T23N, R6W 5	E	180	960	67,000	62,000	55,000	I,D	Thomes Creek area	4,900,000
Newville	North Fork Stony Creek	Sec. 3, T22N, R6W 5	E	238	838	950,000	900,000	204,000	I,P	Stony Creek foothill area	20,880,000
Clark Valley	South Fork Willow Creek	Sec. 34, T20N, R5W 5	E	94	480	6,300	3,000	1,400	R		467,000
Squaw Flat	Logan Creek	Sec. 29, T19N, R4W 5	E	60	315	8,000	3,000	700	R		425,000
High Peak	Hunters Creek	Sec. 9, T18N, R4W 5	E	80	290	11,300	3,800	700	R		515,000
Golden Gate	Stone Corral and	Sec. 20, T17N, R4W 5	CA	63	315	48,000	24,500	1,400	R		904,000
	Funks Creeks	Sec. 9, T17N, R4W 5	E	90							
Pitney Ridge	Middle Creek	Sec. 10, T16N, R10W 5	E & R	77	1,542	5,400	4,600	4,800	I	Clear Lake area	765,000
Lakeport	Scott Creek	Sec. 22, T14N, R10W 5	E	100	1,542	33,100	30,300	20,200	I	Clear Lake area	2,102,000
Kelseyville	Kelsey Creek	Sec. 34, T13N, R9W 7	E & R	150	1,595	36,000	35,000	18,200	I	Clear Lake area	2,557,000
Boggs	Kelsey Creek	Sec. 13, T12N, R9W 7	E	190	2,333	56,500	51,200	16,700	I	Clear Lake area	2,150,000
Excelsior	Copsey Creek	Sec. 11, T12N, R7W 7	E	90	1,420	38,000	35,000	9,800	I	Clear Lake area	1,205,000
Indian Valley	North Fork Cache Creek	Sec. 9, T14N, R6W 5	E	180	1,457	200,000	188,000	48,000	I	Capay and Sacramento Valleys	3,270,000
Bear Valley	Bear Creek	Sec. 9, 10, T14N, R5W 5	E	80	1,323	37,000	20,000	10,600	R		710,000
Middletown	Putah Creek	Sec. 15, T11N, R7W 7	E	65	1,080	14,200	12,400	16,000	I	Middletown area	1,400,000
Goodings	Maxwell Creek	Sec. 19, T9N, R4W 7	E	109	619	50,300	45,100	23,000	I	Pope Valley area	2,838,000
Black Butte	Stony Creek	(Aqueduct feature—see Table 21)									
Guinda or alternative at Wilson Valley or Blue Ridge	Cache Creek	(Aqueduct feature—see Table 21)									
Antelope-Butte Stream Group											
Antelope Basin	Antelope, Salt, and Little Antelope Creeks	Sec. 11, 12, 13, T27N R3W; S18, 19 and 20, T27N, R2W 4	E	65	336	37,000	35,000		FC	Sacramento Valley	5,800,000
Morgan Springs	Mill Creek	Sec. 23, T29N, R4E 4	E	90	4,900	7,600	7,000		D	Divert to Deer Creek Meadows Reservoir	2,500,000
Deer Creek Meadows	Deer Creek	Sec. 20, T28N, R5E 4	E	215	4,705	200,000	178,000	136,000	P	Deer Creek	3,800,000
Butte Creek House	Butte Creek	Sec. 21, T26N, R5E 4	E	100	5,840	10,000	9,400	9,600	I	Keefer Ridge	870,000
Grizzly Gulch	Butte Creek	Sec. 6, T25N, R4E 4	E	180	4,160	12,000	11,000	4,900	I	Keefer and Paradise Ridge areas	3,640,000

TABLE 13—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SACRAMENTO RIVER BASIN

(These works show future development possibilities. They are not project proposals.)

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Antelope-Butte Stream Group —Continued											
Magalia (enlarged)	Little Butte Creek	Sec. 25, T23N, R3E 6	E	121	2,252	6,500	6,400	4,000	I	Paradise Ridge area	$740,000
Forks of Butte	Butte Creek	Sec. 26, T24N, R3E 6	E	280	2,345	57,000	55,000	52,000	I	Paradise Ridge area	6,967,000
Big Chico	Big Chico Creek	Sec. 35, T23N, R2E 6	E	145	800	16,000	15,000	98,500	I,D	Sacramento Valley and divert to Castle Rock Reservoir	1,511,000
Castle Rock	Butte Creek	(Aqueduct feature—see Table 21)									
Brush Basin	Mill, Deer, etc.	(Aqueduct feature—see Table 21)									
Feather River Unit											
Antelope Valley	Indian Creek	Sec. 22. T27N, R12E 4	E	77	5,000	22,000	8,000	5,000	R,I	Upper Feather River	479,000
Dixie Refuge	Last Chance Creek	Sec. 23, T26N, R14E 4	E	81	5,740	14,000	12,000	6,000	R,I	Upper Feather River	620,000
Squaw Queen	Last Chance Creek	Sec. 1, 2, T25N, R12E 4	E	200	5,480	140,000	122,000	37,000	I,P,R	Upper Feather River	3,232,000
Genesee	Indian Creek	Sec. 7, T25N, R11E 4	E	195	3,800	276,000	275,000	82,000	I,P,R	Upper Feather River	8,531,000
Abbey Bridge	Red Clover Creek	Sec. 32, T25N, R13E 6	E	70	5,420	11,000	6,000	7,000	R, I	Upper Feather River	660,000
Indian Falls	Indian Creek	Sec. 35, T26N, R9E 4	CG	50	3,485	500	500	160,000	P	Upper Feather River	1,239,000
Frenchman	Little Last Chance Creek	Sec. 33, T24N, R16E 6	E	119	5,588	50,000	48,000	16,000	I,F	Sierra Valley	1,469,000
Grizzly Valley	Big Grizzly Creek	Sec. 1, T23N, R13E 6	E	116	5,775	80,000	78,000	15,000	I,F	Sierra Valley	916,000
Sheep Camp	Craycroft Creek	Sec. 4, 5, 8, T21N, R14E 6	E	96	5,013	20,000	20,000	70,500	I,F	Sierra Valley	3,823,000
Nelson Point	Middle Fork Feather River	Sec. 16, T23N, R10E 6	E	219	4,030	52,900	49,300	375,000 (Nelson Point and Meadow Valley)	R,D,F	Upper Feather River and diverts to Meadow Valley Reservoir	5,216,000
Meadow Valley	Spanish Creek	Sec. 17, T24N, R9E 6	E	426	3,890	740,000	735,000		I,P,R,F	Upper Feather River	55,062,000
Hartman Bar	Middle Fork Feather River	Sec. 11, T22N, R7E 6	CG	145	2,445				D,F	Divert to Swayne Reservoir	3,196,000
Swayne	French Creek	Sec. 35, 36, T22N, R5E 6	E	418	2,355	404,000	394,000	240,000	P,R		37,644,000
Little Grass Valley	South Fork Feather River	Sec. 31, T22N, R9E 6	E	175	5,016	50,500	50,000	40,000	P,I	Between Feather and Yuba Rivers	3,007,000
Lost Creek (enlarged)	Lost Creek	Sec. 24, T20N, R7E 6	E	370	3,509	140,000	138,000	157,000	P,I	Between Feather and Yuba Rivers	24,723,000
Wicks Corner	Cottonwood Creek	Sec. 28, T20N, R3E 6	E	40	216	2,000	1,000	700	R	Area northwest of Oroville	242,000
South Honcut Creek	South Honcut Creek	Sec. 25, T18N, R5E 6	E	165	886	30,000	28,000	13,000	R	Between Feather and Yuba Rivers	2,273,000
Bangor	North Honcut Creek	Sec. 25, T18N, R4E 6	E	53	275	5,200	2,000	3,600	R		572,000
Clover Valley	Smithneck Creek	Sec. 30, 31, T21N, R16E 6	E	88	5,168	6,000	5,500	6,300	I	Sierra Valley	
Randolph	Cold Stream	Sec. 19, T20N, R15E 6	E	157	5,197	21,000	19,000	23,000	I	Sierra Valley	
Mt. Ararat	Willow Creek	Sec. 14, T23N, R7E 6	E	80	5,480	4,000	3,500	11,000	R		
Whiskey Hill	South Branch Middle Fork	Sec. 34, T22N, R7E 6	E	115	3,900	3,300	3,000	3,600	R		
Quartz Hill	Fall River	Sec. 21, T21N, R7E 6	E	200	3,500	22,000	20,000	36,000	R		
Oroville	Feather River	(Aqueduct feature—see Table 21)									
Yuba-Bear River Unit											
Jackson Meadows	Middle Yuba River	Sec. 18, T19N, R13E 6	E	159	6,010	45,000	43,000	49,200	P,I,F	Yuba and Bear Rivers	5,672,000
Wambo	North Yuba River	Sec. 8, 9, T19N, R8E 6	R	300	2,230	62,000	36,000	199,200	P	North Yuba River	8,490,000
Bullards Bar (enlarged)	North Yuba River	Sec. 24, 25, T18N, R7E 6	R	495	1,850	455,000	450,000	662,400 (Bullards Bar and Freemans)	I,P,FC,F	Yuba River and Sacramento Valley	53,690,000
Freemans	Middle Yuba River	Sec. 32, T18N, R8E 6	R	495	1,850	300,000	295,000		I,P,FC,F	Yuba River and Sacramento Valley	38,220,000

TABLE 13—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SACRAMENTO RIVER BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet[a]	Purpose	Place of water use	Capital cost[b]
Yuba-Bear River Unit —Continued											
Washington	South Yuba River	Sec. 10, T17N, R10E 6	R	400	2,820	125,800	111,000	169,200	I,P,F	Yuba River and Grass Valley-Nevada City area	$22,982,000
Virginia Ranch	French Dry Creek	Sec. 21, T17N, R6E 6	E	120	1,160	36,000	35,000	27,600	I,F	Yuba River foothills	1,990,000
Lake Valley (enlarged)	North Fork of North Fork American River	Sec. 35, T17N, R12E 6	E	150	5,863	41,000	38,000	105,600	P,I,F	Foothill area between Bear and American Rivers	7,505,000
Scotts Flat (enlarged)	Deer Creek	Sec. 10, T16N, R9E 6	E	180	3,090	62,500	62,000	68,000	I,F	Grass Valley-Nevada City area	2,360,000
Anthony House	Deer Creek	Sec. 20, T16N, R7E 6	E	90	1,222	15,000	14,000	28,000	I,F	Smartville area	1,060,000
Rollins	Bear River	Sec. 22, T15N, R9E 6	E	260	2,200	100,000	74,000	256,000	P,I,F	Foothill area between American and Bear Rivers	8,700,000
Coon Creek	Coon Creek	Sec. 8, 17, T13N, R7E 8	E	215	552	59,000	----------	56,000	I	Sacramento Valley	----------
Doty Ravine	Doty Ravine	Sec. 30, 31, T13N, R7E 8	E	115	330	32,000	----------	28,000	I	Sacramento Valley	----------
Auburn Ravine	Auburn Ravine	Sec. 11, 14, T12N, R7E 8	E	185	640	11,700	----------	13,000	I	Sacramento Valley	----------
Parks Bar	Yuba River	(Aqueduct feature—see Table 21)									
Waldo	Dry Creek	(Aqueduct feature—see Table 21)									
Camp Far West	Bear River	(Aqueduct feature—see Table 21)									
American River Unit (Basic Plan)											
Lake Valley (enlarged)	(See Yuba-Bear River Unit)										
The Cedars (or suitable alternative)	North Fork American River	Sec. 13, T16N, R 14E 6	R	75	5,845	2,400	2,000	5,400	F	North Fork American River	540,000
Sugar Pine	North Shirttail Canyon	Sec. 24, T15N, R10E 6	E & R	180	3,670	17,000	17,000	10,400	I	Foresthill Divide	2,061,000
Big (enlarged)	Tributary of Forbes Creek	Sec. 17, T15N, R11E 6	E	92	4,108	6,500	6,500	8,800	I	Foresthill Divide	1,066,000
Forbes	Forbes Creek	Sec. 20, T15N, R11E 6	E	145	4,000	5,300	5,300	7,100	I	Foresthill Divide	1,545,000
French Meadows	Middle Fork American River	Sec. 36, T15N, R13E 6	R	225	5,224	90,000	87,000	72,000	P,F	Middle Fork American River	9,971,000
Lower Hellhole	Rubicon River	Sec. 16, 21, T14N, R14E 6	R	310	4,545	120,000	115,000	175,700	P,F	Middle Fork American River	14,400,000
Loon Lake (enlarged)	Gerle Creek	Sec. 4, 5, T13N, R15E 6	R	106	6,403	56,000	55,000	48,200	P,F	Middle Fork American River	6,092,000
Gerle	Gerle Creek	Sec. 2, 3, T13N, R14E 6	E	60	5,870	8,300	8,000	59,100	P,F	Middle Fork American River	930,000
Parsley Bar	Rubicon River	Sec. 29, T14N, R14E 6	CG	75	4,098	4,000	3,400	237,800	P,F	Middle Fork American River	1,410,000
American Bar	Middle Fork American River	Sec. 33, T14N, R11E 6	E & R	125	1,165	6,300	1,300	248,600	P,F	Middle Fork American River	2,260,000
Stumpy Meadows	Pilot Creek	Sec. 11, T12N, R12E 8	E	225	4,322	47,500	45,700	38,600	I	Georgetown Divide	6,626,000
Junction	Silver Creek	Sec. 30, T12N, R14E 8	CA or R	500	4,810	317,000	309,000	239,900	I,P,F	Placerville Divide	31,782,000
Webber (enlarged)	Webber Creek	Sec. 18, T10N, R12E 8	E	168	2,340	6,100	5,200	235,800	I,P,F	Placerville Divide	1,812,000
Alder Creek	Alder Creek	Sec. 8, T10N, R15E 8	E & R	265	5,385	80,000	79,000	70,700	I,P,F	Placerville Divide	9,965,000
Whitney Ranch	Pleasant Grove Creek	Sec. 11, T11N, R6E 8	E	72	193	10,300	----------	9,500	I	Sacramento Valley	----------
Auburn	North Fork American River	(Aqueduct feature—see Table 21)									
Salmon Falls	South Fork American River	(Aqueduct feature—see Table 21)									
Totals	----------	----------	------	----------	----------	8,661,300	7,861,400				601,332,000

TABLE 13—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SACRAMENTO RIVER BASIN

(These works show future development possibilities. They are not project proposals.)

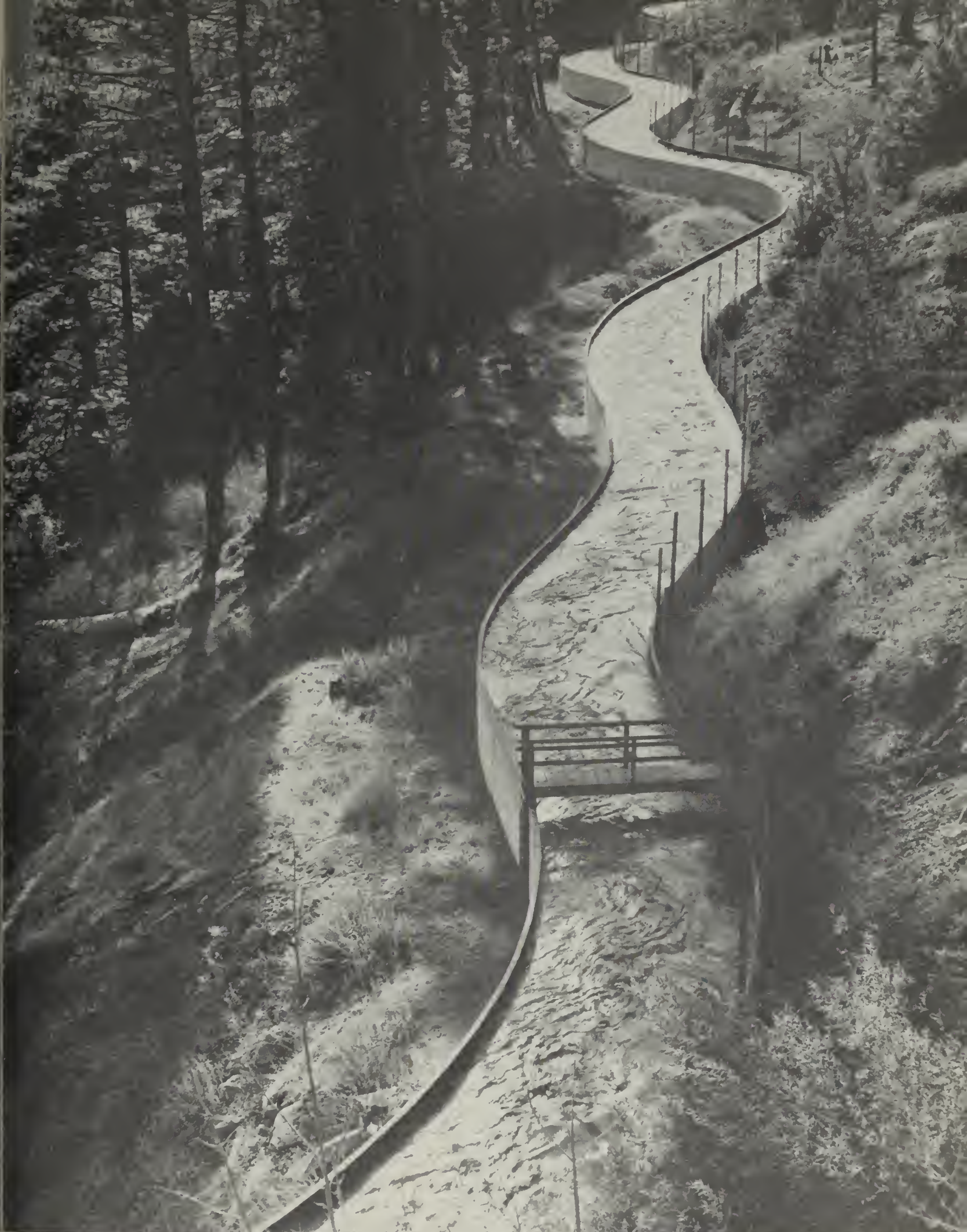
Power plant	General location and sheet of Plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours	Capital cost[b,c]
Sugarloaf Mountain	Hat Creek	4	548	5,000	42,000,000	$2,963,000
Pit No. 2	Pit River	4	105	14,000	95,000,000	3,244,000
Pit No. 6	Pit River	4	118	50,700	210,000,000	15,200,000
Pit No. 7	Pit River	4	182	98,000	333,000,000	22,300,000
Willow	McCloud River	1	1,126	122,000	644,000,000	22,550,000
Chonton Tubas	McCloud River	3	650	86,000	476,000,000	22,310,000
Fiddlers	Middle Fork Cottonwood Creek	3	250	8,000	45,000,000	2,550,000
Newville	North Fork Stony Creek	5	188	8,500	33,000,000	2,100,000
Deer Creek No. 1	Deer Creek	4	1,602	29,200	118,000,000	12,400,000
Deer Creek No. 2	Deer Creek	4	813	27,100	135,000,000	14,420,000
Deer Creek No. 3	Deer Creek	4	1,047	35,400	173,500,000	6,300,000
Deer Creek No. 4	Deer Creek	6	179	5,500	29,700,000	2,750,000
Squaw Queen	Feather River	4	1,660	14,000	51,900,000	3,093,000
Indian Falls	Feather River	4	650	25,000	126,000,000	7,936,000
Meadow Valley	Feather River	4	1,675	125,000	503,300,000	33,120,000
Swayne	Feather River	6	1,365	84,000	300,000,000	10,847,000
Woodleaf	Feather River	6	1,648	70,000	168,800,000	12,527,000
Forbestown	Feather River	6	785	13,000	146,800,000	10,278,000
Spaulding No. 3[d]	South Yuba River	6	318	3,200	9,300,000	475,000
Lake Valley	South Yuba River	6	812	17,500	82,000,000	2,669,000
Spaulding No. 2[d]	South Yuba River	6	305	2,300	14,900,000	385,000
Drum[d]	Bear River	6	1,375	68,000	276,000,000	2,180,000
Dutch Flat[d]	Bear River	6	643	7,000	25,000,000	820,000
Chicago Park	Bear River	6	488	25,000	96,000,000	8,910,000
Rollins	Bear River	6	205	11,000	57,500,000	2,904,000
Halsey[d]	Colfax Divide	8	331	3,500	6,400,000	450,000
Wise[d]	Colfax Divide	8	519	10,000	5,700,000	900,000
Deer Creek[d]	Colfax Divide	6	837	8,100	25,900,000	1,400,000
Devils Slide	South Yuba River	6	935	33,600	100,000,000	11,265,000
Jones Bar	South Yuba River	6	765	23,700	78,000,000	8,130,000
Wambo	North Yuba River	6	385	17,700	116,000,000	4,040,000
Bullards Bar	North Yuba River	6	1,157	131,000	800,000,000	25,650,000
French Meadows	Rubicon River	6	618	11,000	52,300,000	4,110,000
Lower Hellhole	Rubicon River	6	385	18,000	78,300,000	4,060,000
Loon Lake	Gerle Creek	6	512	5,500	26,100,000	2,690,000
Gerle	Rubicon River	6	1,687	21,000	109,700,000	4,810,000
Ralston	Rubicon River	8	2,743	135,000	684,000,000	27,146,000
American Bar	Middle Fork American River	8	203	16,000	106,000,000	6,800,000
Junction	South Fork American River	8	1,120	60,000	301,600,000	15,890,000
Sly Park	Sly Park Creek	8	154	10,000	34,100,000	4,840,000
Camino	Webber Creek	8	838	45,000	184,800,000	9,894,000
Webber	Webber Creek	8	142	7,000	30,900,000	1,200,000
Placerville	Placerville	8	347	19,000	73,600,000	4,760,000
Gold Hill	South Fork American River	8	887	45,000	103,500,000	6,150,000
Alder Creek	Alder Creek	8	1,372	20,000	104,500,000	4,153,000
Totals				1,594,500	7,213,100,000	$373,569,000

Conduits	Length, in miles				Capital cost*
	Canal	Tunnel	Pipe	Total	
Feeders for reservoirs	185	82	11	278	[e]$102,277,000
Power conduits	68	99	21	188	[f]160,836,000
Main upland irrigation conduits	685	8	3	696	48,767,000
Sacramento Valley waste conduit	135		40	175	20,514,000
Totals	1,073	189	75	1,337	$332,394,000

[a] Includes yield of upstream works, if any.
[b] At 1955 price levels.
[c] Cost of each plant includes associated works except reservoirs.
[d] Tabulated data pertain to enlarged portion of existing plant.
[e] Cost included with reservoirs.
[f] Cost included with power plants.

Symbols of Type of Dam
E—Earthfill
R—Rockfill
CG—Concrete gravity
CA—Concrete arch

Symbols of Purpose
I—Irrigation
P—Power
FC—Flood control
F—Enhancement of fish environment
R—Recreation
D—Diversion



San Joaquin River Basin—Diversion Flume From Mokelumne River adequacy of the available water supply to meet many present needs, to support continued expansion, and to sustain and protect the vast agricultural wealth of the basin during periods of drought which may occur at any time. The present annual water deficiency, estimated to be about 2,300,000 acre-feet in 1957, is so great that if a severe drought period, such as those experienced in the past, should now occur, the necessary water conservation and conveyance works could not be constructed fast enough to prevent widespread havoc and economic disaster.

Major reservoirs have been constructed on virtually all streams on the east side of the San Joaquin-Tulare Lake Basin. In addition to this substantial development of surface water sources, many of the local public water districts supplement their water supplies by use of ground water. Many other areas are completely dependent upon ground water supplies. Use of ground water is increasing, and this trend is certain to continue.

Operation of the surface reservoirs and use of the underground basins have resulted in a high degree of conservation and utilization of the natural runoff of the tributary streams of the basin, particularly those streams south of the Merced River. In addition, large quantities of water, amounting to 675,000 acre-feet during 1956, are imported from the Sacramento-San Joaquin Delta in the Delta-Mendota Canal. Despite such extensive development, there is an urgent need for additional supplemental water supplies. There is also a need for works which will make available a portion of the local water supplies for mountain and foothill lands so that these lands may develop. In those stream basins where water supplies are fully utilized on valley floor lands, exchange or purchase agreements will be necessary.

As of 1950, the seasonal requirement for water in the San Joaquin Valley was estimated to be 9,300,000 acre-feet. Ultimate realization of the full potential for agricultural and other types of development would increase this requirement to about 16,300,000 acre-feet annually, a virtual doubling of the water requirement. Runoff of tributary streams, which already has been almost fully developed, can support only about one-half of this requirement; the remainder, over 8,500,000 acre-feet annually, ultimately must be imported.

At the present time there are large overdrafts in all valley hydrographic units in the Tulare Lake Basin and in several of the valley units of the San Joaquin River Basin. These deficiencies are particularly serious in the western and southern portions of the valley and in certain areas of the eastern portion which, although located close to the Friant-Kern Canal, cannot be supplied therefrom because the limited supply available has already been contracted for in other areas.

For some years past the expansion of irrigate areas devoted to permanent crops has occurred chiefl by the utilization of ground water supplies, and th recent and increasing development of the west sid area has been dependent entirely upon the develop ment and use of ground water. Many other area which have limited or no surface supplies, and whic depend mainly upon ground water, are experiencin serious water deficiencies. In many of these localitie particularly in the southeastern part of the valle and, more recently, on the western side of the valley expansion of irrigated areas has continued in th face of this deficiency. With the continued recessio of the ground water levels, amounting to as much a 30 feet per year in some instances, water supplies i some areas have become almost exhausted, while i others pumping lifts have become so excessive as t be nearly economically prohibitive. Annual ove drafts, accumulating for many years, have so d pleted many portions of the ground water basins tha excessive pumping lifts will reduce net agricultur profits for years to come, until costly imported wate supplied in quantities in excess of actual water r quirements, has refilled the basins.

In certain of the west side areas the surface an much of the ground water supplies are of poor qua ity, and it is probable that in some cases their use even now detrimental to the utility of the soil. Oth serious problems of water quality are developing c the west side of the San Joaquin Valley. In much c this area the usable aquifer for pumping is foun between overlying unusable perched water and unde lying connate brines, and improperly construct wells permit a commingling of the waters in the thr zones to the detriment of the usable water. There also a serious water quality problem along the low reaches of the San Joaquin River during much of th irrigation season when the flow is composed entire of drainage and return waters.

There are also many areas in the San Joaqui Tulare Lake Basin where serious drainage proble exist. In some instances increased use of ground wat would alleviate such problems; in other areas surfa drainage systems are needed. There is an urgent ne to intercept, collect, and drain from the basin i creasing quantities of agricultural, municipal, a industrial waste waters and other waters of degrad or impaired quality. As additional supplemen water supplies become available, there will be an i creased need for drainage, particularly in the clos Tulare Lake Basin.

In past years of subnormal runoff and prior to t construction of Shasta Dam on the Sacramento Riv available inflow to the Delta from the Sacrame and San Joaquin River systems was insufficient d ing certain months to meet water demands in t

)elta. During such periods the invasion of saline ater from San Francisco Bay into the Delta chanels rendered the water unfit for irrigation and other ses, not only in the Delta and adjacent uplands but lso in the adjacent upper portions of the San Franisco Bay. At the present time, when necessary, reases of water are made from Shasta Reservoir to ow out into the bay to prevent the recurrence of his situation.

Damaging floods have occurred in past years of rge runoff, and their possible repetition is a menace some of the improved valley lands in populated eas. Although works for flood protection, including ajor flood control reservoirs such as Pine Flat and abella, have been provided for considerable portions the area subject to flooding, there is still a need r additional flood control works on many streams protect many of the valley lands of the basin.

The San Joaquin-Tulare Lake Basin has been subvided into five separate geographical subdivisions, d the development works to meet local requirements e segregated according to these subdivisions for dission herein. Under the first two subdivisions, "San aquin-Sierra Group," and "Tulare-Sierra Group," ajor works of The California Water Plan on east le streams and tributaries of the San Joaquinlare Lake Basin are described. Such works would operated to accomplish the necessarily high deee of conservation of runoff, and would furnish rge amounts of incidental hydroelectric energy and ovide a large measure of flood control. There are so described additional works, generally of smaller e, which would be necessary adjuncts to the major rks, in order that local requirements would be met all foothill and mountain watersheds above the or of the San Joaquin Valley. The two groups inde all mountain and foothill lands of the basin, d their common boundary is the watershed divide tween the San Joaquin and Kings Rivers. The third division, "West Side Group," encompasses the ast Range slopes of the San Joaquin-Tulare Lake sin with its numerous minor peripheral streams, m Marsh Creek on the northwest side to Buena ta Creek near Taft. The fourth subdivision, "North lley Group," includes the northern portion of ley floor lands of the basin. Works in the southern rtion are described in connection with the fifth division, "South Valley Group." The locations of various units are shown on Plate 3. Following the cussion of all works in the basin, there is a sumry statement, with tables, showing principal chareristics of the various works and their estimated ts. The works included in the California Aqueduct stem and lying within the San Joaquin-Tulare ke Basin are described separately in a later part this chapter.

San Joaquin-Sierra Group. The San Joaquin-Sierra Group includes all mountain and foothill lands of the San Joaquin-Tulare Lake Basin lying north of the watershed divide between the San Joaquin and Kings Rivers. Consisting of mountainous and foothill areas, the region is favored by forest, mineral, and recreational resources and developments typical of such areas. There is a considerable amount of irrigable land, approximately 278,000 acres, of which only 11,700 acres were irrigated in 1950. Large timber resources are located in this group.

Much of the flow of the streams draining the San Joaquin-Sierra Group has already been developed for use on the San Joaquin Valley floor and for export to the San Francisco Bay Area. Flood problems within the group are of minor importance; however, foothill reservoirs are now and in the future will be operated to give flood protection to lands on the valley floor. Hydroelectric power is presently developed on the Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. Other streams of the group include the Cosumnes, Calaveras, Chowchilla, and Fresno Rivers, and minor east side streams which are directly tributary to the valley floor.

As of 1950, the seasonal water requirements for lands in the San Joaquin-Sierra Group aggregated about 41,000 acre-feet and were met, for the most part, by direct stream diversion, with only little use of reservoir storage. It is estimated that ultimate water requirements will total about 520,000 acre-feet, which could be met by contemplated future reservoirs and diversion works of The California Water Plan subsequently described. As indicated previously, the streams of this group furnish water not only to foothill and mountain lands therein, but also to lands on the San Joaquin Valley floor and for export to the San Francisco Bay Area. Under full development it is estimated that the firm yield of all reservoirs on streams in the group would be about 4,070,000 acre-feet annually, of which about 520,000 acre-feet would be allocated to foothill and mountain lands.

Development on the Cosumnes River for use in that watershed has been relatively minor. There are several small diversions in the foothills and lower mountain regions for irrigation and domestic purposes; however, the total quantity of water which is now diverted from the upper river for local use is small in comparison with the total runoff of the watershed. The most substantial export from the watershed, about 17,000 acre-feet per season, is conveyed from the recently completed Sly Park Reservoir on Sly Park Creek, with a capacity of 41,000 acre-feet, to the American River watershed.

The Mokelumne River is subject to heavy draft for irrigation, power, and municipal purposes. Salt Springs and Bear River Reservoirs in the headwater area supply the Pacific Gas and Electric Company power development. Pardee Reservoir in the foothills, with a capacity of 239,000 acre-feet, develops municipal water supply for the East Bay Municipal Utility District in Alameda and Contra Costa Counties, with some attendant hydroelectric power generation.

Existing developments on the Stanislaus River include Melones Reservoir, with a capacity of 112,500 acre-feet, owned jointly by the Oakdale and South San Joaquin Irrigation Districts; and the Tri-Dam Project, consisting of Donnells, Beardsley, and Tulloch Reservoirs and associated power plants, presently under construction by the same districts. The Tri-Dam Project will add substantially to the present irrigation supplies and hydroelectric energy developed by Melones Reservoir.

Existing developments on the Tuolumne River include works by the City and County of San Francisco in the upper watersheds to provide water, hydroelectric power, and conveyance of the water to the San Francisco Peninsula for use in the San Francisco Bay Area. These works include three reservoirs, Hetch Hetchy, Lake Eleanor, and Cherry Valley, with a combined storage capacity of 656,000 acre-feet. In 1954-55, about 123,000 acre-feet of water were conveyed in the Hetch Hetchy Aqueduct to the Bay area. Additional works, including Don Pedro Reservoir, with a capacity of 289,000 acre-feet, have been constructed on the main river by the Modesto and Turlock Irrigation Districts to generate power and to provide water for use in their service areas in the San Joaquin Valley.

Exchequer Dam on the Merced River forms McClure Reservoir, owned by the Merced Irrigation District. The reservoir, with a capacity of 289,000 acre-feet, is operated to store water for irrigation use in the valley and for hydroelectric power production.

There are no existing developments of any consequence on the Fresno or Chowchilla Rivers, which rise too far from the crest of the Sierra and at too low an elevation to be snow-fed in the summer months. Runoff from these streams varies from little or no flow to flashy floods.

The San Joaquin River rises on the western slope of the Sierra Nevada and flows southwesterly, discharging from the foothills to the trough of the valley floor, where it turns northwesterly and traverses the San Joaquin Valley to its confluence with the Sacramento River at the head of Suisun Bay. The Southern California Edison Company has developed an extensive system of power plants and four major storage reservoirs on the upper watersheds, comprising Florence, Huntington, Shaver, and Vermillion Lakes Reservoirs, with a combined storage capacity of about 448,000 acre-feet. This system utilizes a large part of the flow of the river for hydroelectric power production. The Pacific Gas and Electric Company, with 46,000 acre-feet of regulatory storage in Crane Valley Reservoir, also develops power in the lower watershed. Releases from the two systems are com bined in the small Kerckhoff Reservoir and are dis charged through the Kerckhoff Power Plant. Frian Dam, forming Lake Millerton with a storage capacit of 520,000 acre-feet, has been constructed at the va ley floor line by the United States Bureau of Reclama tion and is operated for irrigation and flood contr purposes.

Plans for development of the water resources of th San Joaquin-Sierra Group contemplate the eventu construction of 57 dams and reservoirs to make wat available for use on mountain and foothill lands an on the valley floor. The reservoirs would also prote the watershed lands, preserve and enhance fish, wil life, and recreation, and give flood protection to th valley floor. A number of the reservoirs would be ope ated either primarily or partly to produce hydroele tric energy. The contemplated works in each of th major river basins are described separately.

Works in the Cosumnes River Basin would inclu 12 dams and reservoirs on the North, Middle, an South Forks of the Cosumnes River and their trib taries, on the main river, and on Deer, Sutter, an Dry Creeks. Additional water would be made ava able to the basin from works on the South Fork of t American River and by the Amador Canal which co veys water from the Mokelumne River. Works on t North Fork would include Capps Crossing and Midd End Reservoirs. Two reservoirs, Bakersford and Pi l would be located on the Middle Fork. Sopiago Rese voir would be located on Sopiago Creek, a tributary the Middle Fork. Works on the South Fork would i clude two reservoirs, Bridgeport and Case Valle Other reservoirs in the basin would include Volca on Sutter Creek, Deer Creek on Deer Creek, and Iri Hill on Dry Creek.

Water conserved in these reservoirs would supp ment existing diversions to meet water requireme in the Cosumnes River Basin and on adjacent lan above the valley floor. In addition, all of the reservo would be operated to preserve and enhance the fi wildlife, and recreation values of the watershed. T major reservoirs, Nashville and Michigan Bar, wou be constructed on the main river. Water conserved Nashville Reservoir would be discharged through power plant for power generation, and then to t natural channel of the Cosumnes River for dow stream irrigation and to augment low flows in t interests of fish and wildlife. A substantial portion these waters would be diverted immediately below power plant and conveyed in a southerly direction serve lands south of the river. The remaining wat would be impounded downstream in Michigan B Reservoir, together with the intervening tribut runoff, reregulated to meet irrigation demands, a released to the natural channel for downstream di sion and for use on the valley floor. Nashville a ichigan Bar Reservoirs also would be operated to rotect downstream areas from floods and to provide istained flows for fish.

Plans to provide water for a portion of the irrigable nds in the Mokelumne and Calaveras River Basins clude five reservoirs, of which two would be in the okelumne River Basin and three would be in the alaveras River Basin. Certain lands in these basins so would receive water from developments on the orth Fork of the Stanislaus River. The plans contemplate the enlargement of existing Middle Fork eservoir, which is located on the Middle Fork of the okelumne River, and construction of Forest Creek d Jesus Maria Reservoirs on Forest Creek and on sus Maria Creek, respectively. Also included is the largement of the existing McCarty Dam, which is cated on the North Fork of the Calaveras River in alaveras Valley, and construction of San Domingo servoir on San Domingo Creek. Irrigable lands tween the North and South Forks of the Mokelumne ver would be supplied with water from Middle ork and Forest Creek Reservoirs. Lands between the uth Fork of the Mokelumne River and the Stanaus River watershed divide would be supplied with ter from Jesus Maria, McCarty, and San Domingo servoirs and direct diversions from the South Fork the Mokelumne River and the North Fork of the anislaus River. The foregoing reservoirs also would operated to enhance the fish, wildlife, and recreaon potentials. There are, however, other tributaries the rivers on which small reservoirs should be conucted in the headwaters to maintain flows for fish.

Developments on the Mokelumne River proposed by East Bay Municipal Utility District include Railad Flat Reservoir on the South Fork, and Middle r and Camanche Reservoirs on the main river, as ll as enlargement of the existing Pardee Reservoir. ese works would make additional water available export to the East Bay area under water rights rmits already granted. In operation studies of the ervoirs on the Mokelumne River, it was assumed t water in the firm annual amount of 364,000 acre-t would ultimately be exported to the East Bay a. Storage in and operation of Camanche Reservoir flood control is necessary if downstream areas are be protected. Studies of the operation of Camanche servoir indicate that under ultimate conditions the ervoir releases in dry years probably will not suprt the anadromous fishery on the lower Mokelumne ver. This problem should be given further study to termine steps that can be taken to protect and serve the fishery.

Prospective major developments on the Calaveras ver would be confined to the enlargement of existing gan Reservoir. Water released from the reservoir uld be diverted at the dam and would be served to ds north of the river. New Hogan Reservoir would also be operated to protect downstream lands from floods.

Suggested works on the Stanislaus River would include the construction of three new reservoirs and the enlargement of two existing reservoirs. These works would be on the North and South Forks of the Stanislaus River, and would provide water for irrigable lands in the Stanislaus River Basin and in portions of the Mokelumne and Calaveras River Basins. Operation of these works would enhance the fish, wildlife, and recreation resources of the Calaveras and Stanislaus River Basins. Under the plan for the development of the North Fork of the Stanislaus River, an enlarged reservoir would be constructed at the existing Spicer Meadow reservoir site on Highland Creek, a tributary to the North Fork. Water released from the enlarged Spicer Meadow Reservoir would flow down the natural channel of Highland Creek and the North Fork to Ganns Reservoir, which would be constructed on the North Fork of the Stanislaus River about 1 mile downstream from the junction with Highland Creek. Water conserved in Ganns Reservoir would be augmented by these releases from Spicer Meadow Reservoir and by releases from existing Utica, Silver Valley, and Union Valley Reservoirs, which are located on the North Fork of the Stanislaus River. Releases from Ganns Reservoir would be discharged through a power plant and into Ramsey Reservoir, also on the North Fork. From Ramsey Reservoir, the water would be conveyed along the right bank of the North Fork of the Stanislaus River. A portion of the water would be discharged to a power house on Moran Creek and thence to existing Hunter Reservoir and to the existing Murphys Power Plant, from where it would be conveyed to San Domingo Reservoir. The remaining water from the North Fork of the Stanislaus River would be discharged through a proposed power plant on Jesus Maria Creek. From this power plant, a portion of the water would be conveyed to the proposed enlarged McCarty Reservoir on the North Fork of the Calaveras River to supply water to irrigable lands between the North Fork of the Calaveras River and the South Fork of the Mokelumne River. The remaining water would flow down the creek to Jesus Maria Reservoir. All of the foregoing reservoirs would be operated to enhance fish, wildlife, and recreation.

Suggested works on the South Fork of the Stanislaus River would include Big Dam Reservoir and enlarged Lyons Reservoir. Irrigable lands in the Stanislaus River Basin north of the Stanislaus River and its North Fork would receive water conserved in the enlarged Spicer Meadow Reservoir, Ganns Reservoir, Ramsey Reservoir, and in works on Moran Creek and existing Hunter Reservoir, all previously mentioned. These works would also furnish water to lands in the

Mokelumne River Basin which are south of the South Fork of the Mokelumne River. Irrigable lands between the Stanislaus River, the South Fork of the Stanislaus River, and the Tuolumne River watershed divide would receive water conserved in Big Dam and Lyons Reservoirs on the South Fork of the Stanislaus. Lyons Reservoir also would be used as a regulation reservoir for water developed by works on the Clavey River and the North Fork of the Tuolumne River. These waters, so regulated, would be conveyed from Lyons Reservoir in the existing Tuolumne Ditch to Phoenix Power Plant and thence to irrigable lands in Tuolumne County. In addition to providing water to irrigable lands, the foregoing works also would provide sustained flows to enhance fish, wildlife, and recreation.

Other works in the upper watershed of the Stanislaus River would be constructed primarily to produce hydroelectric power and to enhance fish, wildlife, and recreation benefits. They would include Kennedy Meadows and Griswold Reservoirs, Sand Bar and Griswold Power Plants, and the enlarged Stanislaus Power Plant. In addition, it is proposed to enlarge the existing Melones Reservoir to a capacity of 1,100,000 acre-feet to provide flood control and hydroelectric power, and to make additional water available for use on valley floor lands.

Works contemplated in the upper watershed of the Tuolumne River would include reservoirs at sites on the North and South Forks of the main river, on Lily Creek, Clavey River, and Hull and Sullivan Creeks, tributaries to the main stream, and on Big Creek, tributary to the South Fork. These works would enhance fish, wildlife, and recreation. In addition, after reregulation in Lyons Reservoir and discharge through the Phoenix Power Plant, the water would be available for use on irrigable lands in the Tuolumne River Basin.

Works on the South Fork of the Tuolumne River would consist of Hardin Flat and Burch Meadows Reservoirs. These reservoirs would serve water to irrigable lands in the basin which lie south of the main river, and would furnish a limited quantity of water for export to off-stream storage in Mariposa County. Much of the exported water, after reregulation in Coulterville Reservoir, would be returned to lower lands in the Tuolumne River Basin. Irrigable lands in the basin which lie north of the North Fork and north of the Tuolumne River would receive water from Lily Lake, Belle Meadows, Lords, Browns Meadow, and Phoenix Reservoirs, and from Lyons Reservoir as mentioned previously. Lily Lake Reservoir would be constructed on Lily Creek, a tributary of the Tuolumne River; Belle Meadows Reservoir would be on Clavey River, a tributary of the Tuolumne River; Lords Reservoir would be located on Rush Creek, a tributary of Clavey River; and Browns Meadow Reservoir would be located on the Nort Fork of the Tuolumne River. An enlargement of th existing Phoenix Reservoir, located on Sullivan Creek is also contemplated. In addition to providing wate for upstream lands, the foregoing reservoirs would b operated to enhance fish, wildlife, and recreation.

New power developments proposed by the City an County of San Francisco on the Tuolumne Rive would include the Hetch Hetchy Power Plant at Earl Intake and Cherry Creek Power Plant on Cherr Creek. Existing power plants which logically could b enlarged include the Moccasin Creek, Phoenix, an Don Pedro Power Plants. Operation of Don Pedr Reservoir, enlarged to a capacity of about 1,950,00 acre-feet, would protect downstream lands from floo and provide additional regulation of water for use o valley floor lands.

In operation studies of works on the Tuolumn River, it was assumed that water in the firm annua amount of 450,000 acre-feet ultimately would be ex ported to the San Francisco Bay Area through th Hetch Hetchy Aqueduct by the City and County o San Francisco. In the event that the export would b increased above this amount, a similar increase woul be required in the amount imported to the San Jo quin-Tulare Lake Basin through facilities of the Cal ifornia Aqueduct System. The City and County o San Francisco claims large rights of early priority waters of the Tuolumne River.

Works contemplated to provide water for irrigab lands in the Merced River Basin lying north of th Merced River, as well as to enhance fish, wildlife, an recreation in this area, would include Coultervill Butterfly, and Hayward Reservoirs. Lands in th basin lying south of the river could receive water d verted from the South Fork of the Merced River ne Wawona and outside Yosemite National Park, an regulated in reservoirs on tributaries of the We Fork of the Chowchilla River, and on Mariposa an Bear Creeks. These reservoirs would enhance fis wildlife, and recreation, and also would furnish wat to certain land in the Chowchilla River Basin.

Coulterville Reservoir, in addition to conserving t runoff of its own watershed, would regulate wat imported into the area from Hardin Flat Reservoir the South Fork of the Tuolumne River, as previous mentioned. The water would be released from Coult ville Reservoir to Butterfly and Hayward Reservo for further regulation, and to serve irrigable lan and enhance fish, wildlife, and recreation. Water verted from the South Fork of the Merced River the Wawona diversion would be conveyed weste in a tunnel into the upper watershed of the Cho chilla River Basin. As the water would be convey across the upper Chowchilla River watershed, so releases would be made for local application and regulatory storage reservoirs in this basin, as is su sequently described. However, the major portion of the water would be conveyed out of the watershed and discharged into Aqua Fria and Upper Bear Creek Reservoirs, located on Mariposa Creek and Bear Creek, respectively, and served to lands in the vicinity of the two reservoirs.

In addition to the foregoing works, which would serve water to upper watershed lands and would enhance fish, wildlife, and recreation, a major reservoir, Virginia Point, with a storage capacity of about 100,000 acre-feet, would be constructed on the main stem of the Merced River immediately above the existing McClure Reservoir. Releases from Virginia Point Reservoir would be made through a new power plant into McClure Reservoir. From McClure Reservoir, the water would be discharged through an enlarged Exchequer Power Plant, the Merced Falls Power Plant, and then diverted for irrigation in the Merced Irrigation District and adjacent areas in the San Joaquin Valley. Reservoir space in the amount of 10,000 acre-feet would be reserved in Virginia Point Reservoir to control floods on the Merced River. Releases would be made from the reservoirs to sustain flows for the preservation of fish life.

As mentioned previously, a portion of the water diverted from the South Fork of the Merced River would be released in the upper Chowchilla River Basin. This water, which would be released to four small reservoirs, namely, Darrah, Magoon, Pegleg, and Humbug, and to farm-size reservoirs, would meet substantially all water requirements in the upper portions of the Chowchilla River Basin which have no alternative source of supply. Lower lands in the basin would receive water from Buchanan Reservoir on the Chowchilla River, which would also furnish water to and provide flood protection for lands on the San Joaquin Valley floor.

Irrigable lands in the Fresno River Basin would receive water conserved in three small reservoirs, namely, Miami, Lewis, and Nelder Creek, located on tributaries of the Fresno River. Irrigable lands in the lower reaches of the Fresno River Basin would receive water from Windy Gap Reservoir and from Hidden Reservoir. These latter reservoirs would also furnish water to lands in the San Joaquin Valley, and Hidden Reservoir would provide flood protection to the valley floor.

Prospective development of the San Joaquin River would be confined to the undeveloped tributaries of that portion of the main river watershed which extends north from the mouth of Big Creek, excluding the South Fork. The works would be constructed primarily to produce hydroelectric energy and to preserve and enhance the fish, wildlife, and recreation resources of the watershed. Suggested works would include Miller Bridge Dam and Reservoir, Miller Bridge Power Plant, Forks Dam and Reservoir, Forks Power Plant, Mammoth Pool Dam and Reservoir, Mammoth Pool Power Plant, Chiquito Creek Dam and Reservoir, and Chiquito Power Plant. The Southern California Edison Company is proposing the construction of Mammoth Pool Reservoir. No works are specifically contemplated herein to provide for future water requirements in the mountain and foothill watersheds of the San Joaquin River Basin, since such requirements are small and are for lands in scattered valleys adjacent to the main river and its tributaries, which lands could be served by direct diversions and from local farm-size reservoirs.

From Miller Bridge Reservoir on the Middle Fork, a tunnel would convey water to the Miller Bridge Power Plant, located on the Middle Fork about 2 miles above the confluence of the South Fork and on the flow line of Forks Reservoir. From Forks Reservoir a tunnel would convey the water to the Forks Power Plant, which would be located on the flow line of Mammoth Pool Reservoir. From Mammoth Pool Reservoir on the main San Joaquin River the water would be discharged through the Mammoth Pool Power Plant, located above the junction with Big Creek. The power plant would be connected with Mammoth Pool Reservoir by a tunnel. Releases from the power plant would be available for use in three existing downstream power plants before flowing into Millerton Lake.

Chiquito Reservoir on Chiquito Creek would conserve the runoff of its own watershed, plus diversions from West Granite and Jackass Creeks. A tunnel would convey the flow of West Granite Creek to Jackass Creek, where a second diversion would divert the combined flows of both creeks for discharge into Chiquito Reservoir. Water released from Chiquito Reservoir would be conveyed in a tunnel to Chiquito Power Plant, also on the flow line of Mammoth Pool Reservoir.

The new and existing works in the San Joaquin River Basin would produce large amounts of hydroelectric energy and would provide water to meet local water requirements, including that for enhancement of fish and wildlife resources and for development of the recreational potential. Water requirements in the service areas of the Madera and Friant-Kern Canals also would be met. A substantial amount of flood control is provided in the basin by reservation of storage space for that purpose in Millerton Lake.

The 57 prospective reservoirs which would accomplish the local objectives of The California Water Plan in the San Joaquin-Sierra Group, would have a total reservoir storage capacity of about 6,560,000 acre-feet. Their construction and operation in conjunction with existing works in the group would provide about 520,000 acre-feet of water each year to meet requirements in the foothill and mountain watersheds. They also would provide about 3,550,000

San Joaquin River Basin—Headwaters and Delta acre-feet of water for release to lands on the valley floor, together with large quantities of usable spill available for regulation in the ground water reservoir. The existing and new hydroelectric plants, with a total installed capacity of about 1,880,000 kilowatts, would produce about 8.8 billion kilowatt-hours of hydroelectric energy each year, of which 2.9 billion kilowatt-hours would be new energy. Operation of the units of The California Water Plan would provide reservoir pools and sustained stream flows to preserve and enhance the valuable fish, wildlife, and recreation resources in these Sierra watersheds. In addition, about 1,500,000 acre-feet of space would be provided in the major downstream reservoirs, which, when operated in conjunction with existing and proposed levee systems, would prevent flooding of valley lands.

Tulare-Sierra Group. The Tulare-Sierra Group includes all mountain and foothill lands on the east and south sides of the San Joaquin-Tulare Lake Basin lying south of the watershed divide between the San Joaquin and Kings Rivers. The group includes the portions of the Tehachapi Mountains tributary to the basin. The area is characterized by foothill and mountain topography, the peaks being some of the highest in the United States. Forest resources are extensive in the region north of the Kern River. Mineral resources are less fully exploited than in the San Joaquin-Sierra Group to the north. Recreational and scenic values are very high here, although they are less accessible than in other parts of the Sierra Nevada. The major recreational attractions in the group are Sequoia and Kings Canyon National Parks. The national forests are of lesser recreational importance than those farther north, but only because they are less well-developed by access roads.

Small parcels of irrigable land are found scattered throughout the lower portions of the Tulare-Sierra Group. These total about 243,000 acres. In 1950, however, only about 12,500 acres were being irrigated.

Streams of the Tulare-Sierra Group include several major rivers, namely, the Kings, Kaweah, Tule, and Kern; several intervening minor streams draining lower slopes of the Sierra Nevada; and a number of minor streams draining the Tehachapi Mountains from Caliente Creek westward to Bitterwater Creek. The aggregate runoff of these streams constitutes about 30 per cent of the total runoff of streams of the San Joaquin-Tulare Lake Basin as a whole. Present water requirements are met largely by pumping from ground water, inasmuch as the great majority of the irrigated lands is in the area south of the Kern River where surface supplies are limited. The major streams have been developed for hydroelectric power. Two major foothill reservoirs, Pine Flat and Isabella, have been built primarily for flood control on the valley floor, but with some conservation storage. Pine Flat Reservoir is also used to reregulate releases from upstream power developments.

Virtually all of the flow of the streams draining the Tulare-Sierra Group is utilized under prior vested rights on valley floor lands of the San Joaquin Valley. Such utilization is accomplished by surface diversions and widespread use of ground water. There is a need for initiating development of water for use on the irrigable watershed lands above the valley floor; however, such developments would require, in almost every case, the substitution of imported water in approximately an equivalent amount to valley floor lands under negotiated exchange agreements, since there is little, if any, unappropriated water left available for these upper lands.

Flood problems in the Tulare-Sierra Group are of local importance. Foothill reservoirs are now and in the future will be operated to provide flood protection for lands of the valley floor.

In 1950, water requirements for lands in the Tulare-Sierra Group were about 62,000 acre-feet annually. It is estimated that ultimate water requirements would total about 915,000 acre-feet per year. A large portion of the ultimate requirement would be for irrigable land contiguous to the valley floor, which could be served by pumping from major conduits and sources of supply on the valley floor. Another portion of the ultimate requirement would be for lands in scattered valleys and mountain meadows, only some of which could be irrigated by developing limited local water supplies; however, works to accomplish this are not described herein. The remaining portion would be for lands adjacent to and which could be irrigated from the major streams of the group. Works which are subsequently described would make available about 130,000 acre-feet of water each year, which is sufficient to serve such lands. The remaining water from streams in the group would be available to serve valley floor lands. As previously stated, any additional water to be supplied to the upper lands must be obtained through the medium of exchange contracts.

Existing developments and projects under construction on the Kings River include three reservoirs and three power plants. The three reservoirs are Helms and Wishon on the North Fork, presently under construction by the Pacific Gas and Electric Company, and Pine Flat on the main river, recently completed by the Corps of Engineers, U. S. Army, for flood control and irrigation. Releases from Helms and Wishon Reservoirs will pass successively through Haas, Balch, and Kings River Power Plants, finally discharging into Pine Flat Reservoir. These works when completed will provide almost complete development of the water resources of the Kings River and its tributaries. The upstream reservoirs will provide for the generation of power, will protect watershed lands from floods, and will preserve and enhance the fish, wildlife, and recreation resources. Pine Flat Reservoir provides irrigation water and flood protection to valley floor lands.

Existing developments on the Kaweah River consist of three run-of-river power plants located near the junction of the Middle and East Forks.

Existing developments on the Tule River are relatively minor. Two small run-of-river power plants are on the Middle Fork. Diversions are made from all forks of the river for irrigation of approximately 1,400 acres above the valley floor.

Existing developments on the Kern River, the most southerly of the large streams which rise in the Sierra Nevada, include the recently completed Isabella Dam, with a reservoir capacity of 570,000 acre-feet, and four hydroelectric plants. Prior to construction of Isabella Dam by the Corps of Engineers, U. S. Army, all of the works were dependent upon unregulated runoff for operation. Works on the South Fork of the Kern River consist of small diversions and canals to irrigate scattered lands above Isabella Reservoir. Other diversion structures and canals are located on the main stream for service to the valley floor.

Suggested plans for development of the water resources of the Tulare-Sierra Group contemplate the eventual construction of 11 reservoirs to make water available for use on mountain and foothill lands and to provide some additional regulation of water for valley floor lands. The reservoirs would also protect and enhance the watershed lands and the fish, wildlife, and recreation resources, and would provide flood protection to the valley floor. A number of the reservoirs would be operated either primarily or partly to produce hydroelectric energy. Works in each of the major river basins are described separately.

New developments contemplated on the Kings River as features of The California Water Plan would include: Cedar Grove Diversion Dam and Cedar Grove Power Plant on the South Fork; Tehipite Diversion Dam and Tehipite Power Plant on the Middle Fork; Junction Reservoir, located just below the confluence of the Middle and South Forks; Junction Power Plant on the main stream; Dinkey Meadow Reservoir and Dinkey Meadow and Ross Power Plants on Dinkey Creek; an enlarged Kings River Power Plant; and Pine Flat Power Plant immediately below Pine Flat Dam.

Water would be diverted at the Cedar Grove Diversion Dam into a tunnel leading to the Cedar Grove Power Plant, located on the flow line of Junction Reservoir. In the same manner, water would be diverted at the Tehipite Diversion Dam into a tunnel to be conveyed to the Tehipite Power Plant, which would also be located on the flow line of Junction Reservoir and adjacent to the Cedar Grove Power Plant. Junction Reservoir thus would regulate the flow of the Middle and South Forks and the releases from Tehipite and Cedar Grove Power Plants. From Junction Reservoir, a tunnel would convey the water to th Junction Power Plant, located on the main strea about 2 miles above the mouth of Mill Flat Creel This plant would discharge to the main river.

To augment the inflow to Dinkey Meadow Rese voir, the runoff of Bear Creek, tributary to Dinke Creek, would be diverted into the reservoir by mea of a short conduit. From Dinkey Meadow Reservo a tunnel would supply water to the Dinkey Meado Power Plant downstream from the dam. A small d version dam on Dinkey Creek immediately below th power plant would divert water into a tunnel exten ing to the Ross Power Plant on Dinkey Creek abo 2.5 miles above its mouth. From Ross Power Pla the water would be conveyed by tunnel to the exis ing Kings River Power Plant, thus permitting an i crease in the installed capacity of that plant. Wat in the seasonal amount of about 30,000 acre-fe which is required to irrigate scattered lands adjace to the main tributaries in the basin, would be ava able by direct diversion or from small farm-size rese voirs. The remaining water developed by the foreg ing works would be released through Pine Flat Pow Plant, which would be located at Pine Flat Dam.

Construction of works of The California Wat Plan in the Kings River Basin would provide so additional regulation of the runoff to effect bett utilization in downstream areas. The works would al produce substantial amounts of hydroelectric ener Pine Flat Reservoir would be operated to prot valley lands from floods, as at present, and the wor would also provide sustained minimum flows in ma reaches of the Kings River and its tributaries for t preservation and enhancement of fish, wildlife, a recreation.

The only project contemplated on the Kaweah Riv is the federally authorized Terminus Dam and Res voir, located 20 miles east of Visalia. This proje now in the planning stage, will provide flood prot tion and will permit additional regulation for bet service of irrigation water to lands on the valley flo As in the case of the Kings River, the runoff of t Kaweah River has been almost entirely, if not co pletely, developed for use of the valley floor. Wa for use on the small and scattered parcels of irriga lands above Terminus Reservoir, which have aggregate ultimate seasonal requirement of ab 9,000 acre-feet, could be obtained by direct divers or from small farm-size reservoirs; however, it wo be necessary to substitute imported water for use valley lands in approximately an equivalent amo under negotiated exchange agreements.

Developments on the Tule River would consist Success Reservoir, presently under construction the Corps of Engineers, U. S. Army, and two sm upstream reservoirs, North Fork Reservoir and M dle Fork Reservoir. Success Dam is located abou iles east of Porterville and just below the junction the South Fork with the main stream. The reser-ir will provide flood protection and will permit ditional regulation for better service of irrigation ater to lands on the valley floor. North Fork and iddle Fork Reservoirs would supply water to irri-ble lands which are adjacent to the main river above ccess Reservoir and which have an annual water quirement of about 23,000 acre-feet. Other irrigable nds in the watershed, which are small in amount d scattered, would receive water from direct stream versions and from local farm-size reservoirs. As in case of the Kings and Kaweah Rivers, it would necessary to substitute imported water in approx-ately an equivalent amount to valley floor lands der a negotiated exchange agreement, if these per reservoirs were to be constructed. In the case both the Kaweah and Tule Rivers, there is a need r small headwater reservoirs to sustain flows in the mmer months to protect and enhance the fish, wild-e, and recreation resources.

Existing works in the Kern River-Tehachapi Moun-ins area and on the valley floor have fully devel-ed the water resources of the Kern River and its butaries. The works are operated to protect water-d and valley floor lands from floods, to provide igation water to valley floor lands, to provide hy-oelectric power, and to preserve and enhance the h, wildlife, and recreation resources of the water-d. New works contemplated as features of The lifornia Water Plan would provide additional droelectric power and would make water available serve foothill and mountain lands, although it uld be necessary to substitute imported water in proximately an equivalent amount to valley floor ds under negotiated agreements.

Studies indicate that service of water to many of irrigable lands in the Kern River-Tehachapi untains area would be difficult and expensive. ere are 36,000 acres of irrigable land above the rn Canyon Power House on the Kern River, with but 2,400 acres lying above the existing Isabella servoir. These lands have an estimated ultimate sonal water requirement of about 74,000 acre-feet. ater in the amount of about 50,000 acre-feet per son to meet a portion of these requirements could furnished from reservoirs on the South Fork of the rn River and its tributaries, which are subsequently scribed. The remaining higher lands could, in iso-ed cases, be irrigated from farm-size reservoirs ich would develop limited local water resources, but pensive conduits and pumping would be required to igate most of these lands. Works to accomplish this not described herein.

Lands contiguous to the valley floor and north of Kern River could be served by local water re-rces and by pumping from the Friant-Kern Canal, if water could be made available from that source. Lands south of the Kern River and contiguous to the valley floor could be served, in part, by developing limited local waters; in part by the proposed Arvin-Edison Canal, which would divert from the Kern River at an elevation of 680 feet and which is described subsequently in connection with the South Valley Group; and in part from an extension of the Feather River Project Aqueduct around the southern end of the valley.

Service of water to the scattered irrigable valleys and meadows in the Tehachapi Mountains would be difficult and expensive, since most of the lands are above 2,500 feet in elevation. Some of these lands could be irrigated by development of the limited local water supplies, but irrigation of the remaining lands would require expensive pumping from water sources and conduits on the valley floor. Works to accomplish this are not discussed herein.

Major new works contemplated for the Kern River would include Rockhouse Reservoir and Power Plant, and Onyx Reservoir and Power Plant on the South Fork. In addition, three small reservoirs, Kelso, Canebrake, and Lamont Meadows, would furnish irrigation water to other lands above Isabella Reservoir.

Rockhouse Dam would be located on the South Fork. Water conserved in Rockhouse Reservoir would be conveyed in a tunnel to Rockhouse Power Plant for power generation. From Rockhouse Power Plant Afterbay the water would be diverted and conveyed in a tunnel to Onyx Power Plant for power generation. Releases from Onyx Power Plant would be stored in Onyx Reservoir and would be diverted for irrigation of lands in the South Fork Valley below an elevation of about 2,800 feet. Lands in the South Fork Valley above this elevation would receive water from Kelso, Canebrake, and Lamont Meadows Reservoirs.

Releases from Isabella Reservoir would be made to Borel Power Plant for power generation, as is done now. Likewise, the water would be diverted downstream from Borel Power Plant to Kern No. 1 Power Plant and thence to Kern Canyon Power Plant. The capacities of Borel and Kern No. 1 Power Plants would be increased. Below the Kern Canyon Power Plant water would be diverted through existing canals and to the Arvin-Edison Canal to serve the valley floor lands.

Construction of works of The California Water Plan in the Kern River Basin would provide water for watershed lands above and adjacent to Isabella Reservoir. The works would produce large amounts of hydroelectric energy. A flood control reservation would be maintained in Isabella Reservoir, as is provided at the present time. The works would also provide sustained minimum flows in many reaches of the Kern River and its tributaries for the preservation and enhancement of fish, wildlife, and recreation.

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In summary, the 11 reservoirs which would accomplish the objectives of The California Water Plan in the Tulare-Sierra Group would have a total reservoir storage capacity of about 432,000 acre-feet. Their construction and operation in conjunction with existing works in the group would provide about 136,000 acre-feet of water each year to meet requirements in the foothill and mountain watersheds, and would provide some additional regulation to water entering downstream reservoirs. These reservoirs would be operated, as the existing ones are at the present time, to serve valley floor lands. Operation of the reservoirs would make firm water supplies available in the amount of about 1,140,000 acre-feet, together with large quantities of usable spill which would be available for reregulation in the underground reservoir and for use on valley floor lands. As is described subsequently, the water made available at the eastern edge of the valley floor would be served at as high an elevation as possible in order to minimize pumping of imported water supplies. The existing and new hydroelectric plants, with a total installed capacity of about 725,000 kilowatts, would produce a total of about 3.4 billion kilowatt-hours of hydroelectric energy each year, of which about 2 billion kilowatt-hours would be new energy. Operation of these works would provide reservoir pools and sustained stream flows to preserve and enhance the valuable fish, wildlife, and recreation resources in these Sierra watersheds. In addition, about 750,000 acre-feet of space would be provided in the major downstream reservoirs, which, when operated in conjunction with existing and proposed levee systems and terminal reservoirs, would prevent flooding of valley lands.

West Side Group. The West Side Group includes a narrow strip of lands of the San Joaquin-Tulare Lake Basin which lie on the eastern slopes of the Coast Range and above the floor of the valley. The eastern boundary of the group ranges in elevation from less than 500 feet, southwest of the Delta, to about 1,500 feet at the southern end of the valley. The eastern crest of the Coast Range, which varies in elevation from about 2,000 to 4,000 feet, forms the western boundary of the group.

Present (1950) development in the West Side Group is quite minor. There is some mining, but practically no forestry. There are about 109,000 acres of irrigable land, of which only about 1,600 acres were irrigated in 1950. Mercury is mined in important quantities in San Benito County. Petroleum and natural gas are produced from the Coalinga West and Midway-Sunset fields in the southern portion of the group.

Average seasonal precipitation on lands of the West Side Group varies with elevation from less than 10 inches at the base of the foothills to somewhat more than 20 inches along the crest of the Coast Range. This precipitation is largely concentrated in the winter months, practically none of it falling as snow.

A large number of minor streams drain the West Side Group, from Marsh Creek on the northerly west side to Buena Vista Creek near Taft on the south. From north to south they include: Marsh, Del Puerto, Orestimba, San Luis, Los Banos, Ortigalita, Little Panoche, Panoche, and Cantua Creeks; Arroyo Pasajero; and Avenal, Buena Vista, and Bitterwater Creeks, as well as other small streams. Due to the sparse rainfall these streams carry little water. The total runoff of streams of this group is only slightly more than 1 per cent of that for the entire San Joaquin-Tulare Lake Basin. The 1,600 acres of land in the group which were irrigated in 1950 have a seasonal water requirement of about 4,000 acre-feet. It is estimated that this requirement might increase to about 366,000 acre-feet under full development.

Water problems of the West Side Group include a need for supplemental water for irrigable lands which are presently not irrigated. Local surface water supplies are very limited, and it is probable that ground water supplies are almost nonexistent. In addition, water of many streams of the group is characterized by relatively high amounts of dissolved minerals, including significant concentrations of boron in some cases. Floods on these streams are not a major problem because of the limited runoff and because most of the area is virtually undeveloped. However, future developments might, in some instances, warrant measures to control the occasional flood waters.

The total seasonal runoff of streams in the West Side Group is only about one-third of the probable ultimate requirement, and even now is largely utilized in replenishment of ground water supplies below the foothill line. Additional conservation is considered to be impracticable. Consequently, it is assumed that the objectives of The California Water Plan for this group would be met by deliveries through the Delta-Mendota Canal, the Feather River Project Aqueduct and the San Joaquin-West Side Conduit, all facilities of the California Aqueduct System.

The authorized San Luis Reservoir will be physically located in the West Side Group, but it will have no specific function with respect to water requirements of the group, except to reregulate imported water supplies, nor is it expected to result in any appreciable additional conservation of runoff of San Luis Creek, which is believed to be fully utilized at the present time.

North Valley Group. The North Valley Group includes all valley floor lands of the San Joaquin-Tulare Lake Basin which lie north of that reach of the San Joaquin River between Friant Dam and the Mendota Pool. The southwesterly boundary of the group generally parallels the Delta-Mendota Canal west of Mendota Pool and includes within the group

San Joaquin River Basin—Cotton and Irrigated Pasture all lands adjacent to the canal which receive water pumped from Mendota Pool. The group is bounded on the south by San Luis Creek and the San Joaquin River.

The North Valley Group is highly developed for agricultural pursuits. Of about 3,142,000 acres of irrigable land in this area, 1,753,000 acres were irrigated in 1950. The principal urban centers are Stockton, Modesto, and Merced. The predominant manufacturing industry is food processing, although in Stockton there are several machinery manufacturing establishments whose principal products are farm implements. Natural gas from the Rio Vista field is the most important mineral product of the region.

Rainfall on lands in the North Valley Group is largely concentrated in the winter months, and varies from somewhat less than 10 inches per season in the southern portion to approximately 15 inches in the north. Major streams contributing to the water supplies of the group are, from north to south, the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne, Merced, Chowchilla, Fresno, and San Joaquin Rivers. Present and contemplated developments on these streams have been described in connection with developments in the San Joaquin-Sierra Group. The Sacramento-San Joaquin Delta, which is included in this group, also receives water from the north from the Sacramento River. A number of smaller tributary streams, as well as rainfall on the valley floor, also contribute to the fulfillment of water requirements.

The water requirements for lands in the North Valley Group were estimated to be about 5,790,000 acre-feet for 1950 conditions. Although local water supplies are highly developed, ground water overdrafts exist in several local areas and the supplemental requirement was estimated to be about 266,000 acre-feet for 1950 conditions. It is estimated that ultimate water requirements will total 6,470,000 acre-feet. Although the streams tributary to this group provide large quantities of water, nevertheless it will be necessary to import about 1,900,000 acre-feet of supplemental water each year to meet estimated ultimate requirements.

The present requirements for water in the North Valley Group are being met in several ways. First, there are diversions from Delta channels and from the Sierra streams, supplemented on the larger rivers by mountain and foothill reservoir storage. Second, there is considerable but scattered pumping from ground water throughout the group. And third, water from the Sacramento and San Joaquin Rivers is imported in the Delta-Mendota and Madera Canals, respectively, units of the Central Valley Project. Water has been imported in the Madera Canal since 1943, and in the Delta-Mendota Canal since 1951. Water is pumped into the Delta-Mendota Canal from Old River, a Delta channel, and is conveyed by the canal to Mendota Pool on the San Joaquin River, a distance of 117 miles. The Madera Canal conveys water from the San Joaquin River to serve lands of the North Valley Group. The canal, which is 37 miles in length, extends from Friant Dam northward through Madera County to Ash Slough, a channel of the Chowchilla River. In 1956, 675,000 acre-feet of water were imported in the Delta-Mendota Canal and 240,000 acre-feet were transported in the Madera Canal.

Several reclamation districts operate diversion works on channels of the Sacramento-San Joaquin Delta, in addition to their levee maintenance functions. Four irrigation districts divert from Old River in the southwestern portion of the Delta, as does the United States Bureau of Reclamation for the Contra Costa and Delta-Mendota Canals. About 20 public districts along the route of the Delta-Mendota Canal receive water by contract with the Federal Government.

The East Bay Municipal Utility District develops water from the Mokelumne River at Pardee Reservoir for export to cities in western Alameda and Contra Costa Counties. In addition to individual diversions downstream from Pardee Dam, the Woodbridge Irrigation District diverts for irrigation in the vicinity of Lodi. The water supply of the Calaveras River area is developed primarily by the Stockton and East San Joaquin Water Conservation District, which operates the conservation features of Hogan Reservoir in conjunction with diversion and ground water recharge works established, in part, by the Linden Irrigation District.

The Stanislaus River is the source of irrigation water for the Oakdale and South San Joaquin Irrigation Districts. Melones Reservoir provides conservation storage for both districts.

The South San Joaquin Irrigation District operates Woodward Reservoir on Simmons Creek for further regulation of its main supply. At present, the two districts are cooperating in the Tri-Dam Project to augment their water supplies by constructing Donnells, Beardsley, and Tulloch Dams and associated power developments on the Stanislaus River and its tributaries.

On the Tuolumne River the point of diversion for the Hetch Hetchy Aqueduct of the City and County of San Francisco is a considerable distance upstream from the foothill line. Don Pedro Reservoir, near the eastern edge of the valley floor, is operated jointly by the Modesto and Turlock Irrigation Districts. The Waterford Irrigation District also has a right to waters of the Tuolumne River.

The Merced Irrigation District operates McClure Reservoir on the Merced River. The Stevinson Water District diverts from the Merced River near its mouth. Individual diverters also utilize water of this stream. The El Nido Irrigation District, which obtains supplemental water from the Merced Irrigation District nd from ground water, is located along the lower eaches of the Chowchilla River.

Two irrigation districts and six water companies. n addition to a large number of individual diverters, ump from the San Joaquin River between Tracy and he mouth of the Merced River. The San Luis Canal ompany diverts from the west bank of the San Joauin River near Dos Palos for irrigation of a large creage between Los Banos and the river. Diversions re made at Mendota Pool on the San Joaquin River or the Firebaugh Canal Company, the Central Caliornia Irrigation District, the Grasslands and Paoche Water Districts, and other smaller districts. he Columbia Canal Company serves lands near Menota by gravity diversions from Lone Willow Slough, nd by pumping from the Mowry Canal and Mendota ool.

The major users of water from the Madera Canal re the Madera Irrigation District and the Chowchilla Vater District. The former district also has a diveron on the Fresno River.

Water problems of the North Valley Group include need for further development and distribution of ocal water supplies to meet present and ultimate suplemental water requirements. Increased use of round water has resulted in local overdrafts. Connued increases in development will aggravate these onditions unless additional water supplies are made vailable. There are also drainage problems in many reas which are receiving surface water supplies. In any instances increased use of ground water would leviate such problems, in other areas surface drainge systems are needed.

Although water supplies of the North Valley roup are generally of excellent quality, certain limed areas yield ground water of doubtful quality. In ldition, surface water supplies obtained from the wer reaches of the San Joaquin River contain exssive concentrations of mineral constituents during e late irrigation season, due to drainage and return ow from upstream use of the water. Flooding along ajor and minor streams and in the lowlands of the an Joaquin Valley has been a recurring problem nce the first settlements. Existing levees and reseroirs and those now under construction afford a high egree of protection; however, dedication of addional flood control storage space in new and in cerin existing reservoirs is necessary, and improved and oordinated levee systems are needed on some streams.

Under The California Water Plan the water to eet requirements of lands in the North Valley roup would be obtained from streams of the San oaquin-Sierra Group, by imports through the Deltaendota, Madera, and proposed Folsom South Canals, nd by further development of ground water. Runoff streams of the Coast Range, although small in nount, would continue to contribute to the ground ater supplies at the foothill line, as at the present time. Runoff of streams of the San Joaquin-Sierra Group which would be available for use would consist of the combined yield of foothill reservoirs and underground reservoirs operated coordinately in such a manner as to make available for use a large proportion of the mean seasonal natural runoff. Foothill reservoirs on streams tributary to this group, which have been described in connection with developments in the San Joaquin-Sierra Group, would furnish water in the amount of about 3,550,000 acre-feet each year on a firm yield basis, together with large quantities of usable spill available for reregulation in the ground water reservoir and use on valley floor lands.

Works contemplated in The California Water Plan in the North Valley Group would have five principal purposes: first, to convey and distribute water supplies from tributary streams for use on lands in the group; second, to distribute water supplies imported through facilities of the California Aqueduct System for use on lands in the group; third, to protect Delta lands from floods and from the encroachment of saline tidal waters; fourth, to collect and convey to tidal water sufficient quantities of drainage and waste waters to prevent water-logging of irrigated lands and to maintain a favorable salt balance; and fifth, to control floods. To accomplish the first two purposes, it would be necessary to further develop and utilize the underground reservoir.

Under The California Water Plan, water from tributary streams would be conveyed and distributed in existing and extended local canal and ditch systems. Works which would convey and distribute imported water supplies to lands of the North Valley Group would include the existing Delta-Mendota Canal, which conveys water pumped from the Delta to Mendota Pool; the existing Madera Canal, which conveys water northerly from the San Joaquin River; and the proposed Folsom South Canal and the projected Placerville South Conduit, both of which would convey water southward from the American River. In addition, the San Joaquin Waste Conduit would convey undesirable waters from lands of the North Valley Group.

The Delta-Mendota Canal would import about 1,780,000 acre-feet of water each year to the San Joaquin Valley, of which amount about 730,000 acre-feet would be diverted for use in the North Valley Group. The Madera Canal would import about 420,000 acre-feet each year to the group. The Folsom South Canal, described subsequently herein in connection with works of the Sacramento Division of the California Aqueduct System, would be operated to import about 640,000 acre-feet of water each year to the group. The Placerville South Conduit, already described in connection with works in the American River Unit of the Sacramento River Basin, would import about 76,000 acre-feet of water each year from that basin. The San Joaquin Waste Conduit would intercept, collect, and convey agricultural, municipal, and industrial waste waters, and other waters of degraded or impaired quality, to tidal waters, thus maintaining the quality of fresh-water supplies at acceptable levels for beneficial uses. The conduit would be a lined canal about 260 miles in length, and would extend from the vicinity of Buena Vista Lake on the south to its discharge into saline water channels of the Delta on the north.

Plans for the North Valley Group also include works in the Sacramento-San Joaquin Delta which would transport fresh water from the Sacramento River across the Delta, without loss or impairment in quality, to pumping plants along the southern boundary of the Delta; provide flood protection for Delta lands; and provide salinity repulsion. These objectives would be accomplished by the Biemond Plan, which is subsequently described under the Delta Division of the California Aqueduct System.

The estimated ultimate water requirements of the North Valley Group, amounting to about 6,470,000 acre-feet per season, could be met by full conservation of the runoff of the major tributary Sierra streams and by importing water in the Delta-Mendota, Madera, and Folsom South Canals, and in the Placerville South Conduit. The plans would provide for the full development of local water supplies for local use. Consideration was also given to a plan under which a portion of the waters of the Stanislaus, Tuolumne, and Merced Rivers would be diverted into a high-line canal along the east side of the valley for use in the South Valley Group, in exchange for water from Mendota Pool, which would be conveyed in a canal extending northward from Mendota Pool to the vicinity of Farmington. Such an exchange would result in substantial savings to the South Valley Group due to reduction in cost of pumping of imported water supplies, but would depend on the willingness of water users holding prior rights to the use of water from those streams, to enter into an exchange agreement.

Under ultimate conditions, existing, enlarged, and new conduits would convey and distribute local water supplies, together with an average seasonal amount of about 1,900,000 acre-feet of imported water supplies, to lands within the North Valley Group. Utilization of such water supplies would require the conjunctive and coordinated operation of surface reservoirs, surface conveyance systems, and the large underground reservoir. Conjunctive operation is discussed later in this chapter. Under such operation, surface reservoirs and conveyance systems would furnish water during the irrigation season to a portion of the irrigable lands in the group, and to stream channels and other percolating areas during the remainder of the year. The water not consumed would percolate to the underground reservoir and would be available to be pumped to serve the remaining irrigable lands. Present estimates indicate that the gross storage capacity of the underground reservoir of the North Valley Group is about 36,000,000 acre-feet between the limits of 10 and 200 feet below the ground surface. Operation studies indicate that adequate water conservation could be obtained by the use of a maximum of about 11,000,000 acre-feet, or 30 percent of such capacity. The total installed ground water pumping capacity would be about 11,000 second-feet.

Under ultimate conditions, the local and imported water supplies would be adequate, not only in quantity, but in quality, for all uses. Barriers and isolated channels in the Delta would operate to maintain the quality of the water therein. The San Joaquin Waste Conduit would intercept and convey to tidal water the poor-quality surface water wasting from the valley during the late irrigation season and during critical dry periods, thus preventing the mingling of such waters with irrigation supplies. The conduit would also convey sewage and industrial wastes, degraded surface waters of minor west side tributaries drainage waters discharged to maintain proper salt balance, and poor-quality ground water pumped for quality control.

Flood waters of the major rivers would be impounded in foothill reservoirs, as discussed in connection with developments on those streams. During flood periods, all surface diversion and conveyance systems would operate to intercept and distribute waters released from the reservoirs for ground water recharge. Levees would add to the protection of the valley lands. Such works would include existing levees, those now under construction by the State of California on and adjacent to the San Joaquin River above the mouth of the Merced River, and new and improved levees on the lower San Joaquin River such as those proposed by the Corps of Engineers.

South Valley Group. The South Valley Group includes all valley floor lands of the San Joaquin Tulare Lake Basin which lie south of the San Joaquin River and south of the area receiving water from Mendota Pool and the Delta-Mendota Canal. The major economic pursuits in the South Valley Group are agriculture and the production of petroleum and natural gas. Of about 4,360,000 acres of irrigable land in this group, 2,310,000 acres were irrigated in 1950. Principal crops are cotton, potatoes, hay and grain, grapes, and alfalfa. Fresno and Bakersfield are the major urban centers of the group. Food processing is the most important manufacturing activity followed by the manufacture of transportation equipment, principally aircraft, and petroleum refining.

Precipitation on lands of the South Valley Group averages from less than 5 inches to about 10 inches per season. Rainfall is concentrated almost entirely in the winter months and contributes little to surfa unoff. Major streams contributing to the water upply for this group are the Kings, Kaweah, Tule, nd Kern Rivers. Present and proposed developments n these streams have been described in connection vith the Tulare-Sierra Group. Lesser streams, in-luding Caliente Creek, Poso Creek, White River, Deer Creek, and others, also furnish water to this rea. In addition, substantial quantities of water are resently imported from the San Joaquin River in he Friant-Kern Canal.

The water requirements for lands in the South Valley Group were estimated to be 4,850,000 acre-feet er season under 1950 conditions. Substantial over-lrafts exist in all units of the group. The consequent upplemental water requirement, which was deter-nined at about 1,400,000 acre-feet in 1950, is esti-nated to have increased to about 1,900,000 acre-feet n 1957. It is estimated that ultimate water require-nents might total about 9,840,000 acre-feet. To meet uch a requirement, it will be necessary to conserve ully the runoff of the tributary streams, and, in addi-ion, to import about 7,200,000 acre-feet of water ach year.

Present requirements in the South Valley Group re being met by surface diversions from all principal treams, until recently without reservoir storage; by mports, amounting to 1,365,000 acre-feet in 1956, rom the San Joaquin River through the Friant-Kern Canal, a unit of the Central Valley Project; and by xtensive pumping from ground water, with conse-uent overdrafts.

As mentioned previously, most lands of the South Valley Group are tributary to Tulare and Buena Vista Lakes, which are closed basins in the trough of he valley. Such conditions, together with a substan-ial development of use of ground water, have re-ulted in almost complete utilization of waters of ributary streams.

The waters of the Kings River are utilized by a arge number of diverters, whose interests have been pportioned by court decrees and agreements. Most f these diverters have associated themselves into the Kings River Water Association, for the purpose of dministering agreements called the Kings River Water Indentures. The parties at interest represent-ng the largest acreages are the Alta, Consolidated, nd Fresno Irrigation Districts, and the Tulare Lake Basin Water Storage District. The Kings River Con-ervation District has been organized by voters in the Kings River service area, and is currently negotiating contract with the Federal Government for repay-nent of the irrigation allocation for Pine Flat Reservoir.

Westlands Water District in the western portion f Fresno and Kings Counties has been formed to btain desperately needed supplemental water sup-lies. Between the Kings and Kaweah Rivers, the Orange Cove, Stone Corral, and Ivanhoe Irrigation Districts supplement private pumping from ground water with deliveries from the Friant-Kern Canal. The major agencies utilizing waters of the Kaweah River are the Lindsay-Strathmore and Tulare Irriga-tion Districts; the Wutchuma, Visalia, and Kaweah Water Companies; and the Consolidated Peoples, Farmers, and Lakeside Ditch Companies. The irriga-tion districts obtain supplemental water supplies from the Friant-Kern Canal. The Corcoran Irrigation District obtains water from the Kings River via Cross Creek, as well as occasional flows from the Kaweah River. The Exeter and Lindmore Irrigation Districts, located between the Kaweah and the Tule Rivers, distribute Friant-Kern Canal water to supplement ground water pumping.

The major diverters along the Tule River are the Porterville and Lower Tule River Irrigation Districts. These districts, as well as the Terra Bella and Delano-Earlimart Irrigation Districts, also obtain water from wells and from the Friant-Kern Canal.

The Saucelito Irrigation District obtains its water supplies from Deer Creek, from wells, and from the Friant-Kern Canal. The Southern San Joaquin Municipal Utility District distributes Friant-Kern Canal water to an area around Delano and McFar-land, supplementing private supplies from wells.

Many of the canals diverting from the Kern River are operated by public districts. The North Kern Water Storage District operates the Lerdo and Callo-way Canals. The Shafter-Wasco Irrigation District has executed a contract for Friant-Kern Canal water to supplement private pumping from wells. The Buena Vista Water Storage District stores and uses water reaching Buena Vista Lake from the Kern River. The Arvin-Edison Water Storage District is negotiating with the Federal Government and with other Kern River interests for an exchange of water involving importation through the Friant-Kern Canal. Isabella Reservoir on the Kern River is operated pri-marily for flood control purposes, and secondarily for conservation of irrigation water and to produce power.

Water problems of the South Valley Group include the urgent need for additional water supplies to meet present and ultimate supplemental water require-ments, a need for additional flood control, and a need for drainage and maintenance of water quality. Over-drafts exist at the present time in all units of the group. Such annual overdrafts, accumulating over many years, have so depleted many portions of the ground water basins that pumping lifts are nearly prohibitive economically. The excessive pumping lifts are reducing net profits and will continue to do so indefinitely, until costly imported water, supplied in quantities in excess of actual water requirements, has refilled the basins. In addition to works to provide supplemental water supplies, other new physical works are needed to prevent flooding of valley lands.

Both surface and ground water supplies of lands in the eastern portion of the South Valley Group are generally of excellent quality. Water from the west side streams, although the combined flow is small and generally percolates into the alluvial cones, contains relatively high amounts of dissolved minerals, including in some cases significant concentrations of boron. West side ground waters are characterized by a high percentage of sulphate and an abnormal amount of boron, often in toxic concentrations. The usable zone of pumping along the west side is generally found between overlying unusable perched water and underlying brines. Improperly constructed and abandoned wells allow the intermingling of these waters, with consequent degradation of the usable aquifers.

Under The California Water Plan the water to meet requirements of lands in the South Valley Group would be obtained from streams of the Tulare-Sierra Group, by imports in several existing and new major conduits, and from ground water. Runoff of streams of the Coast Range, which is small in amount, would continue to be available to contribute to ground water supplies at the foothill line, as at the present time. Runoff of streams of the Tulare-Sierra Group which would be available for use would consist of the combined yield of foothill reservoirs and underground reservoirs operated, as at the present time, in such a manner as to make virtually all of the mean seasonal natural runoff available for use. Foothill reservoirs on streams tributary to this group, which have been described in connection with developments in the Tulare-Sierra Group, would furnish water in the amount of about 1,140,000 acre-feet each year on a firm yield basis.

Works of The California Water Plan in the South Valley Group would have four principal purposes: first, to convey and distribute water supplies from tributary streams for use on lands in the group; second, to distribute water imported through facilities of the California Aqueduct System, for use on lands in the the group; third, to collect and convey drainage and waste waters in sufficient quantities so as to improve water quality and to maintain favorable salt balance conditions; and fourth, to control floods. To accomplish the first two purposes it would be necessary to develop the underground reservoir further by increased utilization of ground water.

As mentioned previously, water in very large amounts must be imported to the San Joaquin-Tulare Lake Basin. A considerable portion of this water would have to be supplied to lands on the east side of the trough of the Tulare Lake Basin. In order to minimize the pumping of water from aqueducts along the west side of the valley to serve such lands, it was assumed that water supplies of the Kings, Kaweah, Tule, and Kern Rivers, and minor east side streams, and those imported and conveyed in the Friant-Kern Canal, would be served at as high an elevation as possible along the eastern edge of their respective service areas. Canals flowing north and south along the foothill line from Terminus and Success Reservoirs would facilitate such distribution. Remaining lands of the South Valley Group could then be served other imported water supplies which would be pumped from the Sacramento-San Joaquin Delta, conveyed along the west side of the valley, and then diverted or pumped to service areas in the west, central, and east portions of the group as required.

Under The California Water Plan, water from tributary streams would be conveyed and distributed in existing and extended local canal and ditch systems and in the proposed Arvin-Edison Canal, which would divert from the Kern River. Works which would convey and distribute imported water supplies in the annual amount of about 7,200,000 acre-feet to lands of the South Valley Group include: the existing Friant-Kern Canal, which will deliver about 1,200,000 acre-feet of water each year from the San Joaquin River; the authorized Feather River Project Aqueduct, which will convey about 2,200,000 acre-feet of water pumped from the Sacramento-San Joaquin Delta, and which is described subsequently in connection with the San Joaquin Division of the California Aqueduct System; the San Joaquin-Tulare Basin Canal System, which would convey about 3,800,000 acre-feet and which would divert from the San Luis Forebay and extend southerly to Sand Ridge Reservoir at about the Kings-Kern county line, with a main pump lateral extending easterly along the north bank of the Kings River to the Fresno South Canal; the Fresno South Canal, which would extend from the Kings River south to Elk Bayou in the vicinity of Tulare; and the North Kings Canal which would divert from the San Joaquin-Tulare Basin Canal and would flow northward to the San Joaquin River. Imported water could be diverted or pumped from the foregoing conduits to serve lands in all portions of the South Valley Group. In this manner, water requirements in the group would be met by water from tributary streams and by water pumped from the Sacramento-San Joaquin Delta.

In order to reduce the pumping of a portion of the water supply imported to the South Valley Group, further consideration should be given to a plan which would include a high-line canal extending south from the Stanislaus River along the east side of the valley to Elk Bayou near Tulare. A portion of the water from the Stanislaus, Tuolumne, and Merced Rivers would be diverted into the high-line canal for conveyance to and use in the South Valley Group, in exchange for water from Mendota Pool, which would be conveyed in a canal extending northward from

Mendota Pool to the vicinity of Farmington. It would be necessary to negotiate an exchange agreement with the holders of vested rights to the use of waters of these rivers.

Agricultural, municipal, and industrial waste waters, other waters of degraded or impaired quality, and drainage waters would be collected, often in lined or closed conduits, and discharged into the previously described San Joaquin Waste Conduit, a main drainage canal, which would extend along the trough of the valley from the vicinity of Buena Vista Lake to saline water channels in the Delta, and which was described in connection with works in the North Valley Group.

The foregoing major conduits would convey and distribute local water supplies, together with large quantities of imported water supplies, to lands within the South Valley Group. Full utilization of such water supplies would require the conjunctive and coordinated operation of surface reservoirs, surface conveyance systems, and underground storage. Under such operation, surface reservoirs and conveyance systems would furnish water during the irrigation season to a portion of the irrigable lands in the group, and to stream channels and other percolating areas during the remainder of the year. The water not consumed would percolate to the underground reservoir and would be available to be pumped to serve the remaining irrigable lands.

Present estimates indicate that the gross storage capacity of the underground reservoir of the South Valley Group is about 65,000,000 acre-feet between the limits of 10 and 200 feet below the ground surface. Operation studies indicate that adequate water conservation could be obtained by use of a maximum of about 15,000,000 acre-feet, or 23 percent of such capacity. The total installed ground water pumping capacity necessary for such operation is estimated at 17,000 second-feet.

Flood waters of the Kings, Kaweah, Tule, and Kern Rivers would be impounded in Pine Flat, Terminus, Success, and Isabella Reservoirs, respectively, as discussed in connection with developments on those streams. During flood periods, all surface diversion and conveyance systems would operate to intercept and distribute waters released from the reservoirs for ground water recharge. The portion of rare flood flows, particularly snowmelt floods, which could not be thus controlled would, in the case of the Kings River, be discharged through Fresno Slough. No such outlet channel exists, however, for the discharge of unusual floods of the Kaweah, Tule, and Kern Rivers. Therefore, excess flood waters of these streams would be discharged into Sand Ridge Reservoir and would be impounded south of the natural sand ridge between Tulare and Buena Vista Lakes. The capacity of that reservoir would be about 1,400,000 acre-feet. It is considered that the works discussed herein would provide adequate flood control on these streams. An alternative method of disposing of such flood waters would involve the installation of pumping plants which could pump the flood waters into conduits of the California Aqueduct System.

Other streams of the South Valley Group which produce floods are Deer Creek, White River, and Pozo Creek north of the Kern River, and Caliente Creek, Tejon Creek, and other minor streams south of the Kern River. Under The California Water Plan, the plan for flood control on Deer Creek, White River, and Pozo Creek would include construction of a relatively small reservoir on each stream, minor channel improvements along the upper reaches of the streams, and leveed flood channels along the lower reaches which would convey the flood waters to Sand Ridge Reservoir. During floods, water would be released from the reservoirs at rates at which the water would percolate in the stream channels. Releases and spills in excess of these amounts would be conveyed to Sand Ridge Reservoir. In somewhat the same manner, small reservoirs on Caliente and Tejon Creeks and other minor streams of this group would be operated to release water at rates within the percolation capacity of the natural and artificial channels, for ground water recharge.

Summary of San Joaquin-Tulare Lake Basin. The San Joaquin-Tulare Lake Basin is California's principal area of present and ultimate water deficiency. Under The California Water Plan the ultimate requirements for water in the basin would be met by full development of local water resources, supplemented by substantial quantities of imported water. The California Water Plan contemplates the eventual import of 8,550,000 acre-feet of water per season, on the average, to the basin. Water in this amount would be conveyed and regulated by works of the San Joaquin Division of the California Aqueduct System, including San Luis Reservoir.

The California Water Plan also contemplates the eventual addition of about 8,400,000 acre-feet of storage capacity to the present basin reservoir system. This capacity would be contained in 76 strategically disposed storage, diversion, and regulatory reservoirs which would provide additional regulation and some additional conservation of local water supplies. Local water supplies already are substantially developed, but almost exclusively for use on the valley floor lands. The new reservoirs and related works would make available a portion of the local supplies for use in the foothill and mountain watersheds. They would also produce large amounts of hydroelectric energy, preserve and enhance fish, wildlife, and recreation resources, and, together with existing reservoirs, would provide a total of about 3,700,000 acre-

Exchequer Dam on Merced River

Diversion Dam and Irrigation Canal Headgates on Kings River

…t of storage space specifically reserved to protect …lley lands from floods.

In addition to construction of the local reservoirs …d import conduits of the California Aqueduct Sys…m, The California Water Plan also contemplates an …creased and coordinated use of the underlying …ound water basin. It would not be possible by use … surface reservoirs alone to regulate adequately the …al and imported water supplies so that water needs …uld be met as they occur over long-time climatic …cles. However, there is every indication, based upon …nservative assumptions, that the necessary regula…n of local and imported water supplies could be …ained by conjunctive operation of surface and …ound water reservoirs.

Collectively, the present and future local reservoirs, … import conduits of the California Aqueduct Sys…n, and the ground water basin would provide water … the amount of 16,305,000 acre-feet each season to … San Joaquin-Tulare Lake Basin. In addition, 812,-…0 acre-feet would be exported each season to the …n Francisco Bay Area. The new local reservoirs …uld have a combined yield of about 4,600,000 acre-…t per year. Their cost would be in the order of …00,000,000.

There would be about 32 new and enlarged hydro-…ctric power plants associated with the new reser-…rs. These plants would have a combined installed …wer capacity of about 1,100,000 kilowatts and …uld generate an average of about 4.7 billion kilo-…tt-hours per year. Their cost would be in the order … $120,000,000.

Other local works in the San Joaquin-Tulare Lake …sin would consist of new and enlarged main con-…ance and service canals for irrigation; wells for …igation and urban purposes in some areas; addi-…nal levees, floodway channels, and retention reser-…rs; distribution and drainage systems; and a main …inage conduit extending northward from Buena …ta Lake to discharge into the lower Sacramento-…n Joaquin Delta. The cost of this conduit and the …in water supply conduits and pumping plants on … valley floor and in the foothill and mountain areas … the basin would be in the order of $300,000,000. … estimates of cost were made for the various drain-… and distribution systems and other local works …t would be required for complete service and de-…opment of the land and water resources of the …in.

The total cost of all the described local development …rks of The California Water Plan in the San Joa-…n-Tulare Lake Basin would be about $920,000,000.

The general features and costs of the local develop-…nt works of The California Plan in the San Joa-…n-Tulare Lake Basin are presented in Table 14. …ilar information for the import facilities pertinent … the basin are presented later in this chapter in …bles 23 through 26, under the Delta and San Joaquin Divisions of the California Aqueduct System. The locations and layouts of all of the facilities described in the foregoing sections are delineated on Sheets 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, and 21 of Plate 5.

Lahontan Area

The Lahontan Area comprises the easterly slope of the Sierra Nevada, and reaches from the Oregon border on the north to and including the Mojave River drainage basin and Antelope Valley on the south. The area extends over approximately 33,000 square miles, of which about 10,000 square miles are classified as valley and mesa lands, most of which are considered irrigable. The area, as a whole, is one of gross water deficiency insofar as potential development is concerned, although a few of the included stream basins have ample water supplies for their ultimate needs.

The majority of the water resources of the Lahontan Area have been extensively developed in the past. The Truckee, Carson, and Walker Rivers have, for many years, been developed for utilization in both California and Nevada. There are about 80 reservoirs presently located in the area, with an aggregate storage capacity of approximately 1,400,000 acre-feet. More than half of this storage is provided by Lake Tahoe. Reservoirs in the Truckee River Basin, and Topaz and Bridgeport Reservoirs on the Walker River, are used principally to conserve and regulate irrigation water supplies for lands in Nevada.

About 11,000 acre-feet of water per season is imported into the Lahontan Area from the Pit River Basin. For many years, about 7,000 acre-feet of water from the Little Truckee River and 2,000 acre-feet of water from the Echo Lake Basin have been exported to the Central Valley Area. The major export of water from the Lahontan Area is made by the City of Los Angeles, which diverts about 320,000 acre-feet per season from Mono Lake Basin and Owens Valley for municipal use in the Los Angeles metropolitan area.

Because of the inland position of the Lahontan Area, and the high elevation of much of the valley and mesa lands, precipitation generally occurs in the form of snow, which delays the bulk of the resultant runoff to the late spring and early summer months. However, in spite of this natural regulation, deficiencies in water supply for the support of the local economy are felt in many areas during the late summer period. In the desert areas comprising the southern portion of the Lahontan Area, precipitation is generally light, although localized areas have often suffered damaging floods from cloudbursts of extreme intensity.

The estimated mean seasonal natural runoff of streams in the Lahontan Area is about 3,180,000 acre-feet, and, even if fully developed, would constitute

TABLE 14

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN JOAQUIN-TULARE LAKE BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet [a]	Purpose	Place of water use	Capital cost [b]
San Joaquin-Sierra Group											
Nashville	Cosumnes River	Sec. 14, T8N, R10E 8	CG	310	1,065	450,000	440,000	115,000	I,U,P,R, FC,F	San Joaquin Valley	$20,430,000
Michigan Bar	Cosumnes River	Sec. 36, T8N, R8E 8	E	105	285	84,000	81,000	56,000	I,U,R, FC,F	San Joaquin Valley	2,900,000
Deer Creek	Deer Creek	Sec. 11, T8N, R8E 8	CE	80	440	30,000	30,000	30,000	I,U,F	San Joaquin Valley	281,000
Irish Hill	Dry Creek	Sec. 1, T6N, R9E 8	E	134	520	28,000	28,000	14,000	I,U,F	San Joaquin Valley	1,320,000
Capps Crossing	North Fork Cosumnes River	Sec. 11, T9N, R14E 8	R	155	5,205	19,000	19,000	13,000	I,U,R,F	Cosumnes River Basin	6,738,000
Middle End	North Fork Cosumnes River	Sec. 34, T10N, R13E 8	ER	180	3,350	7,000	7,000	6,000	I,U,R,F	Cosumnes River Basin	1,456,000
Bakers Ford	Middle Fork Cosumnes River	Sec. 19, T9N, R12E 8	R	110	1,750	16,000	16,000	8,000	I,U,R,F	Cosumnes River Basin	1,531,000
Bridgeport	South Fork Cosumnes River	Sec. 14, T8N, R11E 8	ER	130	2,090	36,000	36,000	12,000	I,U,R,F	Cosumnes River Basin	1,103,000
Pi Pi	Middle Fork Cosumnes River	Sec. 4, 9, T8N, R14E 8	ER	260	4,090	42,000	42,000	21,000	I,U,R,F	Cosumnes River Basin	4,608,000
Sopiago	Sopiago Creek	Sec. 10, T8N, R13E 8	R	170	3,680	12,000	12,000	7,000	I,U,R,F	Cosumnes River Basin	1,693,000
Case Valley	South Fork Cosumnes River	Sec. 33, T8N, R13E 8	E	190	3,040	16,000	16,000	14,000	I,U,R,F	Cosumnes River Basin	2,186,000
Volcano	Sutter Creek	Sec. 29, T7N, R12E 8	E	210	1,920	15,000	15,000	8,000	I,U,R,F	Cosumnes River Basin	3,229,000
Railroad Flat	South Fork Mokelumne River	Sec. 23, T6N, R13E 8	E	339	2,460	80,000	80,000	41,000	I,U,R,F	San Francisco Bay Area	13,656,000
Middle Bar	Mokelumne River	Sec. 16, T5N, R11E 8	CG	190	690	46,000	30,000	275,000	I,P,U,R, F	San Francisco Bay Area	4,876,000
Camanche	Mokelumne River	Sec. 6, T4N, R9E 8	E	140	202	285,000	244,000	74,000	I,U,R,F	San Joaquin Valley	13,850,000
New Hogan	Calaveras River	Sec. 31, T4N, R11E 8	E	201	711	325,000	310,000	95,000	I,U,R, FC,F	San Joaquin Valley	9,768,000
Middle Fork	Middle Fork Mokelumne River	Sec. 9, T6N, R14E 8	E	200	3,130	10,000	10,000	7,000	I,U,R,F	Mokelumne and Calaveras River Basins	1,882,000
Forest Creek	Forest Creek	Sec. 34, T7N, R14E 8	ER	148	3,388	5,000	5,000	4,000	I,U,R,F	Mokelumne and Calaveras River Basins	2,304,000
Jesus Maria	Jesus Maria Creek	Sec. 23, T5N, R13E 8	CE	130	2,315	8,000	8,000	17,000	I,U,R,F	Mokelumne and Calaveras River Basins	1,165,000
Jesus Maria Forebay		Sec. 13, T5N, R14E 8	CG		4,500				P	Supplies Jesus Maria Power House	40,000
Jesus Maria Afterbay	Jesus Maria Creek	Sec. 11, T5N, R14E 8	CG		3,300				S	Supplies Jesus Maria Reservoir	30,000
Mokelumne Hill Feeder Canal Diversion	North Fork Calaveras River	Sec. 5, T5N, R13E 8	CO	5					D	Mokelumne and Calaveras River Basins	10,000
San Domingo	San Domingo Creek	Sec. 36, T4N, R13E 8	ER	245	1,940	25,000	25,000	52,000	I,U,R,F	Mokelumne and Calaveras River Basins	3,225,000
McCarty	North Fork Calaveras River	Sec. 35, T6N, R13E 8	E	130	2,817	15,000	15,000	15,000	I,U,R,F	Mokelumne and Calaveras River Basins	1,254,000
Black Creek Diversion	Black Creek	Sec. 22, T2N, R12E 8	CO	8					D	Mokelumne and Calaveras River Basins	12,000
New Melones	Stanislaus River	Sec. 11, T1N, R13E 11	CG	447	962	1,100,000	974,000	510,000	I,U,P,R, FC, F	San Joaquin Valley	39,185,000
Kennedy Meadows	Middle Fork Stanislaus River	Sec. 2, T5N, R20E 9	R	121	6,408	10,000	10,000		I,U,R,F	San Joaquin Valley (Partial regulation of inflow to Donnell's Reservoir)	2,379,000
Spring Gap Afterbay	Middle Fork Stanislaus River	Sec. 21, T4N, R17E 9	CG	120	3,005	2,000	2,000		S, F	Supplies Sand Bar Tunnel	500,000
Sand Bar Afterbay	Middle Fork Stanislaus River	Sec. 19, T4N, R17E 9	CG	120	2,750	2,000	2,000		S, F	Supplies Stanislaus Power House	800,000
Stanislaus Afterbay	Stanislaus River	Sec. 7, T3N, R15E	CG	60	1,100	3,000	3,000		S, F	Supplies New Melones Reservoir	150,000
Griswold	Griswold Creek	Sec. 33, T5N, R16E 9	R	180	4,480	10,000	10,000	17,000	I,U,R,P, F	San Joaquin Valley	3,500,000

TABLE 14—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN JOAQUIN-TULARE LAKE BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet[a]	Purpose	Place of water use	Capital cost[b]
San Joaquin-Sierra Group —Continued											
Griswold Creek Diversion	Griswold Creek	Sec. 5, T4N, R16E 9	CO	10	4,100				D	Supplies Griswold Canal	$10,000
Soap Creek Diversion	Soap Creek	Sec. 18, T4N, R16E 9	CO	10	4,055				D	Supplies Griswold Canal	10,000
Griswold Forebay		Sec. 24, T4N, R15E 8	CE	50	4,055				P	Supplies Griswold Power House	100,000
Griswold Afterbay	Middle Fork Stanislaus River	Sec. 25, T4N, R15E 8	CG	40	1,600				S	Supplies New Melones Reservoir	50,000
Big Dam	South Fork Stanislaus River River	Sec. 9, T4N, R19E 9	R	120	7,425	16,000	16,000		I,U,R,F	Stanislaus River Basin (Partial regulation of inflow to Strawberry Reservoir)	2,505,000
Spicer Meadow	Highland Creek	Sec. 3. T6N, R18E 9	R	130	6,500	38,000	38,000	55,000	I,U,R,F	Mokelumne, Calaveras and Stanislaus River Basins	3,326,000
Ganns	North Fork Stanislaus River	Sec. 3, T6N, R17E 9	R	270	5,720	21,000	20,000	94,000	I,U,R,P, F	Mokelumne, Calaveras and Stanislaus River Basins	9,665,000
Ramsey	North Fork Stanislaus River	Sec. 23, T6N, R16E 9	R	205	4,740	32,000	31,000	120,000	I,U,P,R, F	Mokelumne, Calaveras and Stanislaus River Basins	9,231,000
Moran Creek Forebay		Sec. 22, T5N, R15E 8	CE	40	4,526				P	Supplies Moran Creek Power House	115,000
Lyons	South Fork Stanislaus River	Sec. 24, T3N, R16E 9	R	270	4,340	63,000	62,000	75,000	I,U,R,F,	Stanislaus River Basin	7,298,000
Hetch Hetchy Forebay	Middle Fork Tuolumne River	Sec. 14, T1S, R18E 11	CE		3,450	2,000	2,000		P,F	Supplies Early Intake Power House	1,000,000
Cherry Creek Forebay		Sec. 25, T1N, R18E 11	CE		4,400	2,000	2,000		P,F	Supplies Cherry Creek Power House	500,000
Cherry Creek Afterbay	Cherry Creek	Sec. 36, T1N, R18E 11	CG		2,400	2,000	2,000		S,F	San Francisco Bay Area	500,000
Phoenix	Sullivan Creek	Sec. 28, T2N, R15E 8	E	110	2,434	25,000	25,000	62,000	I,U,R,F	Stanislaus and Tuolumne River Basins	2,020,000
New Don Pedro	Tuolumne River	Sec. 35, T2S, R14E 11	CG	515	830	1,952,000	1,610,000	675,000	I,U,P,R, FC,F	San Joaquin Valley	82,315,000
Lily Lake	Lily Creek	Sec. 4, T3N, R19E 9	R	115	7,015	9,000	9,000	9,500	I,U,R,F	Tuolumne River Basin	2,156,000
Belle Meadows	Clavey River	Sec. 36, T4N, R18E 9	R	150	6,410	10,000	10,000	20,000	I,U,R,F	Tuolumne River Basin	3,104,000
Lords	Rush Creek	Sec. 2, T2N, R17E 9	R	130	5,455	10,000	10,000	31,000	I,U,R,F	Tuolumne River Basin	1,500,000
Browns Meadow	North Fork Tuolumne River	Sec. 22, T3N, R17E 9	R	135	4,790	14,000	14,000	46,000	I,U,R,F	Tuolumne River Basin	3,303,000
Hardin Flat	South Fork Tuolumne River	Sec. 35, T1S, R18E 11	ER	215	3,660	40,000	40,000	44,000	I,U,R,F	Tuolumne and Merced River Basins	2,290,000
Burch Meadows	Big Creek	Sec. 32, 33, T1S, R17E 11	ER	140	3,110	25,000	25,000	13,600	I,U,R,F	Tuolumne River Basin	2,691,000
Virginia Point	Merced River	Sec. 26, T3S, R16E 11	CE	540	1,255	1,000,000	755,000	464,000	I,U,P,R, FC, F	San Joaquin Valley	50,150,000
Coulterville	Maxwell Creek	Sec. 34, T2S, R16E 11	CE	200	1,990	22,000	22,000	14,000	I,U,R,F	Merced River Basin	1,436,000
Butterfly	Browns Creek	Sec. 7, T4S, R15E 11	ER	105	520	10,000	10,000	8,000	I,U,R,F	Merced River Basin	828,000
Hayward	Hayward Creek	Sec. 24, T3S, R14E 11	E	75	870	5,000	5,000	4,000	I,U,R,F	Merced River Basin	467,000
Wawona Diversion	South Fork Merced River	Sec. 13, T4S, R20E 11	CO	30	3,665				D	Merced, Chowchilla and Fresno River Basins	287,000
Aqua Fria	Mariposa Creek	Sec. 15, T6S, R18E 11	R	130	1,430	15,000	15,000	13,000	I,U,R,F	Merced River Basin	1,687,000
Upper Bear Creek	Bear Creek	Sec. 10, T5S, R17E 11	ER	240	1,850	50,000	48,000	45,000	I,U,R,F	Merced River Basin	3,416,000
Buchanan	Chowchilla River	Sec. 22, T8S, R18E 11	CE	167	557	94,000	92,000	23,000	I,U,R,FC, F	San Joaquin Valley	4,166,000
Darrah	Tributary of Snow Creek	Sec. 1, T5S, R19E and Sec. 6, T5S, R20E 11	CE	130	3,450	5,500	5,100	5,100	I,U,R,F	Chowchilla and Fresno River Basins	1,114,000
Magoon	Magoon Creek	Sec. 18, T5S, R20E 11	CE	90	3,180	5,500	5,100	4,500	I,U,R,F	Chowchilla and Fresno River Basins	567,000
Pegleg	Pegleg Creek	Sec. 21, T5S, R19E 11	CE	60	2,420	6,000	5,900	3,500	I,U,R,F	Chowchilla and Fresno River Basins	494,000
Windy Gap	Fresno River	Sec. 2, T7S, R20E 11	CE	180	2,045	32,000	30,000	13,000	I,U,R,F	Chowchilla and Fresno River Basins	2,122,000

TABLE 14—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN JOAQUIN-TULARE LAKE BASIN

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet [a]	Purpose	Place of water use	Capital cost [b]
San Joaquin-Sierra Group —Continued											
Hidden	Fresno River	Sec. 34, T9S, R19E 11	CE	139	524	75,000	74,000	11,000	I,U,R,FC, F	San Joaquin Valley	$11,229,000
Humbug	Humbug Creek	Sec. 9, T6S, R21E 11	CE	120	1,850	10,000	10,000	10,000	I,U,R,F	Chowchilla and Fresno River Basins	846,000
Miami	Miami Creek	Sec. 14, 15, T6S, R21E 11	CE	120	3,710	5,000	4,500	3,000	I,U,R,F	Chowchilla and Fresno River Basins	713,000
Lewis	Lewis Creek	Sec. 36, T6S, R21E 11	CE	125	3,075	15,000	14,500	7,000	I,U,R,F	Chowchilla and Fresno River Basins	1,873,000
Nelder Creek	Nelder Creek	Sec. 36, T6S, R21E 11	CE	160	3,100	15,000	14,000	7,000	I,U,R,F	Chowchilla and Fresno River Basins	1,728,000
Miller Bridge	Middle Fork San Joaquin River	Sec. 11, T5S, R25E 12	CG	200	4,790	25,000	25,000	140,000	I,U,R,F	San Joaquin River Basin	5,808,000
Forks	San Joaquin River	Sec. 4, T6S, R25E 11	R	300	3,950	35,000	35,000	204,000	I,P,R,F	San Joaquin Valley	10,039,000
Mammoth Pool	San Joaquin River	Sec. 14, T7S, R24E 11	R	325	3,330	123,000	123,000	360,000	I,P,R,F	San Joaquin Valley	15,629,000
Chiquito	Chiquito Creek	Sec. 17, T6S, R24E 11	R	200	4,980	75,000	75,000	72,000	I,P,R,F	San Joaquin Valley	6,004,000
Granite Creek Diversion	West Fork Granite Creek	Sec. 36, T4S, R24E 11	CO	9	7,200				D	Supplies Chiquito Reservoir	20,000
Jackass Creek Diversion	Jackass Creek	Sec. 26, T5S, R24E 11	CO	11	6,620				D	Supplies Chiquito Reservoir	20,000
Cedar Grove Diversion	South Fork Kings River	Sec. 10, T13S, R30E 14	CG	40	4,480	300	300		D,F	Supplies Cedar Grove Tunnel	650,000
Tehipite Diversion	Middle Fork Kings River	Sec. 14. T12S, R29E 14	CG	45	4,085	300	300		D,F	Supplies Tehipite Tunnel	870,000
Tulare-Sierra Group											
Junction	Kings River	Sec. 35, T12S, R28E 14	CA	240	2,370	14,000	14,000	270,000	I,P,R,F	Tulare Lake Basin	6,500,000
Dinkey Meadow	Dinkey Creek	Sec. 21, T10S, R26E 12	R	305	5,637	60,000	60,000	54,000	I,P,R,F	Tulare Lake Basin	10,800,000
Dinkey Meadow Afterbay	Dinkey Creek	Sec. 15, T11S, R26E 14	CG		3,600				S	Supplies Ross Tunnel	50,000
Ross Power House Afterbay	Dinkey Creek	Sec. 34, T10S, R26E 14	CG		1,750				S	Supplies Kings River Tunnel	50,000
Bear Creek Diversion	Bear Creek	Sec. 22, T10S, R26E 12	CO		5,660				D	Supplies Dinkey Meadow Reservoir	3,000
Terminus	Kaweah River	Sec. 25, T17S, R27E 14	E	208	690	145,000	145,000	115,000	I,U,P,R, FC,F	San Joaquin Valley	16,166,000
Success	Tule River	Sec. 35, T21S, R28E 14	E	120	645	75,000	75,000	24,000	I,U,R, FC,F	San Joaquin Valley	8,350,000
North Fork	North Fork Tule River	Sec. 23. T20S, R29E 14	CE	136	1,400	12,000	12,000	9,000	I,U,R,F	Tule River Basin	2,554,000
Middle Fork	Middle Fork Tule River	Sec. 6, T21S, R30E 14	CE	140	1,289	13,000	13,000	14,000	I,U,R,F	Tule River Basin	3,516,000
Rockhouse	South Fork Kern River	Sec. 34, T23S, R35E 17	R	150	5,640	72,000	72,000	36,000	I,P,R,F	Kern River Basin	4,500,000
Rockhouse Afterbay	South Fork Kern River	Sec. 22, T24S, R35E 17	CG	50	4,600	300			S	Supplies Onyx Tunnel	258,000
Onyx	South Fork Kern River	Sec. 24, T25S, R35E 17	E	150	2,990	25,000	25,000	41,000	I,P,R,F	Kern River Basin	4,660,000
Kelso	Kelso Creek	Sec. 20, T27S, R35E 17	CE	60	3,390	6,000	6,000	3,400	I,U,R,F	Kern River Basin	1,471,000
Canebrake	Canebrake Creek	Sec. 25, 26, T25S, R36E 17	CE	100	4,200	5,000	5,000	2,800	I,U,R,F	Kern River Basin	1,340,000
Lamont Meadow	Chimney Creek	Sec. 25, T24S, R36E 17	R	200	5,485	5,000	5,000	2,800	I,U,R,F	Kern River Basin	3,091,000
South Valley Group											
Sand Ridge		T. 24, 25, 26S, R20 21, and 22E 17	E	40	235	1,400,000	1,400,000		FC,F		15,500,000
White River-Deer-Pozo Creek Project	White River, Deer Creek, and Pozo Creek	17	--			36,000	36,000		FC,F		5,200,000
Caliente-Tejon Creek Stream Group Project		17	--			10,000	10,000		FC,F		20,940,000
						8,443,900	7,632,700				$ 506,772,000

TABLE 14—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN JOAQUIN-TULARE LAKE BASIN

(These works show future development possibilities. They are not project proposals.)

Power plants	General location and sheet of Plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Annual energy production, in kilowatt-hours	Capital cost [b, c]
San Joaquin-Sierra Group						
Nashville	Cosumnes River	8	465	15,000	62,000,000	$1,724,000
Middle Bar	Mokelumne River	8	97	10,000	50,000,000	1,810,000
Jesus Maria	Jesus Maria Creek	8	1,200	10,000	56,000,000	1,170,000
New Melones [d]	Stanislaus River	11	389	34,000	135,000,000	2,840,000
Sand Bar	Middle Fork Stanislaus River	9	180	10,000	44,000,000	1,715,000
Stanislaus [d]	Stanislaus River	8	1,490	35,000	34,000,000	4,225,000
Griswold	Middle Fork Stanislaus River	8	2,400	10,000	47,000,000	1,418,000
Ganns	North Fork Stanislaus River	9	868	20,000	91,000,000	2,356,000
Moran Creek	Moran Creek	8	575	6,000	33,000,000	1,086,000
Murphys [d]	Angels Camp	8	685	6,000	13,000,000	1,039,000
Early Intake	Tuolumne River	11	1,060	75,000	429,000,000	9,550,000
Cherry Creek	Tuolumne River	11	2,000	100,000	530,000,000	10,174,000
Moccasin Creek [d]	Moccasin Creek	11	1,275	30,000	17,000,000	2,230,000
Phoenix [d]	Sullivan Creek	8	1,180	13,000	52,000,000	2,180,000
New Don Pedro [d]	Tuolumne River	11	425	73,000	192,000,000	7,762,000
Virginia Point	Merced River	11	442	50,000	232,000,000	4,260,000
Exchequer [d]	Merced River	11	252	4,000	32,000,000	582,000
Miller Bridge	San Joaquin River	11	850	30,000	140,000,000	2,908,000
Forks	San Joaquin River	11	520	35,000	149,000,000	3,425,000
Mammoth Pool	San Joaquin River	11	1,032	125,000	500,000,000	12,637,000
Chiquito	San Joaquin River	11	1,600	30,000	123,000,000	3,652,000
Tulare-Sierra Group						
Cedar Grove	Kings River	14	2,070	60,000	298,000,000	6,255,000
Tehipite	Kings River	14	1,670	50,000	245,000,000	4,440,000
Junction	Kings River	14	1,163	70,000	359,000,000	7,890,000
Dinkey Creek	Dinkey Creek	14	1,850	25,000	103,000,000	3,386,000
Ross	Dinkey Creek	14	1,790	25,000	123,000,000	3,560,000
Pine Flat	Kings River	14	315	60,000	304,000,000	5,693,000
Kings River [d]	Kings River	14	710	10,000	56,000,000	2,177,000
Rockhouse	South Fork Kern River	17	940	10,000	38,000,000	1,787,000
Onyx	South Fork Kern River	17	1,630	15,000	69,000,000	2,104,000
Borel [d]	Kern River	17	264	7,000	34,000,000	983,000
Kern No. 1 [d]	Kern River	17	877	5,000	68,000,000	699,000
Totals				1,058,000	4,657,000,000	$117,717,000

(Table 14 continued on following page)

only a portion of the estimated ultimate possible mean seasonal water requirements, aggregating about 5,740,000 acre-feet.

The objectives of The California Water Plan for the Lahontan Area cannot be fully met by local development works, as the available water resources are insufficient to provide for the needs of the area and much of the area is remote from areas of surplus in other parts of the State. Because of the difficulty and cost of providing imported water supplies, possible means of importation of sufficient water to the various areas within the Lahontan Area to meet the ultimate possible requirements have not been planned as they have been for other hydrographic areas. Rather, the direction of future development has been indicated, with further plans left for future investigation.

For planning purposes the Lahontan Area has been subdivided into four groups, designated the "Lassen Group," "Alpine Group," "Mono-Owens Group," and "Mojave Group," and their locations are shown on Plate 3. Physical features and costs of all suggested local works for the Lahontan Area are presented in Table 15, following the summary of works for the Lahontan Area.

Lassen Group. The Lassen Group comprises the Surprise Valley, Madeline Plains, and Honey Lake areas, with a combined area of about 3,800 square miles. The group is located in the extreme northeastern portion of the State, lying between the California-Nevada boundary and the crests of the Warner Mountains and the Sierra Nevada. Each of the foregoing areas in this group is essentially a closed and internally draining watershed. The Susan River, largest stream in the group, rises on the eastern slopes of the Sierra Nevada and flows eastward through Susanville, terminating in Honey Lake. Some of the streams draining the Warner Mountains into Surprise Valley provide excellent trout fishing in the mountain reaches.

Approximately 90,000 acres are presently (1950) irrigated in the Lassen Group, and about 2,500 acres are occupied by urban and suburban developments. The present (1950) mean seasonal water requirement is estimated to be about 268,000 acre-feet per

TABLE 14—Continued

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN SAN JOAQUIN-TULARE LAKE BASIN

(These works show future development possibilities. They are not project proposals.)

Conduit	Length of conduit, in miles				Capital cost [b]
	Canal	Pipe	Tunnel	Flume	
San Joaquin-Sierra Group					
Cosumnes River development	105	----	1.0	----	$6,082,000
Mokelumne-Calaveras River development	88	4	1.6	----	8,162,000
Stanislaus River development	37	----	6.6	----	10,683,000
Tuolumne River development	60	----	14.1	1.8	29,505,000
Merced River development	70	----	7.0	----	14,675,000
Chowchilla-Fresno River development	2	----	----	----	100,000
San Joaquin River development	----	----	23.3	----	32,672,000
Tulare-Sierra Group					
Kings River development	38	----	----	1.0	44,203,000
Kaweah River development	----	----	----	----	0
Tule River development	----	----	----	----	0
Kern River development	----	----	9.5	----	10,800,000
North Valley Group					
San Joaquin Waste Conduit	260	----	----	----	54,200,000
South Valley Group					
Arvin-Edison Canal	45	----	----	----	7,140,000
San Joaquin-Tulare Basin Canal	157	----	----	----	38,910,000
North Kings Canal	28	----	----	----	2,515,000
Fresno South Canal	25	----	----	----	4,450,000
Totals	915	4	63.1	2.8	$264,097,000

Pumping plant	Sheet of Plate 5 on which shown	Installed capacity, in kilowatts	Seasonal power consumption, in kilowatt-hours	Capital cost [b]
San Luis Forebay Pumps	11	90,000	260,000,000	$18,600,000
San Joaquin-Tulare Canal Pumps	14	30,000	80,000,000	9,400,000
Kettleman City Pumps	14	20,000	60,000,000	3,400,000
Totals	--	140,000	400,000,000	$31,400,000

Symbols of Type of Dam
- CG—Concrete gravity
- E—Earthfill
- CO—Concrete overpour
- CE—Composite earthfill
- R—Rockfill
- ER—Earth-rock
- CA—Concrete arch

Symbols of Purpose
- I—Irrigation
- U—Urban
- FC—Flood control
- P—Power generation
- R—Recreation
- F—Enhancement of fish environment
- OP—Regulation for use of off-peak power
- S—Reregulation of waters to local demand schedules
- D—Diversion

[a] Includes yield of upstream works, if any.
[b] At 1955 price levels.
[c] Cost of each plant includes associated works except reservoirs.
[d] Tabulated data pertain to enlargement of existing plant.

season, while the yield of the presently developed works, including wells and surface diversions, has been estimated to be only about 172,000 acre-feet.

The short, steep slopes of the easterly face of the Warner Mountains render impracticable the provision of major storage facilities for the conservation of runoff in Surprise Valley. Possible sources of future supplemental supplies for that area include an interbasin importation by tunnel through the Warner Mountains from Goose Lake and importation of water from Cowhead Lake in Oregon to the northeast of Surprise Valley, which are interstate problems; and increased utilization and development of the local ground water supplies. With the exception of the ground water development, however, provision of other water supplies for Surprise Valley would be extremely costly, and no definite development plans have been formulated.

Plans for the provision of supplemental water supplies in the Madeline Plains area have not been prepared. Due to the remoteness of the area, the elevation of the agricultural lands, and the short growing season, irrigable lands in this area have a limited adaptability to general agricultural development. The area is closely associated with the economy of western Nevada, and the lands are currently utilized for sum-

Lahontan Area—Donner Summit

Lahontan Area—Arid Lands in Mono County

mer forage for cattle. A possibility exists of importation of supplemental water supplies from the Pit River or from the area tributary to Eagle Lake, if justified.

Local development works in the Honey Lake area could provide for the conservation of available water supplies though a system of reservoirs and appurtenant facilities. These works would consist of Devils Corral Reservoir on Susan River; Long Valley Dam on Long Valley Creek; and the Pete's Valley-Eagle Lake development, comprising a dike confining the waters of Eagle Lake to the southerly part of the present lake bed, and a dam and reservoir on Willow Creek. All of the foregoing reservoirs would supply about 59,000 acre-feet of water annually for use in the Honey Lake area. However, only a portion of this water supply could be considered to be new water, as most of the flow of the Susan River and the many creeks in the area are presently utilized for the irrigation of crops. The principal benefits to be derived from these works would be the more advantageous regulation of the water supply in accordance with agricultural demands; the provision of adequate water supplies during recurrent periods of deficiency; and the development of additional water supplies, approximately equivalent to the amounts now wasted to Honey Lake, and a portion of that consumed in present evaporation from the surface of Eagle Lake.

It is reported that Eagle Lake is of great scientific interest, particularly to biologists. Varieties of prehistoric aquatic life are found in the waters of the lake and thus provide a definite link with the distant past. Improvements designed to increase the utility of the waters of the lake from a water supply standpoint should be so designed, constructed, and operated as to result in a minimum adverse effect on the existing fish and aquatic specimens. The growing economy of California and the demands of the people of the State for recreational developments will require the maximum utilization of all available facilities. The improvement would provide an excellent opportunity for additional developments of a recreational nature in the Susanville area.

It is probable that the future development of ground water resources in the Honey Lake area may provide an appreciable portion of the ultimate water requirements of the area. Some development of this source has taken place in the past, and ground water is now being utilized for domestic, industrial, and agricultural purposes.

Alpine Group. The Alpine Group, located in the central Sierra Nevada, comprises the California drainage of the Truckee, Carson, and Walker Rivers. Lake Tahoe with its surrounding drainage area, part of which lies in the State of Nevada, forms the headwaters of the Truckee River. This area, centered about Lake Tahoe, has developed into a recreation area and vacation land of major importance, and includes many outstanding and internationally known ski areas. Numerous back trails and some secondary roads provide access to the high mountain valleys.

The existing economy of most lands in the Carson and Walker River Basins is based on the livestock industry, supplemented by recreational activities. The irrigated lands are used both for the production of hay for winter feeding of livestock and for summer pasture for cattle, the majority of which are brought in from Nevada. Recreational opportunities are centered around the fishing, hunting, and scenic attractions of the high mountain areas.

Existing water development works in the Truckee River Basin principally benefit lands in the State of Nevada. About 7,000 acre-feet of water per season is diverted from the Little Truckee River to Sierra Valley in the upper Feather River watershed. Boca Reservoir on Little Truckee River and Independence and Donner Lakes have been developed to provide supplemental water for areas in Nevada. Lake Tahoe, with a storage capacity of 732,000 acre-feet in the 6.1-foot operating range permitted under a federal court decree, conserves and regulates the seasonal snowmelt in the upper basin areas. Releases from the lake, supplemented by water stored in Boca Reservoir and in Donner and Independence Lakes, are utilized for power production in five hydroelectric generating plants of the Sierra Pacific Power Company which are situated on the Truckee River between Floriston, California and Reno, Nevada. No major water developments have been constructed in the upper Carson River Basin. The minor developments which presently exist are privately constructed diversions, small reservoirs, and ditch systems, which utilize the available flows in the various streams. In the Walker River Basin, the principal existing development is for the benefit of lands in Nevada. Topaz Reservoir, an off-stream development on the West Walker River, and Bridgeport Reservoir on the East Walker River, have been constructed by the Walker River Irrigation District, a Nevada agency. These reservoirs store available winter runoff for use as irrigation water supplies during the following growing season.

As stated previously, the Truckee, Carson, and Walker Rivers have been developed for utilization in California to some extent, and in Nevada to a considerably greater extent. At the present time there is a shortage of water from these three stream systems to supply the lands in Nevada which have been developed thereunder. In addition, there is a large acreage of undeveloped land within the basins of these three rivers in both states which could use the water if it were available.

The States of California and Nevada, in 195[illegible] created similar interstate compact commissions to deal with the problems created by the needs in both stat[illegible] for the waters of these three interstate streams. These commissions were formed to cooperate in the formulation of an interstate compact relative to the distribution and use of the waters of Lake Tahoe and of the Truckee, Carson, and Walker Rivers. Meetings held to date between the two commissons have pointed up the fact that there are insufficient water resources in these three interstate watersheds to meet fully the ultimate water requirements of the areas in both California and Nevada.

It is anticipated that the compact negotiations will be governed in the first instance by the necessity for preserving the existing economy, including the use of water for domestic purposes, irrigation, power, recreation, and the preservation of fish and wildlife. The allocation under the compact between the two states of water available for future development would determine to what extent the ultimate water requirements of lands in California could be met from the local stream systems.

Major flood damage in the Alpine Group is experienced from time to time in the Lake Tahoe area. High-water stages on the lake cause destruction of beaches and boating facilities as well as damage to septic tank installations. Suggested solutions for alleviating this damage include reduction of the maximum operating limit of the water surface from its present elevation of 6,229.1 feet above sea level. On the other hand, extremely low water surface elevations are detrimental to the recreation values of the lake by making boat dock facilities unusable and exposing bottom areas not suitable for recreation. A solution to this problem could be achieved by changing the maximum and minimum operating limits of the lake level. However, any reduction in usable storage resulting from the change in operating limits would appear to require that equivalent storage be substituted elsewhere in the area to replace present storage in Lake Tahoe.

Flood damage to agricultural and urban development elsewhere in the Alpine Group is not expected to be of major importance. Minor channel improvements would probably provide adequate protection against all but extreme flood occurrences. Channel improvement on the Truckee River below Lake Tahoe has been authorized by Congress for construction by the Corps of Engineers, U. S. Army.

The Washoe Project was authorized by the Congress in 1956 for construction by the United States Bureau of Reclamation. Among the features of this project located in the Truckee River Basin is Stampede Reservoir on the Little Truckee River, with a capacity of 126,000 acre-feet. Water from this reservoir would be discharged through a tunnel and penstock to the 20,000-kilowatt Calvada Power Plant on the Truckee River. The discharge from this power plant would flow through the Truckee River channel and existing facilities to meet and supplement established rights in Nevada.

In addition to these previously described works, Congress also provided for a fish and wildlife benefit of $2,000,000, part of which is to be used to improve the Truckee River fishery. The works to be constructed for improvement of the fishery were not described in the authorizing act. However, the Bureau of Reclamation has proposed a reservoir on Prosser Creek in order to maintain minimum flows in the Truckee River below Lake Tahoe by means of an exchange of water with Lake Tahoe. The act further provides that Stampede Reservoir shall be constructed in such a manner that it can be raised at a later date to a capacity of 175,000 acre-feet, in conformity with The California Water Plan.

The Washoe Project Act also states:

> "The use of waters of the Little Truckee River solely for the generation of electric power by the Washoe project shall not impair or preclude the appropriation of such waters in the future for beneficial consumptive use within the Little Truckee River watershed in California to the same extent as such waters may be presently available for such appropriation in the State of California: *Provided,* That if and when an interstate compact covering the distribution and use of the waters of the Truckee and Carson Rivers is approved by the Legislatures of the States of California and Nevada and is consented to by Congress, the operation of the Washoe reclamation project shall be in conformance with such compact, and the foregoing restriction shall not apply."

In the Carson River Basin, Watasheamu Reservoir on the East Fork of the Carson River has been authorized for construction under the Washoe Project. Watasheamu Reservoir would be constructed to a capacity of 115,000 acre-feet, and would regulate flood flows now running to waste, together with water presently used by the Newlands Project which would be replaced by Washoe Project water from the Truckee River. Releases from Watasheamu Reservoir would pass through the 8,000-kilowatt Watasheamu Power Plant at the base of the dam. The water then would be reregulated at the 1,040 acre-foot Dressler Diversion Dam and afterbay. Water would be diverted to the proposed Carson Canal, serving new lands along its course through the Carson Valley. Water would also be delivered to the West Fork of the Carson River for distribution by existing canals diverting from that stream.

The Washoe Project Act provides that water users in Alpine County, California, shall have the first opportunity to purchase a water supply from the water made available by Watasheamu Reservoir before such water is available for the development of new lands in Nevada. This would probabaly also involve an exchange of such East Carson River water from Watasheamu Reservoir for West Carson River water now used in Nevada.

In addition to an adequate water supply for habitable (not alone irrigable) lands, the objectives of The California Water Plan in the Alpine Group include: (1) preservation and enhancement of the recreational value of Lake Tahoe and the surrounding areas; (2) preservation and enhancement of the fish and wildlife resources of the streams and surrounding areas; (3) preservation and enhancement of the recreational value of the entire group; and, (4) provision of the maximum assistance to the general economy of the entire group through utilization of the opportunities for the generation of hydroelectric power.

These objectives could be met by further development of the water resources in each of the three watersheds of the group. In general, the waters of each stream system would be utilized to meet supplemental water requirements in its own drainage area, taking full cognizance of the interstate character of present and future water development.

The Lake Tahoe-Union Mills development consists of a diversion from the north shore of Lake Tahoe, connected by tunnel and canal to the Union Mills Power Plant. The water supply developed by this project would be used for the production of about 36,000,000 kilowatt-hours of hydroelectric energy annually.

The Lake Tahoe-Farad development includes the Lake Tahoe-Union Mills development, as described above, and, additionally, would involve a diversion from Truckee River about 3.5 miles downstream from the City of Truckee, connecting with Boca Reservoir through canal and tunnel. A tunnel from Boca Reservoir would transfer the flow to a contemplated hydroelectric plant located near Farad on the Truckee River. Water diverted from the Truckee River below Union Mills and routed through Boca Reservoir would produce about 66,000,000 kilowatt-hours of hydroelectric energy annually.

Preliminary operation studies of this development indicate that in addition to the production of needed power for the Tahoe-Reno area, the problems engendered by high and low stages on Lake Tahoe would be greatly alleviated.

The Stampede-Calvada development would divert flows from Prosser Creek, a tributary of the Truckee River, into a canal terminating at Stampede Reservoir, which would then be enlarged to a total storage capacity of about 175,000 acre-feet. The average seasonal yield for all beneficial purposes would approximate 120,000 acre-feet, of which 20,000 acre-feet could be utilized in service areas in California. Seasonal release of 9,300 acre-feet would be made for maintenance of fish life in the Little Truckee River. The hydroelectric generating facilities of the Calvada Power Plant, under such a plan, would generate about 165,000,000 kilowatt-hours of electrical energy seasonally. Should the Prosser Creek works proposed by the United States Bureau of Reclamation be constructed, the Stampede-Calvada development would probably not be possible of accomplishment.

Hope Valley Reservoir on the West Carson River would provide a firm water supply to meet the irrigation requirements of the 8,000 acres lying in Diamond Valley and in the Fredricksburg area. The reservoir would furnish an estimated firm seasonal yield of 55,000 acre-feet of water. The major portion of this supply would be available for generation of hydroelectric energy at the Paynesville and Woodfords Power Plants and for subsequent application to domestic and agricultural purposes. In addition, releases from the reservoir of about 5,000 acre-feet per season would provide to some extent for the maintenance of fish and wildlife below the dam.

The remaining 5,300 acres of irrigable land in the Carson River Basin, located principally on the East Carson River, would experience a deficiency in supply in most seasons due to practical difficulties and costs of supplying irrigation water requirements to small and isolated tracts.

In California, the flow of the East Carson River would be principally devoted to recreational uses. However, the stream flow would be depleted to an extent of about 5,300 acre-feet annually to provide water on about 4,500 acres of irrigable land. Silver King Reservoir on East Carson River would provide an ample water supply to furnish the necessary flow for maintenance of fish life at all times, except in the driest years of record.

Developments contemplated on the West Walker River include reservoirs at Leavitt and Pickle Meadows, diversion of the Little Walker River into Pickle Meadows Reservoir, and Pickle Meadows and Antelope Valley Power Plants, of 5,000- and 25,000-kilowatt capacity, respectively.

Leavitt Meadows Dam, located at the lower end of Leavitt Meadows, would form a reservoir with a storage capacity of 20,000 acre-feet. Water released from Leavitt Meadows Reservoir would pass through the Pickle Meadows Power Plant prior to being discharged into Pickle Meadows Reservoir, located at the lower end of Pickle Meadows. Stored water from the latter reservoir would be released for production of hydroelectric energy at the Antelope Valley Power Plant, with subsequent use for irrigation in Antelope Valley in California and lower areas in Nevada.

Much of the flow of the Little Walker River above its junction with the West Walker River would be diverted into the 125,000 acre-foot capacity Pickle Meadows Reservoir for storage and use. Storage of available runoff would contribute to flood protection in Antelope Valley and in lower areas in Nevada. In addition to the hydroelectric power and irrigation benefits there would be incidental fishery benefits, consisting largely of protection of the channel and fish habitat from scouring flood flows.

No developments are contemplated above Bridgeport Valley on the East Walker River. However, a hydroelectric generating plant, utilizing the available head between Bridgeport Dam and the state line, of 8,200-kilowatt capacity, could develop 39,700,000 kilowatt-hours of electrical energy per year. Bridgeport Valley forms an excellent potential ground water unit. Bridgeport Reservoir, at the lower end of the valley, has caused high ground water elevations under the town of Bridgeport. Use of the ground water basin might tend to lower such existing water levels. Both the United States Bureau of Reclamation and the Walker River Irrigation District have investigated the possibility of raising Bridgeport Dam. A project of that nature should include works necessary to protect the town of Bridgeport from further damage by high ground water levels.

Mono-Owens Group. The Mono-Owens Group comprises the Mono Lake, Adobe Valley, and Owens River areas in the central part of the State, adjacent to the California-Nevada boundary. The westerly boundary of the group lies along the crest of the Sierra Nevada. The gross area of this group in California is about 4,112 square miles, of which about 984 square miles are valley and mesa lands. Mt. Whitney, the highest peak in the continental United States, rising 14.500 feet above sea level, is the outstanding topographic feature.

Mono Lake is a perennial lake with a surface area of about 88 square miles, at an elevation of 6,400 feet above sea level. The lake waters are highly saline and unsuitable for general use. Many small reservoirs and lakes in the upper reaches of Rush, Leevining, Parker, Walker, and Mill Creeks afford excellent opportunities for fishing and recreation. Grant Lake on Rush Creek, and Walker and Sardine Lakes on Walker Creek are owned by the City of Los Angeles and are operated to facilitate the exportation of water to Los Angeles. Several reservoirs in Mono Lake Basin, used primarily for hydroelectric power production, are owned and operated by the California Electric Power Company. The several small reservoirs in the basin have an aggregate storage capacity of about 90,000 acre-feet.

The Owens River rises in volcanic formations to the north of Owens Valley, flowing across the broad upland meadows of Long Valley. The river then drops steeply through the Owens River Gorge, arriving at the head of Owens Valley at an elevation of about 4,400 feet. The fall through the gorge has been utilized for the production of hydroelectric energy. From the mouth of the gorge, the river follows a meandering course through the valley, finally terminating in Owens Lake. Exportation of water to the City of Los Angeles has reduced the inflow to the lake, and a brine processing industry now conducts extensive operations on the lake bed.

The many lakes and small reservoirs in the Mono-Owens Group provide excellent and much-needed recreational opportunities. In addition to the existing facilities for fishing and camping, the organization and provisioning of groups formed for fishing and hunting is a major activity. Much of the present economy of the group is based upon these recreational aspects, factors which are expected to be of increasing importance to the area. Long Valley Reservoir, also known as Lake Crowley, is a very important recreational asset to the Mono-Owens Group.

Long Valley, Tinemaha, and Haiwee Reservoirs regulate the runoff of the Owens River and the imported waters from Mono Lake Basin. The City of Los Angeles purchased some 300,000 acres of lands in Owens-Mono Basin to obtain water rights for its project. The city now leases lands under agreements which contemplate applying water to varying acreages of these lands, depending upon the availability of water in excess of the carrying capacity of the Los Angeles Aqueduct, which now delivers 320,000 acre-feet per annum, approximately its full capacity.

No plans have been prepared for further local development in the Mono-Owens Group as the City of Los Angeles claims rights to the use of most of the waters of these basins. It is expected, however, that some agricultural development on the more favorable lands will occur in the future, utilizing water presently wasted by phreatophyte infestation. Importation of additional water would be extremely difficult and costly. Every effort must be made to preserve and enhance the fish and wildlife resources of the area and to expand the recreational opportunities.

Mojave Group. The Mojave Group comprises Death Valley, the Mojave River Basin, and Antelope Valley. The group is located in the southern part of the Lahontan Area and is bounded on the west and south by the crest of the Sierra Nevada and other drainage divides separating the Lahontan and Colorado Desert Areas. The group contains a total of about 22,700 square miles, of which 6,800 square miles are valley and mesa lands. Death Valley National Monument, an outstanding vacation land, is located in this group and is bordered on the west by the imposing Panamint Range.

The Mojave Group is unique because all drainage is internal, the streams terminating in dry lakes, or sinks, which are subject to inundation in the occasional periods of exceptionally high runoff. The principal streams in the group, all of which are comparatively minor, are the Mojave River, draining the northerly slopes of the San Bernardino Mountains, Big and Little Rock Creeks in Antelope Valley, and the Amargosa River, draining Death Valley.

Tremendous expansion has taken place in the desert areas during the past few years. Camp Irwin and the Naval Ordnance Test Station at Inyokern are located in the Mojave Group. The recent acceleration of activities of these and other military installations has caused a major influx of population into adjacent urban areas. Antelope Valley has experienced some agricultural expansion during the last decade, but the principal development has been due to expansion of industry with the accompanying commercial development to support the urban growth. In the Palmdale and Lancaster areas, the advent of military and related aircraft industrial installations has resulted in a great increase in population. Major industries in the Mojave Group are the manufacture of portland cement, the production of crops by irrigated agriculture, and the operation and maintenance of railroad plant and equipment. Commercial development has expanded rapidly, due to the growth of population and the increased tourist trade that is being experienced in this group.

Water quality problems are inextricably connected with the development of the native water resources of the Mojave Group and the provision of additional imported supplies. Poor-quality ground water is presently found in many of the individual ground water basins. The existence of borax mines is indicative of present and future problems associated with excessive boron content of otherwise usable water supplies. It is anticipated that other problems will develop as the expansion of economic activity occasions the further development of ground water resources.

Future development of available ground water storage capacity, involving the utilization of large quantities of imported water supplies, would require adequate control over the maintenance of salt balance. This is a serious and aggravated problem under conditions of internal drainage such as are found in the Mojave Group, where all drainage water remains in the immediate vicinity of the primary supply. Salt balance in the usable ground water reservoirs must be maintained by providing facilities to export, or transfer, from the underground basins as great a quantity of salts as is added in the processes of use and re-use.

Flood problems in this group are those principally connected with the Mojave River. Occasional floods on this stream have in the past caused extensive damage in the valley areas. In 1956 the Corps of Engineers, U. S. Army, investigated the problem of floods, and recommended construction of a flood control reservoir on the West Fork of the Mojave River.

In common with most other arid areas, the Mojave Group is subject to cloudbursts, which cause flash floods, during which a large volume of water is discharged down a normally dry stream bed. Floods of this type have caused considerable damage in localized areas, but are so erratic in time and place as usually to make infeasible the provision of adequate safeguards against the prospective flood damage.

The irrigated area in the Mojave Group amounted to about 99,000 acres in 1950. The water supplies required to support this agricultural development, together with necessary urban and suburban requirements, have been principally secured by development of available underground water supplies.

In Antelope Valley, the Little Rock Creek and Palmdale Irrigation Districts have developed available surface supplies originating in the San Bernardino Mountains. In addition to the development of surface supplies, ground water has been extensively developed to supply most of the 74,000 acres presently under irrigation in 1950. As a consequence, an annual overdraft of about 160,000 acre-feet existed at that time; the ground water resources were overdrawn prior to 1946, at least. As a result, ground water levels now (1957) average 176 feet below ground surface. It has been estimated that, under 1950 conditions, the water requirements for the then existing development in Antelope Valley amounted to about 226,000 acre-feet per season. It is estimated that the probable ultimate habitable water service area in Antelope Valley would total about 725,000 acres, of which about 610,000 acres would be irrigated, or approximately eight times the 1949-50 area of irrigated lands. The estimated probable ultimate mean seasonal water requirement is about 1,520,000 acre-feet, of which 1,490,000 acre-feet might be used for irrigated agriculture. Since the native water supply amounts to only about 66,000 acre-feet, it is apparent that, for all practical purposes, the water supplies necessary to support the potential economic development of this area would have to be imported through the facilities of the California Aqueduct System.

It is estimated that the yield available from native water supplies in the Mojave Group is about 200,000 acre-feet per season, including about 135,000 acre-feet from the Mojave River and 66,000 acre-feet from watersheds tributary to Antelope Valley. Although the Amargosa River, draining Death Valley, contributes an unknown amount to the water supply of the area, its effect, in relation to the magnitude of the estimated requirement, is believed to be small.

The objectives of The California Water Plan for the Mojave Group would be met by the importation of about 4,835,000 acre-feet of supplemental water supplies per season from areas of surplus in California through the facilities of the California Aqueduct System, and the transmission and distribution of such water supplies to local agencies throughout the area. It is contemplated that water would be supplied on a constant-flow basis, and that reregulation to the monthly demand schedule prevailing in the service areas would be accomplished by utilization of avail le ground water storage. The flow in excess of re-quirements during the winter months would be placed i underground storage, and, during periods when e demand for water would be greater than the de-ered flow, supplemental water supplies would be mped from the underground reservoirs and dis-ibuted through the existing system.

It is pointed out that the cost of importing water this area would be high because of the elevations d distances involved. This cost might well be be-nd the repayment capacity of irrigated agriculture der current economic conditions. On the other hand, is believed that urban communities, military activi-es, and industrial developments could bear these sts. The feasibility of providing adequate water sup-ies for the Mojave Group in the near future, at st, will be largely dependent upon the probable fu-re trend of economic development, whether it be incipally urban and industrial or agricultural. The partment of Water Resources is currently (1957) ving further and intensive study to the matter.

A unit of the California Aqueduct System would ter the Lahontan Area at the Antelope Afterbay. is described hereafter under the heading "Buena sta-Cedar Springs Aqueduct." It would traverse e area along the southerly edge of Antelope Valley d leave the area at Mojave Junction, from whence would proceed into the South Coastal Area. Diver-n of necessary water supplies for the Mojave Group uld be made as required at various points along the e of the California Aqueduct route.

Summary of Lahontan Area. Objectives of the lifornia Water Plan in the Lahontan Area would met by further development of local water re-urces, supplemented with imported water delivered rough facilities of the California Aqueduct System the southerly portion of the area. Deficiencies in de-loped water supplies to support the existing munic-al and agricultural development in the area have reased rapidly in the past few years, particularly the Mojave Group. The population in the Lahontan ea was about 126,000 in 1955, with much of the rease since 1950 occurring in the southerly portion the area.

Local water resources in the Lassen Group are in-fficient to provide for the water requirements of is group. Projects contemplated herein, while aug-nting the present development, would not suffice meet the probable ultimate requirements. However, ovision of imported water supplies to this area is t considered feasible of accomplishment due to its note geographical location and the difficulties at-ndant on exporting required water supplies from urces of the Central Valley.

In the Alpine Group the yield from local works uld accrue largely to the benefit of lands lying in e State of Nevada. Contemplated works could provide water supplies adequate to meet the estimated ultimate requirements in this group. However, the considerations involved in the distribution of waters of an interstate stream will probably govern the amount of water which could be made available for the ultimate development of the lands in the California portion of the stream system. Projects included in The California Water Plan, together with existing works in this area, would provide a high degree of conservation of surface water resources, developing a yield of about 310,000 acre-feet of water per season. This yield would be additional to the yield from Bridgeport Reservoir on the Walker River and the proposed Watasheamu Reservoir on the East Carson River. In contrast, the estimated probable water requirements of lands in California included in this group are about 144,000 acre-feet per season.

The possible yield from development of local water supplies in the Mojave Group is estimated to be about 200,000 acre-feet of water per season. Required supplemental water supplies in this group would be largely provided from imported water delivered through the facilities of the California Aqueduct System. This would be accomplished principally through the use of ground water storage in conjunction with supplemental water supplies amounting to 4,835,000 acre-feet per season, which would ultimately be imported into the group through the California Aqueduct System, if determined to be feasible, and be distributed by local water service agencies.

The future growth of California will necessitate a considerable increase in the development of recreational areas and facilities. Water development must provide specific features for the enhancement of the sport fishery and the wildlife of California. The recreational aspect of anticipated water development is of outstanding importance in the Lahontan Area, particularly in the Lassen, Alpine, and Mono-Owens Groups. This region of the State has many almost unparalleled advantages for recreational development. Much of the present economic development is based upon supplying the recreational needs of California's population, and it is expected that this activity will increase at a rapid rate in the future.

The general features and costs of the local development works contemplated as features of The California Water Plan in the Lahontan Area are presented in Table 15. The location and layouts of all these facilities are delineated on Sheets 4, 6, and 9 of Plate 5.

Colorado Desert Area

The Colorado Desert Area comprises all lands draining directly into the Colorado River, together with a number of centrally drained desert basins without outlet. The area includes a total of 19,400 square miles, of which about one-half consists of valley and mesa lands. The climate of the area is arid.

TABLE 15

SUMMARY OF WORKS TO MEET WATER REQUIREMENTS IN LAHONTAN AREA

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use	Capital cost[a]
Lassen Group											
Devils Corral	Susan River	Sec. 5, T29N, R11E 4	E	189	4,737	30,000	29,500	31,000	I	Honey Lake area	4,649,000
Long Valley	Long Valley Creek	Sec. 10, T23N, R17E 6	E	104	4,700	20,000	19,100	8,000	I	Long Valley	827,000
Pete's Valley	Willow Creek	Sec. 1, T30N, R13E 4	E	133	4,543	22,000	19,800	20,000	I,R	Willow Creek-Honey Lake area	1,404,000
Eagle Lake Dike	Eagle Lake	Sec. 16, 17, T32N, R11E 4	E,R	30	5,102	83,000	83,000				848,000
Alpine Group											
Stampede[b]	Little Truckee River	Sec. 20, 21, 29, T19N, R17E 6	E	207	5,932	175,000	174,000	120,000	I,P,F,R	Little Truckee-Prosser Creek area	6,375,000
Hope Valley	West Carson River	Sec. 25, T11N, R18E 9	E	176	7,166	100,000	95,000	55,000	I,P,F,R	Carson Valley-Diamond Valley	5,101,000
Silver King	East Carson River	Sec. 2, T8N, R21E	E	75	6,430	8,000	7,900	7,900	F,R	East Carson River area	465,000
Leavitt Meadows	West Walker River	Sec. 27, T6N, R22E 9	E	103	7,183	20,000	19,200	127,000	I,P,F,R	Antelope Valley	1,106,000
Pickle Meadows	West Walker River	Sec. 18, T6N, R23E 9	R	173	6,833	125,000	124,000		I,P,F,R	Antelope Valley	7,867,000
Mono-Owens Group	(no local works)										
Mojave Group	(no local works)										
Totals						583,000	571,500				$28,642,000

Power plants and conduits	Location, MDB&M, and sheet of Plate 5 on which shown	Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours	Length of conduit, in miles: Canal	Tunnel	Pipe	Total	Capital cost[a]
Lassen Group									
Diversion conduits					5.0	----	----	5.0	Included in cost of dams
Alpine Group									
Union Mills	Sec. 8, T17N, R17E 6	500	10,000	36,200,000	5.7	3.8	0.4	9.9	$5,960,000
New Farad	Sec. 12, T18N, R17E 6	425	14,000	66,400,000	2.9	4.4	----	7.3	7,640,000
Calvada[b]	Sec. 31, T19N, R18E 6	890	20,000	81,000,000	----	4.5	----	4.5	8,792,000
Woodfords	Sec. 1, T10N, R19E 9	1,100	10,300	47,200,000	----	4.1	----	4.1	4,932,000
Paynesville	Sec. 17, T11N, R20E 9	952	6,500	24,400,000	----	6.1	----	6.1	1,160,000
Pickle Meadows	Sec. 25, T6N, R22E 9	300	5,000	18,600,000	----		1.1	1.1	805,000
Antelope Valley	Sec. 28, T8N, R23E 9	1,184	25,000	116,600,000	----	8.9	1.0	9.9	14,279,000
Bridgeport	Sec. 31, T7N, R26E 9	500	8,200	39,800,000	8.5	----	0.3	8.8	2,073,000
Diversion conduits					14.7	0.3	----	15.0	731,000
Totals			99,000	430,200,000	36.8	32.1	2.8	71.7	$46,372,000

Symbols of Type of Dam
E—Earthfill
R—Rockfill

Symbols of Purpose
I—Irrigation
P—Power
F—Enhancement of fish environment
R—Recreation

[a] At 1955 price levels.
[b] Stampede-Calvada Project under construction by U. S. Bureau of Reclamation, with Stampede Reservoir storage capacity of 125,000 acre-feet.

·pified by short, mild winters and exceptionally hot, ry summers. In the higher mountain regions, par- cularly in the coastal ranges, precipitation frequently ·curs in the form of snow. A large portion of the ainfall in the valley areas originates from localized aunderstorms, resulting in extreme variability and aldistribution in precipitation. The rainfall on alley and mesa lands is generally so minor in amount aat it has little practical significance with respect to ae water resources of the area.

The economy of the Colorado Desert Area is based rincipally upon agricultural development in the Im- ·rial, Coachella, and Palo Verde Valleys, and in the uma Project, all of which have developed a stable gricultural economy dependent upon Colorado River ater. The mild winter climate and long growing asons have produced a great variety and abundance crops, and have permitted the expansion of spe- alty produce, such as off-season truck crops, citrus, ates, cotton, and table grapes. Much of the irrigable nd in this area is included within the service area agencies holding rights in and to the waters of the olorado River. The remaining lands, two-thirds of hich are located in the northerly portion of the area, uld be supplied with their ultimate water require- ents through major export projects from areas of rplus in northern California.

The Colorado Desert Area has taken its place in cent years as one of the nation's outstanding resort eas. Recreational resorts are located principally in ad adjacent to Palm Springs, Desert Hot Springs, ad Twentynine Palms. The development of dude nch resorts and other desert types of recreational cilities has attracted thousands of seasonal visitors. e principal resort season covers the winter months, ahough there is an appreciable year-round influx of turists and visitors to the area.

Population in the Colorado Desert Area, with the ception of urban and recreational areas in the achella Valley, as of 1950, had not kept pace with t large over-all growth which occurred in other aeas of the State. With exception of the resort com- mnities, urban developments are, for the most part, ajuncts to the agricultural activity, which did not cange greatly in the decade from 1940 to 1950. Pop- ution in the several resort areas, however, more than ubled in the decade preceding 1950, and has con- tued its rapid growth to the present time. It should b noted that population in Palm Springs and other silar areas is subject to wide seasonal variation.

The estimated mean seasonal natural runoff in the lorado Desert Area is about 221,000 acre-feet. This nager runoff, even if fully conserved, would supply oy a small fraction of the total seasonal water re- qrements. The principal streams are the White- wter River and San Felipe Creek, both of which din into the Salton Sea. The stream flow in this area is not ordinarily available for surface diversion, due to the extreme variability in time and amount of its occurrence.

Continued utilization of irrigable lands within the areas presently served from the Colorado River, and which are traversed by or accessible to main canals already constructed, must depend upon the continued availability of Colorado River water to the full extent of California's established rights. California is limited by the Boulder Canyon Project Act and the California Limitation Act to the annual consumptive use of 4,400,000 acre-feet of the waters apportioned to the Lower Colorado River Basin by Article III (a) of the Colorado River Compact, plus not more than one-half of any excess or surplus waters unapportioned by the compact. California considers its entitlement under these statutes to aggregate not less than 5,362,000 acre-feet per annum of beneficial consumptive use, as covered by contracts of California agencies with the Federal Government for the storage and delivery of water, confirming prior appropriations under the laws of California. Of this, districts in the Colorado Desert Area hold contracts aggregating 4,150,000 acre-feet per annum. This figure derives from a "Seven-Party Agreement" among the California users of Colorado River water, made in 1931.

The continued use of ground water is vital to the existing urban and agricultural development in portions of the Colorado Desert Area, although quantities of ground water available are small in comparison to the large surface diversions from the Colorado River. The primary sources of ground water in the area are seepage from the Colorado River into basins bordering the river, precipitation, and percolation of runoff from tributary drainage areas. Ground water use for agricultural purposes is centered principally in the Coachella, Borrego, and Lucerne Valleys. The safe annual yield of these developed ground water basins, however, is only about 78,000 acre-feet, indicating that development may not safely continue without an imported supplemental water supply.

Ground water quality varies greatly both in composition and concentration throughout the Colorado Desert Area, and often within the individual ground water basin. In general, ground water quality is suitable for all uses except in the Imperial Valley, Chuckawalla Valley, and the ground water basins bordering the Salton Sea on the east and west. However, localized areas of poor-quality water are encountered throughout the area.

If the Colorado River represented an unlimited source of supply, the entire Colorado Desert Area, because of geographical proximity, would look to that river for the satisfaction of its needs. The Colorado River is not an inexhaustible river, however, and California's entitlement to the use of its waters has been limited, since 1929, as has been previously stated.

Colorado Desert Area—Power From the Colorado River

These factors, together with the obvious difficulties and cost of importing water from other sources, will probably retard further agricultural development in the Colorado Desert Area.

The total potential water service area in the Colorado Desert Area, as shown in Table 16, aggregates about 1,856,000 acres of lands considered suitable for agricultural and urban development, with an estimated total ultimate seasonal water requirement of about 6,300,000 acre-feet. These totals include three separate components, as follows:

1. The districts served from the Colorado River, which consider that acreage aggregating about 1,065,000 acres within their service areas may ultimately be developed, and for which full development is dependent upon the sufficiency of the 4,150,000 acre-feet per annum to which these areas are entitled from the Colorado River;

2. An additional 566,000 acres, as shown on Sheets 3 through 26 of Plate 5, classified as water service areas by the Department of Water Resources under criteria adopted during the State-wide Water Resources Investigation, with a seasonal water requirement of 1,467,000 acre-feet; and

3. A further additional 224,000 acres, considered by the Colorado River Board of California as susceptible of development, based on planning reports and other material utilizing varying criteria with regard to land use, with an estimated seasonal water requirement of 65,000 acre-feet if Colorado River water were available, as explained later.

In addition to the water supply available from the Colorado River under California's entitlement, the objectives of The California Water Plan in the Colorado Desert Area ultimately could be met by utilization of ground water resources and by imports through facilities of the California Aqueduct System. However, the latter sources would be insufficient to provide fully for the needs of all lands considered susceptible of water service. Further development in the area will be conditioned principally upon the economic feasibility of these contemplated import works.

The ground water storage capacity of the Colorado Desert Area is vital to life and culture. Continued and expanded development of ground water resources is anticipated. There are large areas of irrigable land which, if developed, must depend at least in part on ground water. Ground water is known to occur in each of the 46 hydrologic units which have so far been identified. With the exception of a few basins along the Colorado River, supplied by underflow from that source, the primary source of ground water in all units is precipitation and percolation of runoff from tributary drainage areas. Precipitation throughout the desert area is scanty and irregular and ground water supplies are therefore generally limited. The California Water Plan envisions the utilization of existing ground water storage capacity for the regulation of imported supplemental water supplies.

For planning purposes, the Colorado Desert Area has been subdivided into four groups, designated as the "Whitewater Group," "San Felipe Group," "Colorado River Group," and "Desert Valley Group." The locations of these groups are shown on Plate 3. Physical features and costs of the works which could make water available to the Colorado Desert Area are presented later in Tables 27 and 28, which describe facilities of the Southern California Division of the California Aqueduct System.

Whitewater Group. The Whitewater Group consists of the Coachella Valley and the watersheds tributary thereto. It is located to the northwest of the Salton Sea, principally in Riverside County, and is bounded by the Santa Rosa, San Jacinto, and Little San Bernardino Mountains.

The principal stream in the Whitewater Group is the Whitewater River, with an estimated mean natural seasonal runoff of about 62,000 acre-feet. Seasonal runoff from Snow Creek and Palm Canyon Creek also contributes appreciable amounts to the water supply available in the group. The Coachella Valley constitutes a major ground water unit, and surface runoff from the mountains disappears rapidly after reaching the valley floor. It is estimated that the present safe yield of the ground water basin underlying the Coachella Valley is about 60,000 acre-feet per season.

The total area within the Whitewater Group is about 1,223,000 acres. About 32,000 acres of land were irrigated in 1950, principally by diversions from the Coachella Main Canal, which derives its supply from the Colorado River. The ultimate mean seasonal water requirement, exclusive of requirements of land served from the Colorado River, is estimated to be about 485,000 acre-feet.

Available information indicates that some surface soils in the lower Coachella Valley possess infiltration rates too low to maintain acceptable salt balance relationships in the soil profile. However, most of the saline soils can be, and are being, reclaimed through use of an imported water supply of low sodium percentage. This requires that the water table be kept some distance below the root zone. Drainage, either by means of deliberate pumping from wells in order to lower the ground water table, or by the use of intercepting drains, is a necessary part of any irrigation development program for this area. Additional pumping from wells located in the upper Coachella Valley may assist in lowering piezometric levels in the lower areas. It can be expected, however, that localized tem-

TABLE 16

LAND USE AND WATER REQUIREMENTS, COLORADO DESERT AREA

Hydrographic unit		Gross area, in acres	Ultimate water service areas, in acres				Ultimate mean seasonal water requirements, in acre-feet			
Area number on Plate 3	Name		California Water Plan [a]	Colorado River service area districts [b]	Miscellaneous [c]	Total	California Water Plan [a]	Colorado River service area districts [b]	Miscellaneous [c]	Total
	Whitewater Group									
2	Coachella Valley	1,223,000	50,100	129,800	53,000	232,900	235,500		249,000	
	San Felipe Group									
3	Salton Sea	1,919,000	87,300	17,400	0	104,700	226,900		0	
4	Imperial Valley	1,107,000	12,500	[d]785,000	0	797,500	63,900	[e]4,150,000	0	5,157,300
	Subtotals	3,026,000	99,800	802,400	0	902,200	290,800		0	
	Colorado River Group									
5	Colorado River	2,265,000	30,300	[d]133,200	40,000	203,500	99,700		132,300	
	Desert Valley Group									
1	Twentynine Palms	3,867,000	168,800	0	131,200	300,000	388,700	0	303,300	692,000
6	Lanfair Valley	2,035,000	217,000	0	0	217,000	449,100	0	0	449,100
	Subtotals	5,902,000	385,800	0	131,200	517,000	837,800	0	303,300	1,141,100
	Totals	12,416,000	566,000	1,065,400	224,200	1,855,600	1,463,800	[e]4,150,000	684,600	6,298,400

[a] Gross area of ultimate water service areas to be supplied by The California Water Plan, and ultimate mean seasonal water requirements for those areas, as determined by Department of Water Resources.
[b] Ultimate water service areas in Colorado River service area districts and ultimate mean seasonal water requirements for those areas determined by Imperial Irrigation District, Palo Verde Irrigation District, and Coachella Valley County Water District.
[c] Areas and water requirements of "miscellaneous areas" as determined by Colorado River Board that could be served if additional Colorado River water were available; not included in The California Water Plan. See text.
[d] Pilot Knob Mesa area of Imperial Irrigation District included in Hydrographic Unit No. 4 instead of No. 5.
[e] This quantity represents the minimum contract rights with the Federal Government, as expressed in the Seven-Party Agreement.

orary perched water tables, requiring individual eatment, will occur throughout the irrigated area.

Plans for importation of supplemental water supplies to the Whitewater Group provide for about 58,000 acre-feet per season through facilities of the alifornia Aqueduct System, augmented by the safe eld of the Coachella Valley ground water basin. istribution of this water would be accomplished by main transmission canal originating near Banning nd terminating approximately 5 miles east of abazon. Water remaining in the canal at its terminus ould be released for percolation in the bed of the an Gorgonio River, to provide for augmentation of e ground water supply and permit subsequent repumping for use in the upper Coachella Valley. The ain transmission canal would be about 25 miles in ngth from the point of diversion from the California queduct route to the San Gorgonio River, and ould be constructed with a maximum capacity of out 230 second-feet. Four power plants with a total stalled capacity of 22,000 kilowatts could be located ong the conduit route. Of the total import of 168,000 re-feet per season, 92,000 acre-feet would be served local agencies for distribution along the length of e conduit. Generation of hydroelectric energy in nnection with operation of the proposed works ould amount to about 150,000,000 kilowatt-hours nually.

About 1,900 acres of the irrigable lands in the achella Valley, with an annual water requirement 8,000 acre-feet, lie adjacent to the boundary beteen the Colorado Desert Area and the South Coastal ea, principally at elevations of 4,000 to 5,000 feet. ese tracts could be advantageously served in contion with the service of required water supplies to jacent area in the South Coastal Area, and capacity the delivery of such supplies is provided in the lifornia Aqueduct System.

San Felipe Group. The San Felipe Group is loed in the southwestern portion of the Colorado sert Area and includes the Salton Sea and Imperial lley. The total area encompassed within the group 3,026,000 acres, of which about 902,000 acres are sidered susceptible of ultimate water service.

The mean seasonal full natural runoff in the San lipe Group is estimated to be about 32,000 acre-feet, st of which results from localized thunderstorms l disappears rapidly through evaporation and by colation to ground water. San Felipe Creek, the ncipal stream in the group, frequently continues as ive stream, particularly in its upper reaches, after er drainage channels have ceased to flow.

Little agricultural development has taken place to e in the area lying outside of the Imperial Irrigan District. The principal exception is found in Borrego Valley, where about 2,700 acres are presently under irrigation. The chief source of water supply for this development is the ground water reservoir underlying Borrego Valley. The present pumpage in this area is estimated to be about 10,000 acre-feet annually, which is believed to approximate the safe yield.

About 20,000 acres of irrigable lands are in scattered tracts lying along the western boundary of the Colorado Desert Area between the San Jacinto Mountains and the Mexican border. These lands, with an estimated seasonal water requirement of 52,300 acre-feet, are so located physically and geographically that they could be served with greater facility from works which may be constructed for service of supplemental water supplies in the South Coastal Area. These lands have therefore not been considered in plans for the importation of supplemental water supplies into the Salton Sea and Imperial Valley areas.

Ground water in the Imperial Valley is not suitable for consideration as a source for required supplemental water in the San Felipe Group, due to its poor quality characteristics. Water from deeper wells in this valley, many of which are artesian, is normally warm and contains high concentrations of boron, chloride, and fluoride, and is generally considered unsuitable for either agricultural or domestic use. In areas of the valley where subsurface drainage is good, the quality approaches that of the applied irrigation water. However, in areas where drainage is poor, total dissolved solids may range as high as 73,000 parts per million, which is more than twice as saline as sea water.

Supplemental water supplies, amounting to about 229,000 acre-feet annually, required for the probable ultimate development in the San Felipe Group, could be imported by diversion from the San Diego High-Line Aqueduct of the Southern California Division of the California Aqueduct System in the vicinity of Lake Henshaw. Water thus diverted would be distributed by a system of canals, tunnels, and regulating reservoirs to irrigable areas in the group. At the terminus of the prospective conduits, the remaining flow would be percolated for augmentation of ground water supplies in the lower valley areas.

Primary regulation of the imported supplies would be accomplished in San Felipe Reservoir. Three power plants with a total installed capacity of 35,000 kilowatts could be operated in connection with the import project. Generation of electrical energy could amount to about 162,000,000 kilowatt-hours annually.

Desert Valley Group. The Desert Valley Group comprises the vast undeveloped desert region lying in the northerly portion of the Colorado Desert Area. The group embraces a total area of about 5,900,000 acres, of which about 517,000 acres are classed as ultimate water service areas. The group is composed of typical desert-type lands, with scattered mountain ranges interspersed by arid valleys and dry stream beds. There are an estimated 2,000 acres of presently irrigated lands, located in the Lucerne Valley area east of Victorville, where irrigation is accomplished through the utilization of ground water.

Under The California Water Plan, supplemental water supplies estimated at about 840,000 acre-feet per season, to serve approximately 386,000 acres not served from the Colorado River for reasons previously stated, could be imported through facilities of the California Aqueduct System. Except for about 7,800 acres near Desert Center, these water supplies would be imported into the area through lateral canals diverting from the main California Aqueduct System. Three major conduits, branching from the proposed main transmission canal serving the eastern Mojave Desert, would comprise the principal elements of the plans for importation of water supplies. The conduits would be operated on a constant-flow basis, with regulation to demand schedules effected in the available ground water basins. Here again, it is pointed out that the cost of importing water would be high; probably beyond the repayment capacity of irrigated agriculture as far as can be foreseen now.

Colorado River Group. The Colorado River Group embraces all the drainage tributary to the Colorado River in California (other than the area draining into the Salton Sea) with a total area of about 3,540 square miles. The westerly boundary of the group roughly parallels the Colorado River from Mexico to the California-Nevada state line, a distance of about 175 miles.

The major present agricultural developments in the Colorado River Group are located in the Palo Verde Valley and in the Yuma area. Water supplies required for the irrigation of lands in the Palo Verde area are furnished through the works of the Palo Verde Irrigation District. The permanent Palo Verde Weir on the Colorado River is under construction by the United States Bureau of Reclamation. In the Yuma area, the Yuma Project is operated in both Arizona and California under the jurisdiction of the United States Bureau of Reclamation.

About 70,000 acres of irrigable lands in the Colorado River Group lie outside the area having rights in and to the waters of the Colorado River. The ultimate mean seasonal water requirements of these lands are estimated to be about 232,000 acre-feet, of which about 1,000 acre-feet are presently developed from local sources. Of this requirement, capacity for the provision of about 100,000 acre-feet of water seasonally is provided in the California Aqueduct System. No plans have been prepared for delivery of the water supplies to the Colorado River Group from the main route of the California Aqueduct System.

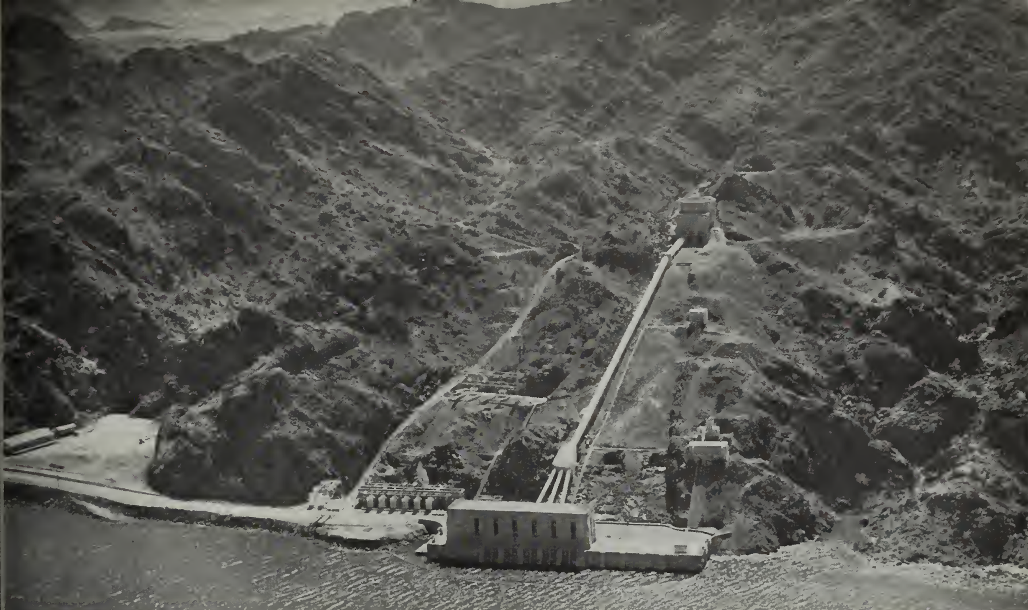
Summary of Colorado Desert Area. In the Colorado Desert Area, The California Water Plan would provide for the development of local ground water supplies to the maximum practicable extent, and the importation of large supplemental water supplies through the facilities of the California Aqueduct System. Deficiencies in developed water supplies to support the existing uses in the area have increased rapidly in the past few years, particularly in the Coachella and Imperial Valleys. Population in the Colorado Desert Area amounted to about 92,000 in 1950 and is estimated to have been about 141,000 in 1955. Much of this increase occurred in the Coachella Valley and Borrego Valley areas.

Of a total water service area of about 1,856,00[illegible] acres, the water which may be imported to the Colo[illegible] rado Desert Area by facilities of the California Aqu[illegible] duct System, together with the rights of the existin[illegible] agencies in the Colorado River, could provide f[illegible] about 1,631,000 acres, assuming that the rights in t[illegible] Colorado River are sufficient for some 1,065,000 acre[illegible] The remaining lands, totaling about 224,000 acre[illegible] would have an estimated seasonal water requireme[illegible] of 685,000 acre-feet. The latter lands, all within [illegible] miles of the Colorado River, might have been d[illegible] veloped, based on a water supply from that river, b[illegible] for the ceiling on uses imposed under the Bould[illegible] Canyon Project Act and the California Limitati[illegible] Act, as implemented by the Seven-Party Agreeme[illegible]

In all parts of the Colorado Desert Area, local wat[illegible] supplies are grossly deficient when considered with [illegible] lation to the probable ultimate demands for water. [illegible] the Whitewater and San Felipe Groups, works und[illegible] The California Water Plan for the importation of t[illegible] required supplemental water supplies are conte[illegible] plated for areas not included in the lands havi[illegible] rights in the Colorado River. It is envisioned that [illegible] development of local supplies in practically all ar[illegible] would be accomplished by continued development [illegible] the ground water resources. Importation of the [illegible] quired supplemental water supplies could be acc[illegible] plished by diversion from the California Aqued[illegible] System.

The difficulty and cost of providing required wa[illegible] supplies to meet ultimate development in the Color[illegible] Desert Area underscore the essentiality to the area [illegible] continued availability of Colorado River water to [illegible] full extent of California's existing rights. Works h[illegible] already been constructed to accommodate these rig[illegible] which are utilized by projects comprising about 9[illegible] cent of the total Colorado Desert Area.

General features and costs of the works neces[illegible] for the delivery of water supplies to portions of [illegible] Colorado Desert Area under The California W[illegible] Plan are presented in Tables 27 and 28, and the l[illegible] tion of these facilities are shown on Sheets 24 an[illegible] of Plate 5.



Colorado Desert Area—Colorado River Aqueduct Intake From Lake Havasu and Date Culture Near Indio

CALIFORNIA AQUEDUCT SYSTEM

The State-wide Water Resources Investigation has shown conclusively that, although California's water resources are adequate to satisfy ultimate requirements on a state-wide basis, surplus water in significant amounts exists in only the North Coastal Area and Sacramento River Basin, while deficiencies in supply will ultimately occur in all other areas of the State. It has also been shown that the nature of occurrence of California's water resources is extremely variable, both within the season and from year to year, thus necessitating vast amounts of reservoir storage for the required control and conservation. These large disparities in both the geographical and seasonal distribution could be equalized by the California Aqueduct System, which would comprise a complex system of works extending from the Oregon line to the Mexican border, providing adequate water supplies for all areas.

The California Aqueduct System would be unprecedented in its concept and scope. It would include many large dams, canals, tunnels, streamways, hydroelectric power plants, pumping plants, drainage ways, and other structures proposed to supplement existing water resource development works. It would ultimately develop nearly 22,000,000 acre-feet of surplus water each year, on the average, about half of which would be from the North Coastal Area and half from the Sacramento River Basin, and would transport this water to deficient areas to the south, as well as providing local benefits in the areas of surplus. The operation of the interbasin transfer facilities of the aqueduct system would assume a major role in coordinating the operation of all features of The California Water Plan. However, as previously explained, the works comprising the California Aqueduct System, hereinafter described, are not to be considered as definite project proposals. These works must be considered as subject to such modifications in design, location, and function as future studies, changed conditions, improved techniques, and other presently unforeseen factors may indicate as necessary or desirable.

It is further contemplated that these facilities would be built progressively, as needed and justified, to supply the water needs of the deficient areas of the State. Continuing, detailed study will be required in order to determine which unit or units should be built, the order in which they should be constructed, and the timing thereof.

These works would provide water supplies to meet the ultimate requirements as determined under the assumption that all habitable and irrigable areas would be utilized. It is quite probable that it will be many years in the future, if ever, before some of the areas which have been classed as irrigable, particularly in the remote desert areas, are developed for irrigated agriculture, especially in view of the hig cost of providing water for such areas. Because o this as well as other presently unforeseen continger cies, some of the more difficult and expensive of thes works may never be necessary. Nonetheless, this ir vestigation and the facilities discussed herein demoı strate that the capability does exist of meeting a foreseeable water needs in all areas of the State.

Many of the structures discussed in the followin sections are of very large size, in fact nearly unprec dented. The preliminary designs developed for pu poses of this report are based upon the best info mation currently available. However, much moı geological and foundation investigation would b necessary before final designs could be made. This particularly true for those facilities to be located the North Coastal Area, where geological and found tion conditions are relatively poor as compared to tl Sierra Nevada, for instance.

For purposes of presentation in this section, th immense interbasin water conservation and transpo tation system has been divided into six component or divisions, designated as follows: Klamath-Trini Division, Eel River Division, Sacramento Divisio Delta Division, San Joaquin Division, and Southe California Division. The locations of these divisio are shown on Plate 6, entitled "The California Aqu duct System."

Klamath-Trinity Division

The Klamath-Trinity Division of the Californ Aqueduct System comprises those features necessa to conserve surplus waters of the Klamath, Trinit Van Duzen, Mad, and South Fork of the Smi Rivers, as well as the pumping plants, condui tunnels, and hydroelectric power plants required f the conveyance of these surplus waters to the Sac mento Valley. This division would include a series major reservoirs which, for the most part, would located contiguously along the Klamath and Trini Rivers upstream from the vicinity of their juncti It would also include: a reservoir below the conflue of the two streams to conserve surplus flows ori nating below the mouth of the Trinity River; a res voir on the South Fork of the Smith River; t reservoirs on the headwaters of the Mad and V Duzen Rivers; and a reservoir on the South Fork the Trinity River. Finally, a series of dams and po plants would be constructed on Clear Creek in Sacramento River Basin for the principal purpose utilizing the considerable drop in elevation to the fl of the Sacramento Valley for development of hyd electric power.

The operation of the contemplated system of da reservoirs, and conveyance facilities would be pri pally for conservation of water. However, second but by no means minor beneficial results from th operation would include hydroelectric power generation and flood control. Additional benefits in the interests of fish, wildlife, and recreation would also accrue.

For purposes of description, the Klamath-Trinity Division is discussed in the ensuing sections under three groupings of works. These consist of developments on, or associated with, the Klamath River, the Trinity River, and Clear Creek.

Klamath River Development. Structures included in the Klamath River Development comprise Hamburg, Happy Camp, Slate Creek or substitute therefor, and Humboldt Dams and Reservoirs on the Klamath River, and their associated power plants; Canthook and Blackhawk Dams and Reservoirs on the South Fork of the Smith River; Blackhawk Pumping Plant at the base of Blackhawk Dam; and Beaver Pumping Plant, located on the Trinity River immediately upstream from its confluence with the Klamath River. Cantpeak Tunnel, connecting the Smith and Klamath Rivers, as well as Deerhorn Tunnel, connecting the Klamath and Trinity Rivers, are also included as features of this development. Recent geologic exploration at the Slate Creek dam site has unearthed unfavorable foundation conditions which indicate that it may be more economical to select an alternative site.

Runoff of the upper Klamath River would first be regulated in Hamburg Reservoir immediately below the confluence of the Scott and Klamath Rivers. It would be a large reservoir with a net storage capacity of 1,570,000 acre-feet. Releases from Hamburg Reservoir would flow through Hamburg Power Plant and then into Happy Camp Reservoir, formed by Happy Camp Dam located about 3 miles downstream from Happy Camp.

Happy Camp Reservoir, the largest reservoir of the Klamath River Development, would have an active storage capacity of 3,488,000 acre-feet. Releases from the reservoir would flow through Happy Camp Power Plant, thence downstream into the Klamath River for further regulation in Slate Creek Reservoir.

It should be pointed out that an initiative measure approved by the electorate in 1924 prohibits the construction of a dam at any point on the Klamath River below its confluence with the Shasta River. There is, however, some doubt as to whether this statute applies to the State or its agencies. This matter will be discussed in more detail in Chapter V.

Surplus flows of the South Fork of the Smith River would be conserved in Canthook Reservoir, located about 10 miles upstream from the main stem of the river. Blackhawk Dam would also be constructed on the South Fork of the Smith River immediately upstream from Canthook Reservoir. The primary purpose of Blackhawk Reservoir would be to provide direct gravity diversion from the South Fork of the Smith River to Slate Creek Reservoir on the Klamath River through a connecting conduit, Cantpeak Tunnel. Waters would be lifted from Canthook Reservoir into Blackhawk Reservoir by Blackhawk Pumping Plant, located within Blackhawk Dam.

Releases from Hamburg and Happy Camp Reservoirs on the Klamath River, Canthook Reservoir on the South Fork of the Smith River, and surface inflow from drainage areas below Happy Camp Reservoir would be further regulated in Slate Creek Reservoir, located on the Klamath River about 7 miles above the mouth of the Trinity River. Slate Creek Reservoir would have an active storage capacity of 1,566,000 acre-feet, and would impound and divert reregulated water in the average seasonal amount of 4,700,000 acre-feet for conveyance by means of Deerhorn Tunnel into Beaver Reservoir on the Trinity River.

Unregulated flows of the Klamath River would be controlled by Humboldt Dam, located on the Klamath River just below its confluence with the Trinity River, nearly on the Del Norte-Humboldt county line. Humboldt Reservoir would back water up the river to the downstream toes of both Beaver and Slate Creek Dams. The waters conserved by Humboldt Reservoir, amounting to about 1,205,000 acre-feet per season, would be lifted into Beaver Reservoir by Beaver Pumping Plant, located just below Beaver Dam. Thus, a total of 5,900,000 acre-feet per season would be delivered to Beaver Reservoir from the facilities of the Klamath River Development, which facilities are shown on Sheets 1 and 3 of Plate 5.

Trinity River Development. The Trinity River Development would involve the construction of Beaver, Burnt Ranch, and Helena Dams on the Trinity River; Eaton Dam on the Van Duzen River; Ranger Station Dam, or a substitute therefor, on the Mad River; and Eltapom Dam on the South Fork of the Trinity River. The development would also include the construction of Helena Power Plant on the Trinity River; Sulphur Glade and Eltapom Power Plants on the South Fork of the Trinity River; and Burnt Ranch Pumping Plant on the Trinity River. Three major tunnels, the Sulphur Glade, War Cry, and Big Flat, would be required to convey conserved surplus waters from the proposed reservoirs to the Sacramento River Basin.

Beaver Reservoir would receive water pumped from Humboldt Reservoir, located downstream on the Klamath River, and all water developed in the Klamath River above Humboldt Reservoir and conveyed by means of Deerhorn Tunnel to Beaver Reservoir, all as previously described under the Klamath River Development. In addition, Beaver Reservoir would conserve the natural runoff from the Trinity River drainage below Burnt Ranch and Eltapom Reservoirs. Beaver Dam would be located on the Trinity River just below Hoopa Valley, about 6 miles up-

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stream from the confluence of the Trinity and the Klamath Rivers.

Burnt Ranch Pumping Plant, located at the upper end of Beaver Reservoir and at the downstream of Burnt Ranch Dam, would lift water from Beaver Reservoir to Burnt Ranch Reservoir. Water would be pumped into Burnt Ranch Reservoir on a uniform monthly flow basis, and off-peak electric energy would be utilized in the interest of minimizing power costs.

Waters of the Van Duzen River would be developed by Eaton Dam and Reservoir, located about 2 miles downstream from the community of Dinsmores, about 4 miles west of the Humboldt-Trinity county line. Surplus flows of the Mad River could similarly be developed by a reservoir on that stream between Butler Valley and the Ruth site. The Ranger Station site was first selected as having several advantages due to its strategic location. However, preliminary geological examination indicated conditions which appear somewhat unfavorable to the most economic construction and, in consequence, further study is in process to find a more favorable alternative. At this time (May, 1957) it appears that satisfactory alternatives to Ranger Station can be found.

The yield from Eaton Reservoir could be conducted by tunnel to the Mad River, and the yield from the two reservoirs could be conveyed by tunnel into the South Fork of the Trinity River above Eltapom dam site. The most advantageous location would be at the Sulphur Glade tunnel site, which would permit construction of the Sulphur Glade Power Plant to make use of the head differential between the Mad River and the South Fork of the Trinity River.

Eltapom Dam and Reservoir, located on the South Fork of the Trinity River immediately downstream from Hyampom Valley, would regulate runoff of the South Fork of the Trinity River, and the releases from Eaton and Ranger Station Reservoirs which, as previously stated, would pass through the Sulphur Glade Power Plant. The total waters thus collected in Eltapom Reservoir would be released through Eltapom Power Plant, located at the base of the dam, and thence diverted through War Cry Tunnel into Burnt Ranch Reservoir on the Trinity River.

Helena Dam and Reservoir, constructed on the Trinity River above Burnt Ranch Reservoir, would conserve the natural flows of the Trinity River and generate hydroelectric energy by releases through Helena Power Plant located at the base of the dam. The reservoir would have a capacity of 3,050,000 acre-feet.

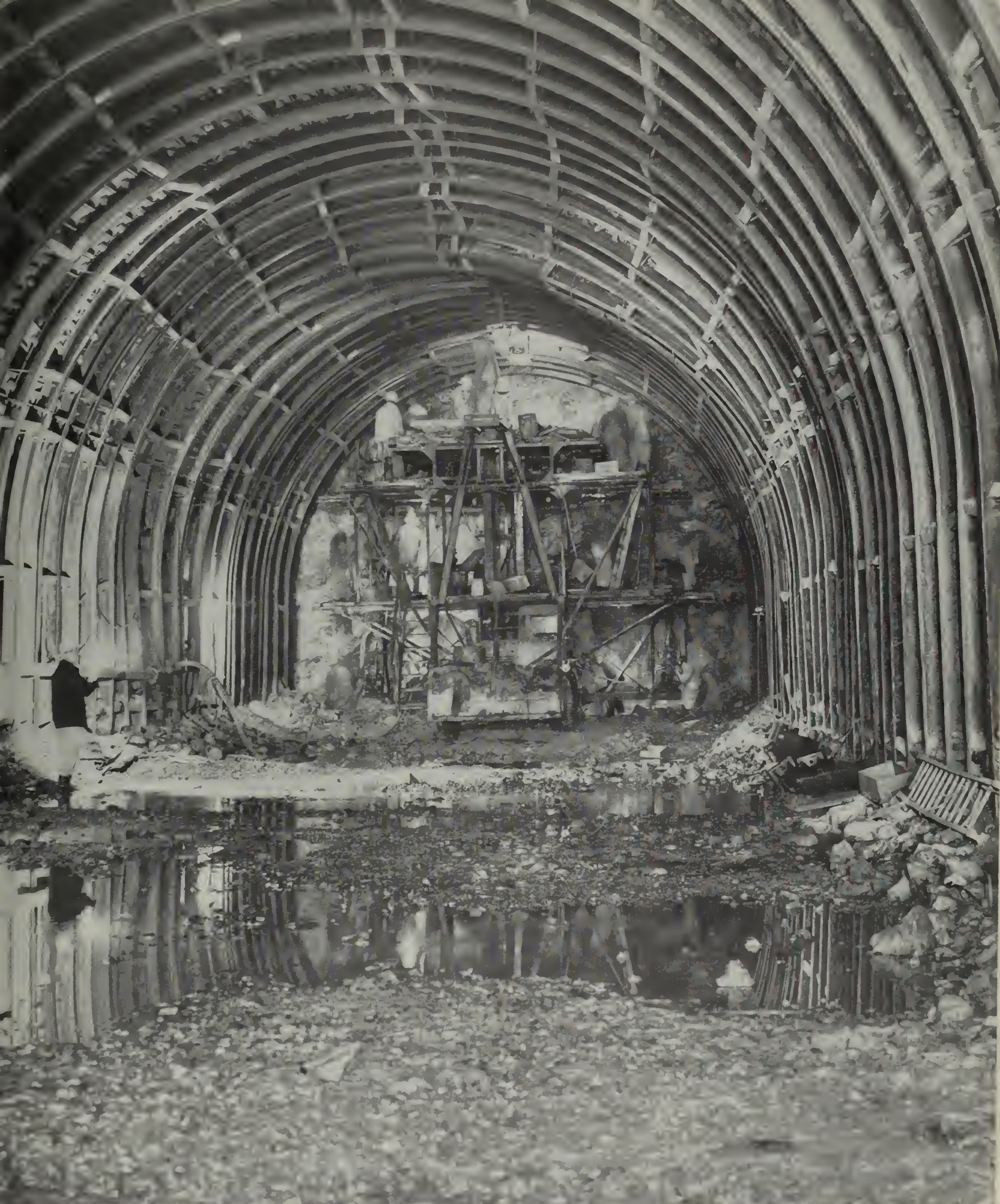
Burnt Ranch Reservoir, formed by Burnt Ranch Dam, located on the Trinity River about 3 miles upstream from the mouth of New River, would be the keystone reservoir of the Klamath-Trinity Division, as it would serve as a point of convergence for all surplus water delivered from the Klamath, Smith, Trinity, Mad, and Van Duzen Rivers. Although th reservoir would have a gross storage capacity o 246,000 acre-feet, only 36,000 acre-feet would be util ized for active storage, in the interest of maintainin maximum water surface elevation to assure necessar discharge into Big Flat Tunnel.

Thus, Burnt Ranch Dam and Reservoir would serv primarily as a forebay for Big Flat Tunnel, th principal interbasin export conduit, which would con vey water to Clear Creek in the Sacramento Valley Because of the tremendous quantities of waters in volved under ultimate conditions and the magnitud of the cost of works required to transfer this wate from Burnt Ranch Reservoir to Clear Creek, it i proposed that Big Flat Tunnel be constructed in tw parallel stages, or bores, each being 35 miles in lengtl The first bore would have a capacity of about 3,20 second-feet and the second bore would have a capacit of 8,100 second-feet. Big Flat Tunnel would discharg into Kanaka Reservoir on Clear Creek in the Sacra mento Valley.

Fairview and Lewiston Dams and Reservoirs, whic divert water from the Trinity River to the Sacra mento Valley through Tower House Tunnel, are pres ently under construction by the United States Burea of Reclamation. This project, known as the Trinit River Division of the Central Valley Project, is con sidered a feature of The California Water Plan. Th operation of this project could be coordinated wit the Klamath-Trinity Division of the California Aqu duct System.

Clear Creek Development. The Clear Creek De velopment would involve construction of Kanaka an Saeltzer Dam on Clear Creek in the Sacrament River Basin, and an appurtenant power plant at eac of the dams. Kanaka Dam and Reservoir, impoundin water delivered from Burnt Ranch Reservoir as we as runoff from Clear Creek, would be located on Clea Creek about 8 miles east of Redding.

Water released from Kanaka Reservoir would flo through the Kanaka Power Plant, located near th base of the dam, into Saeltzer Reservoir located im mediately downstream. Saeltzer Dam would be sit ated at the present site of the Saeltzer Diversion Da about 6 miles upstream from the confluence of Clea Creek with the Sacramento River. Saeltzer Da would function primarily for development of the r mainder of the power head on Clear Creek belo Kanaka Dam, and the final generation of power l facilities of the Klamath-Trinity Division would accomplished by Saeltzer Power Plant, located the base of Saeltzer Dam. The water released fro Saeltzer Power Plant would flow into Girvan Rese voir, which is a part of, and is subsequently describ under, the Sacramento Division of the Californ Aqueduct System.



Klamath-Trinity Division—Head of Tower House Tunnel of the Trinity Diversion Project

TABLE 17

SUMMARY OF KLAMATH-TRINITY DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam			Normal pool elevation, in feet	Storage capacity, in acre-feet		Seasonal yield, in acre-feet	Purpose	Place of water use
		Location, HB&M, and sheet of Plate 5 on which shown	Type	Height, in feet		Gross	Active			
Klamath River Development										
Hamburg	Klamath River	Sec. 31, T46N, R10W, MDB&M 1	CG	445	1,960	1,850,000	1,570,000	1,136,000	I,U,FC,R,F,P	Klamath River Basin and California Aqueduct service area
Happy Camp	Klamath River	Sec. 33, T16N, R7E 1	CG	625	1,570	4,120,000	3,490,000	761,000	I,U,FC,R,F,P	
Slate Creek	Klamath River	Sec. 19, T10N, R5E 1	R	775	1,000	5,480,000	1,570,000	1,985,000	I,U,FC,R,F	
Canthook	Smith River	Sec. 10, T15N, R2E 1	CG	623	1,095	1,230,000	1,030,000	830,000	I,U,FC,R,F	Smith River Basin and California Aqueduct service area
Black Hawk	Smith River	Sec. 19, T15N, R3E 1	CG	413	1,123	88,000	48,000	none	Diversion to Cantpeak Tunnel	
Humboldt	Klamath River	Sec. 10, T12N, R2E 1	CG	410	430	1,940,000	1,330,000	1,205,000	I,U,FC,R,F	Klamath River Basin and California Aqueduct service area
Trinity River Development										
Beaver	Trinity River	Sec. 2, T8N, R4E 1	CG	730	950	7,760,000	1,600,000	720,000	I,U,FC,R,F	Trinity River Basin and California Aqueduct service area
Burnt Ranch	Trinity River	Sec. 13, T5N, R6E 3	CA	355	1,220	245,000	36,000	none	Diversion to Big Flat Tunnel	
Helena	Trinity River	Sec. 36, T34N, R12W, MDB&M 3	CG	575	1,852	3,050,000	2,670,000	611,000	I,U,FC,R,F,P	
Eaton	Van Duzen River	Sec. 5, T1N, R5E 3	E	396	2,700	730,000	500,000	398,000	I,U,FC,R,F,P	Van Duzen and Mad River Basins and California Aqueduct service area
Ranger Station	Mad River	Sec. 17, T1N, R6E 3	E	323	2,700	500,000	435,000			
Eltapom	South Fork Trinity River	Sec. 3, T3N, R6E 3	R	420	1,620	1,260,000	680,000	536,000	I,U,FC,R,F,P	Trinity River Basin and California Aqueduct service area
Eltapom Afterbay	South Fork Trinity River	Sec. 28, T4N, R6E 3	GG	225	1,264	26,000	6,000	none	Afterbay	
Clear Creek Development										
Kanaka	Clear Creek	Sec. 22, T31N, R6W, MDB&M 3	E	460	1,135	415,000	105,000	none	I,U,FC,R,F,P	Sacramento River Basin and California Aqueduct service area
Saeltzer	Clear Creek	Sec. 31, T31N, R5W, MDB&M 3	E	107	650	32,000	6,000	none	P	Conveyance facility only
Totals						28,726,000	15,076,000			

TABLE 17—Continued

SUMMARY OF KLAMATH-TRINITY DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Power plant	Location, HB&M, and sheet of Plate 5 on which shown	Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours
Klamath River Development				
Hamburg	Sec. 31, T46N, R10W, MDB&M 1	388	67,000	384,000,000
Happy Camp	Sec. 33, T16N, R7E 1	476	135,000	787,000,000
Trinity River Development				
Helena	Sec. 36, T34N, R12W, MDB&M 3	468	42,000	248,000,000
Sulphur Glade	Sec. 25, T2N, R6E 3	1,007	94,000	355,000,000
Eltapom	Sec. 3, T3N, R6E 3	324	52,000	266,000,000
Clear Creek Development				
Kanaka	Sec. 22, T31N, R6W, MDB&M 3	473	1,025,000	3,420,000,000
Saeltzer	Sec. 31, T31N, R5W, MDB&M 3	148	330,000	1,110,000,000
Totals			1,745,000	6,570,000,000

Pumping plant	Location, HB&M, and sheet of Plate 5 on which shown	Average head, in feet	Installed capacity, in kilowatts	Seasonal power consumption, in kilowatt-hours
Klamath River Development				
Black Hawk	Sec. 19, T15N, R3E 1	81	72,000	98,000,000
Beaver	Sec. 2, T8N, R4E 1	536	254,000	937,000,000
Trinity River Development				
Burnt Ranch	Sec. 13, T5N, R6E 3	289	762,000	2,792,000,000
Totals			1,088,000	3,827,000,000

Tunnel	Average flow, in second-feet	Length, in miles
Klamath River Development		
Cantpeak	1,147	15.3
Deerhorn	6,500	10.3
Trinity River Development		
Mad	240	0.4
Sulphur Glade	1,375	4.6
War Cry	1,291	9.7
Big Flat	11,300	35.4
Total		75.7

Symbols of Type of Dam
E—Earthfill
R—Rockfill
CG—Concrete gravity
CA—Concrete arch

Symbols of Purpose
I—Irrigation
U—Urban (domestic, municipal, industrial
FC—Flood control
R—Recreation
F—Enhancement of fish environment
P—Power generation

Summary of Klamath-Trinity Division. The Klamath-Trinity Division would involve the construction of 15 major dams and reservoirs with aggregate active storage capacity of about 15,000,000 acre-feet; 7 hydroelectric power plants with installed power capacity of about 1,700,000 kilowatts; 3 pumping plants with total installed capacity of approximately 1,100,000 kilowatts; and 6 tunnels having a total length of about 76 miles. The works would make available some 9,055,000 acre-feet of water annually for export, including the exportable yield estimated at 872,000 acre-feet from the Trinity River Division of the Central Valley Project. The hydroelectric facilities of the Klamath-Trinity Division would generate about 6.6 billion kilowatt-hours of electrical energy each year. Of this amount, 3.8 billion kilowatt-hours of energy would be required to pump water to Burnt Ranch Reservoir, from which it would flow through Big Flat Tunnel beneath the Trinity Divide into the Sacramento Valley.

Construction of the facilities of the Klamath-Trinity Division would be susceptible of logical, progressive staging as the need for water and power in California develops. The major reservoirs would accomplish substantial local benefits in the North Coastal Area in providing control of the very large rain floods characteristic of the area.

The surface elevations of most of the major reservoirs would fluctuate through a relatively limited range and, consequently, would constitute an outstanding recreational attraction.

Under ultimate conditions of development, nearly the entire course of the Klamath River and the greater part of the course of the Trinity River would be inundated, thus necessitating the development of a new environment for the anadromous fish now using those streams. It is planned that conditions will be improved on other smaller coastal streams of the area through construction of stream flow maintenance dams and other measures. It is expected that this will result in an increased anadromous fish population in these streams, thereby compensating, to some extent, for the loss of the famed Klamath system runs. Additionally, the various reservoirs would support fish populations that, while of a different type, would provide a probably greater fishing opportunity than is now available.

It should be pointed out that during the earlier stages of development large reaches of stream channel could be improved by releases from initial upstream reservoirs. Such releases, in conjunction with the operation of fish hatcheries, could possibly improve the present anadromous fishery for a substantial period of time, and it would not be until later stages of development that the Klamath and Trinity Rivers would be inaccessible to the migratory fish.

The general features of the facilities of the Klamath-Trinity Division are presented in Table 17, and their capital costs are shown in Table 18. The component features of the division are delineated on Sheets 1 and 3 of Plate 5.

TABLE 18

SUMMARY OF CAPITAL COSTS, KLAMATH-TRINITY DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Klamath Development	
Hamburg Dam and Reservoir	$57,480,000
Hamburg Power Plant	10,030,000
Happy Camp Dam and Reservoir	96,090,000
Happy Camp Power Plant	17,210,000
Slate Creek Dam and Reservoir	151,230,000
Canthook Dam and Reservoir	92,190,000
Black Hawk Dam and Reservoir	49,660,000
Black Hawk Pumping Plant	13,840,000
Cantpeak Tunnel	36,800,000
Humboldt Dam and Reservoir	70,300,000
Relocation of state highway	35,000,000
Deerhorn Tunnel	78,830,000
Beaver Pumping Plant	26,620,000
Subtotal	$735,280,000
Trinity Development	
Beaver Dam and Reservoir	165,310,000
Burnt Ranch Dam and Reservoir	15,550,000
Burnt Ranch Pumping Plant	73,150,000
Helena Dam and Reservoir	86,260,000
Helena Power Plant	6,510,000
Eaton Dam and Reservoir	15,500,000
Mad Tunnel	650,000
Ranger Station Dam and Reservoir	17,050,000
Sulphur Glade Tunnel	18,690,000
Sulphur Glade Power Plant	16,210,000
Eltapom Dam and Reservoir	41,210,000
Eltapom Power Plant	7,280,000
Eltapom Afterbay	7,630,000
War Cry Tunnel	44,810,000
Big Flat Tunnel	823,440,000
Relocation of state highways	68,000,000
Subtotal	$1,407,250,000
Clear Creek Development	
Kanaka Dam and Reservoir	21,500,000
Kanaka Power Plant	106,000,000
Saeltzer Dam and Reservoir	2,000,000
Saeltzer Power Plant	43,070,000
Subtotal	$172,570,000
Total	$2,315,100,000

* At 1955 price levels.

Eel River Division

The Eel River Division comprises those features o[f] the California Aqueduct System which would develo[p] the waters of the Eel River system. This divisio[n] would convey the conserved surplus waters to the Sa[c]ramento Valley for further transport to areas o[f] deficiency, and would furnish water for local us[e] particularly in Round Valley in Mendocino Count[y]. The Eel River Division would include a series o[f] major conservation reservoirs and associated pumpin[g] plants on the Eel River; a reservoir and power pla[nt] on the Middle Fork of the Eel River; a 12-mile tunn[el] to convey water to Clear Lake in the Sacrament[o] River Basin; a short diversion tunnel from Cac[he] Creek to Putah Creek; and a series of reservoirs an[d] ower plants along Putah Creek. Also included as atures of the Eel River Division are a diversion into e Russian River Basin for delivery of water to the orth Bay area, and a diversion into Napa Valley.

The works of the Eel River Division would be oper- ed primarily for water conservation, but would be odified to the extent necessary to permit stabiliza- on of the water surface levels of Clear Lake, the evelopment of hydroelectric energy, and the control floods in the Eel River Basin. The facilities of this vision would be susceptible of staged construction the need for additional water arises. Initial units ould consist of structures on the upper reaches of e Eel River and a diversion to convey the conserved aters to Clear Lake. The power potential of the di- rted waters could, at that time, be developed in the op to the floor of the Sacramento Valley. Finally, the need for surplus waters would increase, the re- aining storage units and pumping plants would be nstructed farther downstream on the Eel River.

As described earlier in this chapter, the South Fork the Eel River, as well as other nearby streams, ould be developed either solely or primarily in the terests of enhancement of the fishery and of wildlife d recreational opportunities. This would compen- te to some extent for the loss to the anadromous shery due to the major developments on the Eel iver.

For descriptive purposes, proposed features of the el River Division are discussed herein under three oupings of works. These consist of the Eel River evelopment, the Putah Creek Development, and the ussian River Diversion.

Eel River Development. Facilities of the Eel iver Development would consist of Willis Ridge, ell Springs, and Sequoia Dams and Reservoirs on the el River, Etsel Dam and Reservoir on the Middle ork of the Eel River, and Clear Lake on the head- aters of Cache Creek. The associated features of this evelopment would comprise Bell Springs and Willis dge Pumping Plants, Etsel Power Plant, Garrett unnel from Willis Ridge Reservoir to a tributary of ear Lake, and Soda Creek Tunnel from Clear Lake the Putah Creek Basin.

Sequoia Dam and Reservoir would be the lowermost cility of the Eel River, being located about 10 miles ove the confluence with the South Fork of the Eel ver. The reservoir would have a gross storage capac- of about 5,610,000 acre-feet. Water developed by quoia Dam and Reservoir would be pumped into ell Springs Reservoir located immediately upstream.

Bell Springs Dam, located about 5 miles south of e Mendocino-Trinity county line, would develop a orage capacity of about 2,860,000 acre-feet in Bell prings Reservoir. Water would be pumped from quoia Reservoir into Bell Springs Reservoir by Bell Springs Pumping Plant, located at the base of Bell Springs Dam.

Etsel Reservoir would be located on the Middle Fork of the Eel River immediately upstream from the easterly arm of Bell Springs Reservoir. The reservoir would have a capacity of about 1,180,000 acre-feet. Franciscan Dam would be required on Short Creek to prevent flooding of lands in Round Valley. This auxiliary dam, which was discussed earlier in this chapter as the initial development on the Middle Fork, would furnish a water supply for Round Valley. Water released from Etsel Reservoir would pass through Etsel Power Plant, located at the base of the dam, and discharge into Bell Springs Reservoir for regulation.

Willis Ridge Reservoir, located on the main stem of the Eel River directly upstream from Bell Springs Reservoir, would impound water pumped from Bell Springs Reservoir, and would develop natural tributary runoff. The reservoir would have a capacity of 2,230,000 acre-feet and would be formed by Willis Ridge Dam. Willis Ridge Pumping Plant, located at the base of Willis Ridge Dam, would lift the water developed in downstream reservoirs from Bell Springs Reservoir into Willis Ridge Reservoir.

Waters developed on the Eel River and collected in Willis Ridge Reservoir would be conveyed in Garrett Tunnel from Willis Ridge Reservoir to Middle Creek, a tributary of Clear Lake. Garrett Tunnel would be about 12 miles in length and have a capacity of about 2,900 second-feet. About 2,140,000 acre-feet annually could be exported from the Eel River to Clear Lake through this tunnel.

Clear Lake would be utilized to convey water released from Garrett Tunnel to the portal of Soda Creek Tunnel at Clear Lake Dam. Actually, Clear Lake would serve as a forebay to Soda Creek Tunnel. The present outlet of Clear Lake would be improved to permit reduced fluctuations of the water surface of the lake, thus effecting flood control around the rim of the lake, if existing court decrees can be modified.

Soda Creek Tunnel would convey the Eel River water from Clear Lake to Stienhart Reservoir, located on Soda Creek, a tributary to Putah Creek. Soda Creek Tunnel would be about 2.6 miles in length and would be initially constructed to its ultimate capacity of about 2,900 second-feet. As stated, a total of about 2,140,000 acre-feet per season would be delivered from the Eel River to the Putah Creek Basin in the Sacramento Valley Area by facilities of the Eel River Development, which facilities are shown on Sheets 3, 5, and 7 of Plate 5.

Putah Creek Development. The primary purpose of the Putah Creek Development would be for production of hydroelectric energy by development of the available head in the drop to the floor of the

Sacramento Valley. The features of this development would include Stienhart, Jerusalem, Noyes, Snell, and Monticello Dams and Reservoirs, and power plants below each of the dams. An afterbay to reregulate releases from Monticello Reservoir, the lowermost of the chain of reservoirs along Putah Creek, would also be provided below Monticello Dam.

Water conveyed from Clear Lake through Soda Creek Tunnel would be reregulated in Stienhart Reservoir, located on Soda Creek about 7 miles southeast of the town of Lower Lake. Stienhart Reservoir would serve primarily as a forebay to Stienhart Power Plant, located at the base of the dam. Releases from Stienhart Power Plant would be discharged into Jerusalem Reservoir, located immediately downstream.

Jerusalem Dam would be constructed on Soda Creek about 1 mile upstream from its confluence with Putah Creek. Additional hydroelectric energy would be developed by Jerusalem Power Plant, located at the base of Jerusalem Dam. Water released from Jerusalem Power Plant would be further regulated in Noyes Reservoir, located on Putah Creek about 2 miles west of the Napa-Lake county line. Noyes Reservoir would similarly serve as a forebay to the Noyes Power Plant located at the base of the dam.

Water discharged from Noyes Power Plant would flow a short distance down Putah Creek to Snell Reservoir, formed by Snell Dam about 3 miles above Berryessa Valley. Additional hydroelectric energy would be developed by releasing the water through the Snell Power Plant at the base of Snell Dam. From Snell Power Plant, the water from the Eel River would be released into Monticello Reservoir.

Monticello Dam and a downstream diversion structure, presently under construction by the United States Bureau of Reclamation, would be integrated with the Eel River Division as a feature of the California Aqueduct System. The operation for conservation contemplated by the Bureau of Reclamation would not be interfered with under The California Water Plan. However, a power plant would be constructed at a future time at the base of the dam, to develop the energy potential of the water transported from the Eel River.

The final development on Putah Creek would consist of Monticello Afterbay, formed by a dam about 5 miles below Monticello Dam. This afterbay would provide reregulation of power releases from Monticello Power Plant, and would develop the last increment of energy from the Eel River water by releasing it through a power plant located at the base of the dam. The water from this point would flow down Putah Creek to be diverted into the Sacramento West Side Canal, a feature of the Sacramento Division next described.

Napa Valley would be supplied with 224,000 acre-feet of water annually by a diversion from Monticello Reservoir and conveyance westerly by a tunnel through Cedar Roughs Ridge to Conn Creek in Napa Valley. The Cedar Roughs Tunnel would be about 7 miles long and have a capacity of 290 second-feet. It would deliver water from the west shore of Monticello Reservoir to Lake Hennesey, formed by Conn Creek Dam on Conn Creek. The operation of Lake Hennesey, owned and operated by the City of Napa, would be coordinated with that of the Cedar Roughs Diversion.

Conveyance of Eel River water from Clear Lake to the floor of the Sacramento Valley by way of Cache Creek has been considered as a possible alternative to the Putah Creek Development. However, the planning relative to this conveyance is quite preliminary, and would require considerable geologic exploratory work as well as further engineering studies before its feasibility could be established. The alternative development would consist of a series of dams and power plants down the course of Cache Creek in stairstep fashion, very similar to the Putah Creek system.

Briefly, the alternative proposal would consist of five dams on Cache Creek consisting, in descending order down the creek, of Dead Man, Wilson Valley, Glascock, Rumsey, and Guinda Dams and Reservoirs. A power plant would be constructed at the base of each dam, and a canal and flume would convey the water from the Guinda Power Plant along the east side of Cache Creek to a power plant just east of Brooks, thence to a diversion structure and canal leading through the Hungry Hollow area north of Cache Creek to a final power plant on Oat Creek.

Facilities of the Putah Creek Development and of the alternative possibilities on Cache Creek are delineated on Sheets 5, 7, and 8 of Plate 5.

Russian River Diversion. Supplemental requirements for water in Marin and Sonoma Counties in the seasonal amount of 422,000 acre-feet would be supplied by a diversion from Willis Ridge Reservoir on the Eel River through an enlarged Potter Valley Tunnel to the East Fork of the Russian River, and rediversion from the Russian River near Geyserville and conveyance via the Sonoma Aqueduct to the North San Francisco Bay area. In addition to providing supplemental water, hydroelectric energy could be generated by utilizing the drop from Willis Ridge Reservoir to the East Fork of the Russian River in the operation of an enlarged Potter Valley Power Plant.

The new Potter Valley Tunnel would be about 0 mile in length and would convey a continuous flow of about 740 second-feet from Willis Ridge Reservoir to the new Potter Valley Power Plant, located in Potter Valley at the site of the existing power plant, which is owned and operated by the Pacific Gas and Electric Company. The releases from the new Potter Valley Power Plant would be reregulated in an afterbay and conveyed by canal along the east side of Potter

TABLE 19

SUMMARY OF EEL RIVER DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown		Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use
Eel River Development											
Sequoia	Eel River	Sec. 6, T2S, R4E, HB&M	3	R	640	750	5,610,000	2,350,000	826,000	I,U,FC,R,F	Eel River watershed and California Aqueduct service area
Bell Springs	Eel River	Sec. 19, T24N, R14W	5	R	635	1,250	2,860,000	2,280,000	818,000	I,U,FC,R,F	
Willis Ridge	Eel River	Sec. 32, T21N, R13W	5	R	619	1,600	2,230,000	1,000,000	363,000	I,U,FC,R,F	
Etsel	Middle Fork Eel River	Sec. 13, T22N, R12E	5	E	435	1,670	1,180,000	1,040,000	523,000	I,U,FC,R,F,P	
Putah Creek Development											
Stienhart	Soda Creek	Sec. 27, T12N, R6W	7	E	285	1,321	99,000	23,000	0	P	Conveyance facilities only
Jerusalem	Soda Creek	Sec. 14, T11N, R6W	7	R	160	1,045	46,000	0	0	P	
Noyes	Putah Creek	Sec. 30, T11N, R5W	7	E	255	900	110,000	0	0	P	
Snell	Putah Creek	Sec. 5, T9N, R4W	7	R	315	650	394,000	0	0	P	
Monticello Afterbay	Putah Creek	Sec. 36, T8N, R2W	8	CG	75	210	29,000	14,000	0	P	
Russian River Diversion											
Stemple	Stemple Creek	Sec. 10, T5N, R8W	7	E	104	190	57,000	52,000	0	S	Tomales-Bodega and North San Francisco Bay areas
Totals							12,615,000	6,759,000			

TABLE 19—Continued

SUMMARY OF EEL RIVER DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Power plant	Location, MDB&M, and sheet of plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours
Eel River Development					
Etsel	Sec. 13, T22N, R11W	5	365	25,200	166,000,000
Putah Creek Development					
Stienhart	Sec. 27, T12N, R6W	7	272	137,000	517,000,000
Jerusalem	Sec. 14, T11N, R6W	7	139	75,000	253,000,000
Noyes	Sec. 30, T11N, R5W	7	244	130,000	452,000,000
Snell	Sec. 5, T9N, R4W	7	227	110,000	405,000,000
Monticello	Sec. 29, T8N, R2W	8	226	100,000	409,000,000
Monticello Afterbay	Sec. 36, T8N, R2W	8	67	10,800	118,000,000
Russian River Diversion					
New Potter Valley	Sec. 31, T18N, R11W	5	565	36,000	254,000,000
East Fork	Sec. 5, T16N, R11W	5	134	7,000	59,000,000
Totals				631,000	2,633,000,000

Pumping plant	Location, MDB&M, and sheet of plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Seasonal power consumption, in killowatt-hours
Eel River Development					
Bell Springs	Sec. 30, T24N, R14W	5	475	142,500	574,000,000
Willis Ridge	Sec. 32, T21N, R13W	5	404	372,000	1,282,000,000
Russian River Diversion					
Cotati	Sec. 31, T6N, R7W	7	80	7,400	56,000,000
Totals				521,900	1,912,000,000

Conduit	Average flow, in second-feet	Length, in miles	
		Canal	Tunnel
Eel River Development			
Garret Tunnel	2,900		12.0
Soda Creek Tunnel	2,900		2.6
Putah Creek Development			
Cedar Roughs Tunnel	290		7.2
Russian River Diversion			
Potter Valley Tunnel	738		0.9
Sonoma Aqueduct	720	39.3	
Totals		39.3	22.7

Symbols of Type of Dam
- E—Earthfill
- R—Rockfill
- CG—Concrete gravity

Symbols of Purpose
- I—Irrigation
- U—Urban (domestic, municipal, industrial)
- FC—Flood control
- R—Recreation
- F—Enhancement of fish environment
- P—Power generation
- S—Reregulation of waters to local demand schedules

'alley, where the water would drop through the East 'ork Power Plant, located on the shore of Coyote 'alley Reservoir.

The operation of the Russian River Diversion would e coordinated with the operation of Coyote Valley Reservoir, presently under construction by the Corps f Engineers, U. S. Army, as a conservation and flood ontrol project. Water would pass through Coyote 'alley Reservoir and be released into the East Fork f the Russian River, where it would flow down the atural channel to a point near Geyserville.

A diversion structure on the Russian River about a ile north of Geyserville would transfer the comingled Eel River water into the Sonoma Aqueduct, hich would convey the water in a general southerly irection about 40 miles in canal, tunnel, and pipe ne, where it would finally be pumped into a terminal eservoir on Stemple Creek about 3 miles south of he community of Cotati.

Stemple Dam and Reservoir on Stemple Creek ould be operated for terminal storage only. There ould be two outlet works, one for release of water estward to the Tomales-Bodega area, and one for elease of water southward to the San Francisco Bay rea.

Summary of Eel River Division. The Eel River Division would consist of 10 reservoirs, including 4 major conservation reservoirs on the Eel River, 5 regulaon reservoirs for power generation on Putah Creek, nd a terminal reservoir in the Russian River Basin; hydroelectric power plants, including 1 on the Eel iver, 6 on Putah Creek, and 2 on the East Fork of e Russian River; 3 pumping plants, including 2 on e Eel River and 1 on the Sonoma Aqueduct; and 4 innels having a total length of 22 miles. The four ajor conservation reservoirs on the Eel River would ave a gross storage capacity of 11,880,000 acre-feet id a net storage capacity of 8,676,000 acre-feet, and ould develop a yield of 2,566,000 acre-feet annually. he nine hydroelectric power plants would have an istalled power generating capacity aggregating about 50,000 kilowatts and would generate about 2.7 billion ilowatt-hours of electric energy per season. The iree pumping plants would have a total installed ipacity of about 522,000 kilowatts and would require bout 1.9 billion kilowatt-hours of electric energy nnually to lift the water over the divide to the acramento Valley and the San Francisco Bay Area.

The Eel River Division would be adaptable to gical staged construction as the need for water and ower in California develops. The initial stages would irnish water for domestic, agricultural, and instrial purposes in the Eel River Basin, and would ontrol the large rain floods such as occurred during ecember, 1955. Furthermore, a large block of hydroectric power would be developed locally in the area facilitate industrial growth and development. Reservoir releases would also be made to maintain summer and fall stream flow to enhance fish, wildlife, and recreational values. The foregoing objectives do not include the operation of Monticello and Coyote Valley Reservoirs which are under construction by federal agencies.

Pertinent features of the Eel River Division are presented in Table 19, and the capital costs of its component facilities are shown in Table 20. The facilities of the Eel River Division are delineated on Sheets 5, 7, and 8 of Plate 5.

TABLE 20

SUMMARY OF CAPITAL COSTS, EEL RIVER DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Eel River Development	
Sequoia Dam and Reservoir	$96,820,000
Bell Springs Pumping Plant	23,270,000
Bell Springs Dam and Reservoir	102,750,000
Etsel Power Plant	4,290,000
Etsel Dam and Reservoir	47,530,000
Willis Ridge Pumping Plant	61,510,000
Willis Ridge Dam and Reservoir	112,200,000
Railroad and highway relocation	107,000,000
Subtotal	$555,370,000
Putah Creek Development	
Garrett Tunnel	$67,670,000
Middle Creek Channel improvement	500,000
Soda Creek Tunnel	10,120,000
Stienhart Dam and Reservoir	10,060,000
Stienhart Power Plant	16,240,000
Jerusalem Dam and Reservoir	3,190,000
Jerusalem Power Plant	11,850,000
Noyes Dam and Reservoir	7,630,000
Noyes Power Plant	16,180,000
Snell Dam and Reservoir	28,470,000
Snell Power Plant	12,310,000
Monticello Power Plant	11,920,000
Cedar Roughs Tunnel	11,070,000
Monticello Afterbay Dam and Reservoir	4,120,000
Monticello Afterbay Power Plant	2,900,000
Davis Diversion Dam	6,600,000
Subtotal	$220,830,000
Russian River Diversion	
Potter Valley Tunnel and Power Development	$9,590,000
Sonoma Aqueduct	22,370,000
Stemple Dam and Reservoir	4,090,000
Subtotal	$36,050,000
Total	$812,250,000

* At 1955 price levels.

Sacramento Division

The Sacramento Division of the California Aqueduct System comprises the works in the Sacramento River Basin necessary to develop and regulate the surplus waters of the basin for export, and the natural and artificial channels required to convey these waters, together with imports from the North Coastal Area, to Monteznma Reservoir and to the Delta for further transport to areas of deficiency. Part of the export supply developed on the American River by features of the Sacramento Division would be diverted directly from that stream before reaching the Delta. Similarly, a small quantity of export water developed in Monticello Reservoir of the Eel River Division would be diverted directly from Putah Creek before entering the Delta. The power plants associated with the export reservoirs of the Sacramento Division and certain conduits associated with delivery of export water to nearby deficient areas are also included as features of the division. The provision of a trunk line waste conduit along the trough of the valley to prevent pollution of the local and export water supply is considered earlier in this chapter under the discussion of local works.

In the following discussion, consideration is given first to the works above and along a main west side conduit route that would develop surplus waters of the Sacramento River Basin above Red Bluff, and convey these and imported supplies southward along the west side of the Sacramento Valley into Montezuma Reservoir for further disposition. Other features of the Sacramento Division, not directly on the main west side conduit route, are discussed under a separate heading. Except for the direct diversions from the American River and Putah Creek, water developed for export by these latter features would flow through the natural drainage system of the Sacramento Valley to the Delta for further disposition, with the Sacramento River serving as the main conduit. The discussion concludes with a resume of the works of the division and their costs and accomplishments.

Main West Side Conduit Route. The Main West Side Conduit Route of the Sacramento Division would originate below Keswick Dam at a diversion point on the Sacramento River near the mouth of Salt Creek west of Redding. Here, the Redding Diversion Dam would be constructed and operated to divert the stream flow southward 7 miles through the Redding Conduit to Girvan Reservoir on Clear Creek, where a junction would be made with the imported waters of the Klamath-Trinity Division. From Girvan Reservoir the combined flow would be further conveyed about 11 miles southeasterly through the Anderson Conduit, skirting the foothills south of Redding and west of U. S. Highway 99, to the headworks of the Cottonwood Power Plant, located about 2 miles northeast of the town of Cottonwood. Releases from the Cottonwood Power Plant would enter the Cottonwood arm of Iron Canyon Reservoir through an excavated tailrace channel about a mile in length. The water would then flow through the reservoir about 18 miles to Iron Canyon Dam and through Iron Canyon Power Plant, near the base of the dam, into the proposed Redbank Diversion Reservoir of the United States Bureau of Reclamation, all on the Sacramento River near Red Bluff.

After releases of mandatory requirements to the Sacramento River below the Redbank Diversion Dam and to the Tehama-Colusa and Corning Canals of the Bureau of Reclamation, the remaining water would be diverted into the Sacramento West Side Canal and conveyed southward along the west side of the Sacramento Valley about 146 miles to a junction with the imported waters of the Eel River Division of the California Aqueduct System at Putah Creek near Davis. Power drops would be taken along the route of the canal at Willows and Dunnigan. From the Putah Creek junction, the combined waters of the upper Sacramento River Basin and the North Coastal Area would be further conveyed by canal about 21 miles southerly to Montezuma Reservoir in southern Solano County. There they would be available for export westward through the North Bay Aqueduct of the Sacramento Division and southward through an element of the Delta Division of the California Aqueduct System. In the reach between the Redbank diversion point and the junction with the Eel River Division near Davis the Sacramento West Side Canal would, at times, receive inflow of surplus water from streams draining the easterly slope of the Coast Range.

With the exception of Iron Canyon Dam and the 950,000 acre-foot reservoir it would create under The California Water Plan, none of the foregoing works would present unusually difficult construction or consequent problems. Because of especially adverse foundation conditions at the Iron Canyon site, earthfill dam construction would probably be employed, with the reservoir area blanketed near the dam to reduce seepage to safe limits. In the design of the dam and appurtenant works, the first and paramount consideration would be that of safety. Inundation of upstream lands would be limited, insofar as possible by construction of dikes, with new lands brought under irrigation by the construction of associated local reservoirs on Cottonwood Creek and other streams draining into Iron Canyon Reservoir. The anadromous fishery would be preserved to the highest possible degree by construction of a large hatchery downstream and a fish ladder around the dam, together with development of spawning gravels at the hatchery site and along regulated streams entering the reservoir. All of these measures are considered to be warranted because of the strategic location of the reservoir and its importance in any truly comprehensive water development and flood control plan. Although no satisfactory alternative to the use of the Iron Canyon site has as yet been found, continued study in this direction should be undertaken in any future, more detailed investigation of Iron Canyon Reservoir.

The Redding Conduit, consisting of 2 miles of tunnel followed by 5 miles of open channel, would have a capacity of about 13,000 second-feet, and would con-

Shasta Dam, Sacramento River

Putah Diversion Dam, Putah Creek
Sacramento Division—Constructed Features of the California Aqueduct System

vey an average of about 5,600,000 acre-feet of water per year to Girvan Reservoir. The Anderson Conduit would be an open channel with a capacity of about 40,000 second-feet, corresponding to the peaking requirements of the Cottonwood Power Plant. It would convey an average of about 13,800,000 acre-feet of water per year to this 400,000-kilowatt power plant and, by intercepting local drainage, would also afford flood protection for the Anderson-Cottonwood area. The Cottonwood Power Plant would generate an average of about 1.5 billion kilowatt-hours per year.

Operating through a range of only 50 feet, Iron Canyon Reservoir would be utilized for power, conservation, and flood control. Because of this narrow operating range it would also afford unusual opportunities for fishing and recreational development. After accounting for ultimate local water use in upstream areas and the regulatory effects of existing and prospective upstream storage works, as well as unregulated local inflow and imports, releases from Iron Canyon Reservoir would average about 16,850,000 acre-feet per year. Of this, about 13,300,000 acre-feet would be a firm supply, 2,700,000 acre-feet would be secondary yield obtained through the beneficial use of regulated flood releases, and 850,000 acre-feet would be classified as spill. All of this water, except spill, would be released through the Iron Canyon Power Plant. This would be a base load plant with an installed capacity of about 200,000 kilowatts and an annual generation of about 1.7 billion kilowatt-hours.

At the Redbank diversion point on the Sacramento River about 9,850,000 acre-feet per season of the firm water supply would be diverted into the Sacramento West Side Canal, for further conveyance southward along the west side of the Sacramento Valley. This canal would have a capacity of about 15,000 second-feet to its junction with the Eel River Division at Putah Creek, and about 18,000 second-feet between that point and Montezuma Reservoir. The Willows and Dunnigan Power Plants along the canal would have capacities of about 90,000 and 76,000 kilowatts respectively and would generate an average of some 0.7 and 0.6 billion kilowatt-hours per year, respectively.

With the Eel River import, and with accretions enroute assumed to balance losses, the Sacramento West Side Canal would deliver about 11,770,000 acre-feet of water per year to Montezuma Reservoir. Of this, about 11,250,000 acre-feet would be released to the Delta Division of the California Aqueduct System for further conveyance southward; 208,000 acre-feet would be diverted for local use; and 308,000 acre-feet would be released to the North Bay Aqueduct for delivery to the North Bay area, comprising lands in Solano, Napa, Sonoma, and Marin Counties. The North Bay Aqueduct, consisting of alternating sections of canal and pipe line, with a few miles of tunnel, would extend westward about 59 miles past Fairfield and Cordelia to a small terminal reservoir about 2 miles northeast of Novato. Its capacity would progressively decrease from about 900 second-feet at the point of diversion to about 100 second-feet at the terminal near Novato.

The reservoirs along the main conduit route, namely, Redding Diversion, Girvan, Iron Canyon, Redbank Diversion, and Montezuma, would have a combined gross storage capacity of 1,336,000 acre-feet, of which about 355,000 acre-feet would be inactive, and 250,000 acre-feet would be reserved in Iron Canyon Reservoir for flood control. Additional flood control storage space, in the amount of about 300,000 acre-feet, would be available in Kanaka Reservoir on Clear Creek and in the local reservoirs of the Redding Stream Group, all draining into Iron Canyon Reservoir. The reservation of a total of 550,000 acre-feet of storage space for flood control in the reservoirs between Red Bluff and Shasta Dam may make it possible in the future to reduce the amount of such space now reserved in Shasta Reservoir, with consequent increased power and conservation benefits. The four power plants along the Main West Side Conduit Route would have a combined installed capacity of about 766,000 kilowatts and would generate an average of about 4.5 billion kilowatt-hours per year. The continuance of mandatory releases to the Sacramento River below Redbank Diversion Dam, together with the conveyance of sewage and industrial wastes from the Redding area by separate channel, would preserve the quality of water in the river and maintain its highly important fishery and recreational status.

Other Features of Sacramento Division. The works considered under this heading comprise both existing and prospective surface and ground water storage reservoirs in the Sacramento River Basin that would develop and regulate water for export from the Delta and from the American River; the power plants associated with these reservoirs; the Sacramento River and streams tributary thereto, through which the regulated water would flow to the Delta; and the Folsom South Canal, diverting from Lake Natoma on the American River into the lower east side of the San Joaquin Valley. Water supplies for export are presently or will in the near future be developed in Shasta, Folsom, and Monticello Reservoirs. These reservoirs and the new reservoirs considered herein would also perform important local as well as export functions. They have been described, together with their associated power plants, earlier in this chapter under the heading of "Development to Meet Local Requirements."

Prospective new reservoirs would consist of Guinda on Cache Creek, or alternative thereto, Wilson Valley or Blue Ridge, both on Cache Creek; Black Butte on Stony Creek; Brush Creek Basin comprising off stream storage principally for Mill and Deer Creeks; Castle Rock on Butte Creek, with connecting diversion tunnel from Big Chico Creek; Oroville on the Feather River, including afterbay power and regulatory facilities; Parks Bar on the Yuba River; Waldo on Dry Creek, a tributary of the Bear River, providing off-stream storage for Yuba River water; Camp Far West on the Bear River; Auburn on the North Fork of the American River; and Salmon Falls on the South Fork of the American River or, alternative thereto, Nashville on the Cosumnes River which would provide off-stream storage for water from the South Fork of the American River. All of these reservoirs would be located at or near the foothill line. On the major streams they would be large multipurpose reservoirs; and on less important streams their principal local function would be irrigation and/or flood control. Together with Folsom and Shasta, these reservoirs would have a combined capacity of nearly 12,000,000 acre-feet, of which about 1,250,000 acre-feet would be inactive and 2,700,000 acre-feet would be reserved for flood control. Additional flood control storage space in the amount of about 1,000,000 acre-feet would be reserved in all other reservoirs of the Sacramento River Basin, including the 550,000 acre-feet previously accounted for in Iron Canyon and associated reservoirs.

After taking into account the requirements for local use in upstream areas and on the Sacramento Valley floor, the existing and prospective reservoirs considered under this heading would make available for use in the Delta and for export from the Delta and from the American River, an average of about 9,300,000 acre-feet of water per year. Depending upon the manner in which the reservoirs may eventually be operated in conjunction with ground water storage in the alluvium of the Sacramento Valley, 60 to 80 per cent of the water would be made available for export on a firm basis each year, while the remainder would be a variable supply available only in years of heavy runoff. Further firming of the variable supply would be accomplished by operation of ground water storage in the San Joaquin Valley. The subject of conjunctive operation has been briefly considered earlier in this chapter in connection with developments to meet local requirements in the Sacramento River Basin. The subject is also discussed more fully later in this chapter under the heading "Utilization of Ground Water Storage."

New power plants associated with the prospective reservoirs would be located at the bases of Oroville, Parks Bar, Auburn, and Salmon Falls or Nashville Dams. The Parks Bar Power Plant, however, would utilize water diverted by tunnel from Englebright Reservoir, instead of a direct connection to Parks Bar Reservoir. The power head available below Oroville Dam would be developed by one or more power plants located on the Thermalito Power Canal, between a diversion dam on the river below the main Oroville Power Plant and an off-stream afterbay reservoir. The new power plants would have a combined installed capacity of about 710,000 kilowatts and would generate an average of about 2.9 billion kilowatt-hours per year. Of this amount about 0.6 billion kilowatt-hours would be required for operation of ground water pumping facilities. New power developed by releases from Shasta Reservoir at the Cottonwood and Iron Canyon Power Plants is credited to works along the Main West Side Conduit Route.

About 640,000 acre-feet per season of the export supply would be diverted from Lake Natoma, afterbay for Folsom Reservoir, into the lower east side of the San Joaquin Valley through the Folsom South Canal, currently proposed for construction by the United States Bureau of Reclamation. This canal would divert with a capacity of about 3,550 second-feet and terminate at Lone Tree Creek, 63 miles to the south, with a capacity of 330 second-feet. An additional quantity of water amounting to about 76,000 acre-feet per season would be diverted from the South Fork of the American River into the upper Cosumnes River Basin.

If off-stream storage for water from the South Fork of the American River is obtained in Nashville Reservoir on the Cosumnes River instead of in Salmon Falls Reservoir, a far larger quantity of water would be diverted from the South Fork into the upper Cosumnes River Basin. Similarly, subsequent studies may indicate the desirability of doubling the diversion southward from Lake Natoma; but it is assumed for purposes of this report that the bulk of the export supply from the American River would flow to the Delta for further conveyance to other areas of the State. All of the remaining export supply of the Sacramento River Basin, not previously accounted for, would flow to the Delta through the Sacramento River and tributary channels. Releases from Shasta Reservoir, for example, after further regulation in Iron Canyon Reservoir, would flow down the Sacramento River to the Delta with diversions enroute for local use, as at present. In this connection, it is pertinent to note that the present deleterious effects of seepage from the river may be alleviated to a considerable degree by lowering of ground water levels along the river as a consequence of the planned utilization of ground water storage.

Summary of Sacramento Division. The Sacramento Division comprises the storage, power, and conveyance facilities in the Sacramento River Basin that would conserve and regulate the surplus waters of the basin and convey these and imported supplies to terminal diversion points for export. There would be 15 major reservoirs, including Shasta and Folsom which presently serve these purposes; 4 diversion dams and

Sacramento Division—Constructed Features of the California Aqueduct System, Folsom and Nimbus Dams (top and bottom) on the American River

TABLE 21

SUMMARY OF SACRAMENTO DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location, MDB&M, and sheet of Plate 5 on which shown		Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use
Redding	Sacramento River	Sec. 27, T32N, R5W	3	CG	50	513			a	D	1
Girvan	Clear Creek	Sec. 26, T31N, R5W	3	E	70	500	26,000	6,000	a	P	1
Iron Canyon	Sacramento River	Sec. 35, T28N, R3W	4	E	155	400	950,000	750,000	a	I,U,P,FC,R,F	1
Red Bank	Sacramento River	Sec. 33, T27N, R3W	4	CG	50	252			a	D	1
Montezuma	Montezuma Slough	Sec. 14, 23, T4N, R1W	8	E	54	50	360,000	225,000	a	S	1
Guinda [c]	Cache Creek	Sec. 32, 33, T12N, R3W	7	E	170	510	303,000	295,000	b	I,U,P,FC,R,F	2
Black Butte	Stony Creek	Sec. 31, T23N, R4W	5	E	115	474	160,000	145,000	b	I,U,P,FC,R,F	2
Brush Creek Basin	Brush Creek	——T23, 24N, R1W	6	E	62	278	100,000	92,000	b	I,U,P,FC,R,F	2
Castle Rock	Butte Creek	Sec. 36, T22N, R2E	6	E	178	503	100,000	90,000	b	I,U,P,FC,R,F	2
Oroville	Feather River	Sec. 1, 2, T19N, R4E and Sec. 35, T20N, R4E	6	CG	730	900	3,523,000	3,068,000	b	I,U,P,FC,R,F	2
Oroville											
Afterbay No. 1	Feather River	Sec. 5, T19N, R4E	6	CG	126	220			b	P	2
Afterbay No. 2	Feather River (off-stream)	Sec. 31, 32, 33, T19N, R3E	6	E	29	125			b	P	2
Parks Bar	Yuba River	Sec. 29, T16N, R6E	6	E	300	480	243,000	200,000	b	I,U,P,FC,R,F	2
Waldo	Dry Creek	Sec. 33, T15N, R6E	6	E	227	437	300,000	290,000	b	I,U,P,FC,R,F	2
Enlarged Camp Far West	Bear River	Sec. 21, T14N, R6E	6	E	225	350	242,000	240,000	b	I,U,P,FC,R,F	2
Auburn	North Fork American River	Sec. 26, T12N, R8E	8	E&R	480	920	868,000	768,000	b	I,U,P,FC,R,F	2
Salmon Falls	South Fork American River	Sec. 30, T11N, R9E	8	R	395	830	630,000	600,000	b	I,U,P,FC,R,F	2
Totals							7,805,000	6,769,000			

TABLE 21—Continued

SUMMARY OF SACRAMENTO DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Power plant	Location, MDB&M, and sheet of Plate 5 on which shown		Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours
Cottonwood	Sec. 6, T29N, R3W	3	120	400,000	1,500,000,000
Iron Canyon	Sec. 4, T27N, R3W	4	120	200,000	1,700,000,000
Willows	Sec. 13, T18N, R4W	5	80	90,000	700,000,000
Dunnigan	Sec. 21, T12N, R1W	8	68	76,000	600,000,000
Oroville	Sec. 2, T19N, R4E	6	558	440,000	1,720,000,000
Thermalito	Between Oroville Power Plant and Afterbay Dam		90	68,000	230,000,000
Parks Bar	Sec. 20, T16N, R6E	6	270	48,000	172,000,000
Auburn	Sec. 26, T12N, R8E	8	439	110,000	485,000,000
Salmon Falls	Sec. 31, T11N, R9E	8	358	43,000	235,000,000
Totals				1,475,000	7,342,000,000

Conduits	Maximum capacity in second-feet	Length, in miles			
		Canal	Tunnel	Pipe	Total
Redding	13,000	5	2	--	7
Anderson	40,000	11	--	--	11
Sacramento West Side Canal					
Red Bluff to Putah Creek	15,000	146	--	--	146
Putah Creek to Montezuma Reservoir	18,000	21	--	--	21
North Bay Aqueduct	1,000	40	3	11	54
Folsom South Canal	3,600	63	--	--	63
Totals		286	5	11	302

[a] Including imported supplies from the North Coastal Area, these reservoirs would make 11,708,000 acre-feet of water per year available for export from Montezuma Reservoir to the North Bay area and other deficient areas south of the Delta.

[b] These reservoirs, operated in conjunction with Shasta and Folsom Reservoirs and with ground water, would, after full satisfaction of local requirements, develop an average of 8,579,000 acre-feet of water per year.

[c] Wilson Valley or Blue Ridge Reservoir, alternative to Guinda Reservoir.

[1] South of Delta and in North San Francisco Bay area.

[2] Sacramento Valley and south of Delta.

Symbols of Type of Dam
E—Earthfill
R—Rockfill
CG—Concrete gravity

Symbols of Purpose
D—Diversion to conduit
P—Power generation
R—Recreation
F—Enhancement of fish environment

Symbols of Purpose
I—Irrigation
FC—Flood control
U—Urban (domestic, municipal, industrial)
S—Reregulation of waters to local demand schedule

terbays; 9 or 10 hydroelectric power plants; 185 iles of large-capacity conduit that would convey irt of the surplus waters of the basin and imports om the North Coastal Area to Montezuma Reser-ir; 117 miles of delivery conduit; and the Sacra-ento River and other natural channels of the basin ed for conveyance of water to the Delta.

The reservoirs of the Sacramento Division would ve a combined storage capacity of about 13,300,000 re-feet, of which about 1,600,000 acre-feet would inactive and 11,700,000 acre-feet would be used for nservation and flood control. These reservoirs would operated in conjunction with local storage works d eventually with part of the available ground wa-r storage in the Sacramento Valley. After allowing r ultimate requirements in upstream areas and on e Sacramento Valley floor, and taking into account e availability of return flow, these reservoirs would instrumental in developing an average of about ,280,000 acre-feet of water per season for export. Of is amount, about 790,000 acre-feet would be diverted om the Sacramento River near Red Bluff and con-yed, together with imported supplies from the North oastal Area, to Montezuma Reservoir for further dis-ibution. About 720,000 acre-feet of the remaining port supply would be diverted from the American ver, and about 8,700,000 acre-feet would serve pres-t and future local and export requirements at the lta. Another 55,000 acre-feet per season, not pre-ously accounted for in this discussion, would be di-rted from Putah Creek below Monticello Reservoir the Eel River Division. Local and imported water pplies made available for export from Montezuma servoir would aggregate about 11,770,000 acre-feet r year. In their local function the reservoirs of the cramento Division would provide opportunities for creational development, regulate water supplies for al use, enhance and improve stream flow for fish, ldlife, and recreation, and maintain navigable pths on the Sacramento River, as required by law.

The new power plants of the Sacramento Division ould have a combined installed capacity of about 476,000 kilowatts. They would generate an average about 7.4 billion kilowatt-hours per year, of which out 0.6 billion killowatt-hours would be required operate the ground water pumping facilities in the cramento Valley associated with development of e export supply.

Features of the Sacramento Division could be con-ructed singly or in combination, on a logical and derly basis, as demands for water, power, and flood ntrol develop. The works of the Main West Side nduit Route, for example, between the Redding and d Bank diversions, could be undertaken to conserve e local water supply, develop the present power po-ntial between these points, provide flood protection r the Sacramento Valley, and afford opportunities for recreational development. These facilities would then be available to accommodate the future imports from the Klamath-Trinity Division if and when these works become necessary.

The general features of the Sacramento Division are presented in Table 21, and the capital costs are summarized in Table 22. The facilities comprising the Sacramento Division are shown on Sheets 3 through 8 of Plate 5.

TABLE 22

SUMMARY OF CAPITAL COSTS, SACRAMENTO DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Features Along Main West Side Conduit Route	
Redding Diversion Dam	$1,000,000
Redding Conduit	18,750,000
Girvan Dam and Reservoir	4,650,000
Anderson Conduit (including measures to prevent seepage)	14,700,000
Cottonwood Power Plant	55,000,000
Iron Canyon Dam and Reservoir	61,000,000
Fish facilities at and below Iron Canyon Dam	12,500,000
Iron Canyon Power Plant	32,000,000
Redbank Diversion Dam	5,600,000
Sacramento West Side Canal	293,000,000
Willows Power Plant	24,200,000
Dunnigan Power Plant	23,100,000
Montezuma Dam and Reservoir	14,600,000
North Bay Aqueduct	26,700,000
Local diversions from Montezuma Reservoir	1,900,000
Other Features	
Guinda Dam and Reservoir, or alternative at Wilson Valley or Blue Ridge	14,000,000
Black Butte Dam and Reservoir	17,000,000
Brush Basin Dam and Reservoir, including floodway channels from Mill, Deer, and Rock Creeks	12,200,000
Castle Rock Dam and Reservoir, including diversion tunnel from Big Chico Creek	8,700,000
Oroville Dam and Reservoir	374,000,000
Oroville Power Plant	37,000,000
Oroville Diversion Dam	5,000,000
Oroville Afterbay Dam and Reservoir	5,500,000
Thermalito Power Plant	13,000,000
Thermalito Power Canal	9,000,000
Parks Bar Dam and Reservoir	16,900,000
Parks Bar Power Plant	3,000,000
Waldo Dam and Reservoir, including diversion conduit from Yuba River and Deer Creek Diversion	14,450,000
Camp Far West Dam and Reservoir	15,550,000
Auburn Dam and Reservoir	36,000,000
Auburn Power Plant	11,000,000
Salmon Falls Dam and Reservoir	22,500,000
Salmon Falls Power Plant	5,100,000
Folsom South Canal	40,000,000
Ground water pumping facilities	36,400,000
Total	$1,285,000,000

* At 1955 price levels.

Delta Division

The Delta Division of the California Aqueduct System would accomplish the transfer of water across the Sacramento-San Joaquin Delta on its journey from northern areas of water surplus to central and southern areas of deficiency. It would be the "hub" of the California Aqueduct System, bringing together the surplus waters developed by the Klamath-Trinity, Eel River, and Sacramento Divisions, and lifting these waters from the southerly side of the Delta into major conduits for conveyance southward and westward. It would also provide urgently needed flood protection and salinity control for the Delta lands.

The major works of the Delta Division would consist of two features: first, the Cross-Delta Canal of the Biemond Plan, utilizing natural and modified channels hydraulically isolated from the remainder of the Delta, and a siphon under the San Joaquin River to transfer the greater portion of the water developed in the Sacramento River Basin; and second, a conduit leading from Montezuma Reservoir to the southerly edge of the Delta, and including a siphon beneath the Sacramento and San Joaquin Rivers near Antioch to transfer the water developed in the North Coastal Area and the upper Sacramento River Basin and delivered to the Delta by the Sacramento West Side Canal. Hydraulic separation is necessary to prevent undue loss in transit and impairment in quality. Associated facilities of the Biemond Plan would include control structures on the Sacramento River and Steamboat Slough, a system of master levees along flood channels, floodways and control structures at several locations, barge locks, and fishways to pass anadromous fish. These facilities are described herein under the heading "Trans-Delta System."

Other features of the Delta Division are the South Bay Aqueduct and the Kirker Pass Aqueduct, which would serve the southern portions of the San Francisco Bay Area and the northern portions of the Central Coastal Area. Both of these aqueducts are distribution features of the Delta Division, as contrasted with other features designed as primary transmission facilities. They are subsequently discussed in this section under their respective headings.

The general location of the Delta Division is shown on Plate 6, and its component facilities are delineated on Sheets 8, 10, and 13 of Plate 5.

Trans-Delta System. Facilities of the Trans-Delta System would ultimately transfer some 18,330,000 acre-feet of water per season, on the average, across the Delta for conveyance to areas of deficiency in central and southern California and in the San Francisco Bay Area. The ultimate transfer across the Delta of water developed in the Sacramento River Basin would be accomplished by construction of an isolated canal and control structures, as hereinafter explained. As unregulated flows of the Sacramento and San Joaquin Rivers are reduced in the future by increased upstream storage developments for local use and for export of water, it will become necessary to segregate and prevent commingling, during transit, of the imported and locally developed waters of high quality with the drainage and flushing waters of poor quality which occur in and drain to the Delta. Segregation of these waters would be accomplished by facilities of the Biemond Plan. Controlled releases of water to Suisun Bay for salinity repulsion would lik wise be reduced.

1. *Biemond Plan.* Alternative barrier plans f salinity control in the Delta and for transfer of wat across the Delta were studied under authorization the Abshire-Kelly Salinity Control Barrier Act 1953. Ir. Cornelus Biemond, Consulting Engineer fro The Netherlands, who was retained during that i vestigation, recommended a plan with facilities f fresh-water transfer in an isolated system of channe and a master levee system along principal floo channels for flood protection to the Delta islands. Th details of that investigation are presented in th report of the Water Project Authority of Californ entitled "Feasibilty of Construction by the State Barriers in the San Francisco Bay System," date March 1955. In 1955, the Legislature enacted th Abshire-Kelly Salinity Control Barrier Act of 195 which directed further study of barrier plans, an the Biemond Plan, as presently proposed, was deve oped during this investigation, currently (1957) i progress. Details of this investigation are present in a report of the Department of Water Resource Bulletin No. 60, entitled "Salinity Control Barri Investigation."

The Biemond Plan was designed to transfer wat across the Delta, to provide flood protection to th Delta, and to conserve salinity control flows. Son flood flows would be conveyed through the Cros Delta Canal, thereby reducing the lengths of mast levees and the costs of construction and maintenanc

The Biemond Plan would have control structur on the Sacramento River and Steamboat Slough divert water through the existing Delta Cross Chann into the proposed Cross-Delta Canal, and to provi sufficient hydraulic gradient in the canal to conv water to the major pumping plants on the southe fringe of the Delta. A barge lock and fishway wou be located at the Sacramento River control structu The Cross-Delta Canal would follow improved exis ing channels, and water would pass under the Stoc ton Deep Water Channel in large, inverted sipho located near Little Venice Island in the center of t Delta. Flood flows of the Mokelumne and Cosumn River would be conveyed in the Cross-Delta Canal Little Venice Island where the flood waters would discharged through a floodway structure into the S Joaquin River. All or a portion of these flows cou be conveyed to the major pumping plants. A fishw would also be provided at Little Venice Island. A p tion of the flood flows of the San Joaquin River wou be diverted via Paradise Cut and Grant Line Ca to the major pumping plants. The portion of the flo not required for diversion by the major pumpi plants would be discharged from the Cross-Delta C nal through a floodway structure into Franks Tr and then into the San Joaquin River. A barge lo ould also be located at this structure. The structure the head of Paradise Cut would be designed to ivert San Joaquin River water whenever the quality satisfactory. The portion of the flood flows not iverted into Paradise Cut would be carried in the an Joaquin River channel.

A system of master levees would be constructed on e Cross-Delta Canal, on Paradise Cut, on Grant ine Canal, and on the San Joaquin River. Bear reek would be diverted to the Calaveras River which ischarges into the San Joaquin River near Stockton. aster levees would also be constructed on the Cala-eras River. During flood periods on the Sacramento iver, the control structure on the river and on teamboat Slough would be opened to permit unim-eded passage of flood waters. A system of master vees would restrict the flood water of the Sacra-ento River system to the river, to Steamboat Slough, nd to the Yolo By-Pass.

The system of master levees throughout the Delta ould reduce the length of levees now requiring aintenance against flood and tidal forces from about 000 miles to 450 miles. The interior channels, which ould be severed during construction of the master vee system and would not be subject to tidal or ood waters, would continue to serve as irrigation nd drainage channels. Water would be released into ese channels from the Cross-Delta Canal, and fa-lities would be provided for pumping drainage ater out of the channels. Operation of the Biemond lan would provide adequate circulation and high-uality water in the interior channels.

Salinity intrusion into the Delta from sea water ould be controlled under operation of the Biemond lan by regulated outflows into Suisun Bay. Under peration of the Biemond Plan, salinity could be con-olled at the western end of the Delta with an aver-ge outflow of about 1,200 second-feet as compared to n average outflow of about 3,800 second-feet for com-arable control under present conditions. This major duction in outflow would result from the reduction the tidal prism, or the volume of water which flows to and out of the Delta during a tidal cycle, by vering many Delta channels from tidal action. The duction in required outflow under operation of the iemond Plan would be a measure of the con-rvation by that plan. This conserved water would available for distribution to water-deficient areas.

The Biemond Plan would ultimately transport some 080,000 acre-feet of water per season, on the aver-ge, across the Delta. Facilities also would be provided distribute some 756,000 acre-feet per season to meet onsumptive use requirements of agricultural lands the Delta. Finally, it would provide releases of ater averaging 876,000 acre-feet per season, for re-ulsion of sea water from the Delta, which would be substantially less than the presently required releases, as previously explained.

2. *Antioch Crossing.* The Antioch Crossing, comprising the second major feature of the Trans-Delta System, would provide the means by which waters developed in the North Coastal Area and the upper Sacramento River Basin, and conveyed through the Sacramento Valley in the Sacramento West Side Canal, would be transported across the Delta. It would convey the water in a canal from Montezuma Reservoir, the terminus of the Sacramento West Side Canal, southeasterly to the Sacramento River about 4 miles east of Collinsville. It would then pass beneath the Sacramento River in a 3,000-foot siphon consisting of four 25-foot diameter concrete pipes. After crossing the western portion of Sherman Island it would pass beneath the San Joaquin River in a similar siphon, discharging into two parallel, concrete-lined canals near the town of Antioch.

The Antioch Crossing would then skirt the southwesterly edge of the Delta, finally terminating in the intake channel of the Mountain House Pumping Plant at approximately sea level elevation. The total length of the crossing would be 33 miles. It would have a capacity of 17,000 second-feet, and would transport about 11,250,000 acre-feet per season. Installation of identical parallel conduits would lend itself to staged construction of the Antioch Crossing.

3. *Delta Pumping Plants.* Virtually all water conveyed across the Sacramento-San Joaquin Delta by the Trans-Delta System would be lifted from the Delta by three pumping plants: the existing Tracy Pumping Plant which is a part of the Central Valley Project; the proposed Delta Pumping Plant of the Feather River Project; and the Mountain House Pumping Plant. All three would be located in close proximity to each other in an area about 10 miles northwest of the town of Tracy. Water transported through the Biemond Plan facilities would be lifted into the Delta-Mendota Canal and the Feather River Aqueduct by the Tracy and Delta Pumping Plants, respectively. The Mountain House Pumping Plant would lift water from the Antioch Crossing into the San Joaquin West Side Conduit. The Feather River Project Aqueduct and the San Joaquin West Side Conduit are described as part of the San Joaquin Division of the California Aqueduct System.

In summary, the Trans-Delta System would be comprised of three major facilities. These are: (1) the Biemond Plan, which would transfer water across the heart of the Delta in an isolated channel, and provide flood protection and salinity control for the Delta, (2) the Antioch Crossing, which would convey water beneath the Sacramento and San Joaquin Rivers by siphon, and (3) the Delta Pumping Plants, which would lift some 18,020,000 acre-feet per season, into facilities of the San Joaquin Division.

Delta Division—Constructed Features of the California Aqueduct System. Delta Cross-Channel Headworks on the Sacramento River and the Tracy Pumping Plant on Old River

Kirker Pass Aqueduct. The Kirker Pass Aqueduct would consist of those facilities necessary to serve areas in Contra Costa County not considered susceptible to service by the East Bay Municipal Utility District or the Contra Costa Canal. This aqueduct would convey about 164,000 acre-feet of water per season from the Antioch Crossing of the Delta Division in a general southwesterly direction about 21 miles to a terminal storage reservoir located about 2 miles west of the community of Clayton.

In pipe line and canal, water would be pumped from the Antioch Crossing siphon on the south shore of the San Joaquin River, about 4 miles east of Antioch, through a series of three pumping plants to an elevation of 500 feet to the portal of a tunnel through Kirker Pass, generally south of Camp Stoneman.

The water would flow by gravity through the 2 miles of Kirker Pass Tunnel, and then would be conveyed by canal to Lime Ridge Reservoir. Lime Ridge Reservoir would be a terminal reservoir, with water surface elevations varying from a maximum of about 400 feet to a minimum of 370 feet, which would be sufficient to serve most of the water service areas by gravity.

South Bay Aqueduct. The South Bay Aqueduct of the Delta Division would pump and deliver 755,000 acre-feet of water per season from the Feather River Project Aqueduct to the service areas in the Southeast Bay Group of the San Francisco Bay Area and in the San Benito and Santa Cruz-Pajaro Groups of the Central Coastal Area. The necessity of avoiding conflict or duplication between the service area of the City of San Francisco for municipal and industrial water and the proposed service area of the South Bay Aqueduct is recognized. Any deviation from the foregoing should be made only after a showing of convenience and necessity. The aqueduct would be built in two stages. The initial stage would comprise the Alameda-Contra Costa-Santa Clara-San Benito Counties Branch of the authorized Feather River Project Aqueduct. Deliveries of water would be increased to the ultimate stage by subsequent construction of additional diversion and conveyance works which would parallel the facilities of that branch.

The initial stage of the South Bay Aqueduct would divert water from the Feather River Project Aqueduct about 2 miles south of the aqueduct headworks, about 8 miles west of Tracy. A re-lift pumping plant at that location would lift the water from the Feather River Project Aqueduct to a tunnel through Brushy Peak in the Coast Range at an elevation of about 7[illegible] feet. From Brushy Peak Tunnel water would be conveyed by canal, tunnel, and pipe line around the east and south sides of Livermore Valley, through Mission Pass. The conduit, in pipe line, would then continue southerly, passing to the east of Mission San Jose and Warm Springs to the proposed Airpoint Reservoir on Arroyo de las Coches, 2 miles east of Milpitas, and to Evergreen Reservoir on Silver Creek, about 6 miles southeast of San Jose. These reservoirs, with storage capacities of 23,000 and 32,500 acre-feet respectively, would be constructed for regulation of the continuous diversion to the variable monthly demands in the Santa Clara Valley and San Benito County. Recent subsurface exploration at Airpoint dam site indicates that considerable leakage might develop through the fractured rocks that comprise its abutments. Further investigation of this site may indicate the desirability of selecting an alternative reservoir.

A conduit, principally canal section, would extend southeasterly along the base of the hills on the east side of Santa Clara Valley to a terminus near Pacheco Creek north of Hollister. Water would be released into Pacheco Creek from the terminus of the South Bay Aqueduct for use in the San Benito and Santa Cruz-Pajaro Groups in the Central Coastal Area.

The initial stage of the South Bay Aqueduct would deliver 195,000 acre-feet per season to units of the Southeast Bay Group and 50,000 acre-feet to the San Benito and Santa Cruz-Pajaro Groups in the Central Coastal Area. The remaining ultimate supplemental requirements in those units, amounting to an estimated 510,000 acre-feet per season, would be provided by construction of additional diversion and conveyance facilities which would parallel and supplement deliveries by the initial stage. The additional works would comprise a diversion from the Feather River Project Aqueduct and conveyance facilities of the same types, lengths, and locations previously described for the initial stage between the point of diversion and Evergreen Reservoir.

Water for the San Benito and Santa Cruz-Pajaro Groups would be conveyed at a uniform rate in the canal of the initial stage of the South Bay Aqueduct southward to the Harper Canyon regulatory storage reservoir on Pacheco Creek. At a future time the canal of the initial stage of the South Bay Aqueduct would be extended 7 miles to Harper Canyon Reservoir. Additional regulatory storage would also be constructed on Arroyo del Valle in Livermore Valley.

Under ultimate operation of the South Bay Aqueduct, the major portion of storage in Sanatorium Reservoir on Arroyo del Valle would be utilized to regulate the continuous flow to the variable monthly demand schedule in Livermore Valley and southern Alameda County. Deliveries to the San Benito and Santa Cruz-Pajaro Groups in the Central Coastal Area would be increased from the initial quantity of 50,000 acre-feet per season, to an ultimate quantity of 128,000 acre-feet per season, and would be regulated in Harper Canyon Reservoir on Pacheco Creek about 12 miles east of Gilroy. Harper Canyon Reservoir

TABLE 23

SUMMARY OF DELTA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Conveyance facilities	Conduits						Pumping plants		
	Maximum capacity, in second-feet	Length, in miles					Total number	Total installed capacity, in kilowatts	Total seasonal power consumption, in kilowatt-hours
		Canal	Tunnel	Pipe	Siphon	Total			
Trans-Delta System									
Cross-Delta Canal	20,000	54.9			0.1	55.0	2	378,000	1,607,000,000
Antioch Crossing	17,500	32.0			4.0	36.0	1	276,000	2,080,000,000
Kirker Pass Aqueduct	220	15.2	1.0	3.7		19.9	3	17,000	130,000,000
South Bay Aqueduct	1,040	73.8	2.3	31.3		107.4	4	67,000	456,000,000
Totals		175.9	3.3	35.0	4.1	218.3	10	738,000	4,273,000,000

Dam and reservoir*	Location. MDB&M, shown on Sheet 10 of Plate 5	Type of dam	Height of dam, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet	Place of water use
Trans-Delta System (transmission only)						
Kirker Pass Aqueduct						
Lime Ridge Reservoir	Sec. 16, T1N, R1W	E	148	472	12,100	Contra Costa County
South Bay Aqueduct						
Sanatorium Reservoir	27,000 acre-feet of storage allocated to regulation of deliveries by South Bay Aqueduct, 17,000 acre-feet to local development. See Table 10.					Livermore Valley
Airpoint Reservoir	Sec. 4, T6S, R1E	E	250	611	22,500	Santa Clara County
Evergreen Reservoir	Sec. 29, T7S, R2E	E	197	538	31,700	Santa Clara County
Harper Canyon Reservoir	Sec. 5, T11S, R6E	E	150	413	65,000	San Benito and Santa Cruz Counties
Total					148,300	

Symbol of Type of Dam
E—Earthfill

*Provide regulation of imported water to monthly schedule at place of water use.

ɔuld permit the conveyance of water to the Central ɔastal Area on a continuous-flow basis, rather than ı a variable monthly demand schedule.

Should the need be indicated, water could be de- ;ered to the northern portion of Livermore Valley ıd the southern portion of Contra Costa County by ı alternative route of the South Bay Aqueduct. This ternative would convey water from Brushy Peak ınnel along the northern edge of Livermore Valley a regulatory reservoir in Doolan Canyon, and ɔuld then proceed southwesterly across the valley to e main alignment west of La Costa, as shown on ıeet 10 of Plate 5.

Summary of Delta Division. The Delta Division ɔuld transfer some 18,330,000 acre-feet of water veloped in the North Coastal Area and Sacramento ver Basin, across the Sacramento-San Joaquin Delta r further conveyance to areas of deficiency. The ossing of the Delta would be accomplished by facil- es of the Trans-Delta System, utilizing two major utes. One route, the Biemond Plan, would consist of isolated fresh-water channel and flood channels, th master levees, and control structures at several ations to facilitate the transfer of water and the ntrol of flood flows. Salinity intrusion into the lta would be controlled by regulated outflow into uisun Bay. About 7,080,000 acre-feet of water per ason would be conveyed across the Delta by this ute. The other route, the Antioch Crossing, would nsist of a canal from Montezuma Reservoir to the inity of Collinsville, a number of siphons under the cramento and San Joaquin Rivers to the vicinity of ıtioch, and a canal skirting the edge of the Delta to erminus at Mountain House Pumping Plant. About ,250,000 acre-feet of water per season would be ınsferred across the Delta by this route.

Water delivered to the southern edge of the Delta facilities of the Trans-Delta System would be lifted o conduits of the San Joaquin Division by three ıjor pumping plants, namely (1) the Tracy Pump- ig Plant of the Central Valley Project, (2) the lta Pumping Plant of the authorized Feather River oject, and (3) the Mountain House Pumping Plant. ese pumping plants would lift 1,780,000 acre-feet, 55,000 acre-feet, and 10,185,000 acre-feet, respec- ely, from the Delta to facilities of the San Joaquin vision.

An additional 164,000 acre-feet per season would diverted from the Antioch Crossing and conveyed the Kirker Pass Aqueduct to service areas in ntra Costa County not considered susceptible of vice by the East Bay Municipal Utility District or e Contra Costa Canal. Finally, the South Bay Aque- ct would pump and deliver about 755,000 acre- t of water per season to the Southeast Bay Group the San Francisco Bay Area and to the San Benito and Santa Cruz-Pajaro Groups of the Central Coastal Area.

The general features of the Delta Division are presented in Table 23 and the capital costs of its component facilities are shown in Table 24. The facilities comprising the Delta Division are shown on Sheets 8, 10, and 13 of Plate 5.

TABLE 24

SUMMARY OF CAPITAL COSTS, DELTA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Trans-Delta System	
Biemond Plan	
Control structures	$16,340,000
Cross-Delta Canal	39,830,000
Flood control channel levees	12,500,000
Irrigation and drainage	1,170,000
Antioch Crossing	212,840,000
Pumping Plants	
Tracy Pumping Plant	existing facility
Delta Pumping Plant (Feather River Project)	37,260,000
Mountain House Pumping Plant	57,300,000
Subtotal	$377,240,000
Kirker Pass Aqueduct	
Pumping plants	$2,610,000
Conduit	6,030,000
Lime Ridge Reservoir	4,340,000
Subtotal	$12,980,000
South Bay Aqueduct	
Initial stage (Alameda-Contra Costa-Santa Clara-San Benito Counties Branch of Feather River Project Aqueduct)	
Pumping plants	$3,510,000
Conduit	37,440,000
Airpoint Reservoir	8,820,000
Evergreen Reservoir	7,090,000
Additional works under ultimate stage	
Pumping plants	5,780,000
Conduit	27,980,000
Santorium Reservoir (see Table 10)	----------------
Harper Canyon Reservoir	7,560,000
Subtotal	$98,180,000
Total	$488,400,000

* At 1955 price levels, with exception of Biemond Plan which is based on 1956 levels.

San Joaquin Division

The San Joaquin Division of the California Aqueduct System would accomplish two objectives in the disposition of regulated surplus waters from the northern part of the State, delivered to the southerly end of the Delta by the previously described Delta Division. First, it would convey and deliver supplemental water to deficient areas in the San Joaquin Valley and the Central Coastal Area; and second, it would transport water to the Buena Vista Forebay of the Southern California Division for delivery to areas south of the Tehachapi Mountains. In the delivery of water to the San Joaquin Valley, substantial use would be made of the extensive ground water storage capacity beneath the valley floor, particularly for providing final regulation of the variable seasonal secondary waters imported from the Sacramento River Basin during wet years.

The San Joaquin Division would consist of the existing Delta-Mendota Canal of the Central Valley Project and the authorized Feather River Project Aqueduct as its initial features, and an additional conduit under ultimate operation. These facilities will be described herein under the heading "Main Aqueduct Route." Also included as features of the division are the Central Coastal Aqueduct, which would divert water from the Main Aqueduct Route in Kings County near Devils Den to serve San Luis Obispo and Santa Barbara Counties, and the Carrizo-Cuyama Aqueduct, which would divert water from the California Aqueduct about 5 miles south of Buena Vista Lake to serve lands in southeastern San Luis Obispo County and the eastern portion of Santa Barbara County. It should be pointed out that the Carrizo-Cuyama Aqueduct would actually divert water from facilities of the Southern California Division; but since the aqueduct would serve the Central Coastal Area, it has been included as a feature of the San Joaquin Division. These additional features of the San Joaquin Division will be described herein under their respective titles.

Further and more detailed investigations of the Feather River Project Aqueduct System are currently (May, 1957) in progress as part of the final engineering studies looking toward construction of the project. These studies may result in substantial modification of the system as it relates to service of water to lands south of Devils Den in the San Joaquin Valley and to southern California, from that described herein. Water may be supplied to central coastal areas from the Feather River Project if justified by the demand there. These studies have not yet been sufficiently completed to enable the inclusion of any results herein.

The general location of the San Joaquin Division is shown on Plate 6, and its component facilities are delineated on Sheets 8, 10, 13, 14, 16, 17, and 20 of Plate 5.

Main Aqueduct Route. In addition to the existing Delta-Mendota Canal, features of the Main Aqueduct Route would ultimately include three parallel concrete-lined canals extending some 250 miles southward from the Delta Pumping Plants to the Buena Vista Forebay near Taft in the upper end of the San Joaquin Valley. These are the Feather River Project Aqueduct, comprising the initial stage, and two additional parallel canals, designated the "San Joaquin West Side Conduit," which would complete the Main Aqueduct Route to its ultimate stage. San Luis Reservoir would be operated to provide required regulation in conjunction with all these facilities.

The location of the Feather River Project Aqueduct, and of the two canals of the San Joaquin West Side Conduit between San Luis Reservoir and Buena Vista Forebay, as shown on Sheets 11, 13, 16, and 17 of Plate 5, is tentative only, and is possibly subject to considerable future modification. Subsidence of the land surface on west side lands has been observed in several areas and could markedly affect the final selection of the route and detailed location of these canals. Further geological, topographic, engineering and cost investigations and studies will be necessary to resolve the problem and to provide the basic information for selecting the most economic location for construction.

The Delta-Mendota Canal presently conveys water from the Tracy Pumping Plant south along the west side of the San Joaquin Valley to Mendota Pool on the San Joaquin River near the community of Mendota. The design capacity of the canal at its head is about 4,600 second-feet. It is contemplated that the canal would convey about 1,780,000 acre-feet per season for use in the San Joaquin Valley under ultimate operation.

The authorized Feather River Project Aqueduct will begin at the Delta Pumping Plant, located about 11 miles northwest of Tracy. The aqueduct will be a concrete-lined canal with a capacity of 11,000 second-feet, and will generally parallel the Delta-Mendota Canal southerly to San Luis Creek. Water will be delivered by gravity to the San Luis Forebay on San Luis Creek at an elevation of about 225 feet. The forebay will extend upstream along San Luis Creek to a pumping plant located near San Luis Dam, where pumping units will lift the water into San Luis Reservoir or directly into the extension of the Feather River Project Aqueduct at an elevation of about 36[illegible] feet, for further conveyance southward.

San Luis Dam and Reservoir will be located about 12 miles west of the City of Los Banos, and have an ultimate storage capacity of about 2,100,000 acre-feet with a water surface elevation of 550 feet. This reservoir will regulate the variable flows pumped from the Delta to the irrigation demand schedule in the San Joaquin Valley and to a continuous flow in the aqueduct to southern California. In the operation of the Feather River Project Aqueduct, the bulk of the water delivered to the San Luis Forebay will be pumped directly into the southerly continuation of the aqueduct which will originate at San Luis Reservoir. The remainder of the water delivered to the forebay, or that quantity exceeding the demand at the particular time, will be pumped into San Luis Reservoir where it will be held in storage until such time as diversion from the Delta is insufficient to meet the demand. Releases of water from San Luis Reservoir will be made directly into the continuation of the aqueduct.

The operation of the San Luis Forebay in conjunction with San Luis Reservoir will enable the utilization of off-peak power for pumping into the reservoi[r]

San Joaquin Division—The Delta-Mendota Canal and the Irrigated San Joaquin Valley with resultant reduction in pumping costs. The San Luis Afterbay, located near San Luis Reservoir at an elevation of about 352 feet, will similarly enable the utilization of off-peak power for pumping water directly into the continuation of the Feather River Project Aqueduct.

From San Luis Reservoir the Feather River Project Aqueduct will continue southward along the west side of the San Joaquin Valley, passing west of Westhaven, Kettleman City, Lost Hills, and Tupman to the Buena Vista Hills. At this point it will discharge into the Buena Vista Forebay at an elevation of about 310 feet. As previously noted, further studies of the Feather River Project Aqueduct system are now (1957) in progress, which may lead to some modifications as to locations and areas served. Lands in the San Joaquin Valley along the aqueduct route, and those above the aqueduct, will be served directly from the aqueduct, while lands lying at lower elevations will be served by easterly extending laterals.

The San Joaquin West Side Conduit would complete the Main Aqueduct Route to its ultimate stage. This conduit would comprise two parallel concrete-lined canals, each with a capacity of 7,200 second-feet, which would originate at the Mountain House Pumping Plant at an elevation of about 167 feet. The conduit would convey about 10,185,000 acre-feet of water per season, on a continuous-flow basis, for use in the San Joaquin Valley and Central Coastal Area and for further delivery to southern California. It would follow, on grade, the general route of the Feather River Project Aqueduct, but at a slightly lower elevation.

A pumping plant located near the San Luis Forebay at an elevation of about 150 feet would lift the water from the San Joaquin West Side Conduit into the forebay. An additional plant located on the forebay would lift the water further to an elevation of 350 feet into the continuation of the conduit, which, in parallel canals, would convey the water by gravity to the base of the Buena Vista Forebay at an elevation of about 300 feet. At this point a pumping plant would lift the water into the Buena Vista Forebay for further conveyance over the Tehachapi Mountains.

Initial operation of the Main Aqueduct Route would be as proposed for the Feather River Project Aqueduct. About 3,700,000 acre-feet would be taken from the Delta on a constant seasonal basis, but on a "when available" monthly basis. Storage space in San Luis Reservoir would be utilized to regulate the variable monthly deliveries to the monthly demand schedule satisfactory to the needs of the San Joaquin Valley, and for delivery at a uniform rate to the Buena Vista Forebay for further conveyance to southern California.

Under ultimate operation, conveyance of water in the Feather River Project Aqueduct would be increased from the initial operation of 3,700,000 to 5,300,000 acre-feet per season. The Delta-Mendota Canal would be coordinated with the Feather River Project Aqueduct, and would deliver 1,780,000 acre-feet per season into the San Joaquin Valley, a portion of which would be lifted into San Luis Forebay by means of a pumping plant and conduit. Thus, the two interconnected systems would ultimately convey an average of about 7,080,000 acre-feet per season from the Delta to the San Luis Forebay. Delivery of a portion of this water would occur on a variable yearly schedule, because of the irregularity of occurrence of surplus secondary waters in the Sacramento Valley. While temporary regulation of these waters would be provided in San Luis Reservoir, final regulation would be accomplished by the vast natural underground storage of the San Joaquin Valley.

Detailed studies of the growth of irrigation demands, the economic staging of construction, and the routing of seasonally variable water imported from the Sacramento River Basin are necessary to a final determination of the amount of regulatory surface storage required in the San Joaquin Basin. These studies were beyond the scope of the current investigation. Should the requirement for regulatory surface storage exceed that which can be furnished at San Luis Reservoir, it may be necessary to utilize a reservoir site at Avenal Gap, capable of maximum storage of 500,000 acre-feet. The operation of Avenal Gap Reservoir for regulation would be similar to that described for San Luis Reservoir. Avenal Gap Forebay presently included as a feature of the Central Coastal Aqueduct, would, in such an eventuality, serve as a forebay for off-peak pumping to Avenal Gap Reservoir. Necessary diversions through the Central Coastal Aqueduct would then be made directly from Avenal Gap Reservoir.

As future water demands in the San Joaquin Valley and southern California increase to their ultimate potential, the Antioch Crossing and Mountain House Pumping Plant of the Delta Division would deliver an additional 10,185,000 acre-feet per season which would be transported southward along the west side of the San Joaquin Valley by the San Joaquin West Side Conduit. This water would be conveyed on a continuous-flow basis, both monthly and from year to year and would require no regulatory storage.

Folsom South Canal, previously described as a feature of the Sacramento Division, would deliver an additional 640,000 acre-feet per season, on the average to the eastern portion of the lower San Joaquin Valley on a variable yearly schedule. Ground water storage in the valley would be utilized to accomplish the final regulation of the water delivered by that conduit.

Central Coastal Aqueduct. The Central Coastal Aqueduct of the San Joaquin Division would divert from the Main Aqueduct Route in the San Joaquin alley near Devils Den, and would deliver a seasonal nount of 760,000 acre-feet of water to deficient areas San Luis Obispo and Santa Barbara Counties. This livery would meet the ultimate supplemental water quirements in those counties, with the exception of e Cuyama Valley and Carrizo Plain. Possible serv- e to the Central Coastal Area under the Feather ver Project is now (1957) being studied.

The Central Coastal Aqueduct would begin at a di- rsion from the San Joaquin West Side Conduit near venal Gap. Water would be pumped from the con- uit and conveyed westerly to Avenal Gap Forebay, om which it would be lifted through a series of mping plants and short canals up the easterly slope the Cholame Hills to a 5.5-mile tunnel passing west- ly through the hills into the Salinas Basin at an el- ation of about 1,180 feet. From the westerly portal the tunnel the aqueduct, in canal, would pass south the communities of Shandon and Cholame and ould discharge into Shedd Canyon Reservoir on In- an Creek. An irrigation supply of 60,000 acre-feet r season would be released for use on lands near the mmunity of Cholame. The capacity of this initial ach of the aqueduct would be 2,200 second-feet, or ice the average flow rate, in order to utilize off- ak power, with resultant reduction in costs of elec- ic energy.

Shedd Canyon Reservoir would provide regulation r delivery of 160,000 acre-feet per season for irriga- on of lands along the easterly slope of upper Salinas lley. The aqueduct would continue westerly from hedd Canyon Reservoir to a crossing of Huerhuero reek where a release of 115,000 acre-feet would be ade to Huerhuero Reservoir, which would regulate e supply to a suitable demand schedule for delivery lands along the upper Salinas River.

The Central Coastal Aqueduct would then continue om Huerhuero Creek westerly and southerly, pass- g east of Templeton, Atascadero, and Santa Mar- rita. An extended series of tunnels, totaling about miles in length, would convey the water from the cinity of Santa Margarita through the Santa Lucia ange to Tar Springs Reservoir, located on a tributary Arroyo Grande Creek, about 8 miles east of Arroyo rande. Tar Springs Reservoir would provide regula- on for delivery of 30,000 acre-feet per season to the royo Grande Valley and Nipomo Mesa on a monthly mand schedule. The aqueduct would then continue utherly, releasing 35,000 acre-feet per season for livery to lands in the Nipomo Valley. After cross- g the Cuyama River about 8 miles southeast of pomo, the aqueduct would convey water southeast- ly along the edge of Sisquoc Valley to the Sisquoc ver. Here 105,000 acre-feet per season would be leased into Round Corral Reservoir for regulation d delivery to the Santa Maria Valley.

From the Sisquoc River the Central Coastal Aque- duct would pass southward through the Solomon Hills to San Antonio Creek, where a seasonal amount of 50,000 acre-feet would be released into the creek for delivery to lands in San Antonio Valley, thence south- ward an additional 12 miles to the vicinity of Los Olivos, where 100,000 acre-feet per season would be released in the Santa Rita Valley and in the Santa Ynez upland. The aqueduct would finally terminate at the existing Cachuma Reservoir, into which it would deliver a seasonal amount of 105,000 acre-feet. Cachuma Reservoir would reregulate this water and deliver it through the existing Tecolote Tunnel to the south slope of the Santa Ynez Mountains on a monthly demand schedule. Passage of peak flows through the tunnel would require installation of pumping facili- ties which would subject the tunnel to a 95-foot head, corresponding to the present operating head on the tunnel when water levels in Cachuma Reservoir are at maximum stage.

In providing the foregoing seasonal deliveries of 760,000 acre-feet of water to the Central Coastal Area, the Central Coastal Aqueduct would successively de- crease from an initial capacity of 2,200 second-feet, representing an average flow of 1,100 second-feet, to a capacity of 300 second-feet at its terminus at Cachuma Reservoir. The total length of the aqueduct from the diversion point on the Main Aqueduct Route in the San Joaquin Valley to the terminus at Cachuma Reservoir would be about 207 miles.

Carrizo-Cuyama Aqueduct. The Carrizo-Cuyama Aqueduct would divert from the California Aqueduct route in the San Joaquin Valley about 5 miles south of the Buena Vista Forebay, and would deliver a seasonal amount of 325,000 acre-feet to water-deficient areas in the Cuyama Valley and Carrizo Plain, which delivery would meet the ultimate supplemental water requirements in those areas.

The Carrizo-Cuyama Aqueduct would begin at a canalside pumping plant located about 2 miles north- east of Maricopa. Water would be lifted up the east- erly slope of the Temblor Range to an elevation of 2,500 feet by a series of four pumping plants so de- signed that they would operate only during periods of off-peak power demand. The final pumping plant would discharge water into two separate pipe lines. One line, the Carrizo Lateral, would continue west- ward and would discharge into a channel leading through the Elkhorn Plain to Elkhorn Reservoir about 8 miles southwest of Taft. The other line, the Cuyama Lateral, would turn southward to Bitterwater After- bay on Bitterwater Creek, about 5 miles southwest of Maricopa. From this afterbay a 4-mile tunnel would pass southwesterly through the ridge to the Cuyama Valley.

Water would be diverted into the Cuyama Lateral only when needed and only in the amounts needed. Daily and weekly flow variations due to off-peak operation would be regulated in Bitterwater Afterbay. A total of 80,000 acre-feet of water per season would be delivered to Cuyama Valley, comprising 53,000 acre-feet for consumptive use, 4,000 acre-feet for evaporative losses, and 23,000 acre-feet for over-applications of irrigation water. These over-applications would return to the Cuyama River, thereby maintaining a favorable salt balance in the Cuyama Basin, and would become available for use downstream in the Santa Maria Valley.

The remaining 245,000 acre-feet of water per season delivered by the Carrizo-Cuyama Aqueduct would be conveyed in the Carrizo Lateral to Elkhorn Reservoir which would regulate the supply to a monthly demand schedule for the Carrizo Plain.

In order to provide for off-peak operation, the con-veyance capacity of the Carrizo-Cuyama Aqueduc would be 900 second-feet, or twice the average diver-sion rate of 450 second-feet.

Summary of San Joaquin Division. The San Joa-quin Division would deliver some 8,165,000 acre-fee per season of regulated waters from northern areas o surplus to the San Joaquin Valley and Centra Coastal Area, and would transport an additiona 9,100,000 acre-feet of water to the Buena Vista Fore bay for delivery to areas south of the Tehachap Mountains. Facilities of the division would consist o the Main Aqueduct Route, the Central Coastal Aque duct, and the Carrizo-Cuyama Aqueduct. The Mai

TABLE 25

SUMMARY OF SAN JOAQUIN DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Conveyance facilities	Conduits: Maximum capacity, in second-feet	Conduits: Length, in miles: Canal	Tunnel	Pipe	Total	Pumping plants: Total number	Total installed capacity, in kilowatts	Total seasonal energy required, in kilowatt-hours
Main Conduit Route								
Delta-Mendota Canal	4,600	103			103	1	16,000	70,000,00
Feather River Project Aqueduct	11,000	264			264	2	450,000	920,000,00
San Joaquin West Side Conduit	14,400	245			245	3	409,000	3,100,000,00
Central Coastal Aqueduct	2,200	154.2	37.7	14.8	206.7	5	224,000	985,000,00
Carrizo-Cuyama Aqueduct	820			7.2	7.2	4	177,000	776,000,00
Cuyama Lateral	74		4.1	0.7	4.8			
Carrizo Lateral	338		0.5	0.7	1.2			
Totals		766.2	42.3	23.4	831.9	15	1,276,000	5,851,000,00

Reservoir[a]	Location, MDB&M, and sheet of Plate 5 on which shown		Type of dam	Storage capacity, in acre-feet	Normal pool elevation, in feet	Height of dam, in feet	Place of water use
Main Conduit Route							
San Luis Forebay[b]	Sec. 1, 12, T10S, R8E	11	E	[b]	225	60	[b]
San Luis Reservoir	Sec. 15, T10S, R8E	11	E	2,174,000	550	310	San Joaquin Valley an southern California
San Luis Afterbay[b]	Sec. 15, T10S, R8E	11	E	[b]	400	75	[b]
Central Coastal Aqueduct							
Avenal Gap Forebay[b]	Sec. 16, T24S, R19E	16	E	[b]			[b]
Shedd Canyon Reservoir	Sec. 26, T26S, R14E	16	E	81,000	1,188	188	Upper Salinas Valley
Huerhuero Reservoir	Sec. 9, T27S, R13E	16	E	40,000	997	144	Upper Salinas Valley
Tar Springs Reservoir	Sec. 15, T32S, R14E	16	E	10,000	650	140	Arroyo Grande Valley an Nipomo Mesa
Round Corral Reservoir	Sec. 22, T9N, R31W, SBB&M	20	E	45,000	875	226	Santa Maria Valley
Carrizo-Cuyama Aqueduct							
Elkhorn Reservoir	Sec. 4, 5, T32S, R22E	17	E	134,000	2,500	120	Carrizo Plain
Bitterwater Afterbay	Sec. 6, T10N, R24W, SBB&M	20	E	1,000	2,500	10	Cuyama Valley
Total				2,485,000			

Symbol of Type of Dam
E Earthfill

[a] Provide regulation of imported water to monthly schedule in area served. San Luis Reservoir would also provide regulation for conveyance southward at a const rate, and for ground water replenishment in San Joaquin Valley.
[b] Provide regulation for use of off-peak power.

Aqueduct Route would comprise the existing Delta-Mendota Canal and the proposed Feather River Project Aqueduct as its initial features, and the San Joaquin West Side Conduit which would complete the Main Aqueduct Route to its ultimate stage.

Combined seasonal conveyances to service areas in the San Joaquin Valley by the Delta-Mendota Canal and the Feather River Project Aqueduct would amount to some 7,080,000 acre-feet. An additional 690,000 acre-feet per season would be transferred from the Sacramento Valley to the easterly side of the lower San Joaquin Valley by the Folsom South Canal. Finally, the San Joaquin West Side Conduit would convey 10,185,000 acre-feet per season, of which 1,085,-000 acre-feet would be delivered to the Central Coastal Area by the Central Coastal and Carrizo-Cuyama Aqueducts, and the foregoing 9,100,000 acre-feet would be transported to the Buena Vista Forebay of the Southern California Division. Thus, the total seasonal transfer of waters south of the Delta, with the exception of deliveries to the San Francisco Bay Area, would aggregate 17,905,000 acre-feet.

The total diversion capacity of the Main Aqueduct Route from the Delta would be 30,000 second-feet, distributed as follows: Delta-Mendota Canal, 4,600 second-feet; Feather River Project Aqueduct, 11,000 second-feet; and San Joaquin West Side Conduit, 14,400 second-feet, divided equally between its two component canals. The Delta-Mendota Canal is 103 miles in length, and terminates at Mendota Pool. The Feather River Project Aqueduct and the San Joaquin West Side Conduit, consisting of three generally parallel concrete-lined canals, would extend southward along the west side of the San Joaquin Valley about 70 miles to the San Luis Forebay, at which point the water would be lifted about 200 feet and the conduits would continue southerly an additional 180 miles to the Buena Vista Forebay.

San Luis Reservoir, a feature of the Main Aqueduct Route, would serve a three-fold purpose in providing temporary regulation of the water delivered by the foregoing facilities; namely (1) regulation to the variable monthly demand in the San Joaquin Valley, (2) regulation to a continuous flow to Buena Vista Forebay, and (3) regulation to rates within the absorptive capacity of soils overlying the ground water basin in San Joaquin Valley. Final regulation of the variable deliveries of water developed in the Sacramento Valley would be accomplished by the extensive ground water storage in the San Joaquin Valley.

The Central Coastal Aqueduct, diverting from the Main Aqueduct Route near Avenal Gap, would deliver 760,000 acre-feet per season over and through the Cholame Hills to the upper Salinas Basin and coastal area of San Luis Obispo County and the westerly portion of Santa Barbara County. The aqueduct would be 207 miles in length from the diversion point to its terminus at Cachuma Reservoir.

The Carrizo-Cuyama Aqueduct, diverting from the California Aqueduct route 5 miles south of the Buena Vista Forebay, would deliver 325,000 acre-feet of water through the Temblor Range at an elevation of 2,500 feet to the Cuyama Valley and to Carrizo Plain.

The general features of the San Joaquin Division are presented in Table 25 and the capital costs of its component facilities are shown in Table 26. The facilities comprising the division are shown on Sheets 8, 10, 11, 13, 14, 16, 17, and 20 of Plate 5.

TABLE 26

SUMMARY OF CAPITAL COSTS, SAN JOAQUIN DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Main Conduit Route	
Feather River Project Aqueduct	
Conduit	$114,690,000
San Luis Reservoir	94,350,000
San Luis Forebay	1,520,000
Pumping Plant No. IIA	38,120,000
Pumping Plant No. IIB	30,930,000
San Joaquin West Side Conduit	
Conduit	505,190,000
Delta-Mendota Relift Pumping Plant	6,810,000
San Luis Pumping Plant No. 1	35,000,000
San Luis Pumping Plant No. 2	49,300,000
Buena Vista Pumping Plant	25,560,000
Subtotal	$901,470,000
Central Coastal Aqueduct (to Cachuma Reservoir)	
Conduit	$113,540,000
Avenal Gap Forebay	2,110,000
Shedd Canyon Reservoir	9,620,000
Huerhuero Reservoir	2,770,000
Tar Springs Reservoir	2,030,000
Round Corral Reservoir	6,660,000
Avenal Gap Pumping Plant	3,380,000
Badger Hill Pumping Plant	7,420,000
Wagon Wheel Pumping Plant	12,520,000
Sawtooth Pumping Plant	8,880,000
Aido Pumping Plant	8,280,000
Subtotal	$177,210,000
Carrizo-Cuyama Aqueduct	
Conduit	$16,940,000
Elkhorn Reservoir	6,210,000
Bitterwater Afterbay	1,160,000
Pumping Plant No. 1	5,240,000
Pumping Plant No. 2	5,240,000
Pumping Plant No. 3	5,240,000
Pumping Plant No. 4	8,700,000
Subtotal	$48,730,000
Total	$1,127,410,000

* At 1955 price levels.

Southern California Division

The Southern California Division of the California Aqueduct System would extend southward from Buena Vista Forebay through the Tehachapi Mountains to the Mexican border, and would serve supplemental water to the South Coastal Area, the southern portion of the Lahontan Area, and the Colorado Desert Area, excepting that portion having rights in and to the waters of the Colorado River. A supply of water in the amount of about 9,100,000 acre-feet per season would be conveyed through facilities of this division. Of this amount, about 2,880,000 acre-feet would be supplied to the South Coastal Area and the remainder would be delivered to the Lahontan and Colorado Desert Areas.

The Department of Water Resources is currently (May, 1957), conducting further engineering, geologic, and economic investigations of the Feather River Project Aqueduct system to determine the most feasible aqueduct routes to serve San Luis Obispo, Santa Barbara, and Kern Counties, Antelope Valley, and the South Coastal Area, preparatory to construction. Results of these studies are not yet sufficiently complete for inclusion herein, except with respect to the Second San Diego Aqueduct, subsequently described. Substantial modification of some of the aqueducts described herein, which are based on prior engineering studies, may be necessary, at least insofar as the Feather River Project is concerned. Should these studies demonstrate an advantage in utilizing the coastal route as the principal aqueduct location as compared to the so-called "high-line" route, the facilities leading to the South Coastal Area could be constructed on the alternative coastal alignment, as shown on Sheets 16, 20, and 21 of Plate 5, or along some modification of that alignment. However, the basic concepts and the areas to be served will remain the same, irrespective of the final locations of the aqueducts, when constructed.

The Tehachapi Mountains at the southern end of the San Joaquin Valley constitute a formidable barrier to transfer of water from the valley to the South Coastal Area. Prior studies for the Feather River Project demonstrated the engineering feasibility of an aqueduct route passing through the Tehachapi Mountains at an elevation of about 3,350 feet, crossing Antelope Valley, passing along the north edge of the San Gabriel and San Bernardino Mountains, and leading into the South Coastal Area at Cajon Pass near San Bernardino.

The Southern California Division, as presently conceived, would include pumping facilities and tunnels through the Tehachapi Mountains. Off-peak power would be utilized to lift the water to the tunnels, and the more valuable on-peak power would be generated by that portion of the water supply delivered to lands at lower elevations in the South Coastal Area. In order to make it possible to pump only during periods of off-peak power demand, thereby minimizing demand charges for pumping power, forebay and afterbay storage reservoirs would be provided along the aqueduct route. Deliveries of supplemental water to the service areas of the Southern California Division would be effected at various strategic locations by several aqueduct routes. These routes and points of delivery were selected mainly on the basis of integration with and utilization of existing water supply and distribution facilities, in order to avoid unnecessary overlap and duplication of such works. The effect of the physical characteristics of the service area with respect to regulation and distribution of the supplemental supply were also considered.

For purposes of presentation herein, the Southern California Division has been divided into seven units, which are discussed in the following order: Buena Vista-Cedar Springs Aqueduct, which, in addition to carrying water to aqueducts farther south, would serve the extreme southern portion of San Joaquin Valley, the Antelope Valley, and the desert areas to the east; San Fernando-Ventura Aqueduct which would serve the San Fernando Valley, the coastal plains of Los Angeles and Ventura Counties, the Malibu area, and upper Santa Clara River Valley; Devil Canyon Power Development, which would deliver water through the San Bernardino Power Plant to spreading grounds in upper Santa Ana Valley and to the Chino-San Gabriel and Barona Aqueducts; Chino-San Gabriel Aqueduct, which would serve upper Santa Ana and San Gabriel Valleys; Second San Diego Aqueduct, which, by coordinated operation with the existing San Diego Aqueduct, the Barona Aqueduct, and the facilities of the San Diego High-Line Aqueduct, could supply the ultimate requirements in San Diego and southwestern Riverside Counties; Barona Aqueduct, which would serve lower lying lands in upper Santa Ana Valley, San Jacinto Valley, and in Orange, San Diego, and southwestern Riverside Counties; and San Diego High-Line Aqueduct, which would serve the higher portions of the upper Santa Ana and San Jacinto Valleys, the San Gorgonio Pass area and desert lands to the east, higher lands in Riverside and San Diego Counties, and the Borrego Valley area.

The general location of the Southern California Division is shown on Plate 6, and its component features are delineated on Sheets 17, 20, 21, 22, 24, 2[illegible] and 26 of Plate 5.

Buena Vista-Cedar Springs Aqueduct. The Buena Vista-Cedar Springs Aqueduct would comprise two conduits extending from Buena Vista Forebay in the San Joaquin Valley to Cedar Springs Forebay on the desert side of the San Bernardino Mountains, and a system of lateral aqueducts serving the Lahontan and Colorado Desert areas. One of these conduits, designated the "Upper Aqueduct," would comprise the facilities under consideration for the high-line route of the Feather River Project Aqueduct as far as Quail Lake Reservoir, and would be the initial stage of the Buena Vista-Cedar Springs Aqueduct. A second conduit would be required in the future for ultimate delivery of water to Cedar Springs Forebay. This conduit is designated the "Lower Aqueduct al would generally parallel the alignment of the Upper Aqueduct, but at a lower elevation.

The Upper Aqueduct would convey water from Buena Vista Forebay at a minimum elevation of 327 feet, through a series of 4 pumping plants and some 4 miles of canal, tunnel, and pipe line, to the inlet portal of a tunnel through the Tehachapi Mountains at an elevation of 3,357 feet, about 6 miles east of Grapevine. The aqueduct would pass about 3 miles northeast of Maricopa and 2 miles west of Wheeler Ridge on its course up the northerly slope of the Tehachapis. Two consecutive tunnels, totaling 10.5 miles in length, would deliver the water southeasterly through the Tehachapis to Quail Lake Reservoir, which would be formed by enlarging the existing Quail Lake. About 1,000,000 acre-feet of water per season would be diverted from Quail Lake Reservoir into the San Fernando-Ventura Aqueduct, as hereinafter described.

As stated, the section of the Upper Aqueduct from Buena Vista Forebay to Quail Lake Afterbay would comprise the facilities of the high-line route for the Feather River Project Aqueduct. It would have a conveyance capacity of 6,000 second-feet, and would deliver a seasonal supply of about 1,800,000 acre-feet to Quail Lake Reservoir, at an elevation of about 3,300 feet. The aqueduct and pumping plants would be designed to operate to the greatest extent feasible during periods of off-peak power demand, in order to utilize less costly electric energy available during such periods. In addition to the large forebay and afterbay capacities required for off-peak pumping, small reservoirs at each pumping plant would provide for the necessary flexibility of operation.

From Quail Lake Reservoir the Upper Aqueduct would extend southeasterly along the south edge of Antelope Valley, and would terminate in Cedar Springs Forebay, about 9 miles south of Hesperia in the southern portion of the Mojave Desert, at an elevation of 3,252 feet. The Upper Aqueduct between Quail Lake and Cedar Springs Forebay would be constructed on grade, and would consist of cut-and-cover conduit, tunnels, and canal sections. The capacity of the aqueduct in this reach would be 1,300 second-feet, and it would deliver about 800,000 acre-feet per season to Cedar Springs Forebay.

Construction of the Lower Aqueduct would complete the Buena Vista-Cedar Springs Aqueduct to its ultimate stage. The Lower Aqueduct would have a greater capacity than the Upper Aqueduct, diverting a seasonal supply of 7,301,000 acre-feet. The Lower Aqueduct would generally parallel the route of the Upper Aqueduct, at a higher elevation north of Wheeler Ridge and at a lower elevation south of that point. As presently conceived, the Lower Aqueduct would be constructed in stages and would probably consist of two aqueduct units.

The Lower Aqueduct would convey water from Buena Vista Forebay to Antelope Afterbay, located about 3 miles northeast of Quail Lake Reservoir, in twin parallel conduits. Between Buena Vista Forebay and the tunnels through the Tehachapi Mountains, the aqueduct would consist of about 45 miles of canal, pipe line, and short tunnels through the Buena Vista Hills and Wheeler Ridge. Three pumping plants would lift the water from an elevation of 327 feet in the Buena Vista Forebay to 3,140 feet at the inlet portal of the Tehachapi tunnels. These tunnels would be approximately 9 miles in length, and would terminate at the Antelope Afterbay, with a maximum water surface elevation of 3,095 feet. The reach of the Lower Aqueduct just described would have a design capacity of 24,600 second-feet, equally divided between component twin conduits. The aqueduct and pumping plants would also be operated to utilize off-peak energy, and the necessary forebay and afterbay capacity would be provided.

From Antelope Afterbay, the Lower Aqueduct would extend southeasterly nearly 100 miles along the southerly edge of the Antelope Valley, terminating in Cedar Springs Forebay. This section of the aqueduct would consist of a single canal with an initial capacity of 9,000 second-feet at the Antelope Afterbay, and would be progressively reduced to 2,500 second-feet at the point of discharge in Cedar Springs Forebay. Diversions totaling 5,710,000 acre-feet per season would be made along the route to laterals comprising the Antelope-Majove Aqueduct system. The remaining 1,535,000 acre-feet per season would be lifted into Cedar Springs Reservoir at an elevation of 3,253 feet, by a pumping plant near Hesperia.

San Fernando-Ventura Aqueduct. The San Fernando-Ventura Aqueduct would extend southerly from Quail Lake Reservoir and then westerly to deliver about 1,000,000 acre-feet of water per season from the Buena Vista-Cedar Springs Aqueduct to San Fernando Valley and the coastal plain of Los Angeles County, Ventura County, the Malibu area, and the upper Santa Clara River Valley.

Beginning at Quail Lake Reservoir at an elevation of 3,300 feet, the San Fernando-Ventura Aqueduct would pass southerly about 22 miles to Castaic Creek Reservoir in a short canal section and a series of tunnels through the divide between Antelope Valley and the Santa Clara River drainage area. Castaic Creek Reservoir would be located on Castaic Creek, a tributary of the Santa Clara River, about 3 miles north of Castaic Junction. Power would be developed enroute along the aqueduct by a power drop of about 700 feet into Liebre Gulch, where regulatory storage capacity would be provided by construction of the Liebre Gulch Afterbay. Power would also be developed by construction of a power plant at Castaic

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Creek Reservoir, utilizing available head of about 1,100 feet.

The San Fernando-Ventura Aqueduct between Quail Lake and Castaic Creek Reservoirs would have a capacity of 3,100 second-feet, and would be operated only during periods of on-peak power demand. Castaic Creek Reservoir would provide regulation of the fluctuating discharge of the aqueduct to the monthly demand schedules in the aqueduct service area. The upper Santa Clara River Valley would be served 68,000 acre-feet of water per season directly from this reservoir.

From Castaic Creek Reservoir the San Fernando-Ventura Aqueduct, with an initial elevation of 1,250 feet, would continue southerly to a 5-mile tunnel, in the vicinity of Newhall, passing through the divide between the upper Santa Clara River and San Fernando Valleys. The tunnel outlet portal would be about 1 mile to the west of the existing Upper San Fernando Reservoir of the City of Los Angeles Department of Water and Power. Here a seasonal supply of water of 717,000 acre-feet would be delivered, at an elevation of 1,160 feet, on a monthly demand schedule, for use in the San Fernando Valley and coastal plain of Los Angeles County.

From the tunnel portal, the San Fernando-Ventura Aqueduct, with a capacity of 300 second-feet, would continue westerly, delivering 215,000 acre-feet per season into Ventura County on a uniform flow basis. Enroute, the aqueduct would pass through the Simi Hills, near the town of Chatsworth, and into the Simi Valley. It would extend along the southerly side of Simi Valley to terminate in Conejo Reservoir, immediately above Santa Rosa Valley about 6 miles east of Camarillo. Conejo Reservoir, with a maximum water surface elevation of 398 feet, would provide terminal storage for aqueduct supplies delivered to the Ventura County service area. Deliveries to lands between the Simi Hills tunnel and the reservoir would be made directly from the aqueduct. Water service would be provided from Conejo Reservoir to the Oxnard Plain area, the Calleguas Creek drainage area, and the Ventura River Basin. If desired, water deliveries could also be made to the vicinity of Santa Barbara by extending the aqueduct and increasing its capacity.

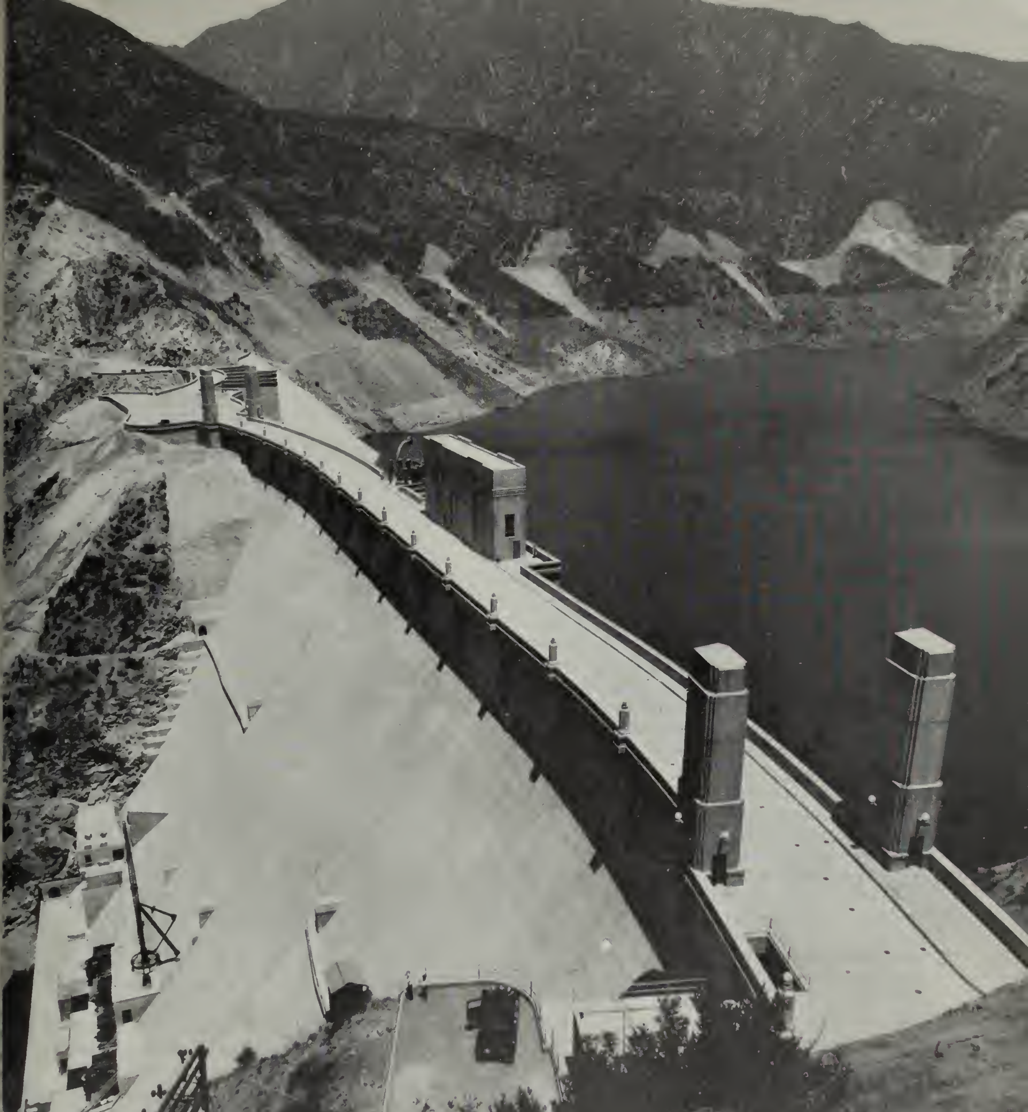
Devil Canyon Power Development. Facilities of the Devil Canyon Power Development would generate power by a 1,340-foot drop through the San Bernardino Power Plant at the base of the San Bernardino Mountains, and would deliver about 1,510,000 acre-feet per season for further conveyance by the Chino-San Gabriel and Barona Aqueducts, subsequently described. The power development aqueduct would lead southerly from Cedar Springs Reservoir, at an elevation of about 3,222 feet, through the San Bernardino Mountains in a 5-mile tunnel parallel to that of the previously mentioned San Diego High-Li Aqueduct. From the tunnel outlet near the junctio of Devil Canyon with its east fork, the aquedu would continue southward, crossing the east fork i siphon and entering penstocks to the San Bernardi Power Plant immediately north of the City of Sa Bernardino. The aqueduct would extend eastwar from the power plant tailrace by pipe line to th Arrowhead Springs Afterbay on East Twin Cree The Twin and Waterman spreading grounds in th upper Santa Ana Valley would be supplied abou 64,000 acre-feet per season directly from the rese voir.

The San Bernardino Power Plant would be ope ated only during periods of peak power demand, an would have an installed capacity of 400,000 kilowatt Arrowhead Springs Afterbay would provide reregu lation of the power releases to a uniform delivery fo further conveyance to service areas.

Chino-San Gabriel Aqueduct. The Chino-Sa Gabriel Aqueduct would divert at a hydraulic gra line elevation of about 1,760 feet from a low point i the pipe line connecting the tailrace of the San Be nardino Power Plant and Arrowhead Springs Afte bay, and would proceed, in pipe line, westerly alon the base of the San Bernardino Mountains a distan of 35 miles, to a terminus in the existing Morris Re ervoir on the San Gabriel River at an elevation about 1,150 feet. The aqueduct would deliver a se sonal supply of 429,000 acre-feet to the upper San Ana and San Gabriel Valleys.

Arrowhead Springs Afterbay would provide reg lation of the tailwater from the San Bernardi Power Plant to a continuous flow in the Chino-Sa Gabriel Aqueduct by releases thereto during perio when the power plant would not be in operation, th reversing the direction of flow. Water would be r leased from the aqueduct to spreading grounds ove lying the Chino and other smaller ground water basi for regulation and distribution by underground sto age. Direct water service could also be provided fro the aqueduct to lands in the vicinity. By terminati the aqueduct in Morris Reservoir, a physical conne tion would be provided with the artificial rechar facilities of the Los Angeles County Flood Contr District in the San Gabriel Valley and Montebel Forebay area of the coastal plain of Los Angel County and to the facilities of The Metropolit Water District of Southern California.

Second San Diego Aqueduct. Pursuant to prov sions of the Budget Act of 1956 of the Californ Legislature, the Department of Water Resources r cently completed a detailed investigation of altern tive routes for the next aqueduct to San Diego Coun and the most economical capacity thereof. The faci ties of the Second San Diego Aqueduct described



Southern California Division—The Proposed Terminal for the Chino-San Gabriel Aqueduct—Morris Reservoir Near Pasadena two conduits, the Upper Aqueduct and the Lower Aqueduct. The Upper Aqueduct would consist of the facilities of the high-line route of the Feather River Project Aqueduct as far as Quail Lake Reservoir, and would deliver 1,800,000 acre-feet of water per season to that reservoir. The Lower Aqueduct would complete the Buena Vista-Cedar Springs Aqueduct to its ultimate stage, conveying a seasonal supply of 7,300,000 acre-feet through the Tehachapi Mountains, for service to the Antelope Valley and desert areas to the east in the amount of 5,710,000 acre-feet, and delivering 1,560,000 acre-feet to Cedar Springs Reservoir.

The San Fernando-Ventura Aqueduct would deliver about 1,000,000 acre-feet of water per season from Quail Lake Reservoir to the San Fernando Valley and coastal plain of Los Angeles County, Ventura County, the Malibu area, and the upper Santa Clara River Valley.

The Devil Canyon Power Development would generate power by dropping 1,510,000 acre-feet per season of water from the Cedar Springs Forebay through the San Bernardino Power Plant at the base of the San Bernardino Mountains. The water would then be conveyed easterly to the Arrowhead Springs Afterbay on East Twin Creek.

The Chino-San Gabriel Aqueduct would divert from the aqueduct of the Devil Canyon Power Development, and would deliver a seasonal supply of about 429,000 acre-feet to the upper Santa Ana and San Gabriel Valleys, terminating in Morris Reservoir.

The Second San Diego Aqueduct would extend generally southerly about 90 miles from the west portal of the San Jacinto Tunnel of the Colorado River Aqueduct to a terminus in Minnewawa Reservoir on Jamul Creek near the City of San Diego. The aqueduct would generally parallel the route of the existing San Diego Aqueduct, and its coordinated operation with facilities of the existing San Diego Aqueduct, the Barona Aqueduct, and the San Diego High-Line Aqueduct would make available 1,300,000 acre-feet of water per season to lands in San Diego and southwestern Riverside Counties.

The Barona Aqueduct would deliver about 1,020,000 acre-feet of water per season to the lower-lying lands south of the San Bernardino Mountains. The aqueduct would originate at the Arrowhead Springs Afterbay of the Devil Canyon Power Development, and would extend southerly to a connection with the Colorado River Aqueduct at the westerly portal of the San Jacinto Tunnel. From this point the aqueduct would continue southerly some 50 miles, generally paralleling, but to the east of, the existing San Diego Aqueduct, and would terminate in Barona Reservoir near Ramona. The Barona Aqueduct would make seasonal deliveries of 200,000 acre-feet to the water-spreading grounds in the Bunker Hill Basin of San Bernardino County, and 820,000 acre-feet to the San Jacinto Valley and to areas to the south in San Diego County. The Barona, existing San Diego, and Second San Diego Aqueducts would be operated on an integrated system.

The San Diego High-Line Aqueduct would extend southerly from Cedar Springs Forebay, through the San Bernardino Mountains, generally following the alignment of the high-line route of the Feather River Project Aqueduct, to a terminus at Horsethief Canyon in San Diego County, near the Mexican border

TABLE 27

SUMMARY OF SOUTHERN CALIFORNIA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Conveyance facilities	Conduits					Pumping plant		
	Maximum capacity, in second-feet	Length, in miles				Total number	Total installed capacity, in kilowatts	Total seasonal power consumption, in kilowatt-hours
		Canal	Tunnel	Pipe	Total			
Buena Vista-Cedar Springs Aqueduct								
Feather River Project Aqueduct	6,000	163.8	14.6	6.3	184.7	4	837,000	6,874,000,00
Lower Aqueduct	24,600	160.9	3.9	3.9	168.7	4	7,114,000	23,635,000,00
Antelope-Mojave Aqueduct system	7,420	1,081.2	6.7	44.8	1,132.7	7	537,000	2,064,000,00
San Fernando-Ventura Aqueduct	3,100	1.9	19.3	39.4	60.6			
Devil Canyon Power Development	4,680		4.8	5.8	10.6			
Chino-San Gabriel Aqueduct	600		1.8	33.6	35.4			
Second San Diego Aqueduct	500			90.6	90.6			
Barona Aqueduct	1,540		4.3	96.3	100.6			
San Diego High-Line Aqueduct (Feather River Project)	1,300	33.2	91.4	15.0	139.6	1	7,000	20,000,00
Whitewater Aqueduct	229	24.2		1.1	25.3			
San Felipe Aqueduct	316	53.4	9.0	2.5	64.9			
Barona-High Line Interconnection	140			8.4	8.4			
Totals		1,518.6	155.8	347.7	2,022.1	16	8,495,000	32,593,000,0

TABLE 27—Continued

SUMMARY OF SOUTHERN CALIFORNIA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Power plant	Location, SBB&M, and sheet of Plate 5 on which shown	Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours
B na Vista-Cedar Springs Aqueduct				
ntelope-Mojave Aqueduct System [a]	b	a	222,000	1,090,000,000
S Fernando-Ventura Aqueduct				
iebre Gulch	Sec. 4, T6N, R17W 21	737	168,000	651,600,000
astaic Creek	Sec. 2, T5N, R17W 21	1,077	244,000	951,900,000
D il Canyon Power Development				
in Bernardino	Sec. 31, T2N, R4W 22	1,337	400,000	1,570,500,000
S Diego High-Line Aqueduct				
anning	Sec. 5, T3S, R1E 24	500	8,200	67,800,000
athaway	Sec. 35, T2S, R1E 24	144	2,200	14,500,000
abazon	Sec. 9, T3S, R2E 24	691	9,400	54,500,000
hitewater	Sec. 9, T3S, R3E 24	339	2,100	14,600,000
in Felipe	Sec. 33, T12S, R5E 25	407	12,900	54,000,000
arrows	Sec. 12, T12S, R6E 25	494	17,400	68,300,000
ane Springs	Sec. 34, T12S, R8E 25	572	4,600	40,000,000
Totals			1,090,800	4,577,700,000

rom preliminary plans prepared for water distribution in the high desert areas when the need develops. Individual works are not shown.
Not shown on Plate 5.

TABLE 27—Continued

SUMMARY OF SOUTHERN CALIFORNIA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Reservoir	Location, SBB&M, and sheet of Plate 5 on which shown	Type of dam	Height of dam, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet	Purpose	Place of water use
B na Vista-Cedar Springs Aqueduct Route							
uail Lake Reservoir	Sec. 13, T8N, R18W 21	E	29	3,343	16,200	OP	
uena Vista Forebay	Sec. 26, T31S, R24E, MDB&M 17	E	55	350	49,000	OP	
ntelope Afterbay	Sec. 3, T8N, R17W 21	E	100	3,095	42,000	OP	
edar Springs Forebay	Sec. 32, T3N, R4W 22	E	111	3,252	14,200	OP	
S Fernando-Ventura Aqueduct							
ebre Gulch Afterbay	Sec. 9, T6N, R17W 21	E	250	2,500	9,400	P	
astaic Creek Reservoir	Sec. 18, T5N, R16W 21	E	192	1,377	100,000	S	Upper Santa Clara Valley-Los Angeles County
onejo Reservoir	Sec. 25, T2N, R20W 21	E	185	398	37,000	S	Ventura County
D il Canyon Power Development							
rowhead Springs Afterbay	Sec. 11, T1N, R4W 22	E	313	1,850	12,200	P	Los Angeles County
C io-San Gabriel Aqueduct (transmission ily)							
S nd San Diego Aqueduct							
eys Canyon Reservoir	Sec. 18, T10S, R2W 24	E	270	765	70,000	S	San Diego County
nlarged Lower Otay Reservoir	Sec. 18, T18S, R1E 26	CG	200	527	112,000	S	San Diego County
B na Aqueduct							
arona Reservoir	Sec. 28, T14S, R1E 26	E	150	1,390	55,000	S	San Diego County
S Diego High-Line Aqueduct							
in Felipe Reservoir	Sec. 22, T12S, R5E 25	E	103	2,237	10,000	S	Salton Sea area
inta Ysabel Reservoir	Sec. 19, T12S, R3E 24	E	240	2,975	75,000	S	San Diego County
Total					602,000		

S bols of Type of Dam
—Earthfill
G—Concrete gravity

Symbols of Purpose
OP—Regulation for use of off-peak power
P—Power generation
S—Reregulation of waters to local demand schedule

This aqueduct would convey about 825,000 acre-feet per season, of which 368,000 acre-feet would be delivered to the South Coastal Area and 457,000 acre-feet would be conveyed to the Colorado Desert Area.

TABLE 28

SUMMARY OF CAPITAL COSTS, SOUTHERN CALIFORNIA DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Buena Vista-Cedar Springs Aqueduct	
Feather River Project Aqueduct	$251,470,000
Pumping Plant No. III	13,060,000
Pumping Plant No. IV	16,790,000
Pumping Plant No. V	31,560,000
Pumping Plant No. VI	74,410,000
Quail Lake Reservoir	500,000
Cedar Springs Forebay	4,870,000
Upper Aqueduct	593,820,000
Pumping Plant No. 4	79,640,000
Pumping Plant No. 5	123,400,000
Pumping Plant No. 6	406,000,000
Pumping Plant No. 7	11,290,000
Buena Vista Forebay	6,940,000
Antelope Afterbay	10,330,000
Antelope-Mojave Aqueduct System	410,000,000
Subtotal	$2,034,080,000
San Fernando-Ventura Aqueduct	
Conduit	$142,570,000
Liebre Gulch Power Plant	17,720,000
Liebre Gulch Reservoir	3,130,000
Castaic Creek Power Plant	23,590,000
Castaic Creek Reservoir	18,740,000
Conejo Reservoir	5,030,000
Subtotal	$210,780,000
Devil Canyon Power Development	
Conduit	$87,161,000
San Bernardino Power Plant	41,320,000
Arrowhead Springs Afterbay	16,500,000
Subtotal	$144,981,000
Chino-San Gabriel Aqueduct	
Conduit	$16,153,000
Second San Diego Aqueduct	
Conduit	$63,700,000
Keys Canyon Reservoir	5,701,000
Enlarged Lower Otay Reservoir	3,045,000
Subtotal	$72,446,000
Barona Aqueduct	
Conduit	$178,934,000
Barona Reservoir	2,156,000
Subtotal	$181,090,000
San Diego High-Line Aqueduct (Feather River Project)	
Conduit	$230,880,000
Santa Ysabel Pumping Plant	1,450,000
Santa Ysabel Reservoir	7,230,000
Whitewater Aqueduct	
Conduit	5,140,000
Banning Power Plant	920,000
Hathaway Power Plant	440,000
Cabazon Power Plant	1,000,000
Whitewater Power Plant	330,000
San Felipe Aqueduct	
Conduit	21,800,000
San Felipe Dam and Reservoir	970,000
San Felipe Power Plant	1,440,000
Narrows Power Plant	1,690,000
Kane Springs Power Plant	570,000
Subtotal	$273,860,000
Total	$2,933,390,000

* At 1955 price levels.

Deliveries to high lands in the upper Santa Ana an San Jacinto Valleys, to the San Gorgonio Pass are and desert lands to the east, and to high lands i Riverside and San Diego Counties, would be mad directly from the aqueduct. Near Lake Henshaw, diversion by tunnel on a continuous flow basis woul be made to the Borrego Valley area. About 85,00 acre-feet of water per season would also be provide from the San Diego High-Line Aqueduct to Baron Reservoir by the Barona High-Line Interconnectio for use on lower-lying lands.

The general features and capital costs of the Cal fornia Aqueduct System in the Southern Californi Division are presented in Tables 27 and 28. The loca tion of these facilities are delineated on Sheets 16, 1 20, 21, 22, 24, 25, and 26 of Plate 5.

UTILIZATION OF GROUND WATER STORAGE

Inherent in the concept of development, and vitall necessary to the successful implementation and ope ation of The California Water Plan, is the avail bility of adequate facilities for storage, regulatio and transportation of the developed water supplie Transportation facilities would consist of the man local and transbasin conduits, and the Californ Aqueduct System. Because of the many possible alte native means of accomplishing the transfer of wat from areas of surplus to areas of deficiency, both a local and on a state-wide scale, the problem water transportation, from an engineering point view, is not likely to present insurmountable dif culties in the implementation of The California W ter Plan.

There are, on the other hand, no alternative mea of developing the physical storage space required provide the necessary control and regulation of t large volumes of water over long climatic cycl Early in the studies concerning The California Wat Plan it became apparent that such control and reg lation cannot be accomplished by surface stora alone, within foreseen economic limits. It was the fore necessary to examine in detail the feasibility utilizing the natural storage capacity available underground basins in order to supplement t available surface storage. Based on such examinati there is every indication that storage capacity, a quate by a relatively safe margin, exists in Calif nia's major underground basins to enable t necessary regulation, and that such regulation physically possible under conservative assumptio

Under The California Water Plan, sufficient res voir storage capacity would be necessary in regi of water surplus to so regulate water supplies t they may be exported at a nearly uniform rate, t reducing the sizes of transport conduits. Similar addition to further conservation of local water re-urces, reservoir storage space would be necessary in e areas of water deficiency to provide reregulation imported water, since such a rate of water delivery oes not correspond to the demand rates. Adequate urface reservoir storage capacity was found to be vailable in the North Coastal Area to accomplish the quired regulation. However, in the Sacramento and an Joaquin-Tulare Lake Basins and in the Lahontan, olorado Desert, and South Coastal Areas, the large olumes of required storage could not be provided ntirely in surface reservoirs.

In the case of the Sacramento River, San Joaquin iver, and Tulare Lake Basins, studies of the rela-on which would exist between historical inflow and timated ultimate water requirements indicate that maximum of approximately 53,000,000 acre-feet of clic storage capacity would be required to regulate e water supply so that water demands could be et as they occur, without shortages. It is further dicated that foothill storage reservoirs could be eco-omically constructed in the basins to an aggregate gulatory capacity of about 22,000,000 acre-feet. onsequently, the additional 31,000,000 acre-feet of quired storage space necessarily would be provided rough utilization of ground water basins. Estimates the storage capacity existing in the alluvium of e Central Valley, made by the United States Geo-gical Survey and the Department of Water Re-urces, indicate that some 133,000,000 acre-feet of oss storage capacity is available within 200 feet of e land surface. Taking into consideration areas of uestionable water quality and areas where rates of charge and extraction might present problems, it indicated that the usable storage capacity might nount to about 98,000,000 acre-feet.

se of Ground Water Storage

For the most part, the total storage capacity which available in the alluvial valley fills is the sum of e volumes of the innumerable small pore spaces, voids, that exist around the particles comprising e alluvial fill. Not all of this volume, however, is able; in clays and fine silts, the interparticle spaces e too minute to permit sufficient rates of water ovement. Moreover, not all of the water stored in e interstices of the alluvium will drain out as the ater table drops. Primarily, the larger pore spaces und in sand and gravel strata and deposits pro-de the usable underground storage space. Even in ese larger interstices, the movement of ground ater is so slow that rates of placing surface water storage, flow within the ground water basin itself, d rates of extracting water from storage by means wells are prime problems in the utilization of the orage capacity of a ground water basin.

In addition to the physical problems, economic and ater quality criteria must be considered fully in estimating usable ground water storage capacity and in selecting water supply sources. For each water use and for each source of supply there is an economic limit to the price which could be paid for the supply. Thus, there is a limiting depth from which ground water could be obtained economically. This economic depth, of course, varies with the use of the water. Profitable agricultural endeavors in certain areas of the State are now obtaining water from depths in excess of 600 feet. However, under The California Water Plan pumping depths of such magnitude are not envisaged.

If parts of the alluvium contain water of unsuable quality, or if soluble minerals exist within the subsurface basin which would degrade water placed in storage, these volumes of the alluvium cannot be considered as usable for water storage. In time, such zones or areas might be flushed of their degradants and become usable. However, since sufficient information is not now available concerning these processes, such areas are presently classed as unusable. In those areas where the upper fresh ground waters are underlain by connate saline water or where the possibility of sea-water intrusion exists, the draft on the usable ground water must be controlled, as to both rate and total annual amount, to the extent necessary to maintain the quality of those waters at acceptable levels. Operators of a ground water basin must exercise constant care to assure that usable storage space is not rendered unusable by an accumulation of damaging concentrations of undesirable minerals. This can be accomplished by controlling the quality of water placed in storage; by adjusting the relative use of surface and ground water throughout the basin; by controlling the rate, amount, and areal pattern of extractions; and by providing requisite drainage or outflow from the basin to maintain salt balance. The California Water Plan envisions the maintenance of the utility of ground water basins in perpetuity.

Surface reservoirs and subsurface basins are similar in that they each have replenishment and discharge characteristics. Surface reservoirs will store water as fast as the inlet channels permit, and may be designed to discharge at any rate. In the case of ground water basins, however, the recharge or replenishment capacities are not so completely subject to artificial control. At the same time, they constitute primary factors in determining the utility of the basin. Under natural conditions water enters the ground by infiltration from direct precipitation and by percolation from streams and ponds. Under artificial development, additional important means of recharge, namely, canal seepage, deep percolation of unconsumed applied irrigation water, return flow from cesspools and the like, become effective, as well as does artificial recharge by spreading and other means. In addition, an area lying at higher elevations that receives an abundance of surface water may serve as a source of replenishment to a lower-lying area by providing subsurface flow to the lower area.

The significance of the problem of ground water recharge rates is apparent when a comparison is made between the short duration and large volume of flood flows, or even the usual peaks of seasonal runoff, and the low rates at which stream percolation occurs. Furthermore, this problem is exaggerated where surface reservoirs capture all but the larger flows, thus reducing the ground water recharge period to a relatively few days of peak discharge. In addition, there are many instances where the natural recharge opportunity is so limited that additional capacity must be developed artificially. Artificial recharge may take the form of stream channel modification to increase the wetted stream bed area; construction of spreading ponds or ditches, recharge wells, and shafts; and operation of the irrigation canal system during the nonirrigation season to effect recharge during the period when canals and ditches normally would not be full. Such operation would provide additional opportunity for seepage from the surface distribution system.

Artificial recharge operations should be so located with respect to the geologic structure of the ground water basin as to achieve the most efficient utilization of the storage capacity and of the transmissibility of the aquifers. In selecting a location, consideration must likewise be given to the surface soil texture and subsurface structure in order to obtain the best percolation rates. Artificial recharge works may involve considerable areas of land, with consequent cost and possible interference with other potential land uses. There are other problems involved which necessitate careful consideration, including: construction and maintenance of diversion works from streams; control of silting; maintenance of percolation rates; and prevention of nuisance and protection of the public health through adequate mosquito control and other measures.

Storage of water underground through artificial recharge has been widely practiced in California since 1895. Much information and data are available both from actual operating experience and from controlled research, but further study and evaluation are needed. It is emphasized that thorough knowledge of the physical characteristics and geologic structure of a ground water basin is a prerequisite to successful artificial recharging operations therein.

Deep percolation of unconsumed applied irrigation water is an important means of ground water recharge. Drainage problems frequently develop in areas receiving abundant supplies of surface water, and the possibility that such problems may arise must be considered in planning the utilization of ground water basins. Such problems, however, can be prevented by controlled pumping of water from the ground water basin so as to maintain a lowered water table. The water thus pumped could be discharged from the area as drainage water, or could be utilized to irrigate adjacent or overlying lands, thus reducing the amount of the required surface supply. For example, if only the water requirement necessary to satisfy consumptive uses were imported to an area, and surface and ground water service areas were properly balanced, the amount of water entering ground water storage would be equal to the amount leaving ground water storage and water levels would not fluctuate appreciably from season to season, thereby preventing serious drainage problems. However, with such constant recharge and constant discharge, no cyclic regulation would be provided, and the underground basin would be ineffective in providing beneficial regulation of water supplies over long-time climatic cycles. Problems of salt accumulation in the ground water would undoubtedly arise.

On the other hand, if the entire service area were supplied with surface water to the maximum extent possible during wet periods and the ground water drawn upon to a much greater degree during dry periods, the ground water basin operated in conjunction with surface reservoirs could serve to regulate the available water supply over long-time climatic cycles.

Under the concept of planned utilization, the ground water in storage would be deliberately drawn down for beneficial use either on overlying lands or by export during dry periods, thus creating greater storage space to be refilled with excess runoff during ensuing wet periods under a carefully planned and managed program. The operation of available surface and ground water storage reservoirs would be so coordinated as to achieve the maximum feasible degree of conservation. This method of operation has been used in the studies for the Central Valley which are described subsequently.

In some regions, such as the South Coastal Area, where the runoff is extremely erratic both in season and from year to year, with dry periods of several years' duration, and where surface storage is very limited, the ground water basins must be relied upon for long-time cyclic storage. Under such circumstances, surface reservoirs are often used primarily to regulate the runoff to the extent necessary to enable the storage of the water underground through artificial recharge operations. It is anticipated that this practice will become increasingly prevalent in the more arid portions of the State in order to obtain the maximum practicable conservation of local water resources.

Under conditions of full development and planned utilization of ground water resources, the rate, the amount, and the areal pattern of extractions must be carefully planned and controlled if most efficient use is to be made of a basin. These withdrawal factors must be properly related to: the geologic structure both areally and vertically, of the basin; the areas of greatest potential usable storage capacity; the sources and areas of recharge; the transmissibility and permeability of the aquifers; the areas of water use; the possibility of water-logging in the lower portions of the basin; and the necessity of controlling subsurface outflow and effluent seepage from the basin. Here again it is obvious that full knowledge of the characteristics of the ground water basin is a prerequisite.

Certain legal and financial problems involved in the planned utilization of ground water basins are discussed in Chapter V.

Conjunctive Operation in the Central Valley

The coordinated operation of surface reservoirs with underground storage basins in the manner described, to produce the desired yield at minimum cost, is termed "conjunctive operation." Several trial operation studies were made for assumed conditions of ultimate development in the Central Valley. In these studies, the costs of operation with various combinations of surface reservoir release schedules and surface water transport capacities were compared with the costs of required ground water pumping, in order to determine the most economical, or optimum, balance between the two. The method of operation thus selected, and described in part herein, is presented not as the only method which would serve the purpose, but rather to illustrate in a general manner that the required conservation results could be attained.

The conjunctive operation of the entire Central Valley would not involve completely untried and unproved principles, but, before being put into practice, would require much additional study and investigation, particularly as to geologic conditions and economics. The only new aspects would be the valley-wide application of the operation and, to a certain extent, the flexibility in serving irrigated areas from both surface and ground water sources. However, in the operation herein described, provision was made for service to portions of the valley entirely from either surface sources or from ground water, where topographic, geologic, and ground water quality considerations dictate. Recharge to the ground water basins would occur mainly from deep percolation of the unconsumed surface application of water for irrigation and from seepage from unlined canals and distribution systems. In localized areas where normal ground water recharge is limited, artificial methods would be employed.

For studies of conjunctive operation, the Central Valley was separated into four parts: the Sacramento Valley, the Delta-Mendota Area, the San Joaquin Valley-West Side Area, and the San Joaquin Valley-East Side Area. The location of the four areas, and the major foothill storage reservoirs that were utilized in the studies, are depicted schematically on Plate 7, entitled "Conjunctively Operated Storage in the Central Valley."

The period chosen for detailed study of conjunctive operation of foothill and ground water reservoirs in the Central Valley was the 10-year period 1926-27 through 1935-36. This period includes the 6-year critical drought period, 1928-29 through 1933-34. In addition, water supply conditions prior to the 10-year period were such that the ground water reservoir could be considered to be full at the beginning of the period if conjunctive operation had been practiced on a long-term basis. Assuming an available water supply equivalent to the 10-year operation period, and assuming conditions of ultimate water demand, the operation study demonstrated that it would be possible to provide not only the ultimate water requirements for the entire Central Valley but also to provide a seasonal export to other areas of the State in excess of 1,700,000 acre-feet of water from the Sacramento Valley. Moreover, studies indicated that the ground water basins would again fill to the levels existing at the beginning of the 10-year period. A summary of results of the operation study is given in Table 29.

Several of the values given in Table 29 merit comment. For instance, the studies indicate that under the method of operation discussed herein, only 32 per cent of the usable ground water storage capacity within 200 feet of the ground surface would be required to accomplish the necessary cyclic regulation. Furthermore, since the selected 10-year period includes the most critical years during the 50-year mean period 1897-98 through 1946-47, from a water supply standpoint, it follows that the indicated maximum depths to ground water may occur about once in 50 years.

Under conjunctive operation, ground water pumping units would be distributed more uniformly over the underground basins, in comparison to the present over-concentration of wells in regions that derive their entire supply from underground sources. Furthermore, through use of an integrated surface distribution system, wells could be operated on a more continuous basis, thus reducing the number of installations required, and also reducing the unit costs of pumping by savings in stand-by charges.

In summary, utilization of the ground water storage capacity of the Central Valley is essential to the full ultimate development of the water resources of the State. There is economically available about 98,000,000 acre-feet of usable ground water storage capacity in the Central Valley, of which only 31,000,000 acre-feet would be required in the operation of The California Water Plan. In order to utilize effectively this subsurface reservoir, its conjunctive operation with the foothill surface reservoirs of the Central Valley would be required. A possible means of ob-

"Storage of water underground through artificial recharge has been widely practiced in California since 1895."

Hansen Spreading Grounds Near Burbank

TABLE 29

AMARY OF RESULTS OF CONJUNCTIVE OPERATION OF SURFACE RESERVOIRS AND GROUND WATER BASIN OF THE CENTRAL VALLEY UNDER CONDITIONS OF ULTIMATE WATER REQUIREMENTS DURING THE CRITICAL OPERATION PERIOD 1926-27 THROUGH 1935-36

Item	Main subdivisions				Total Central Valley
	Sacramento Valley	Delta-Mendota Area	San Joaquin Valley		
			West Side Area	East Side Area	
able foothill reservoir storage capacity, in millions of acre-feet	13.8	------	2.1	6.5	22.4
ired ground water storage capacity, in millions of acre-feet	4.0	6.8	6.4	13.7	30.9
ated usable ground water storage capacity within 200 feet of land surface, in millions acre-feet	27.7	10.9	15.3	43.8	97.7
on of usable ground water storage required, in per cent	14	62	42	31	32
on of gross local water demand satified by ground water, in per cent, in:					
Dry season	80	74	53	68	67
Wet season	30	31	35	14	25
Average season	60	38	38	42	45
mum gross seasonal recharge of ground water basin, in millions of acre-feet	7.2	1.3	2.8	5.0	16.3
mum seasonal depletion of ground water in storage, in millions of acre-feet	3.1	1.3	1.1	3.1	8.6
mum installed ground water pumping capacity, in millions of gallons per minute	6.2	2.3	2.5	7.5	18.5
oximate number of pumping plants required	6,000	3,250	2,500	7,500	19,250
ge depth to ground water, in feet from ground surface	25	60	40	30	30
mum mean depth to ground water, in feet	50	130	90	70	70

aing much of the recharge capacity necessary to rate the ground water basins of the Central Val- would be to have sufficient distribution capacity enable, on occasion, the service of about 75 per t of the area from surface supplies. Thus, the page from canals and deep percolation of uncon- ied applied irrigation water, plus certain artificial harge works, would recharge the underground ns so that they would be filled and be available heavy draft during drought periods.

tudies of conjunctive operation indicate that in t areas where considerable present development ts, the average depth to ground water would be than at present and, in areas where little ground er development has occurred, the depths to ground er would be reasonable.

s pointed out, there are actually no new principles olved in the operations just described. Further- e, there is every indication that the required und water storage capacity is available and that required recharge rates could be obtained. A ewhat similar method of operation is being prac- d at the present time in parts of the Tulare Lake in, notably in the service areas of the Kaweah, e, and Kern Rivers. The Raymond Basin area in hern California has been operated since 1945 on a planned basis.

ased upon present knowledge and the assumptions have been made regarding available water sup- s and ultimate water requirements, it is indicated it will be necessary to operate the underground ns in coordination with foothill reservoirs in ewhat the manner which has been described. thermore, there is every reason to believe that such operation could develop by local initiative and under local control to a considerable degree, although region-wide guidance in planning and control in operation would be necessary for most effective results. The legal problems involved in conjunctive operation are discussed in Chapter V.

SUMMARY OF THE CALIFORNIA WATER PLAN

There has been described in this chapter a vast system of integrated works, both local and inter-basin, which serves to demonstrate that the objectives of The California Water Plan are physically possible of accomplishment within the limits of available water resources. While it is acknowledged that ultimate development of the land and other resources of the State may be achieved by works differing in many respects from those described herein, certain basic factors will remain essentially the same, regardless of the actual works ultimately selected for construction. Among these factors are: the probable ultimate water deficiency in the central and southern parts of the State; the ultimate surplus in the North Coastal Area and the Sacramento River Basin; the total storage requirement for the necessary regulation and control of water; and the approximate lengths and sizes of major aqueducts required to equalize geographically the water resources and the ultimate water requirements in California. In view of these factors, and of the inherent limitations of any plan for the indefinite future, it is considered that the works summarized in this section are as realistic as can now be foreseen.

TABLE 30

SUMMARY OF FEATURES, ACCOMPLISHMENTS, AND COSTS OF PHYSICAL WORKS UNDER THE CALIFORNIA WATER PLAN

(Excluding existing works)

Feature	Reservoirs				Conduit length, in miles			Pumping plants			Power plants			Capital costs of all works
	Total number	Capacity, in acre-feet		Mean annual yield, in acre-feet				Total number	Installed capacity, in kilowatts	Average seasonal pumping requirements, in millions of kilowatt-hours	Total number	Installed capacity, in kilowatts	Average seasonal power generation, in millions of kilowatt-hours	
		Gross	Active		Canal	Pipe	Tunnel							
Local Development Works														
North Coastal Area	50	3,652,000	3,100,000	1,295,000	47	13	3	12	91,900	158	1	90,000	344	274,425,000
San Fracisco Bay Area	11	235,000	231,000	103,000	10	43		10	4,500	24				34,064,000
Central Coastal Area	30	1,850,000	1,800,000	364,000	119	95		3	5,700	7				172,884,000
South Coastal Area	9	1,063,000	1,020,000	93,000		32								93,386,000
Sacramento River Basin	102	8,661,000	7,861,000	3,746,000	1,073	75	189				45	1,594,500	7,213	1,307,295,000
San Joaquin-Tulare Lake Basin	95	8,444,000	7,633,000	4,639,000	915	4	63	3	140,000	400	32	1,058,000	4,657	919,986,000
Lahontan Area	9	583,000	572,000	369,000	37	3	32				8	99,000	430	75,014,000
Colorado Desert Area														
Subtotal	306	24,488,000	22,217,000	6,863,000	2,201	265	287	28	242,100	589	86	2,841,500	12,644	2,877,054,000
California Aqueduct System														
Klamath-Trinity Division	15[a]	28,726,000	15,076,000	8,182,000			76	3	1,088,000	3,827	7	1,745,000	6,570	2,315,100,000
Eel River Division	10[b]	12,615,000	6,759,000	2,530,000	39		23	3	522,000	1,912	9	631,000	2,633	812,250,000
Sacramento Division	17[c]	7,805,000	6,769,000	6,395,000	286	5	11				9	1,475,000	7,342	1,285,000,000
Delta Division	5	148,000		Regulatory	176	39	3	10	738,000	4,273				488,400,000
San Joaquin Division	10	2,485,000		Regulatory	766	23	42	15	1,276,000	5,851				1,127,410,000
Southern California Division	13	602,000		Regulatory	1,519	348	156	16	8,495,000	32,593	11	1,091,000	4,578	2,933,390,000
Subtotal	70	52,381,000	28,604,000	17,107,000	2,786	415	311	47	12,119,000	48,456	36	4,942,000	21,123	8,961,550,000
Totals	376	76,869,000	50,821,000	23,970,000	4,987	680	598	75	12,361,100	49,045	122	7,783,500	33,767	11,838,604,000

[a] Includes two regulatory reservoirs.
[b] Includes six regulatory reservoirs.
[c] Includes six regulatory reservoirs.

The general features of the local development orks and facilities of the California Aqueduct Sys- m, their requirements for pumping and accomplish- ents in terms of power generation, and their capital sts are presented in Table 30. Of a total of 376 servoirs shown in Table 30, 282 would be con- rvation reservoirs. 30 would be operated primarily r power generation, 60 would serve as regulatory or version reservoirs, and 4 would be operated solely r flood control.

Water transferred through conduits of the Califor- a Aqueduct System would be captured, controlled, d regulated by 26 major reservoirs, of which 15 ould be in the North Coastal Area and 11 in the cramento River Basin. The reservoirs in the Sac- mento River Basin would be operated in conjunc- n with ground water storage capacity in the Cen- l Valley for the regulation of additional variable asonal surplus flows. Of the remaining reservoirs the California Aqueduct System, 11 would be op- ated primarily for generation of power, 4 would rve as diversion reservoirs, and 29 would be op- ated for regulation of imported water to the de- nd schedule prevailing in the particular area rved.

Of the total of 49 billion kilowatt-hours of energy r season required to deliver water to all potential vice areas in the State, about 30 billion kilowatt- urs would be required to serve the high desert areas southern California. However, the total seasonal ergy production of about 34 billion kilowatt-hours, suming all facilities of The California Water Plan be in operation, would be reduced by nearly 11 lion kilowatt-hours, should the facilities which uld develop and distribute waters to the high desert areas not be constructed. Thus, the net seasonal energy requirement associated with the service of the high desert areas would be 19 billion kilowatt-hours.

Based on present price levels, the total cost of all the features of The California Water Plan would be about $11,900,000,000, of which the facilities of the California Aqueduct System would cost an estimated $9,000,000,000. The cost of the Plan, as its component features become successively implemented over an indefinite number of years, would be borne by the Federal Government, the State Government, and local agencies, in a coordinated and cooperative common effort to solve California's water problems.

Data on the accomplishments of The California Water Plan in terms of development and transfer of water are presented in Table 31. As shown in that table, about 7,000,000 acre-feet of new yield would be developed by local works, and nearly 22,000,000 acre-feet per season would be developed and transferred from areas of surplus to areas of deficiency by facilities of the California Aqueduct System, for a total of some 29,000,000 acre-feet per season of water, which would be made available by The California Water Plan. The development of this quantity of water cannot be accomplished by surface storage alone. It is estimated that some 31,000,000 acre-feet of ground water storage capacity would ultimately be utilized in the Central Valley to achieve the required degree of control and regulation of the water resources of the Sacramento River and San Joaquin-Tulare Lake Basins. Furthermore, operation of substantial ground water storage capacity in other parts of the State would be required in conjunction with the delivery of imported water supplies.

TABLE 31

SUMMARY OF ULTIMATE DEVELOPMENT AND TRANSFER OF WATER UNDER THE CALIFORNIA WATER PLAN

(In acre-feet per season)

Hydrographic area	Water requirements		Supplemental water requirements		Requirement met by existing local development works	Potential transfer under existing or claimed rights[a]		Additional yield from prospective local development works	Development and transfer of water by facilities of California Aqueduct System		Total ultimate available water supplies
	Present, 1950	Probable ultimate	Present, 1950	Probable ultimate		Export	Import		Export	Import	
North Coastal	513,000	2,064,000	13,000	1,564,000	500,000	----------	----------	1,564,000	11,620,000	----------	2,064,000
San Francisco Bay	710,000	3,512,000	42,000	[b]2,257,000	420,000	----------	835,000	103,000	----------	2,154,000	3,512,000
Central Coastal	630,000	2,246,000	65,000	1,681,000	565,000	----------	----------	468,000	----------	1,213,000	2,246,000
South Coastal	1,907,000	5,552,000	370,000	3,027,000	1,066,000	----------	[c]1,459,000	149,000	----------	2,878,000	5,552,000
Sacramento River Basin	3,819,000	7,427,000	124,000	3,732,000	3,668,000	34,000	27,000	3,732,000	10,274,000	----------	7,427,000
San Joaquin-Tulare Lake Basin (excluding Delta)	8,539,000	15,549,000	1,661,000	8,671,000	6,878,000	830,000	----------	877,000	----------	7,794,000	15,549,000
Sacramento-San Joaquin Delta	834,000	756,000	----------	[d]756,000	----------	----------	----------	----------	----------	756,000	756,000
Operation of Salinity Control Barrier	----------	876,000	----------	876,000	----------	----------	----------	----------	----------	876,000	876,000
Lahontan	741,000	6,736,000	279,000	6,148,000	451,000	329,000	11,000	126,000	----------	4,835,000	5,423,000
Colorado Desert	3,340,000	6,410,000	----------	2,181,000	79,000	----------	[e]4,150,000	----------	----------	1,388,000	5,617,000
Totals	21,033,000	51,128,000	2,554,000	30,893,000	13,627,000	1,193,000	[f]6,482,000	7,019,000	21,894,000	21,894,000	49,022,000

[a] Does not include imports or exports of water by facilities considered as features of the California Aqueduct System.
[b] Includes delivery of 146,000 acre-feet per season through Contra Costa Canal, considered a feature of the California Aqueduct System.
[c] Does not include conveyance and regulation loss of 73,000 acre-feet from Colorado River Aqueduct.
[d] Under ultimate conditions, Delta would be served an imported water supply.
[e] From Colorado River Aqueduct.
[f] Includes California's rights in and to the waters of the Colorado River, amounting to 5,362,000 acre-feet per year.

CHAPTER V

IMPLEMENTATION OF THE CALIFORNIA WATER PLAN

ere have been discussed and described so far in bulletin the water problems of California and a system of physical works which could accomplish objectives of The California Water Plan. Briefly, Plan has as its objectives the full satisfaction of ent and future water requirements for all bene- l purposes and uses in all parts of the State to maximum practicable extent. It has been pointed that development and operation of facilities ccomplish these objectives would bring about ad- nal engineering problems which must be con- ed and reconciled.

is chapter discusses certain considerations which basic to implementation of The California Water , and without which the Plan could never be tuated. These considerations, which are essentially nonengineering nature but which govern all engi- ing considerations, are described under the gen- heading "Prerequisites to Implementation of California Water Plan." In addition, this chap- discusses various other considerations which, ough not essential to the implementation of the , could exert a considerable effect on its scope accomplishments. These are discussed herein r the heading "Other Considerations Affecting California Water Plan."

REQUISITES TO IMPLEMENTATION OF THE CALIFORNIA WATER PLAN

ansformation of a system of physical works, such ose described in Chapter IV, from a plan to a ty, will require careful study and evaluation of and economic problems. Legal problems which be reconciled involve the inadequacy of present for accomplishment of comprehensive coor- ted water resource development, and the require- ts for amendment thereof or addition thereto. Eco- ic problems involve determinations of the need specific water development projects, benefits as ared to costs, and appropriate means of financ- Finally, and this cannot be emphasized too ngly, the solution of engineering, legal, and eco- ic problems would be of little avail toward actual ementation of The California Water Plan with- a high degree of cooperation and close coordina- of efforts of all agencies and individuals at the . state, and federal levels.

Legal Considerations

State-wide coordinated development of California's water resources, as contemplated under The California Water Plan, will necessarily pose many legal problems. Such problems relate to inadequacies and uncertainties of present statutes; the required procedure for acquisition of water rights in furtherance of the coordinated plan; the nature and extent of vested rights to use of surface and ground water; the extent of unavoidable interference with any such rights and the methods by which such rights may be compensated or otherwise adjusted in order to permit full operation of the Plan; preferential rights of areas in which water originates; effectiveness of contract rights in assuring areas of deficiency of a dependable water supply; and relations between the State and other agencies.

No attempt is made in this discussion to consider all legal problems that might arise. As might be expected, many of the legal questions connected with such a vast undertaking have not been resolved by the courts and the Legislature, and many of the questions which may arise cannot now even be anticipated. It has been necessary, therefore, in many cases merely to identify the problem and to limit the discussion to problems having the most general application and interest.

As previously stated, The California Water Plan is designed to include and supplement, rather than to supersede, existing water resource developments, and incorporates certain of the planned works now proposed or authorized for construction by public and private agencies and individuals. Agencies of the State and Federal Governments and water users' organizations may all construct and operate features of the Plan. The legal considerations vary considerably with the agency involved, but generally they fall within the same framework of law.

Water Rights. Any agency constructing or operating a unit of The California Water Plan would have to acquire or adjust water rights. If the operating agency were not the user, it would acquire and hold water rights for the benefit of the actual users. To the extent that unused water not now subject to vested rights would be made available by construction of storage and diversion facilities, the law pertaining to acquisition of rights to the use of unappropriated water would be applicable. Where necessary, vested

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rights might be acquired either by agreement or condemnation.

1. *Appropriative Rights.* The Legislature has established procedures for the appropriation of surplus water. Water flowing in a natural channel not already subject to appropriative or riparian rights is public water of the State and subject to appropriation in accordance with the provisions of the Water Code (Water Code § 1201). However, the statutory provisions relate only to surface water in a stream, lake, or other body of water, and to subterranean streams flowing through known and definite channels (Water Code § 1200).

The foregoing requirements are applicable to state agencies, as well as to private corporations, organizations, and individuals, and to the United States. There is no provision for withdrawing water from appropriation; a priority may be preserved, however, by filing an application to appropriate unappropriated water and following the procedures prescribed by law.

The Department of Water Resources is authorized by the provisions of Part 2, Division 6 of the Water Code, to file applications to appropriate water which "in its judgment is or may be required in the development and completion of the whole or any part of a general or coordinated plan looking toward the development, utilization or conservation of the water resources of the State . . ." (Water Code § 10500). Such applications are, in general, subject to the requirements and rules which govern applications by others, except that the Legislature has provided from time to time that they are not subject to the statutory requirements relating to diligence.

A number of applications have been filed since 1927 pursuant to the foregoing authorization. Provision has been made by the Legislature for assignment of or release from priority under any such applications when the release or assignment is for a "development not in conflict with such general or coordinated plan" (Water Code § 10504). The assignee of any such application is subject to the requirements of diligence provided in Part 2 of Division 2 of the Water Code. A number of these applications have been assigned, including some to the United States as operator of the Central Valley Project.

The foregoing procedure, whereby the Department of Water Resources may file applications to appropriate unappropriated water for general or coordinated plans of development, is the only presently authorized method whereby rights to the use of unappropriated water may be preserved in furtherance of planning by the State.

The California Water Plan involves utilization of much of the remaining surpluses in California streams. As the Plan is carried forward, consideration must be given to the filing of additional applications to appropriate the water covered by it, or in the alternative, to some other method of insuring orderly de velopment and maximum beneficial use of this re source.

2. *Acquisition of Existing Rights.* The Californi Water Plan is designed to minimize interference wit vested water rights, but a few instances of confli with senior rights would be inevitable in a plan o such magnitude. Water rights are property within th meaning of the rule that private property may n be taken or damaged for public use without paymen of just compensation. This means that to the exten vested water rights might be adversely affected b operation of The California Water Plan, they mu be acquired either by agreement, purchase, or co demnation.

Some theoretical problems arise in connection wit the purchase or condemnation of riparian rights but in practice if all the riparian owners adversel affected are compensated or otherwise satisfied, the is no one to complain. One who acquires an appropr ative water right may change the point of diversi and the place and purpose of use to conform with h project, provided other lawful users are not injure thereby. Permission to make such changes with respe to appropriations initiated under provisions of t Water Code must be secured from the State Wat Rights Board in accordance with the provisions Sections 1700 through 1705 of the Water Code.

The power of eminent domain may be exercised favor of a public use of water. The State Constituti provides that the use of all water appropriated for sa rental, or distribution is a public use and subject the regulation and control of the State, in the mann prescribed by law (Constitution, Article 14, Se tion 1).

The power of eminent domain may be exercised b the State or Federal Governments directly throu their immediate officers or agents, or the power m be exercised by public agencies, private corporatio and individuals when delegated by statute. If wat rights are damaged without compensation havi been made, the owner may file an action in inver condemnation to recover compensation.

3. *Exchange of Water.* It is probable that fu operation of The California Water Plan would requi exchanges of water between watersheds in so instances in order to achieve the most effective a economical distribution to areas of need. An exchan of existing supplies for water imported from anoth source has previously been effected by agreeme between the United States, as operator of the Cent Valley Project, and certain water users in the S Joaquin Valley. Of course, there is no legal obsta to such agreements, and it is contemplated that a exchange necessary would be effected under ne tiated agreements. Whether an exchange could imposed in the absence of agreement and, if so, up

what conditions and under what circumstances under present law, is open to question. Although it is stated in negative terms, the Department of Water Resources may be authorized to effect exchanges of water in the Central Valley Project by Section 11463 of the Water Code. This section provides that in the construction and operation of the project no exchange of the water of any watershed or areas for the water of any other watershed or area may be made unless the water requirements of the watershed or area in which the exchange is made are at all times met and satisfied to the same extent as though the exchange had not been made, and no right to the use of water shall be gained or lost by reason of any such exchange. No comparable provision in present law would govern units of The California Water Plan not included in the Central Valley Project. Further consideration must be given to the problem as water development in California proceeds.

4. *Rights of Areas of Origin and Areas of Deficiency.* For purposes of analysis, the so-called "county of origin" problem may be divided into two parts: first, the problems with respect to the *areas of origin;* and, second, those with respect to the *areas of deficiency.* As these terms are generally used, the principal areas of origin occur in the northern portion of the State above the latitude of Sacramento. In these northern California areas water occurs in excess of the ultimate requirements of the areas, and the surplus could be exported and used in other portions of the State without detriment to the areas of surplus. There are, however, localized areas within the areas of origin which may be correctly termed areas of deficiency, due to either their geographic location or the time of the occurrence of water.

The areas of deficiency include, generally speaking, the areas south of the latitude of Sacramento including the San Joaquin Valley, the San Francisco Bay Area, the Central Coastal Area, the desert areas, and Southern California.

The county of origin problem had its beginning about 30 years ago when plans for the Central Valley Project were being developed. Insofar as the areas of origin are concerned, the problem is one of insuring the reservation of adequate water for their future development. It is generally recognized that efficient utilization of the State's water resources requires reservations now for the future needs of mountain and foothill areas. Unless this is done, difficult exchange of water or expensive pumping installations might become necessary when these needs develop. With respect to the areas of deficiency, the problem is one of having reasonable assurance of a dependable water supply. The problem is basically physical in nature, having been created by unequal distribution of the State's water supplies, both as to time and place of occurrence. A full solution will require not only changes in the existing law, but, more importantly, the construction of physical works to meet the water needs in all areas of the State as such needs arise. With the ever-increasing competition among areas and uses for available water resources, a solution must be reached now. The solution to the problem must be state-wide in scope and must stem from attack of the whole problem rather than of the individual problems created by any specific project. It must be workable and must permit continued development of the State's water resources.

The only legal protection now afforded the counties or areas of origin for water for their future development is contained in Section 10505 and Sections 11460 through 11463 of the Water Code. As previously noted, the Department of Water Resources is authorized to file applications to appropriate water which is necessary for the coordinated development of the State's water resources. Applications have been filed by the State in furtherance of state plans. Some of these state filings have been assigned to the United States to be used as a basis for water rights in connection with the Central Valley Project, and others have been or are in the process of being assigned for various other projects. However, under the so-called "county of origin" law, the department is expressly prohibited from assigning or releasing the priority under any such application when, in its judgment, the effect would be to deprive the county in which the water originates of any such water necessary for its development (Water Code § 10505). Consequently, several of the assignments that have been executed contain conditions either reserving a specific amount of water for future use in the counties of origin, or making a reservation in terms of the law. To the extent, therefore, that a unit of The California Water Plan must depend upon a State application for necessary water rights, under present law, only water in excess of that necessary for development of the counties of origin would be availabe for use elsewhere.

The "county of origin" law under Section 10505 of the Water Code has the following marked limitations:

1. Section 10505 is applicable only where State filings have been made under Section 10500 of the Water Code, and can be effective only where an assignment or release of these filings is made. The streams upon which there are no State filings are not included under the so-called "county of origin" law as set forth in Section 10505.

2. The exemption from the ordinary legal requirements of diligence under State applications filed pursuant to Section 10500 of the Water Code is subject to renewal periodically by the Legislature. Should the Legislature fail to renew this exemption from diligence, the protection afforded to the counties of origin thereunder would probably be lost. The current ex-

tension of exemption from diligence expires on September 30, 1959.

3. There is the further problem as to how water reserved under State filings which have been assigned would be made available to users within the county of origin. There is some question at the present time as to whether any reservations for areas of origin would be effective as against anyone other than the assignee of State filings.

Under Water Code Sections 11460 through 11463, commonly referred to as the "watershed protection law," it is provided that, in the operation of the Central Valley Project, water may not be transported from a watershed in which it originates to other areas if it would deprive that watershed or areas adjacent thereto of water necessary for their future development. These sections of the code are limited in their applicability to the Central Valley Project, and present very serious problems for the operator of that project, since it is entirely conceivable under these sections that the substantial quantities of water developed under the Central Valley Project, and contracted for by numerous water users' organizations in the San Joaquin Valley, could be recalled for use in the watersheds of origin or areas immediately adjacent thereto. With such uncertainties, it is extremely difficult for the State or the Federal Government to plan intelligently or to operate the facilities of the Central Valley Project.

In addition to the cited problems, the question has been raised as to whether the existing county of origin and watershed protection statutes are in accordance with Article 14, Section 3, of the California Constitution.

As indicated by the foregoing discussion, there are now no constitutional guarantees for either the areas of origin or the areas of deficiency. The present statutes, insofar as the areas of origin are concerned, in some instances afford no protection and in other instances the protection is uncertain. The uncertainty created by the existing law makes any protection afforded to the areas of deficiency indefinite to the point where it is impossible to determine with certainty the quantities of water to be made available from certain projects for a specific service area on a continuing basis. This uncertainty with respect to the operation of any project has been of grave concern not only to the State but also to the Federal Government, and to local agencies attempting to construct water projects of their own.

In summary, the present statutes afford only limited and decidedly uncertain protection to the areas of origin with respect to reservation of adequate water for the future development of those areas. Water rights adverse to the future needs of the areas of origin continue to become vested. These areas now have no assurance that they will receive any assistance in the future in the construction of needed water development projects. They cannot depend upon unregulated stream flow for their future water supplies; conservation works must be constructed to regulate and conserve the natural stream flow. The present statutes create serious problems and uncertainties in the planning and operation of projects; these difficulties affect not only the State, but also the Federal Government and local agencies.

The areas of deficiency which may obtain water supplies under contract with the State as the operator of an export project now have no positive assurance that they will continue to receive a right to a dependable water supply under those contracts. Furthermore, some concern has been expressed that under the principles of a recent California court decision [*Mallon* v. *Long Beach*, 44 Cal. 2d. 199, 282 P. 2d. 481 (1955)], the State may, with complete immunity abrogate its contracts with its political subdivisions.

It has become increasingly clear that the only fina[l] solution lies in the adoption of a proper constitu[-] tional amendment and of implementing legislative en[-] actments. The solution must provide: (1) positive as[-] surance to the areas of origin that adequate water wil[l] be reserved for their future development, (2) positiv[e] assurance to the areas of deficiency that when the[y] contract with the State for water they can depen[d] upon the right to that supply, (3) removal of th[e] uncertainty inherent in existing statutes, and (4) a[n] adequately financed, continuing program of water de[-] velopment to meet the needs for water in all areas o[f] the State, as those needs arise and as projects t[o] satisfy them are found to be feasible.

Power of Eminent Domain. The power of emi[-] nent domain is necessary in constructing water pro[-] jects, not only for the acquisition of water right[s] but also for the acquisition of other real propert[y]. The Federal Government and most water users' orgar[n-] izations possess this power with few restrictions. Th[e] Department of Water Resources is specifically em[-] powered to condemn property in the name of the Stat[e] for construction and operation of the Central Valle[y] Project, including the Feather River Project. (Wate[r] Code § 11575 et seq.) There are certain restriction[s] upon its power to condemn rights to water appropr[i-] ated to public use prior to January 13, 1934, and t[o] condemn appurtenant works which were dedicated t[o] public use prior to July 1, 1933. Also, in the absen[ce] of agreement, the department may not take or destro[y] the line or plant of a common carrier railroad, publ[ic] utility, or state agency, or the appurtenances thereo[f] until new facilities of like character and equal usefu[l-] ness have been provided. The department also ha[s] authority, without these restrictions, to condem[n] rights of way for flood control works (Water Code [§] 8304). It has not been granted authority, however, t[o] condemn land and water rights for features of Th[e] California Water Plan not included in the Centr[al] alley Project, nor has it been specifically authorized acquire excess lands or lands required for ture use.

Planned Utilization of Ground Water Basins. onservation of the State's water resources to the tent that ultimately may be necessary would require njunctive operation of surface and underground orage capacity and use of the underground storage tential as terminal storage, as well as full developent of local ground water resources, under a carelly planned and managed method of operation. The neral manner in which these objectives could be complished and some possible methods of operation e described in other sections of this report. Planned eration of ground water storage would result in mporary lowering of ground water levels during y periods, possibly lower than the levels that otherise would have occurred, until replenishment could effected during later periods of surplus water pply. Present statutory law (Water Code § 1242) cognizes the storing of water underground as a neficial use if such water is later applied to a beneial purpose.

Each owner of land which overlies a ground water sin has a right correlative with the similar right each other such owner, to the reasonable beneficial e of water upon his land from the common ground ater supply. This right is closely analogous to the parian right pertaining to surface streams, and is a sted property interest which cannot lawfully be ken or damaged without observing the requirements due process of law.

Although some cases look in that direction, it is t definitely settled that a particular entity could tain a right to place water imported from another urce into a ground water basin for purposes of orage, and to subsequently withdraw an equivalent antity of the resultant commingled water, even if ere were no material impairment of vested rights the use of the natural supply. Legal problems ould also be encountered if an attempt were made create storage space in a ground water basin by liberately lowering the water level, even though e withdrawn water were put to beneficial use. Prest law realistically recognizes that minor inconvennce to existing rights caused by subsequent uses ay be unavoidable and is not actionable so long as is not unreasonable. Any substantial diminution of e available water supply or unreasonable interferce with means of diversion, however, entitles vners of prior rights to appropriate relief either by junction or, where a public use has attached, to mpensation. Substantial lowering of ground water vels, with consequent material increase in pumping fts, would fall within one or the other of these rules, epending on the degree.

From the foregoing it is clear that major changes in the regimen of ground water basins must be accompanied or preceded by a determination of the rights of the water users. Such determination by the courts is the only method of control over the operation and management of a ground water basin which is possible under existing statutes. An efficient method of determining rights to the use of ground water should be available.

There are two procedures provided by present statutes whereby the State Water Rights Board may assist the courts in the adjudication of water rights. Only one of these procedures, notably the "court reference" procedure, can be applied to percolating ground water. Under the court reference procedure, any action for the determination of water rights may be referred by the court to the board. Another procedure, commonly referred to as a "statutory adjudication," is restricted to surface bodies of water and to subterranean streams flowing through known and definite channels. Under this procedure, all claimants to water from a stream system can be brought before the State Water Rights Board upon petition filed with the board and signed by one or more claimants to the waters involved; and upon the filing of the board's findings with the Superior Court, a judgment that is conclusive on all parties can be entered. A large number of the smaller stream systems, particularly in northern California, have been adjudicated under the statutory procedure. A number of ground water adjudications have been completed and others are in process under the court reference procedure. Conclusions relative to ground water adjudications which appear to be warranted by the considerable experience of the State Water Rights Board and the Department of Water Resources in this field are:

(a) The boundaries of ground water basins can be determined only after competent and thorough geologic and hydrologic investigations.

(b) The safe yield of a ground water basin is not a fixed quantity but varies with (among other factors) the state of development in the basin and in the watersheds tributary thereto. Accordingly, periodic redeterminations must be made of the allowable extractions of water from the basin if effective utilization of the ground water is to be achieved.

(c) It will invariably take a considerable period of time and substantial expense to obtain the data necessary to determine the safe yield of a ground water basin with reasonable accuracy, but without these data the basin cannot be operated properly.

(d) Because of the obscurities inherent in the occurrence of ground water and the multiplicity and variable nature of the factors affecting the safe yield of a ground water basin, measurement and collection of the basic data required for adjudication should be initiated long prior to the actual adjudication and carried on continuously, so that, when the need therefor arises, the information will be available for use.

(e) In many instances it would be difficult to establish that excessive extractions of water have resulted in irreparable damage to a basin. Some basins could be pumped substantially dry without irreparable damage resulting to such basins, for upon cessation of pumping, the basin would gradually refill with water of satisfactory quality by natural processes. On the other hand, where compaction and subsidence occurs, or in coastal ground water basins where sea-water intrusion occurs due to overdraft, or in other special cases, a finding of irreparable damage might be made.

A program should be adopted for continuing investigation of the ground water areas of the State, particularly those determined to be required for effective operation of The California Water Plan, supported by adequate appropriations. By this means, as and when it becomes necessary to adjudicate rights to the use of these ground water basins, to the extent the necessary data are available, the expense and delay of adjudication thereof would be minimized.

In 1955, Part 5 was added to Division 2 of the Water Code, providing a procedure for filing notices with the State Water Rights Board by every person who extracts ground water in excess of a certain minimum amount in the Counties of Riverside, San Bernardino, Los Angeles, Ventura, and Santa Barbara. Any person may request the board to investigate and determine the facts stated in a notice. The determination of the board is prima facie evidence of such facts in any action or proceeding in which they are material. By operation of this procedure, there will in time be accumulated much relevant information concerning rights to the use of ground water, which will be available if and when it becomes necessary to adjudicate such rights, and which will serve to minimize expense and delay in such adjudications.

In proceeding with The California Water Plan, consideration should be given to the adequacy of existing law and administrative procedures to accomplish its purposes. Over the course of time, it is believed that it will become necessary to adjudicate the rights to ground water in most of the underground basins in the State. Among other things, consideration should now be given to existing procedures for the collection of data concerning ground water, existing procedures to determine rights to its use, existing procedures for handling overdraft situations, and to the adequacy of present law to allow full utilization of ground water basins. The following modifications to the court reference and statutory adjudication procedures have been proposed in order to simplify, improve, and minimize the expense involved,[1] and careful consideration should be given to legislation to accomplish them.

(a) A practical lis pendens procedure should be supplied. This should apply to both the court reference and statutory procedures.

(b) The trial court should be authorized to refer any case involving the determination of water rights surface or underground, at any time after filing of the complaint, to the State Water Rights Board, with direction to follow either the statutory adjudication procedure or the court reference procedure. This would supply a most desirable flexibility.

(c) The trial court should be authorized to impose from time to time, trial distribution schedules. This also should apply to both procedures.

(d) The State Water Rights Board should be authorized to investigate and report upon all rights to the use of water, including ground water rights. This modification is necessary only in the statutory adjudication procedure.

(e) Provision should be added to the statutory adjudication procedure to the effect that initiation of a proceeding tolls the statute of limitations, and that, on motion of the Water Rights Board, an action to adjudicate the rights, in whole or in part, involved in any such proceeding, filed during the pendency thereof, shall be abated.

(f) The trial court should be authorized to impos a physical solution, either as recommended by th referee or as suggested by the parties, and to ente any other order as the interests of justice may re quire. This should apply to both procedures.

(g) In entering its judgment the trial court shoul retain broad jurisdiction, in accordance with th principles approved by the Supreme Court of Cali fornia. This also should apply to both procedures.

In 1955 the Legislature enacted the Water Re plenishment District Act as Division 18 of the Wate Code. Although various other types of districts ar authorized to replenish ground water, water replen ishment districts organized under the provisions o this act would have the advantage of being author ized to levy assessments in proportion to wate pumped from the underground. This is particularl important in making equitable assessments of thos holding appropriative and prescriptive rights to us water on non-overlying land. These water users migh not be adequately assessed on an ad valorem basi

The organization of water replenishment district is limited to the Counties of Santa Barbara, Ventur Los Angeles, San Diego, Riverside, San Bernardin and Orange. As yet, no water replenishment distric has been organized, so it cannot be said definitel

[1] Based on statement of Henry Holsinger, then Principal Atto ney, Division of Water Resources (now Chairman, Sta Water Rights Board), before the Joint Legislative Interi Committee on Water Problems, December 14, 1954.

whether this will be an effective type of organization for utilizing a ground water basin. If it should prove to be so, consideration should be given to extending the coverage of the Water Replenishment District Act to other areas of the State.

In 1953, The Orange County Water District Act (Stats. 1933, Ch. 924) was amended to give the district similar assessment powers. The validity of these powers was sustained in *Orange County Water District* v. *Farnsworth,* 138 Cal. App. 2d. 518, 292 P. 2d. 97 (1956).

While it is not an immediate problem, it is evident that effective administration of the development and utilization of ground water resources, either by the State or by local agencies, or by both, will become mandatory as the stage of full water development is approached. When it becomes necessary to operate the major ground water basins for import-export purposes, as envisioned under The California Water Plan, the requisite authority to do so must exist. Studies should be initiated now as to the adequacy of existing statutes to accomplish these ends, so that the necessary amendments and additions thereto may be made at the appropriate time. The following items are suggested for consideration in this connection:

1. A constitutional amendment to authorize and accompanying statutes to set up procedures for (a) the planned utilization of ground water basins for carry-over storage, and (b) adjustment of conflicts with existing rights either by delivery of water or by cash compensation.

2. The requirement of permits and licenses for the appropriation of ground water.

3. Control and supervision of recharge of depleted ground water basins.

To protect and maintain the quality of the State's ground water resources, it is believed that minimum standards of water well construction and adequate procedures for the maintenance and abandonment of wells should be enforced as necessary throughout the State. This cannot be done under existing state law; consideration should be given to the enactment of necessary legislation at an early date.

Relationships With Other Agencies. 1. *Integration With Projects of Other Agencies.* Features of the California Water Plan constructed and operated by the Department of Water Resources would of necessity be integrated with features already constructed and to be constructed by other agencies. This is particularly important in connection with projects operated by the Federal Government.

The Sacramento River and Delta channels will be used as a common water conveyance system by both the Central Valley Project and the Feather River Project. The San Luis Reservoir would also be utilized by both projects under current proposals. It is apparent that detailed operational agreements will be necessary for the integrated operation of these features, so as to avoid conflict and to obtain the highest degree of beneficial use of water in an efficient manner. Both the Central Valley Project and the Feather River Project rely in part on water right applications filed by the State on the same day. In general, use of natural stream flow by the two projects will be inextricably interrelated. Both projects require an agreement or determination as to the water available for their use—as between each other, and in relation to water users in the Sacramento-San Joaquin Stream System holding senior rights. There is no reason to believe that all of these problems cannot be solved by agreement if all of the parties approach them in good faith.

2. *The Federal Power Act.* The Federal Power Act authorizes the Federal Power Commission to issue preliminary permits and licenses for the purpose of investigating, constructing, operating, and maintaining project works "necessary or convenient for the development and improvement of navigation and for the development, transmission and utilization of power" in navigable waters of the United States or upon public lands and reservations of the United States (except national parks and monuments), or to utilize surplus water or water power from any government dam [41 Stat. 1063, 1065 (1920) as amended, 16 U.S.C. s. 797 (e) (1952 ed.)]. Construction, operation, or maintenance of any such project works by any person, state, or municipality without first securing a license from the Commission is unlawful. The act also contains provisions designed to accommodate state and federal law. Since the Federal Power Commission has authority over the planning and construction of certain hydroelectric projects within the states, conflicts may occur if the projects licensed by the commission differ from those approved by the state by the granting of necessary water rights. If conflicts should occur between federal power projects and The California Water Plan, they would have to be settled by the courts or by the Congress.

Water Development for Fish and Wildlife and for Recreational Use. In order to provide sufficient flowing water in a stream for fish and wildlife and for the enhancement of recreational aspects of a stream, it may be necessary to store water in headwater reservoirs to permit planned releases during low-water periods. The combined releases and natural flows would be planned for a desirable all-year regimen of flow in the interests of protection and enhancement of fish, wildlife, and recreation.

In order to accomplish the foregoing objectives, the planned stream flows should be protected against appropriations of water for other purposes. However, present law does not provide positive and reliable protection for such natural or unregulated flows in a watercourse where such flows are not otherwise taken under control. As is elsewhere pointed out, there is no method for broadly reserving unappropriated water from appropriation under the general law pertaining to that subject. Furthermore, continuance of the unobstructed natural flow of a stream probably cannot be assured by making an appropriation of water for that purpose, because an essential element of an appropriation is generally considered to be the exercise of physical control and dominion over an identifiable quantity of water by either diverting it from the stream channel or by artificial regulation of the flow within the channel.

Section 525 of the Fish and Game Code requires the owner of a dam to allow sufficient water to pass the dam to keep fish in good condition below the dam. Other sections of the code permit the planting of fish or construction of a hatchery in lieu of a fishway over or around a dam in certain instances. Section 526.5 of the code prohibits issuance of a permit or license to appropriate water in Fish and Game District 4½ (Inyo and Mono Counties), unless conditioned upon full compliance with Section 525. These sections have not been construed by California courts, but the Attorney General has concluded that Section 525 "is not a reservation of water for the preservation of fish life but is rather a rule for the operation of dams where there will be enough water below the dam to support fish life, i.e., it is a standard for the release of water in excess of what is needed for domestic and irrigation purposes so that what is available for fish life shall not be wastefully withheld" [18 Ops. Cal. Atty. Gen. 31, 37 (1951)].

Statutory Restrictions Upon Projects. 1. *Klamath River.* A restriction upon the construction and maintenance of dams and other obstructions on the Klamath River is contained in an initiative measure approved by the electorate on November 4, 1924, which provides in part:

> "Section 2. Every person, firm, corporation or company who constructs or maintains any dam or other artificial obstruction in any of the water of said Klamath river fish and game district [The Klamath River below its confluence with the Shasta] is guilty of a misdemeanor . . . and any artificial obstruction constructed, placed or maintained in said district is hereby declared to be a public nuisance." [Cal. Stat. (1925), p. XCIII, Deering's Gen. Laws, Ann., Act 2941.]

Whether the prohibition of the statute applies to the State or its agencies is an undetermined question. It assumes importance since The California Water Plan contemplates dams on the Klamath River at some future date, as yet undetermined. It is well established that a sovereign is not bound by general words limiting the rights and interests of its citizen unless such sovereign is included within the limitation expressly or by necessary implication. Assuming tha the State and its agencies are bound by the statut its amendment or repeal would be a prerequisite t construction of dams within the specified reach of th river. Such action would require favorable vote c the electorate. On the other hand, assuming th statute does not have that effect, legislation might b enacted authorizing an agency of the State to co struct one or more dams and diversion works at desig nated points on the river, and such constructio could proceed without further authorization.

2. *American River.* By California Statutes c 1955, Chapter 1583, Section 10001.5 was added t the Water Code excluding the Coloma Dam an Reservoir Project from the State Water Plan, an providing that no permit to appropriate water sha be issued by the State for the purposes of a proje which will flood any portion of the Gold Discover Site State Park at Coloma "unless such issuance specifically authorized by law." Under The Californ Water Plan a dam at this site, or a more expensi alternative means of storage by a diversion from th South Fork of the American River to Nashvil Reservoir on the Cosumnes River, is considered to b necessary in the future for full conservation of th waters of the American River. It is believed that th situation should be reviewed again by the Legislatu at the appropriate time when a choice between the two alternatives must be made.

Summary. The accomplishment of a plan whic would make possible the maximum utilization c California's water resources presents a large numb of legal problems, many of which can, at presen only be posed. Those of most immediate interest a of two types: (1) questions as to the adequacy c present law for the accomplishment of integrat water resource development, and (2) situations which the law has not yet been definitely determine by the Legislature or the courts.

Some of the questions in the first class are as fo lows:

Are administrative procedures for the appropri tion of unappropriated water, including the autho ity of the Department of Water Resources to file an assign applications, adequate to bring about th orderly development and maximum beneficial use c California's water resources? Is present law adequa to make possible the highest development of Califo nia's recreational resources under The Californ Water Plan, and, in particular, is it adequate to allo maintenance of stream flow for the purpose of pr serving and enhancing fishing and recreational us of California streams?

Still more numerous are the important questions as to which the controlling law has not been clearly formulated. Foremost among these is that pertaining to rights of counties and areas of water origin. A solution to this problem which will provide guarantees to the areas in which water originates that they will have enough water for their development, but at the same time will allow acquisition of firm contract rights to imported water, is for consideration by the Legislature and the electorate. Also unresolved is the question as to whether an owner of water rights could be required to accept a substitute water supply of comparable quality and quantity to that to which his rights attach. The California Water Plan has been developed so as to minimize interference with existing water rights, and where these rights are adversely affected, adequate adjustments must be made or the rights must be acquired either by purchase or condemnation.

Other unresolved questions concern relationships with other agencies. They involve settlements of water rights in the Sacramento-San Joaquin Stream System and operational agreements with other agencies, including the Federal Government. Close coordination must be maintained with the Federal Power Commission because of its jurisdiction over hydroelectric power developments on many of the State's streams.

Some Economic Considerations

If the sources of capital funds needed by any entity to construct features of The California Water Plan were unlimited, the attendant problems of implementation would be obviously simplified. However, in the allocation of scarce resources, such as capital and labor, among the various projects of the Plan, there should be simultaneous consideration of criteria for priority, justification, and scale of projects. While reasonable theoretical criteria may be used to accomplish orderly development of the State's water resources, it must be recognized that political, operational, and other considerations may alter the theoretical optimum.

Basically, the over-all objective of The California Water Plan is to enhance the general welfare of the people of the State; that is, to satisfy their needs and desires. These needs and desires are being continually increased by nearly half a million new people each year. This results, among other things, in the necessity of making available more than 500,000 acre-feet of new water each and every year if the growth trend is to continue. Consequently, the work that should be undertaken in the field of water resource development is of too large a magnitude to be pre-empted by any single agency, be it local, federal, or state. The efforts and capabilities of all agencies must supplement rather than supplant each other.

Some Considerations in Implementation of The California Water Plan. Implementation of The California Water Plan poses a number of major questions, such as: (1) why implement the Plan; (2) who should control the Plan and construct its component projects; (3) how should need and priority of construction be determined; and (4) how might projects of the Plan be financed.

1. *Why Implement the Plan.* Regarding the first question, Chapter II and III of this bulletin have stressed California's water problems and the resulting need for The California Water Plan. Hence, only two further comments are required. First, it is believed that coordinated, comprehensive, and progressive development as envisioned in the Plan would greatly increase the efficiency of use of the required capital, labor, land, and water.

Secondly, it should also be stated that as a result of California's water problems being so varied both in their nature and occurrence, and of such large magnitude, there is a strong state-wide interest in their solution, an interest long recognized by the Legislature. The state-wide interest implicit in implementing the Plan includes: effecting a balanced use of water resources for all purposes; obtaining maximum benefit from the use of storage capacity; resolving conflicts between groups representing particular purposes and/or particular areas; protecting the interests of future generations of Californians; accepting responsibility for those effects of a project which extend beyond the boundaries and/or jurisdiction of the project-sponsoring agency; and, for those projects which receive state financial aid, effecting the equitable distribution of benefits and costs, and avoiding the concentration of gains at public expense, insofar as possible.

2. *Control and Construction.* In order to receive the greatest value from The California Water Plan, basic responsibility for and control thereof should be vested in an agency which is state-wide in scope. The State of California is the logical, in fact the only, agency in a position to assume the leadership in the required coordination and control. The State is interested in the solution of all the water problems in all parts of California. The several agencies of the Federal Government which by law are engaged in water resource development are each interested only in certain phases of that development, within the limitations of federal policy and appropriations. Local groups, of course, are primarily concerned with the problems which face them locally. However, it is acknowledged that financial and other recognized limitations preclude any single agency from being able to carry out the financing, construction, and operation of all of the yet-to-be completed features of the Plan. Instead, leadership and participation by the State Government and continued participation by local water-using organizations and the Federal Government

will be needed to implement the Plan if the primary objectives thereof are to be substantially obtained.

3. *Determination of Need and Priority of Construction.* This refers to economic evaluation of water resources projects. In this regard, recommended criteria to be used by both the State and federal agencies in their evaluation of such projects were submitted to the United States Senate in a report entitled "Views of the California State Department of Water Resources on United States Senate Resolution 281, 84th Congress, 2d Session," dated November, 1956. Comments which follow on this subject are substantially contained in the foregoing report.

Construction of component projects of The California Water Plan should take place when a need for the products and services thereof is demonstrated. Once this is determined, then choice of the particular project to be constructed should be established by considering alternative sites and methods of providing the equivalent products or services. That is, each project chosen should accomplish the purpose or purposes intended more economically than by any other means.

A proper evaluation of any project requires balanced consideration of (1) an economic appraisal of those benefits and costs which are reasonably measurable in monetary terms, and (2) adequate consideration of all values and aspects not measurable in monetary terms. Policy determinations of what constitutes "benefits" and "costs" will have a great influence upon estimating both economic justification and financial feasibility. The question of "what project should be built" involves one of the most important matters of all, that of project selection.

In order to facilitate the ensuing discussion of some aspects of economic evaluation of projects, several of the terms used are defined as follows:

"Project"—any integral physical unit or several component and closely related units or features required for the control or development of water and/or related land resources within a specific area, and which can be considered as a separate entity on the basis of physical characteristics, functional accomplishments, or economic evaluation.

"Benefits"—all the net (gross gain less associated costs) identifiable gains or values which are measurable in monetary (tangible) or nonmonetary (intangible) terms which accrue to a project. Obviously, a benefit-cost ratio can include monetary values only.

"Primary Benefits"—all identifiable net gains or values which are realized directly by project beneficiaries through use of products or facilities of the project, but which may or may not be measurable in monetary terms.

"Secondary Benefits"—all net gains or net values which may or may not be measurable in monetary terms, which are properly creditable to the project, and which are realized over and above those include in primary benefits.

"Intangible Benefits"—all net gains or value attributable to a project which are not measurable in monetary terms, but which are nevertheless entitle to qualitative consideration on the basis of significan contributions to the economic strength, social struc ture, and welfare of the State or Nation.

"Economic Costs"—all of the monetary costs asso ciated with construction, operation, and maintenanc of a project, as well as all other identifiable expense losses, and liabilities, whether measurable in monetar or nonmonetary terms, that are associated therewith

An economic approach to the development of wate resources is essential, for such a study not only wil substantially show whether benefits exceed costs, bu comparison of such studies made of different project will show the order of their economic desirability.

Determination of the relative merits of projects and selection from alternative projects, are usuall best accomplished by comparing the benefits with th costs of each project. A benefit-cost ratio greater tha 1 to 1 is generally desirable in selecting a project fo further consideration, but it never should be the sol determinant. Such a ratio cannot reflect intangibl values which may be of substantial significance, no can it reflect completely the public interest. However if projects are proposed which do not show an exces of benefits, expressed in monetary terms, over cost the reasons for such should be clearly stated. Main re liance for project selection should be placed on a com parison of primary benefits with primary projec costs, although secondary benefits and costs, whe properly evaluated, may be separately considered.

Project costs are relatively simple to ascertain, in sofar as the application of principles and concepts ar concerned. Most of the project costs would usually b incurred over a short period of time and in the near term future. On the other hand, project benefits ca be of great variety and character, as can the projec detriments which also must be considered; they ca be both measurable and immeasurable; and the usually occur in increasing quantity over time an continue to occur over the useful life of the project Consequently, sound analysis of benefits becomes o the utmost importance, because the findings of suc an analysis provide the most substantial answer as t whether the project should be built either now o later, or not built at all.

Benefits stemming from a project of The Californi Water Plan could include some or all of the followin an increase in net income to the farmer using irriga tion water; a reduction in flood damages and improve ment in possible land use; augmentation of municipa water supplies so that new factories and shops an homes may be built; increase in the availability of hy droelectrical energy for peak-load purposes; preve tion of encroachment of saline waters into a ground water basin; maintenance of more favorable stream flows than under natural conditions, for enhancement of fish and wildlife values; increases in water recreational opportunities other than those derived from fish and wildlife; creation of more economically stable irrigated agricultural areas and adjacent urban communities; enhancement of the navigability of certain waterways; improvement in water quality brought about by project releases of water downstream during otherwise low-flow periods; and the increase in supplies of food and fiber which tends to reduce price increases that would occur otherwise during periods of full or near-full employment.

After appraisal has been made of the costs and benefits of a project, the need for cost allocation then arises when a project serves two or more purposes. The object of cost allocation is to provide for equitable distribution of the total multipurpose cost among the purposes served. The use of one structure to serve several purposes generally involves less total cost than if separate structures were provided for each purpose. An equitable distribution of multipurpose project costs should rest on the values created by the project. Benefits are the measure of these values, but they may be limited by the alternative cost of producing them. No one method of cost allocation is suitable for all conditions. However, on the basis of comparative advantages and disadvantages, the separable cost-remaining benefit method is generally recommended for use in the cost allocation of large projects; but in certain cases other methods of cost allocation may prove of value. Only after project costs have been allocated can repayment policies be selected within the framework of the laws and policies of the project-sponsoring agency.

The project should not be built until financial feasibility, that is, the sources of required capital funds and repayment of the reimbursable costs, is indicated. Such a feasibility study should indicate: the costs to be repaid; the contemplated repayment period; the probability of repayment; the rates to be charged for water and power to pay off their allocated share of the costs; and the extent to which each project purpose would have to be subsidized, if any, and, if so, the source of the subsidizing funds. Reimbursable project costs should be repaid by the beneficiaries of the project goods and services.

4. *How Projects of the Plan Could Be Financed.* As has been stated heretofore, it is contemplated that local water service agencies, the Federal Government, and the State would participate in financing and construction of The California Water Plan. Each of these groups has its own methods of raising capital funds and disbursing them.

Districts and cities customarily finance their projects by means of the issuance and sale of general obligation bonds and revenue bonds. Whereas revenue bonds are redeemed from project revenues only, general obligation bonds may be redeemed both from project revenues and from taxation of property in the district or city.

In the recent past the Federal Government has been assisting in the development of the State's water resources to the extent of about $70,000,000 a year, through appropriation by the Congress for reclamation and flood control projects. The Federal Government finances, constructs, and in some cases operates, its own works. It also appropriates certain nonreimbursable funds for its own water projects and for certain of those sponsored by non-federal entities, such as for flood control. Loans and grants are also made to non-federal public entities through such means as Public Law 566, 83rd Congress, the Watershed Protection and Flood Prevention Act, the Small Reclamation Projects Act of 1956, and Public Law 130, 84th Congress, which latter law provides for loans for the construction of distribution systems on authorized federal reclamation projects.

With respect to state financing and construction of some of the contemplated projects of The California Water Plan, methods to be used in raising funds and repaying them will depend upon policies yet to be established by the Legislature. However, a course of action should be followed which will expedite the objectives of the Plan. There are several possibilities by which the State could raise funds to be used in financing water development projects. These include provision of funds derived from current revenue, including oil royalty revenues, from the sale of general obligation and/or revenue bonds, and from the use of state trust funds backed by state guarantee.

It is proposed that the State immediately embark upon a long-range water resources development program which perforce would require a long-range financing program. A Water Development Fund is needed to finance and operate state-constructed water developments, to aid political subdivisions of the State in the construction of such developments, and to assist joint-use projects between the State and the Federal Government, or between the State and political subdivisions thereof.

Governor Goodwin J. Knight has recommended the creation of a water development fund, and on April 9, 1957, he further recommended to both houses of the Legislature that this fund should include the following moneys:

(1) Uncommitted tidelands oil revenues and income from this source through July 1, 1958. These will amount to approximately $101,000,000 after deducting the $38,000,000 appropriation now (May, 1957)

pending for continuation of the preparatory work at the Oroville Dam and Reservoir site.

(2) Future revenues from tidelands oil revenues in excess of $10,000,000 per year.

(3) The $75,000,000 now in the Revenue Deficiency Reserve Fund ("rainy day" fund), in the State Treasury.

(4) Moneys from the General Fund in amounts to be determined by the Legislature.

(5) Such moneys in other funds as may be determined by the Legislature to be available for this purpose.

(6) Net revenues derived from water projects operated by the State. In this regard, project revenues would be used first to pay for operation, maintenance, replacement costs and secondly for debt service charges before being transferred to the Water Development Fund.

(7) Proceeds from any bond issues that may be voted and sold in the future for construction of the Feather River Project and of other elements of The California Water Plan as they are authorized, and for financial participation in projects of the Federal Government and local agencies.

(8) Interest derived from the investment of moneys held in the Water Development Fund.

It is believed the most desirable method of obtaining the moneys for the Water Development Fund would be from current funds and revenue and by sale of bonds as and when needed to make up the balance of the total capital required. It would result in a combination of pay-as-you-go and pay-as-you-use. The use of current funds and revenues provides equity capital and reduces the over-all project costs to the State through large savings in interest payments that would otherwise have to be paid by the State. By holding down the total amount of bonds that must be sold by the State, it also mitigates any possible adverse effect on the current state program of selling general obligation bonds for school building and veterans' loan purposes.

Related to the State's proposed financing and construction activity are a number of most important policy matters, most of which are not as yet defined by statute. These include the question of whether certain of the project capital costs should be nonreimbursable or reimbursable. Should the State declare as public policy that project costs allocated to flood control, recreation, fish and wildlife, and water quality protection be nonreimbursable, due partly to the state-wide and also the federal interest inherent in such matters, and due partly to the difficulty in collecting the costs thereof from the beneficiaries? In this regard, it is believed that the State should consider the following as nonreimbursable: costs of flood control features of a project in those instances in which federal flood control contributions are unavailable; costs of lands, easements, rights of way, and utility relocations required for flood control projects, as have been assumed in the past pursuant to Part 6 of Division 6 of the Water Code; costs of lands, easements, rights of way, and utility relocations required for major projects having a high degree of state-wide interest; costs associated with the protection and enhancement of fish and wildlife; and at least a large proportion of the recreational costs associated directly with water development projects, provided there is a large state-wide interest, and further provided that the operation and maintenance costs thereof be not assumed by the foregoing Water Development Fund.

It is also believed that the reimbursable costs allocated to irrigation and municipal and industrial uses of water, as well as for hydroelectric power generation, should be repaid by the users thereof with interest.

Another policy matter is that of pricing or rate fixing with respect to the sale of power and marketing of water. It is considered that rates for sale of hydroelectric power should properly be based upon the cost of competitive thermal power for the same type of service, including taxes, as if it were under a privately owned utility. Full advantage should be taken of the increased values of hydroelectric energy as peaking power in establishing rates. First priority for vendible power, that is, power not required for project purposes, and in accordance with Part 3 of Division 6 of the Water Code, should be given to public agencies at established rates. Rates for irrigation and other vendible uses of water should be sufficient to cover all appropriate capital and annual operating, maintenance, and replacement costs required to make the water available; provided, that irrigation water rates should not be in excess of the water user's ability to pay after allowance for a reasonable margin of profit; and further provided, that net surplus revenues derived from the sale of power and other sources should be applied toward repayment of the capital costs associated with water deliveries for beneficial use, with preference being given to irrigation use.

All of the foregoing, as well as other policy matters, require much more thorough study than has been possible in the preparation of this bulletin. They are discussed briefly herein to outline the problems and to indicate the trend of current thinking by the Department of Water Resources.

There is within the State property estimated to have a current market value of about $100,000,000,000. From the income-generating portion of this value, the people who work with it produce an annual current disposable income of about $30,000,000,000. Under conditions of the State's population increasing ultimately to about 40,000,000 and the irrigated area expected to increase to about 20,000,000 acres, the market value of property in the State is expected to amount to at least $300,000,000,000 and the annual disposable income to increase to at least $90,000,000,-000, assuming current purchasing power values. For this as well as for other reasons, it is believed that adding a $12,000,000,000 system of major water works over a period of many decades by state, federal, and local agencies would not require appreciable financial sacrifices on the part of the people of California. Indeed, the incurring of such costs could be regarded as income-generating or opportunity investment.

Cooperation

It has been estimated that the over-all value in terms of present costs of all of California's water resource development works up to the present time is in the order of $6,000,000,000. These works have been achieved by individuals, private enterprise, public utilities, public districts, cities, and counties, with active participation by the State. Much has also been done by the several agencies of the Federal Government, including the Departments of Agriculture, Army, and Interior, under administrative control by the State through the mechanism of water rights. All of these enterprises required and received a high degree of cooperation among the participating groups to bring them into being and to keep them in operation. This cooperation usually began at grass roots level among the people affected, and in one way or another extended through all the participating agencies. Development began with simple, near-by, single-purpose water projects. As these opportunities progressively became scarcer, development inevitably moved into the larger, more difficult, and more expensive works, involving greater numbers of people and agencies. This in turn called for the addition of more purposes and water uses. Thus, the multipurpose projects of great size and relative economy, compared to a series of single-purpose works, have evolved. The need for cooperation between the large number of groups and agencies involved in the multipurpose project of today is readily apparent.

Cooperation between the Federal Government and local agencies has been manifested in the construction of flood control projects, and of multipurpose projects incorporating flood control features. Cooperation between local, State, and Federal Governments is exemplified in the Sacramento River Flood Control Project, in which all have participated in financing the construction, and in operation and maintenance of project facilities. The State has made substantial contributions to certain local districts in southern California for the repair of damaged flood control works, and, under provisions of the State Water Resources Act of 1945, has participated in the costs of lands, easements, and rights of way required of local agencies in connection with authorized federal flood control projects throughout the State.

There has also been cooperation between the Federal, State, and local governments in the planning and construction of major water conservation projects, of which the Central Valley Project is the most outstanding example. Mutual cooperation in the planning efforts of the Federal and State Governments is evidenced by federal statutes requiring the submission of certain federal reports to the states affected, for review and comment prior to their final release, and by the attendance by state representatives at pertinent congressional hearings in connection with water resources development planning. This mutual cooperation between all levels of government is not only highly desirable, but vitally necessary, and must continue.

Important as cooperation has been in the past and is at present, it will undoubtedly play an even more prominent role in the future development of California's water resources. The full development and proper use of the remaining uncontrolled waters of the State will require the construction of many projects which will be state-wide in scope. Close coordination in the planning, financing, construction, and operation by all agencies in the water development field will be necessary, in order to avoid overlapping of activities and duplication of effort, with resultant unnecessary cost increases, and to ensure optimum stream basin development. The State should logically assume the responsibility as coordinator of all activities, to the end that optimum water resource development is achieved by proper implementation of local, state, and federal policies. The basis for state responsibility for development of the water resources of California is set forth in Sections 100, 102, 104, and 105 of the State Water Code, which are discussed in Chapter I. The California Water Plan would serve as the framework for guidance and coordination of the activities of all agencies.

Notwithstanding the trend toward the need for state-wide water development projects, construction by local agencies will continue to play an important part in California's future. However, construction of major features of the California Aqueduct System would probably be beyond the capacity of local agencies, and would require the efforts of the State and Federal Governments. Moreover, the State should implement a program for furnishing assistance to local development, in the interest of the general welfare, to assure optimum development when such is beyond the capacity of local interests. An example of this might be the granting of state assistance to provide for the construction of a multipurpose project at a site where a local agency might have need or the means for construction only of a single-purpose project. The role of the State should fit into the existing framework of local-federal relationships.

Finally, in order that a construction program may be implemented so that the objectives of The California Water Plan can be accomplished, harmony and mutual good faith must be achieved between the various interests in different areas of the State to ensure passage of enabling legislation for authorizing, financing, and operating state-wide water development projects. Thus, with The California Water Plan to set the goal and to serve as a guide, the people of California can move forward with confidence and assurance that the water requirements of all areas in all parts of the State will be adequately provided for.

OTHER FACTORS AFFECTING ACCOMPLISHMENTS OF THE CALIFORNIA WATER PLAN

As previously stated, the water development works described in Chapter IV demonstrate one way believed practicable of accomplishing the objectives of The California Water Plan. It is acknowledged, however, that additional knowledge gained in the future, coupled with advancements in technology, may disclose more suitable alternatives to the works described herein. Moreover, continuing study of water requirements throughout the State as the future unfolds, may reveal that the requirements in certain areas may never eventuate in the amounts forecast herein. On the other hand, ultimate water requirements in other areas may possibly exceed the forecast amounts. In either of these eventualities, the water development works and conveyance facilities would have to be modified accordingly if and when the need arises.

In further investigation and planning for projects under The California Water Plan, every reasonable effort must be made to minimize the taking of irrigable and habitable land out of productive use, either present or future. To do otherwise might well penalize future Californians.

Advances in technology which would have a substantial influence upon The California Water Plan might be, among others, improvement in watershed management practices, which might increase the available water resources and decrease the destructive sedimentation in reservoirs. Also, the development of lower-cost energy in abundance might exert a vast influence over the selection of major aqueduct routes and the balance between pumping lifts and tunnel lengths, as well as the capacities of reservoirs for maintenance of elevation to reduce pumping lifts. Furthermore, discovery of an economically feasible method of saline water conversion and the provision of adequate supplies of energy therefor, might well decrease the total amount of water that would otherwise have to be imported ultimately to coastal metropolitan areas. The United States Department of The Interior and the University of California and other agencies are actively engaged in research in the field of conversion of saline to fresh water. At the present time, it does not appear that there is much prospect of providing significant amounts of additional water by this means, at economically competitive costs, within the next 25 years, at least. In another field of technology, effective methods of weather modification on a large scale may be found which would increase the total amount of water available for use. Several of these significant factors are further discussed hereafter.

Watershed Management

The impact of watershed management upon The California Water Plan would be manifested in several possible ways: first, by the influence on the regimen and characteristics of runoff following storms, with the consequent effect on erosion and resultant silt deposition in storage reservoirs; and second, by the influence on the quantity of water available for capture and regulation. The objectives of watershed management in relation to The California Water Plan would be (1) to reduce the silt deposition, or sedimentation, which impairs or destroys the effectiveness of expensive and frequently irreplaceable reservoirs, and clogs stream channels, and (2) to increase watershed yield by improving the regimen and characteristics of runoff and, perhaps, by increasing the total water production as well.

Fortunately, these two objectives are generally compatible, in that the measures taken to reduce destructive soil erosion, which not only reduces reservoir storage capacity but results in an economic loss from reduced productive capacity of watershed lands, would also improve the regimen of runoff. Although the over-all effects of various soil conservation measures have not been conclusively evaluated from the standpoint of their effects on water yield, there is universal agreement regarding the need for reduction in soil erosion which is detrimental from all aspects.

The effects of erosion, with resulting sedimentation of streams and, more particularly, of the reservoirs built on those streams, can be illustrated by two typical examples. Sweasey Reservoir on the Mad River was constructed in 1938 at a cost of a million dollars, to provide water for the City of Eureka. Today this reservoir is virtually filled with stream debris and has no effective storage capacity. Its regulatory effect has been rendered useless, and the dam serves only to divert into a pipe line whatever water is available in the stream. Another such example is evidenced by Gibraltar Reservoir on the Santa Ynez River, which serves water to the community in and adjacent to the City of Santa Barbara. Gibraltar Dam was constructed in 1920 with an initial storage capacity of 15,000 acre-feet. By 1950, the accumulation of silt

"The objectives of watershed management . . . to reduce sedimentation . . . to improve the regimen of stream flow . . ."
Sierra Nevada Snowfield

and debris had reduced available capacity to 7,000 acre-feet, and it was necessary to raise the dam 15 feet to restore the original capacity. These are only two of many similar occurrences in the State. Inasmuch as good dam and reservoir sites are becoming increasingly difficult to find, and are becoming exceedingly costly, it is apparent that an effective means of reducing reservoir sedimentation is an important consideration in present and future water resource development. In addition, sediment transport and deposition in stream channels adds significantly to flood control problems.

From yet another important viewpoint, erosion and subsequent silt deposition in streams is of serious concern in the northern part of the State. Silt deposits are harmful to the spawning activities of anadromous fish such as steelhead and salmon, and detract from the recreational value of the streams. Much of the future economy of the northern areas has been forecast to be recreational, and the streams and watersheds are key assets to recreation. Preservation of the recreational value of California's streams is important to the present and future welfare of the people.

It is generally known that proper watershed management, in terms of its effects on downstream reservoirs, are those which will tend to minimize erosion. It is also generally agreed by the operators of watershed lands—the ranchers, stockmen, and foresters—that the most desirable watershed management practices are those which preserve the valuable soil mantle. To this extent, the objectives of both the operator of the watershed and the operator of the downstream reservoir are in harmony. However, a very real need exists for long-range research, and for objective investigation and study of the many factors involved in soil erosion on watershed lands and silt deposition in streams and reservoirs.

In addition to the purely soil conservation practices, other aspects of watershed management are of importance in relation to California's future water supply. Forest and range management and snowpack management offer possibilities for improvement in water yields by a more favorable seasonal distribution in most cases, and by an increase in quantity of runoff under some conditions. However, sufficient knowledge has not been gained in these fields to permit evaluation of their effects.

Forest and range management consists of the adoption of good logging and lumbering practices, prevention and control of fire, and the control of recreation, mining, road building, and other types of miscellaneous human activity. Major fires can be extremely damaging to watersheds, as has been recently demonstrated again in southern California. The overall effects of controlled light burning under certain conditions are not known exactly. Lumbering and logging activities, if not managed carefully, can contribute seriously to erosion, particularly from tractor operations, skid trails, and logging roads. More efficient range management, in terms of replacement of uneconomic brush lands by annual and perennial grasses, offers a possibility for increasing the water yield. However, there is considerable lack of agreement on the effects of such practices on the yield of water and on erosion.

A new concept in the field of watershed management involves the manipulation of snowpack in such a way that it can be made to contribute more effectively to downstream water supplies. The objectives of snowpack management would be to direct logging operations in the snowpack areas in such a manner as to (1) maximize the accumulation of snow on the ground by minimizing losses of water from evaporation and transpiration, and (2) extend the snowmelt period. With respect to the first objective, conifers, particularly spruces and firs, intercept a significant portion of the snowfall, which is then lost through direct evaporation. Provision of adequate amounts of open space would increase the amount of snowpack by decreasing this direct evaporation. With respect to the second objective, studies indicate that snow accumulates to greater depths in more open areas, but that melting is more rapid. Recent studies have also indicated that melting occurs less rapidly when the snow has accumulated in drifts than when it is in an even blanket. There is a possibility of increasing the water supply and prolonging the snowmelt period by narrow strip clearings, taking advantage of prevailing winds to form drifts which would be protected by the shade from the bordering forests.

Research with respect to snowpack management has recently been undertaken by the California Forest and Range Experiment Station of the United States Forest Service in cooperation with the State Department of Water Resources, and by the United States Forest Service in the Fraser Experimental Forest in Colorado.

Future Development of Electric Power

The concept of electric power as an essential partner in water resource development is not new in California. The early and extensive use of electric power for pumping water at reasonable cost has contributed much to the development of irrigation and municipal water supplies, and the inclusion of hydroelectric generation in multiple-purpose developments has resulted in moderate charges for water.

The California Water Plan contemplates a large total output of hydroelectric power, and an even greater power requirement for pumping associated with the transfer of water from areas of surplus to areas of deficiency. Because of these considerations and the large capital costs of the water development works involved, it is imperative that The California

Water Plan make maximum use of revenue from hydroelectric generation and of low-cost off-peak power for pumping. It therefore is evident that the future development of electric power, as it relates to the market for and value of hydroelectric output, and to the availability and cost of off-peak power for pumping, is a vital consideration affecting the Plan.

The magnitude of new power generation and power required for pumping under operation of The California Water Plan will be more readily grasped by comparison with the total California power load in the year 1955, which was 7,800,000 kilowatts and 44 billion kilowatt-hours. The estimated new installed hydroelectric capacity under operation of the Plan would coincidentally be 7,800,000 kilowatts and the energy output would be 34 billion kilowatt-hours, while the estimated ultimate pumping capacity would be 12.3 million kilowatts and the energy requirement would be 49 billion kilowatt-hours.

One of the factors to be considered in estimating the market for hydroelectric power output and the availability of off-peak pumping power is the power load growth, which is closely related to California's industrial expansion, rapidly increasing population, and the marked trend toward greater per capita consumption of power. It is estimated that by the year 2000 the State's power load will have increased to more than 10 times the present load. In such terms the power output and the pumping requirement of The California Water Plan would be relatively moderate portions of the total.

Inherent Advantages of Hydroelectric Power Plants. Hydroelectric power plants based upon stored water have several inherent advantages over steam-electric plants which, for all practical purposes, are now the only other source of electric power production. Among the more important advantages are: (a) outstanding operating flexibility; (b) significantly greater reliability; (c) lower cost of incremental capacity; (d) higher adaptability to automatic operation and production of peaking power; (e) greater resistance to inflationary trends, due to longer life and lesser proportion of nonfixed charges; and (f) less vulnerability to wartime exigencies of scarcity of fuel, fuel transportation bottlenecks, and bombing.

Hydroelectric Power Plants for Peaking Operation. The magnitude of the system electric power load varies continuously throughout the day. These varying demands, plotted against hours of the day, comprise the daily load curve. The continuous, or base load, portion of the daily load curve is equal in magnitude to the minimum demand, which occurs during the early morning hours. This period of the day is frequently referred to as the period of "off-peak power." The period of maximum demand is also referred to as the period of "peak load and power." No two daily load curves are identical, and there is considerable variation throughout the week and from month to month.

The usual measure of the value of hydroelectric power output is the cost of alternative steam-electric production. This cost, or value, has two parts: first, a capacity component, equal to the total annual fixed cost associated with each kilowatt of dependable steam capacity; and, second, an energy component, which is the variable cost, largely fuel, of a kilowatt-hour of energy. It follows that those hydroelectric power plants having low incremental capacity costs are most economic when developed to the maximum capacity which is dependable in supplying a definite part of the varying load requirements. Such plants may be operated at full capacity for only a few hours each day in supplying the extreme peak of the daily load. Other hydroelectric power plants and steam-electric plants must be operated for longer periods in supplying the base load and the remainder of the peak of the load.

The degree of peaking is designated by the term "plant load factor," which is defined as the ratio of the average load on the plant (for a specific time period) to the dependable capacity of the plant. Low plant load factor signifies a high degree of peaking.

The effect of the degree of peaking upon hydroelectric power revenues can be illustrated with the aid of the two-part cost of producing alternative steam-electric power, as was used for estimating the value of hydroelectric power output under The California Water Plan, which was, as follows:

Capacity component	$22.00 per kilowatt-year
Energy component	2.8 mills per kilowatt-hour

The composite values of revenue corresponding to a wide range of plant load factors are:

Plant load factor, in per cent	80	60	40	20	15	10
Approximate total unit value, in mills per kilowatt-hour	6	7	9	15	20	28

It is apparent that the incremental capacity costs of many existing and proposed hydroelectric power plants would be such that plant load factors of 20 per cent or less could be justified for total unit values in the range of 15 to 30 mills per kilowatt-hour.

Hydroelectric power plants have great advantages for peaking, in addition to their low incremental capacity costs. They have marked operating advantage since they can pick up or drop load almost instantaneously, whereas large modern steam boilers and turbine-generators are relatively inflexible. The latter, moreover, must be operated as nearly continuously as possible in order to capitalize on the high efficiency which is built into them at considerable cost, whereas the intermittent operation of hydroelectric power plants involves no sacrifice in efficiency. In addition, the simple, low-speed, rugged construction of hydroelectric plants provides outstanding reliability in comparison with the high-speed, increasingly complicated steam-electric plants.

Hydro-Steam Ratio and Prospects for Hydroelectric Peaking. The ratio of dependable hydroelectric capacity to steam-electric capacity is of great importance in relation to the degree of hydroelectric peaking with its favorable effect on revenue, and also with respect to the availability of low-cost off-peak power for pumping. The role of hydroelectric power has changed markedly in recent years. Prior to World War II the hydro-steam ratio in California was about 2 to 1, and hydroelectric power plants commonly were used to supply the base load. Following the war, with rapid construction of steam-electric power plants to keep pace with the increasing load, the ratio declined sharply, until by 1953 it was less than 1 to 1, and hydroelectric capacity normally was used for peaking operation. The hydro-steam ratio in northern California as of the end of 1956 was 1 to 1.4; that in southern California was 1 to 2.0. The southern California ratio is expected to continue its rapid decline. The hydro-steam ratio in northern California probably will remain fairly constant until about 1965; thereafter, the ratio should resume its downward course.

With the decline in the hydro-steam ratio, steam-electric capacity has supplied more and more of the base load, and now also supplies a portion of the peaking requirement. This permits hydroelectric power plants to operate higher in the peak of the load, at lower plant load factor. In this way, water which at one time would have been utilized for base-load generation now is stored during off-peak hours and used to generate more of the high-value on-peak power than formerly.

By projecting present power load, resource, and operating characteristics into the future, and also by allowing for further decline in the hydro-steam ratio, it can be seen that there will be continuing need for much additional hydroelectric power capacity for peaking at low plant load factors Because of this need, and the fact that water supplies and economic sites for conventional types of hydroelectric power plants are relatively limited, the future role of pumped storage hydroelectric power plants is of interest.

Pumped Storage Hydroelectric Power Plants. Pumped storage hydroelectric power plants are peaking plants which pump all or a portion of their own water supply, requiring only afterbay and forebay reservoirs. Low-cost, off-peak, steam-generated energy, or seasonal hydroelectric energy, is used to pump water from the afterbay to the forebay. The pumped water then is used to generate higher-value on-peak energy by reversing the pumping units and operating them as generating units as the water is released to the afterbay. In the extreme case of pure pumped storage, the drainage area or other source of water must be sufficient merely to make up water losses.

A corollary to pumped storage hydroelectric power would be found in the Californa Aqueduct System. One instance would occur in crossing the Tehachapi Mountains. In this case, using off-peak energy, water would be pumped to an elevation where the topography and geology is favorable for an economical crossing, and then would be released to generate on-peak energy as it descends to lower elevations on the other side of the mountain range. Of course, forebay and afterbay storage and larger pumping and generating capacities would be required for the off-peak operation.

Pumped storage plants generally would have an over-all efficiency of about 67 percent. This means that, currently, the economic balance of pumped storage in northern California is not as favorable as would be the case when a higher degree of peaking becomes possible due to a further decline in the hydro-steam ratio. It is possible that for southern California, with its rapidly declining hydro-steam ratio and limited supply of water, it may be possible to justify a considerable amount of pure pumped storage in the near future. An increase in the difference between the value of on-peak energy and the cost of off-peak energy also would encourage installation of pumped storage plants.

Cost of Fossil Fuels and the Hydro-Steam Ratio. Fossil fuels comprise coal, petroleum, and natural gas. Although California does not have commercial deposits of coal, many persons have assumed that this State was blessed with ample oil and natural gas reserves for decades to come. The fact is that these reserves have always been limited in comparison to today's rate of use. Currently California imports some oil and the major part of the natural gas to meet its requirements.

Having in mind the continuing rapid increase in total energy requirement, it is clear that increases in fossil fuel cost may be expected, limited by the availability of Utah coal, the oil shale deposits of northwestern Colorado and vicinity, and the importation of foreign oil. It appears inevitable that the fuel component of fossil steam-electric power cost will increase in spite of continued increase in efficiency of steam plants.

One effect of disproportionate increases in fossil fuel costs would be to encourage construction of conventional hydroelectric power plants. However, such fuel cost increases would tend to increase the cost of off-peak energy for pumping, and would thereby tend to discourage development of pumped storage hydroelectric power plants. In view of the fact that most of the State's undeveloped hydroelectric power resources are in northern California and that southern California, because of limited opportunities for further

›velopment of hydroelectric power resources, should ‹perience an earlier development of pumped storage ‹droelectric power, it appears that the net effect of ›ssil fuel cost increases would be to moderate the ›cline of the hydro-steam ratio in northern Califor-ia, but accelerate the decline in southern California.

Market for Hydroelectric Power Output. With a ›wer load that has been doubling each 10 years and hich is estimated to reach 85,000,000 kilowatts by the ›ar 2000, there is no question about there being a ıarket ultimately for all of the hydroelectric power ıtput of The California Water Plan. While the ulti-ıate market for power is significant, the market dur-ıg the next two or three decades presently is also ıportant.

Currently the dependable hydroelectric generating ıpacity in northern California is about 2,000,000 ilowatts. Is is estimated that by 1980 the total hydro-lectric power capacity may be 6,500,000 kilowatts, r approximately one-third of the total capacity re-uired to supply a forecast load of 17,000,000 kilo-atts. By using load, resources, and operating char-cteristics similar to those estimated by the Pacific ias and Electric Company for its power system in 961, and by assuming the peak of the load to be sup-lied by hydroelectric power, the plants supplying the ›p 27.3 per cent of the load, or about 4,600,000 kilo-atts, would, on the average, operate at the low-plant ›ad factor of about 15 per cent. Of course, portions f both the new and existing hydroelectric power apacity would not be used for high-degree peaking. 'or the assumed condition the hydro-steam ratio in orthern California would be 1 to 2 in 1980, com-›ared to the current ratio of 1 to 1.4.

The foregoing illustration clearly points up the fact hat in northern as well as southern California a eady market for the power output of hydroelectric ›lants of multiple-purpose developments may be ex-›ected at considerably higher degrees of peaking and alue than were assumed in the estimates for The California Water Plan. The minimum plant load fac-or assumed in the Plan was 40 per cent under ad-erse hydroelectric power conditions.

Value of Hydroelectric Power Output. The usual ıeasure of the value of hydroelectric power output, as tated earlier, is the cost of alternative steam-electric ›roduction; and, as stated, the two-part rate used for valuating the hydroelectric power output under The 'alifornia Water Plan was:

Capacity component	$22.00 per kilowatt-year
Energy component	2.8 mills per kilowatt-hour

'his value was applied at the high-voltage side of he transformers at the hydroelectric power plant, and ncluded allowance for a transmission distance of 100 o 150 miles. For convenience, the rate was applied ıniformly to all projects.

Looking to the future, it appears probable that the capital costs (in constant value dollars) of steam-electric power plants will be relatively constant. The cost of fuel per kilowatt-hour, however, is expected to increase, in spite of continuing improvement in efficiency, due to probable increases in the cost of fossil fuels. Inasmuch as no credit was taken for the comparative advantages of hydroelectric power in deriving the capacity component of value, it appears that the two-part rate for value of hydroelectric power output used in studies for The California Water Plan is conservative. On this account and in view of the probable utilization of higher degrees of peaking than were assumed, it appears that the estimated hydroelectric power revenues under the Plan also are conservative.

Availability and Cost of Off-Peak Steam-Electric Energy for Pumping. The annual pumping energy requirement, largely off-peak, of the initial unit of The California Water Plan—the Feather River Project—is estimated to be about 5 billion kilowatt-hours by 1980 and nearly 10 billion by 1991. It is possible, also, that by 1980 the total requirement for off-peak pumping energy for pumped storage hydroelectric power plants may be appreciable.

In order that off-peak steam-electric energy may be available for pumping, the total system steam-electric capacity, including steam reserve, must exceed the system base, or continuous, load. This condition now exists in California. As yet the margin in some months of a dry year is not great in northern California. However, it is estimated that by the end of 1957 southern California will have an energy margin of 4.2 billion kilowatt-hours under adverse hydroelectric power conditions. Assuming no change in the hydro-steam ratio, the increase in the supply of surplus energy would be roughly proportional to the increase in power load. It is further estimated that in southern California alone some 20 billion kilowatt-hours of surplus energy should be available annually by 1980. A considerable portion of this surplus energy would be usable as off-peak energy for pumping. It is expected that higher-voltage transmission lines, interconnecting major loads and generating sources, will be available to a much greater degree than at present (1957) for transmitting both on-peak and off-peak energy throughout the State. It therefore appears that ample off-peak energy will be available for all pumping requirements as they develop.

Impact of Atomic-Electric Power. The discussion to this point has assumed no appreciable expansion of the atomic-electric industry. This approach was followed not because of any doubt that safe, competitive atomic power plants ultimately will be built; rather, it stemmed from uncertainty as to when this goal will be attained and as to the rate of expansion of this industry.

With respect to timing, the future supply of fossil fuel in relation to the rapidly expanding total energy requirement is of great significance. Development of atomic-electric energy is desirable to avoid rising fuel costs, and to conserve the relatively limited supply of nonrenewable fossil fuels for special, higher-value applications.

Presently a few small pilot-type atomic power plants are planned or are under construction in the United States, including two in California. Numerous difficult problems must be solved before safe, competitive atomic plants can become a reality. Because of the many uncertainties involved, forecasts as to when such plants would be in common use are still of doubtful value. In view of expected population and power load growth, it appears reasonable to assume that California would ultimately experience an atomic power industry expansion comparable, percentage-wise, to that of the United States as a whole.

Initially, the fixed or capacity costs of atomic-electric power plants probably would be higher than for fossil-electric plants, but it is claimed in some quarters that ultimately such costs may decrease to the level of fossil-electric capacity costs. It may be assumed that the operation of atomic-electric power plants would be similar to fossil-electric plants, in that they would be less adapted to noncontinuous operation, that is, on peak load. Therefore, hydroelectric power peaking plants would complement atomic-electric plants in the same manner that they now complement fossil-steam electric plants.

Summary. Generally speaking, with the rapidly expanding power load, there will be a market for the hydroelectric power output contemplated under operation of The California Water Plan, when and as that output becomes available. The great advantages of hydroelectric power, particularly for peaking operation, coupled with a declining hydro-steam ratio, will enable it to complement rather than compete with atomic-electric power plants, just as it now does with fossil-steam electric power plants. This is especially true of multiple-purpose projects having low incremental capacity costs and adequate water control. Single-purpose power projects which are not suited to high-degree peaking operation may feel the impact of competition provided by pumped storage hydroelectric power plants utilizing low-cost off-peak energy for pumping. It is concluded that ample off-peak energy will be available for pumping as required under The California Water Plan.

As conceived and formulated, The California Water Plan is a flexible pattern of water development which can be modified to fit changing conditions. It now appears that the declining hydro-steam ratio and future expansion of the atomic-electric power industry may lead to the modification of some contemplated hydroelectric power projects. The principal change would be in the direction of a higher degree of peaking, with lower plant load factors, including wide application of the pumped storage principle.

Needed Basic Investigation and Research

In spite of the years of experience and the store of knowledge that have been accumulated, there still are many factors or facets of the occurrence and use of water about which comparatively little is known. For instance, most of the water falling on the land as precipitation is disposed of by consumptive use. Yet the fundamental data upon which estimates of consumptive use of water must be based are quite meager and limited in duration. An extensive program to obtain more reliable basic data on consumptive use for a wide variety of vegetative cover and crops under different conditions and over a considerable period of time is urgently needed.

In the water quality field, more information is required concerning the effects of differing concentrations of various dissolved minerals on the yields of different agricultural crops under varying conditions of soil, drainage, climate, irrigation practices, and the like. More study is needed of the tolerances of various kinds of fish life to the many materials which may be added to streams by the disposal of sewage and industrial wastes, even though treated. With the increasing complexity of industrial wastes, this is a pressing problem if fishery resources are to be preserved.

Much remains to be learned about drainage, the characteristics of water-bearing materials in ground water basins, artificial recharge of ground water basins, methods to achieve more efficient use of water, sewage reclamation, saline water conversion, possibilities of utilization of atomic energy, decreasing evaporation from reservoirs, and a host of other factors, all of which are important to the implementation of The California Water Plan. Carefully controlled experimental work and evaluation of weather modification procedures over a period of several years and involving several large watersheds should be undertaken. Study is being devoted to these now to some extent, but it should be expanded and expedited.

The foregoing by no means encompass all the factors involved in the supply, distribution, utilization and disposal of water, concerning which current basic data are quite inadequate. They do serve to illustrate the scope of needed investigations and research and the urgency thereof. Research programs, adequately financed, must be prosecuted diligently to supply the needed information; the need for more data concerning consumptive use of water is particularly urgent.

ternative of Lower Dams in orth Coastal Area

Considerable question has been raised regarding e feasibility of the high dams discussed herein as atures of the California Aqueduct System in the orth Coastal Area. The opinion has been expressed at the objectives of The California Water Plan, articularly in terms of water conservation, could be ore satisfactorily achieved by a greater number of ms of conventional heights and types, instead of e fewer structures of unprecedented size.

Although it has been reiterated several times herebefore. it is again emphasized that the works deribed in Chapter IV represent only one possible eans of achieving the required degree of developent of California's water resources. These works ve been selected as a result of preliminary studies constituting the most feasible over-all development heme. The choice between the "super" and the conntional dams remains for future determination, sed upon intensive geologic, engineering, and ecomic studies, to be made as the need for exported ater supplies from the North Coastal Area develops. owever, some of the more pertinent factors bearing the selection of heights of dams in studies basic to e preparation of this bulletin are worthy of discuson.

Features of the Klamath-Trinity and Eel River ivisions of the California Aqueduct System were lected on the basis of net unit cost of water delivered the Sacramento Valley. The major items considered the evaluation of various alternative schemes were: 1) capital costs of dams and associated facilities, (2) st of electric energy for pumping, and (3) revenue om power developed. The plans selected and prented in this bulletin were those which would develop e required amounts of water at the lowest over-all st, considering these factors. As a result of these reliminary studies, certain of the reservoirs contemlated on the Klamath River would have large nounts of inactive storage for maintenance of miniım heads for power generation. Likewise, certain the prospective reservoirs on the Trinity and Eel ivers would have high percentages of inactive storge in order to minimize pumping lifts to the tunnels ading to the Sacramento Valley.

Geologic information available in the North Coastal rea is meager, and knowledge to be gained from deiled geologic exploration may definitely preclude gh dams at certain locations, thus forcing the selecon of alternative sites or the choice of lower dams. ther presently indeterminate factors, such as the ssibility of low-cost electric energy, might so affect e present economic balance between pumping lifts nd capital costs of dams and tunnels as to change bstantially the most feasible heights of dams.

In conclusion, the facilities herein described as features of the California Aqueduct System in the North Coastal Area serve only to demonstrate the physical possibility of developing and exporting some 11,000,000 acre-feet of water per year. While it is not known with certainty at the present time by just which means this water will be developed, it is reasonably certain that essentially the same aggregate amount of active reservoir storage capacity would be required, regardless of the final plan selected.

Alternative Future Development of High Desert Areas

As has been stated, The California Water Plan is an ultimate plan under which water supplies adequate for the development of the land and other resources of the State to their full potential could be provided. It is realized that the works required to conserve and convey water long distances to irrigate certain lands of limited crop adaptability, or lands lying at high elevations, or both, are not now, and may possibly never be, within limits of economic justification and financial feasibility. However, the economics of the distant future cannot now be foreseen, and the planning effort is deemed necessary in order that provision may be made for serving such lands, if and when the need arises.

As the future unfolds, The California Water Plan, by its inherent flexibility, would enable the staging of construction of those works which would most economically meet the increasing water requirements of all areas of the State, wherever and at whatever rates such increases may occur. In this respect, the probability of future development of the high desert areas of central and southern California is of interest. The effect upon estimated capital costs of The California Water Plan of inclusion of works to provide for the forecast ultimate development of those areas is significant.

The forecast ultimate full development of high-elevation desert areas of central and southern California might require an aggregate seasonal water import of about 6,000,000 acre-feet, distributed as follows:

Area	*Acre-feet per season*
Inyo-Kern area	1,600,000
Antelope and Mojave Valleys	2,250,000
Southeastern Lahontan area	1,850,000
Carrizo-Cuyama Valleys	300,000
Total	6,000,000

With exception of an anticipated import need for municipal-industrial purposes of about 200,000 acre-feet of water per season in the Antelope and Mojave Valleys the foregoing import requirements are based upon essentially a possible agricultural water demand. Present economics appear unfavorable for further extensive development of irrigated agriculture in these areas, due primarily to the limited local water supplies, the high cost of imported water, and climatic limitations. These economic factors, however, are not expected to control the already mushrooming urban, industrial, and military development in the Antelope and Mojave Valleys; in fact, such development may well continue to expand, and water to meet its requirements could be made available at costs well within the repayment capacity.

Should the projected agricultural development of the high-elevation desert areas fail to materialize, expansion of the California Aqueduct System would stop some 5,800,000 acre-feet per season short of its contemplated ultimate capacity of about 22,000,000 acre-feet per season. It is estimated that in this event the capital cost of the California Aqueduct System, constructed to a capacity of about 16,000,000 acre-feet per season, would aggregate about $5,100,000,000, or approximately $3,860,000,000 less than the capital cost of the system to meet all the forecast requirements, as summarized in Table 30.

The foregoing estimate is based upon the premise that construction of the California Aqueduct System would be orderly, in planned stages, with the timing of each stage dictated by needs for water and by economics. For purposes of illustration of this premise, assume that a point of time is reached when all water-deficient areas of the State would be receiving the forecast ultimate water service, except the high desert areas wherein demand for agricultural water would not have developed. In such a case, all prospective facilities of The California Water Plan would have been constructed, except those necessary to conserve and transport agricultural water for the high desert areas. The amount of this water, as has been stated, is estimated to be about 5,800,000 acre-feet a season. Let it be further assumed that, under such conditions, the relatively inexpensive export yields of the Sacramento Division of the California Aqueduct System would have been developed. This would leave certain of the most costly projects of the North Coastal Area undeveloped because of their physical location. These distant works would probably be the last in the chain of developments of the Klamath-Trinity and Eel River Divisions. In addition, the affected transport features of the California Aqueduct System would have been constructed to appropriately smaller capacities.

Features which could either be deleted from The California Water Plan or reduced in capacity, through elimination of service of irrigation water to the high desert areas of central and southern California, if such should prove unnecessary, and the magnitude of the resulting reduction in capital costs of the California Aqueduct System, are listed in Table 32.

TABLE 32

REDUCTION IN ESTIMATED CAPITAL COST OF THE CALIFORNIA WATER PLAN, ASSUMING PROJECTED AGRICULTURAL DEMAND OF HIGH-ELEVATION DESERT LANDS FAILS TO DEVELOP

Eliminated feature of California Aqueduct System	Reduction in capital cost
Klamath-Trinity Division	
Unconstructed features:	
Smith River (Canthook Dam and Reservoir; Black Hawk Dam, Reservoir, and Pumping Plant; Cantpeak Tunnel)	$190,000,000
Klamath River (Hamburg Dam, Reservoir, and Power Plant; Happy Camp Dam, Reservoir, and Power Plant; Humboldt Dam, Reservoir; Beaver Pumping Plant)	300,000,000
Mad, Van Duzen, and Trinity Rivers (Eaton Dam and Reservoir; Mad Tunnel; Ranger Station Dam and Reservoir; Sulphur Glade Tunnel and Power House; Eltapom Dam, Reservoir, Power House, and Afterbay; War Cry Tunnel)	170,000,000
Transport features constructed to partial capacity	620,000,000
Subtotal	$1,280,000,000
Eel River Division	
Unconstructed features:	
Eel River (Sequoia Dam and Reservoir; Bell Springs Pumping Plant)	$120,000,000
Transport features constructed to partial capacity	80,000,000
Subtotal	$200,000,000
Sacramento Division	
Unconstructed features:	
(Sacramento West Side Canal)	$360,000,000
Transport features constructed to partial capacity	40,000,000
Subtotal	$400,000,000
Delta Division	
Unconstructed features:	
(Antioch Crossing)	$210,000,000
Transport features constructed to partial capacity	30,000,000
Subtotal	$240,000,000
San Joaquin Division	
Unconstructed features:	
Carrizo-Cuyama Aqueduct	$50,000,000
Transport features constructed to partial capacity	350,000,000
Subtotal	$400,000,000
Southern California Division	
Unconstructed features:	
Antelope-Mojave Aqueduct System	$410,000,000
Transport features constructed to partial capacity	900,000,000
Subtotal	$1,310,000,000
Total Reduction in Capital Cost	$3,830,000,000

The reduction in capital costs shown in Table 32 i based upon the premise that the Sacramento Wes Side Canal and the Antioch Crossing would not b constructed, should the agricultural demands of th high desert lands fail to develop. Without these fea tures, conveyance of export water from Iron Canyo Reservoir on the Sacramento River the Mountai House Pumping Plant near Tracy would be accom plished through natural channels of the Sacrament River and the Sacramento-San Joaquin Delta. How ever, even with the deletion of 5,800,000 acre-feet o water per season from contemplated deliveries fro ıe North Coastal Area, there would still remain some ,000,000 acre-feet of largely urban water supplies to e transported to and conveyed across the Delta. Proection of the quality of this water might, at some uture time, require the construction of an isolated onduit along the west side of the Sacramento Valley nd across the Delta.

In addition to the cited delivery of agricultural ater to the high desert areas, a substantial portion f the contemplated deliveries by the San Diego Iigh-Line Aqueduct of the Southern California Diviion would be for the service of agricultural lands in ıe Whitewater and San Felipe Groups of the Coloado Desert Area. Should these lands fail to develop, ıe necessity of constructing the San Diego High-Line queduct might never materialize, as the greater ortion of water delivery by that aqueduct would be or that agricultural purpose. However, water service hich would have been provided to urban and induscrial areas by the San Diego High-Line Aqueduct ould have to be met from an alternative source, amely, by pumping from the Barona Aqueduct, for hich purpose additional aqueduct capacity would be equired.

Based upon studies of a preliminary nature, it is ıdicated that the further reduction in capital costs of The California Water Plan by eliminating the contemplated delivery, through the San Diego High-Line Aqueduct, of some 500,000 acre-feet of water per season to agricultural lands in the Whitewater and San Felipe Groups, would be on the order of $600,-000,000.

In summary, the deletion of those facilities of The California Water Plan which would develop and convey some 5,800,000 acre-feet of water per season to the high desert areas in southern California would reduce the total capital cost of the Plan by about $3,900,000,000. In the event that the San Diego High-Line Aqueduct is not constructed, due to the failure of agricultural lands in the Whitewater and San Felipe Groups of the Colorado Desert Area to develop, water deliveries under The California Water Plan would be further reduced by some 500,000 acre-feet per season, and the capital cost of the Plan would be correspondingly reduced by an additional $600,000,000. Thus, by eliminating water service to all agricultural lands requiring high pump lifts in southern California, the total amount of water developed and transferred by facilities of The California Water Plan would be reduced by 6,300,000 acre-feet per season, and the total capital cost of the Plan would be reduced by some $4,400,000,000.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In 1947, the California Legislature authorized the initiation of the State-Wide Water Resources Investigation to formulate a comprehensive master plan for the full control, conservation, protection, distribution, and utilization of all the State's water resources, both surface and underground, to meet the present and future needs for water for all beneficial purposes and uses in all areas of the State to the maximum practicable extent. As a result of intensive study, analysis of engineering and geologic data, and information made available during the planning phase of that investigation, and on the basis of estimates and assumptions discussed hereinbefore, the following summary, conclusions, and recommendations are presented.

SUMMARY

Problems

1. California's rapid and continuing population, agricultural, and industrial growth of recent years has given rise to unprecedented expansion in the needs for water for consumptive demands, comprising those for agricultural, industrial, and municipal purposes, and nonconsumptive uses, including those for flood control, hydroelectric power, recreation, and fish and wildlife. Corollary problems have developed, such as overdraft on ground water basins, intrusion of saline and other degraded waters into ground water basins, problems of control of mineral and organic quality of surface and underground waters, drainage, and related problems.

2. California's water problems result primarily from the unbalanced distribution of its water resources and water requirements. The major sources of water are in northern California where the waters of many streams now waste into the ocean virtually unused. The major urban areas and productive agricultural lands of California are in that portion of the State to the south in which occurs only 30 per cent of the total natural runoff. Great distances and rugged mountains separate source areas from areas of demand. About 70 per cent of the total stream flow occurs north of the latitude of Sacramento, but 77 per cent of the present use of water, and 80 per cent of the forecast ultimate use lie south of that line.

3. Water problems of California are further intensified by the large variations of runoff within the season and from year to year. Most of the runoff occurs during the winter and spring when the demand for water is least. Runoff is also subject to marked annual variations, with droughts of several years' duration characteristically being followed by one or more years of above-normal runoff. The periodic droughts impose the need for very large reservoir storage capacity for cyclic regulation, in addition to lesser storage requirements for seasonal regulation.

4. The largest problems of water deficiency occur in the San Joaquin Valley and southern areas of the State, the areas of greatest water demand. However, water deficiencies do occur in all areas throughout the State, especially in connection with seasonal unbalance of available water. In many instances, increasing water requirements have been provided for by drawing on the large but presently diminishing supplies available in ground water reservoirs. Withdrawals from ground water storage presently (1957) exceed mean annual replenishment by an estimated 4,000,000 acre-feet for the State as a whole, with resultant perennial lowering of ground water levels.

5. Periodic floods from rivers and streams throughout the State, in the valleys and flood plains where most of the 14,000,000 population live, have resulted in major damage and loss of life. Some of the flood problems have been solved. However, with the intensification and expansion of urban and industrial areas, many flood problems will become more severe until remedial action is taken. As land becomes more of a limiting factor in the ultimate development of the State, it will be increasingly important to prevent creation of blighted areas subject to recurring uncontrolled floods.

6. Deleterious effects on the quality of natural water supplies have resulted from deficiencies in surface and ground water development, from lack of drainage, and from improper disposal of wastes. Quality problems are common to nearly all other water problems. In several locations in the coastal plain, excessive draft has resulted in the intrusion of sea water into underground aquifers, thus impairing valuable sources of water supply. In many parts of the Central Valley, continuing ground water overdraft threatens quality degradation of fresh-water aquifers by upward movement of deep connate brines which were entrapped in underground basins in past geologic ages. In other areas, unfavorable salt balance is a practical certainty as the result of persistent overdraft conditions, unless additional water is imported and used. When more salt is brought into a basin than is carried out of it by the outgoing water, the salt balance is termed unfavorable. Another phase

of the water quality problem has resulted from inadequate treatment of sewage and industrial wastes and their disposal to streams and ground water basins, although this problem is rapidly being brought under control. Unless the quality of the State's water resources is maintained at proper levels, full satisfaction of California's ultimate water requirements will not be possible. Standards for the quality of water in relation to the beneficial uses thereof must be the subject of continuing study and should be changed when necessary in the light of further knowledge.

7. A serious problem associated with irrigated agriculture and stemming from it is the necessity for adequate drainage. Extensive drainage systems and proper disposal of drain waters of high mineral content are important factors in maintaining soil fertility and ground water quality.

8. Further extensive development of hydroelectric power is a necessary part of future water resource development. Full future satisfaction of water demands in all parts of the State will require mass movement of water over great distances and high mountains. This will ultimately require far more power than the presently undeveloped potential for hydroelectric power. Hydroelectric power now finds its greatest value in providing "peaking" energy (i.e., that portion of the daily load when, for a few hours, demands exceed the base demand) in combination with steam-generated power from fossil fuels, and would combine equally well with future atomic power generation. It is expected that the power market will absorb hydroelectric power output as rapidly as it can be made available. It is likewise believed that ample cheap "off-peak" energy will be available for pumping requirements.

9. Increasing demands have developed for enhancement of the fish and wildlife resources of the State, and for increasing the outdoor recreational opportunities associated with reservoir areas and live streams in valleys, hills, and mountains. These demands have increased at an accelerated rate, concurrently with the expanding population and urban and industrial development; their satisfaction is vital to the future welfare of California's citizens.

10. An additional problem in the further development of the water resources of California involves the optimum use of available ground water basins and potential surface storage reservoirs. Remaining combinations of satisfactory dam sites with reservoir storage sites of adequate capacity are relatively few, and must be utilized to the maximum practicable extent.

Concepts of The California Water Plan

1. The California Water Plan is a master plan to guide and coordinate the activities of all agencies in the planning, construction, and operation of works required for the control, development, protection, conservation, distribution, and utilization of California's water resources for the benefit of all areas of the State and for all beneficial purposes.

2. As such a master plan, The California Water Plan:

a. Evaluates the water supply available to California, and describes the places and characteristics of its occurrence;

b. Estimates the water requirements, both present and future, for all beneficial purposes for each area of the State, as those requirements can be foreseen;

c. Points out the watersheds where present estimates indicate surplus waters exist over and above future needs for local development, gives estimates of such surpluses, indicates the areas of deficiency, and gives the estimated deficiency for each such area;

d. Describes existing and prospective water problems in each area of the State;

e. Describes the uses to which the remaining unappropriated waters of the State should be put for maximum benefit to the people of all areas of the State;

f. Suggests the means by which the waters of the State could be distributed for the benefit and use of all the people in all areas;

g. Proposes objectives toward which future development of the water resources should be directed in all areas of the State, and suggests broad patterns for guidance toward these objectives;

h. Defines these objectives in terms of potential physical accomplishments which may be used to measure the merits of projects proposed for construction by any agency; and

i. Demonstrates that the waters available to California, including the State's rights in and to the waters of the Colorado River, are not only adequate for full future development of the land and other resources, but also that physical accomplishment of these objectives is possible.

3. The California Water Plan is conceived as:

a. A comprehensive plan which will meet the requirements for water at some unspecified but distant time in the future when the land and other resources of California have essentially reached a state of complete development; and

b. A flexible pattern, susceptible of orderly development by logical progressive stages as the growing demands of the State may dictate, into which future definite projects may be integrated in an orderly fashion, and which may be substantially altered and improved in accordance with advances in technology and changes in conditions which cannot be fully foreseen today.

4. The California Water Plan is designed to include or supplement, rather than to supersede, exist-

"The California Water Plan . . . for the control, development, protection, conservation, distribution, and utilization of California's water resources . . ."

ing water resource development works. It also incorporates certain of the planned works now proposed or authorized by public and private agencies and individuals. Of special significance in this respect is the authorized Feather River Project, which is the initial unit for construction under the Plan, and on which construction will start in May, 1957.

5. Although The California Water Plan is capable of accomplishment from an engineering standpoint, its component features have widely variant relationships to present concepts of economic and financial feasibility. It is realized that certain of the works would be extremely costly under present value criteria. Such works are for the indefinite future, and their need may never materialize. However, the economics of the distant future cannot be foreseen, and the planning effort is deemed necessary at this time in order that provision may be made for such developments, if and when they become needed and justified.

6. The California Water Plan gives full consideration to the use of water for agricultural, domestic, and industrial purposes; to hydroelectric power development; to flood control and protection; to drainage; to salinity control; to protection of the quality of water; and to the interests of fish, wildlife, and recreation.

7. Under The California Water Plan, water would not be taken from those who will need it; rather, it would provide for the needs of areas of inherent deficiency by transfer only of excess or surplus water from areas of abundance. Legislative acceptance of the Plan, and firm provisions for its progressive implementation as successive component projects become feasible, would tend toward elimination of sectional concern as to future availability of necessary water supplies.

8. The California Water Plan is neither an inflexible regulation nor a construction proposal as it is presented herein. It does not purport to include all possible water development projects in the State. Rather, it serves to demonstrate that the full satisfaction of ultimate water requirements in all parts of the State is physically possible of accomplishment. Therefore, the omission of any project from description in this bulletin does not preclude its future integration into the Plan.

The California Water Plan

1. The full natural seasonal runoff of streams in California, amounting to about 71,000,000 acre-feet on the average, is sufficient to provide for the full satisfaction of ultimate water requirements for all areas of the State, considering California's rights in and to the waters of the Colorado River in the amount of 5,362,000 acre-feet per season.

2. Existing and potential areas of intensive water service in California total about 23,600,000 acres, of which approximately 20,000,000 acres are classified as suitable for irrigated agriculture, and 3,600,000 acres for urban, suburban and industrial types of development. It is expected that under ultimate development, the majority of the remaining 77,300,000 acres of land will be only sparsely settled and will have only very minor requirements for water service. The remaining areas of California for the most part include only scattered water service areas, largely in mountainous and desert regions and in national forests and monuments, public beaches and parks, private recreational areas, wildlife refuges, and military reservations.

3. Water requirements in California will aggregate some 51,100,000 acre-feet per season under ultimate conditions of development. Of this amount, irrigated lands will require about 41,100,000 acre-feet; urban, suburban, and industrial areas will use 8,300,000 acre-feet; and 1,700,000 acre-feet will be utilized for other miscellaneous purposes.

4. The extreme seasonal and cyclic variation, and the geographic maldistribution in the occurrence of California's water resources, will necessitate:

a. The development and use of vast regulatory and carry-over storage capacity, both surface and underground, in order to attain the degree of conservation required to meet water needs under ultimate conditions of development; and

b. The construction and operation of a major system of works to convey the regulated excess waters from areas of inherent surplus to areas of inherent deficiency.

These major conservation and conveyance facilities, collectively designated the "California Aqueduct System," would constitute a coordinated comprehensive system of works, reaching from Oregon to Mexico.

5. The ground water storage capacity underlying the floor of the Central Valley, the key ground water basin in the State under operation of The California Water Plan, is estimated to exceed 130,000,000 acre-feet within 200 feet of the ground surface. Regulation of water supplies in the Central Valley would be accomplished by conjunctive operation of some 31,000,000 acre-feet of available ground water storage capacity with 22,000,000 acre-feet of storage capacity in major surface reservoirs. In addition to the Central Valley, there are more than 200 significant valley fill areas capable of conserving and regulating substantial amounts of water in other parts of California.

6. The California Water Plan would provide for:

a. Development of the water resources of the North Coastal Area to meet all future local needs in that area, and to furnish about 11,600,000 acre-feet of surplus water per season for export to other areas of the State;

b. Development of the water resources of the Sacramento River Basin to meet all future local needs within that basin, and to furnish about 10,-300,000 acre-feet of surplus water per season for export to other areas of the State; and

c. Full practicable development of local water resources in all remaining areas of the State, to assist in meeting future needs in those areas.

7. Local developments to meet local water require-ents under The California Water Plan would make vailable some 7,000,000 acre-feet of new yield per eason. In addition, the surplus waters from the North oastal Area and Sacramento River Basin, amounting some 21,900,000 acre-feet per season, would be de-eloped by the California Aqueduct System and dis-ributed to areas of deficiency as follows: San Fran-sco Bay Area, 2,200,000 acre-feet; Central Coastal rea, 1,200,000 acre-feet; South Coastal Area, 2,900,-00 acre-feet; San Joaquin-Tulare Lake Basin, 600,000 acre-feet; Lahontan Area, 4,800,000 acre-et; Colorado Desert Area, 1,400,000 acre-feet. An lditional 900,000 acre-feet of water per season would e required for operation of a salinity control barrier the Sacramento-San Joaquin Delta.

8. The California Water Plan would involve the ventual construction of:

a. Some 376 new reservoirs throughout the State, with a total gross storage capacity of about 77,000,-000 acre-feet to be added to the 20,000,000 acre-feet of storage capacity in existing reservoirs;

b. New hydroelectric power generating facilities in connection with the water development works, with a total installed power capacity of about 7,800,000 kilowatts and a seasonal energy production of about 34 billion kilowatt-hours;

c. Pumping installations with an aggregate installed capacity of about 12,300,000 kilowatts, and a seasonal energy requirement of about 49 billion kilowatt-hours.

Of the total energy requirement for pumping, about 30 billion kilowatt-hours per season would be needed for conveyance of water to the high desert areas of southern California, the development of which cannot be foreseen at the present time. However, some 11 billion kilowatt-hours of this energy would be recovered by power generation from the water involved in the drops to the Sacramento Valley floor and on the southern side of the Tehachapi Mountains, thus reducing the net seasonal energy requirement to 19 billion kilowatt-hours for service to those high desert areas.

9. The Feather River Project will conserve Feather iver water and convey flows of water across the elta, thence along the west side of the San Joaquin alley and over the Tehachapi Mountains into southern California. It will furnish supplemental water supplies to the San Francisco Bay Area, the San Joaquin Valley, and southern California. This project was authorized by the Legislature in 1951 for construction by the State as the initial unit of The California Water Plan. Urgent need will exist for the supplemental water supplies this project will transport to water-deficient areas by the time it can be constructed. It is estimated that supplemental water supplies can be provided in the San Joaquin Valley in 1963 and in southern California by 1970.

10. Construction of all features of The California Water Plan, which would be accomplished over a long period of time, would involve a total capital expenditure of some \$11,800,000,000, based upon present (1955) price levels and economic conditions. Of this total amount, the cost of developments to meet local water requirements would aggregate some \$2,800,000,000, and the California Aqueduct System would cost about \$9,000,000,000. Of this latter amount, about \$4,400,000,000 would be required to develop and convey agricultural water to the high desert areas of southern California. Development of the demand for this water service cannot be foreseen at the present time.

11. The prospective market for hydroelectric energy generated under The California Water Plan would be favorable because of:

a. The advantages of hydroelectric power as an ideal working partner with fossil or atomic thermal power, wherein the inherent capability of hydroelectric plants for generation of on-peak energy would be employed; and

b. The advantages of hydroelectric power in connection with pumped storage projects.

Implementation of The California Water Plan

1. There exists immediate and urgent need for construction and operation of major water development works in California, particularly in the interests of water conservation and utilization, and in the interests of flood control and protection. The agricultural and urban economy of the State is threatened with the dangerous consequences of continuing and rapidly increasing overdrafts on the developed water supplies. These overdrafts, resulting largely from excessive use of ground waters, are now (1957) estimated to aggregate some 4,000,000 acre-feet per season, an amount equivalent to the anticipated new seasonal yield of the Feather River Project. The needs of the people and the economy for protection from the ravages of uncontrolled flood waters was tragically demonstrated by the flood of December, 1955.

2. The present and future protection of the high quality of the waters of the State must be assured. Without this safeguard, full implementation of The California Water Plan will not be possible. Required

objectives for maintenance of the quality of water should not apply only to current water uses but also should provide protection under future projects and developments.

3. Sound implementation of The California Water Plan will require the intensive and continuing program of investigation and planning by the Department of Water Resources, known as the "California Water Development Program." This program, using The California Water Plan as a guide, would: ascertain the specific local and state-wide water projects next needed for development; analyze and determine their engineering practicability, economic justification, and financial feasibility; and determine the logical priority of their construction. This program would enable the planning endeavor to keep in step with the rapidly expanding water needs of the State.

4. State-wide coordinated development of California's water resources under The California Water Plan will require the solution of a number of legislative and legal problems, including the following:

a. The adoption of a proper constitutional amendment and implementing legislative enactments which must provide: (1) positive assurance to the areas of origin that adequate water will be reserved for their future development; (2) positive assurance to the areas of deficiency that when they contract with the State for water they can depend upon the right to that supply; (3) removal of the uncertainty inherent in existing statutes; and (4) an adequately financed, continuing program of water development to meet the needs for water in all areas of the State, as those needs arise and as projects to satisfy them are found to be feasible.

b. The definition and determination of the nature and extent of vested rights to the use of surface and ground water, and the establishment of methods and procedures by which such rights as are affected may be compensated or otherwise adjusted in order to permit full operation of the Plan, including conjunctive operation of surface and ground water basins;

c. The authorization of eminent domain for water development projects not included in the Central Valley Project, as authorized by the State;

d. The definition of federal, state, local public, and private responsibilities in connection with water development projects, and establishment of procedures governing the several relationships; and

e. The re-evaluation of statutory restrictions upon certain water development projects.

5. The adoption of sound economic criteria, and the wise and just application of those criteria to projects of The California Water Plan are essential to success of the Plan.

6. The adoption of policies and methods that will provide for the repayment of reimbursable costs of The California Water Plan is required for implementation of the Plan.

7. It is essential that a course of action for state financing of projects of The California Water Plan be adopted in order to achieve the objectives of the Plan. Reference is made to the recommendations of Governor Goodwin J. Knight to the State Legislature for financing The California Water Plan through establishment of the Water Development Fund, as set forth in Chapter V.

CONCLUSIONS

It is concluded that:

1. The future growth of California will depend in large measure upon the early acceptance and implementation of a coordinated, state-wide, multipurpose program of water control, conservation, protection, and utilization.

2. The California Water Plan constitutes such a program, and should be accepted and implemented now as the master plan to guide and coordinate the planning, construction, and operation by all agencies of works required for the control, protection, conservation, and distribution of the water resources of California for all people and beneficial uses in all areas of the State.

3. Critical and increasing needs for supplemental water supplies, for flood control, and for preservation and protection of water resources now exist in many areas of California.

4. The waters originating in California, together with the rights of California in and to the waters of the Colorado River, are adequate in quantity and quality to satisfy all water requirements of the State after it has reached full development, if the waters are properly controlled, conserved, protected, and distributed.

5. The control of floods to provide protection to the growing population and expanding economy of the State must be attained and at all times maintained at a degree commensurate with the need therefor.

6. The quality of waters which are available to meet the full ultimate requirements of all parts of California must be protected and maintained at requisite high levels to make this achievement possible.

7. Minimum standards of well construction and proper procedures for the abandonment of wells should be enforced in order to protect adequately the quality of the State's ground waters.

8. Water development works to satisfy present and future needs of local areas are an essential part of any comprehensive plan for solution of the water problem of the State.

9. Solution of California's water problems must assure adequate provision for municipal, industrial

nd agricultural water supplies, quality of water con-rol and protection, flood control and protection, rainage, navigation, hydroelectric power generation, nd protection and enhancement of recreation and sh and wildlife resources, and other related water se activities.

10. The authorized Feather River Project, the first nit of The California Water Plan, should be financed nd constructed at so vigorous a rate as will assure elivery of water to the San Joaquin Valley not later han 1963 and to southern California not later than 970.

11. The California Water Development Program hould be financed and prosecuted on a continuing asis adequate to provide plans for meeting the growth n demand for water resource development in Cali-ornia.

12. Immediate action should be taken by the Legis-ature and the people of the State of California to rovide the constitutional amendment, and by the egislature to provide the enabling legislation neces-ary for early and orderly implementation of The alifornia Water Plan.

13. The Legislature should provide for the financ-ng, on an adequate and continuing basis, of the tate's share of costs of construction, operation, and aintenance of projects under The California Water lan, as such projects are authorized by the Legis-ture.

RECOMMENDATIONS

It is recommended that:

1. The California Water Plan be accepted by the egislature as the general and coordinated master lan for the progressive and comprehensive future de-elopment of the water resources of California by all gencies, subject to: (a) more detailed investigation nd study of component features of the Plan to de-rmine their need, engineering feasibility, economic stification, financial feasibilty, and recommended iority of construction; and (b) continuing review, odification, and improvement of the Plan in the ght of changing conditions, advances in technology, lditional data, and future experience.

2. Projects to achieve the objectives of The Cali-rnia Water Plan be constructed as their need, ngineering feasibility, economic justification, and nancial feasibility are demonstrated by further in-estigation.

3. Adequate funds be provided by the Legislature, n an assured and continuing basis, for support of the alifornia Water Development Program, comprising: a) continuation of the compilation and publication f basic water resource data necessary for implementa-on of The California Water Plan; (b) more detailed vestigation and study of component features of the Plan, to determine their need, engineering fea-sibility, economic justification, financial feasibility, and recommended priority of construction; and (c) continuing review, modification, and improvement of The California Water Plan in the light of changing conditions, advances in technology, additional data, and future experience.

4. Research programs to supply needed basic and experimental data concerning hydrology, hydraulics, water quality, and other pertinent matters be given authorization and adequate financial support.

5. The efforts of all agencies and entities engaged in the planning, financing, construction, and opera-tion of water development projects be coordinated within the framework of The California Water Plan to the end that maximum ultimate objectives may be achieved.

6. The quality of the water resources of the State be protected against unreasonable deterioration from all sources of impairment. In the administration of the statutes governing the disposal of sewage and in-dustrial wastes to waters of the State, consideration should be given not only to the present uses of the waters concerned but also to the future developments and uses envisioned in The California Water Plan. In planning for future urban and industrial develop-ments, consideration should be given to the necessity of adequate waste disposal without endangering the future utility of the State's waters.

7. Proper watershed management practices and methods be formulated and followed to protect and enhance the State's water resources.

8. Positive assurances, to the maximum practicable extent, be provided, by constitutional amendment and legislative enactments, that water required to meet all future beneficial uses in all areas of the State will be available in adequate quantity and quality, when and where needed, and on a dependable basis.

9. A long-range water development fund and enab-ling policies to assure the financing and construction of needed water development works in California on a continuing, progressive basis be established by the Legislature at the earliest practicable date.

10. The financing and construction of the author-ized Feather River Project, the initial unit of The California Water Plan, be expedited in order that urgently needed flood protection will be provided at an early date, and in order that supplemental water supplies will be available to areas of serious water deficiency in the San Francisco Bay Area and in the San Joaquin Valley not later than 1963, and in south-ern California not later than 1970. The financing and construction of other presently needed water develop-ment works should likewise be undertaken immedi-ately.

11. Study be initiated now of the additional legis-lation that will be necessary for progressive imple-

mentation of The California Water Plan, and that such legislation be enacted when and as required. This includes policy recognition of the interests of recreation, fish, and wildlife as important and necessary factors in water development, and the maintenance of live stream flow in the interests of fish, wildlife, and recreation as a beneficial use of water. It further includes: provisions authorizing and implementing administration of ground water development and utilization; the planned operation of ground water basins as storage reservoirs, when necessary in the public interest; the enforcement of minimum standards of well construction and of adequate procedures for abandonment of wells; and legislation to simplify and strengthen the current procedures for the determination of water rights.

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PRESENT WATER PROBLEMS

SCALE OF MILES
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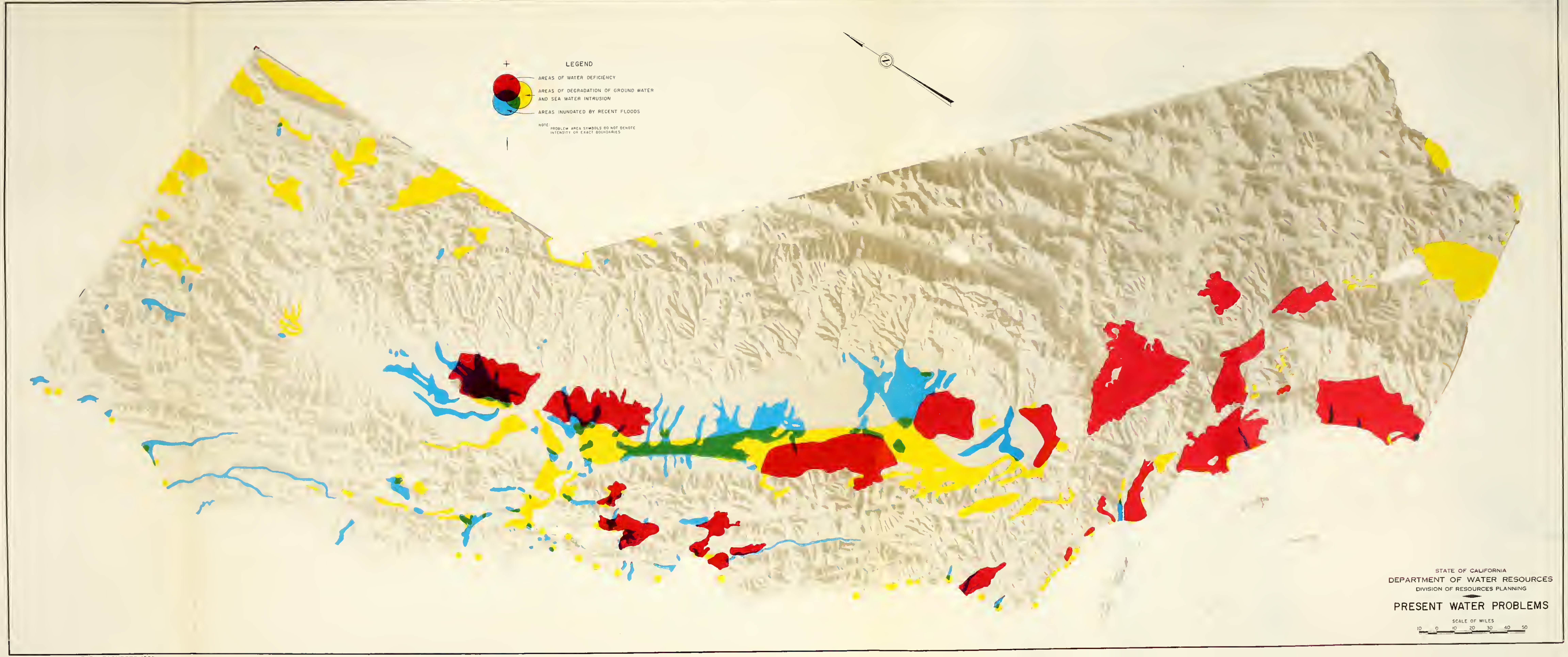
LEGEND
AREAS OF WATER DEFICIENCY
AREAS OF DEGRADATION OF GROUND WATER AND SEA WATER INTRUSION
AREAS INUNDATED BY RECENT FLOODS
NOTE:
PROBLEM AREA SYMBOLS DO NOT DENOTE INTENSITY OR EXACT BOUNDARIES
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DIVISION OF RESOURCES PLANNING
PRESENT WATER PROBLEMS
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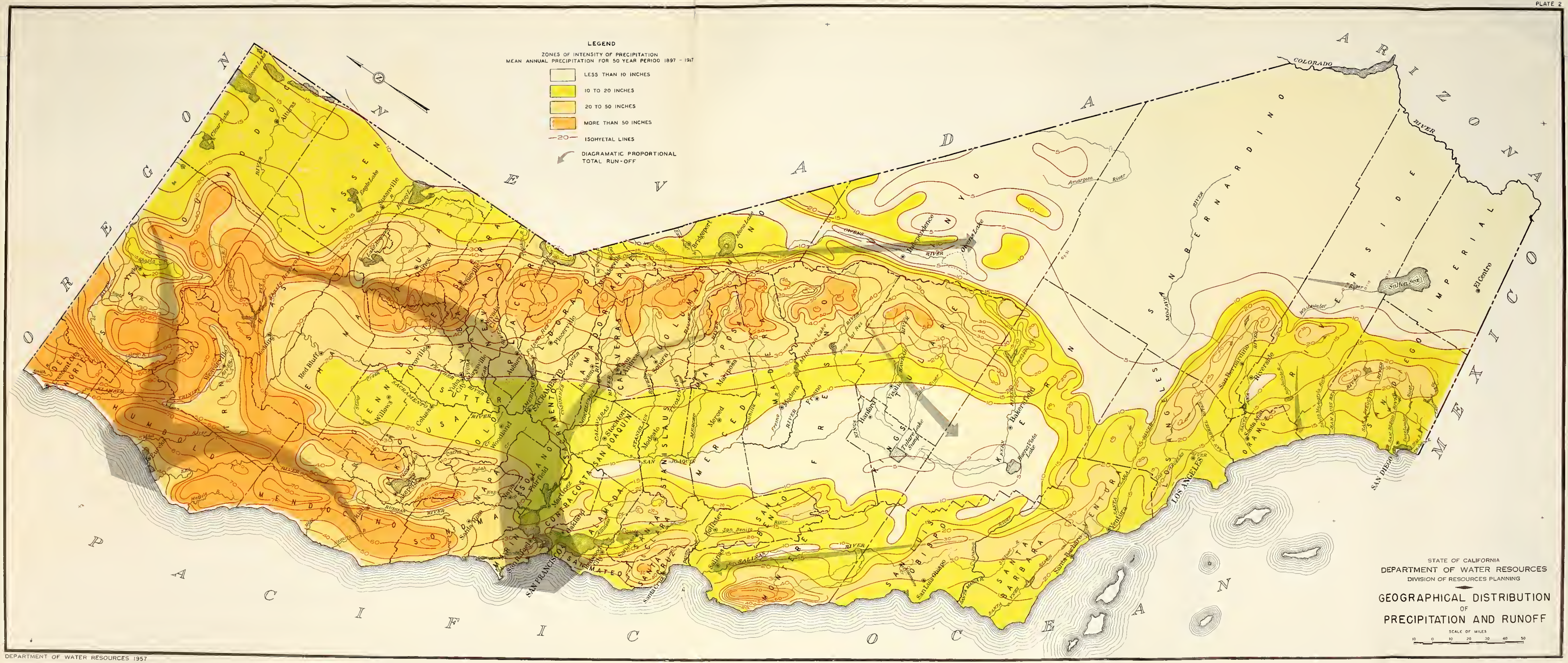

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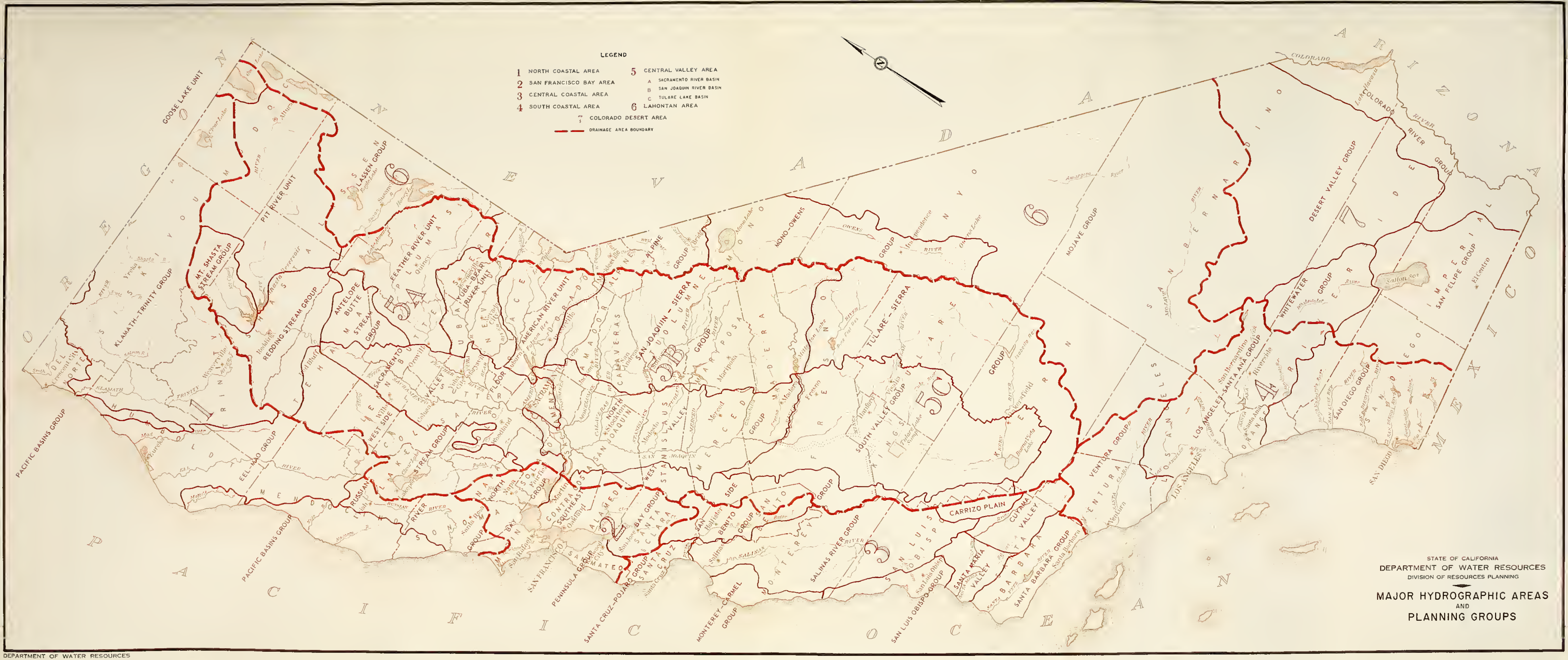
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1 NORTH COASTAL AREA
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4 SOUTH COASTAL AREA
5 CENTRAL VALLEY AREA
A SACRAMENTO RIVER BASIN
B SAN JOAQUIN RIVER BASIN
C TULARE LAKE BASIN
6 LAHONTAN AREA
7 COLORADO DESERT AREA
DRAINAGE AREA BOUNDARY
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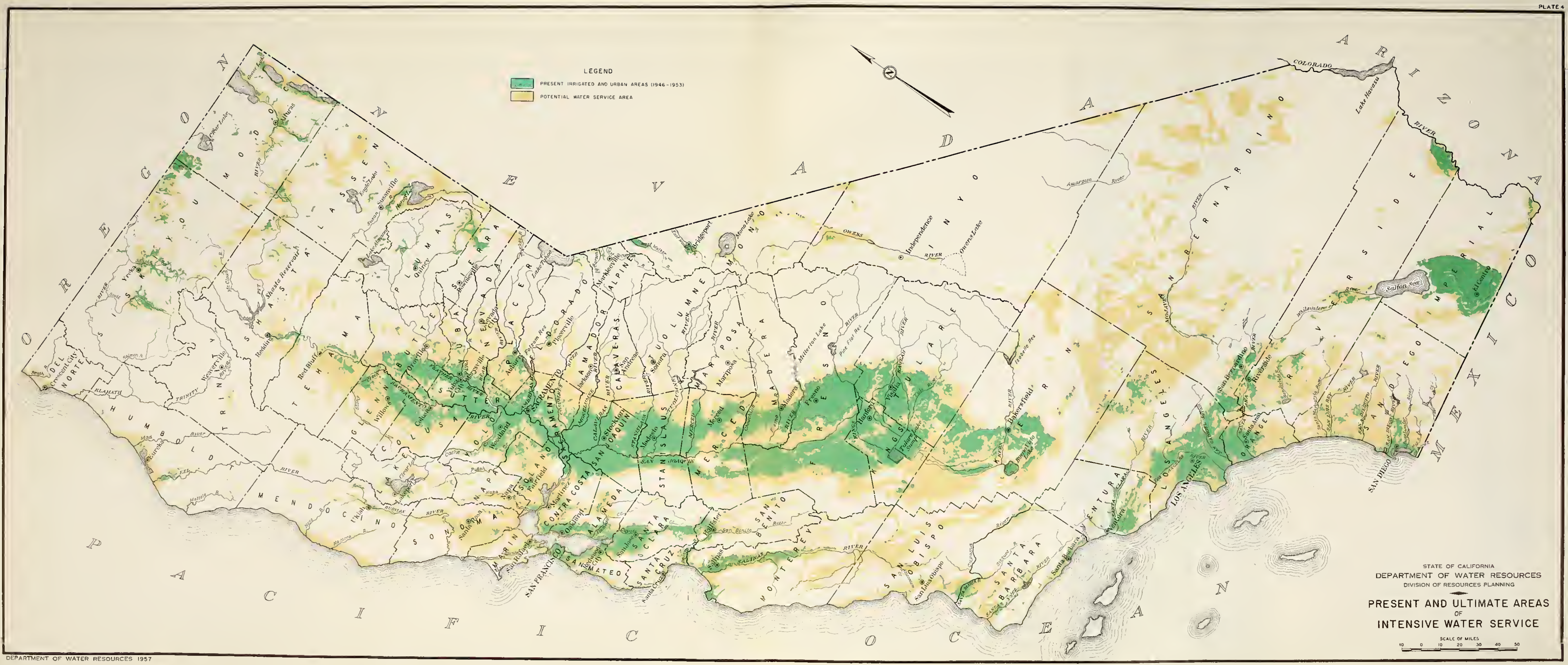
MAJOR HYDROGRAPHIC AREAS
AND
PLANNING GROUPS



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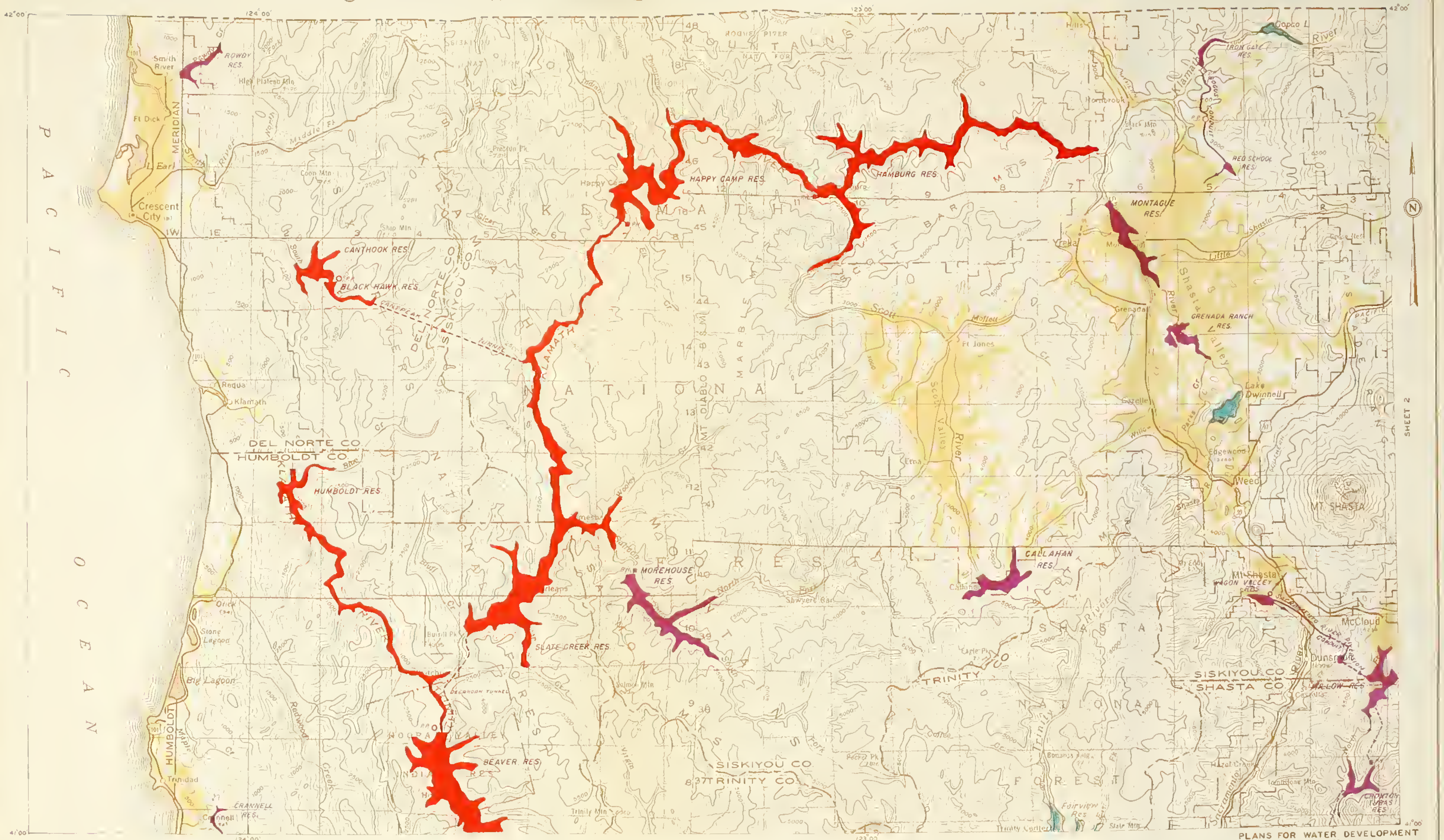
LEGEND

FEATURE	EXISTING WORKS: CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC	EXISTING WORKS: FLOOD CONTROL ONLY	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	PROSPECTIVE WORKS: DEVELOPMENT FOR LOCAL NEEDS	PROSPECTIVE WORKS: FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE			PH	PH	PH	
PUMPING PLANT			PP	PP	PP	
LEVEE						
IMPROVED CHANNEL						
ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL						
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN						



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PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM (FEATURE RIVER PROJECT (INITIAL UNIT) — ADDITIONAL UNITS) — DEVELOPMENT FOR LOCAL NEEDS — FLOOD CONTROL ONLY
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ALTERNATIVE RESERVOIR
CONDUIT
ALTERNATIVE CONDUIT
TUNNEL
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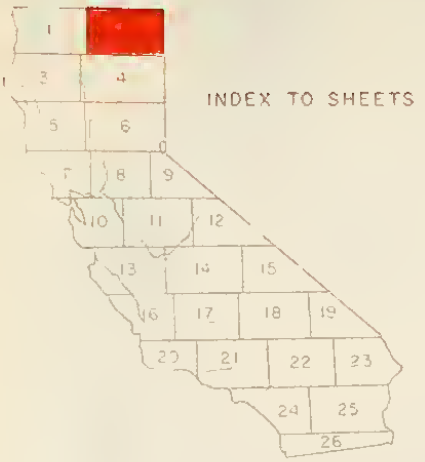
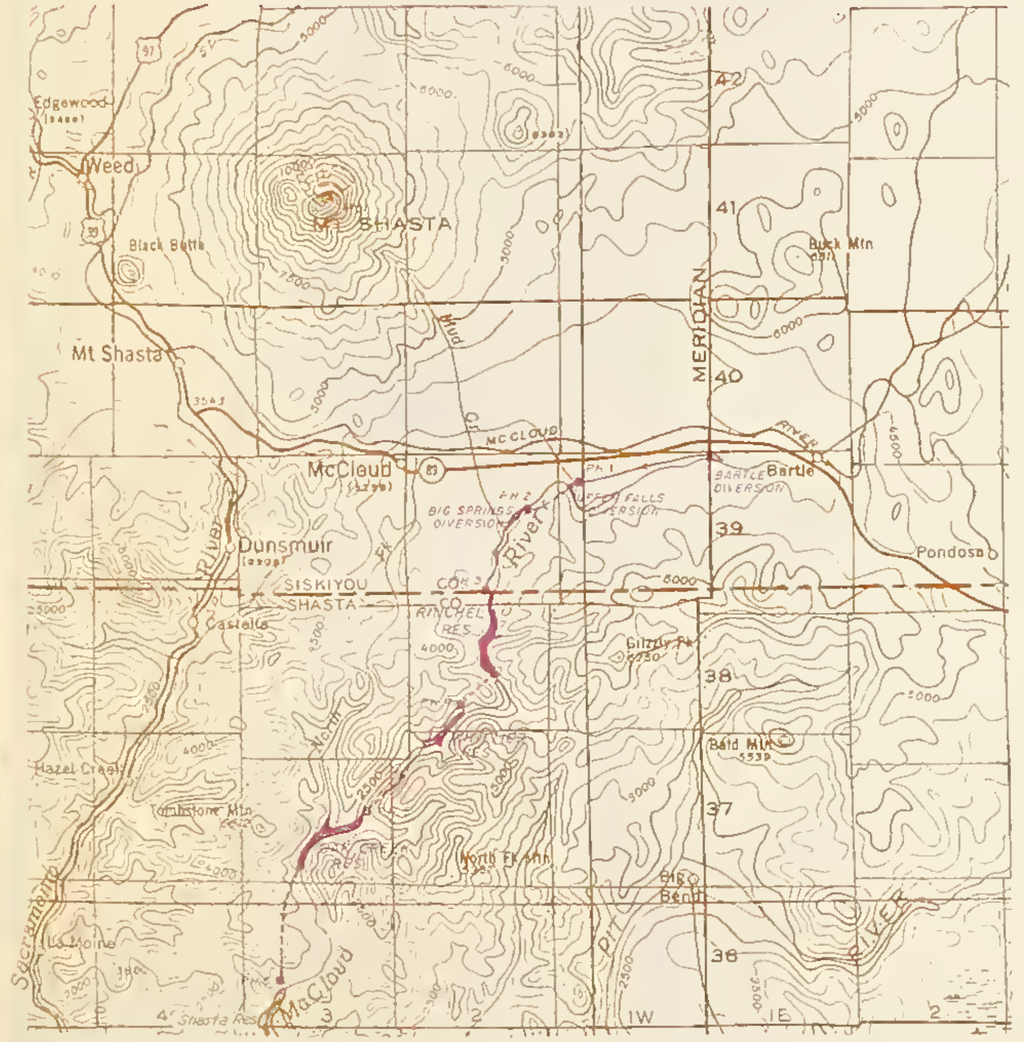
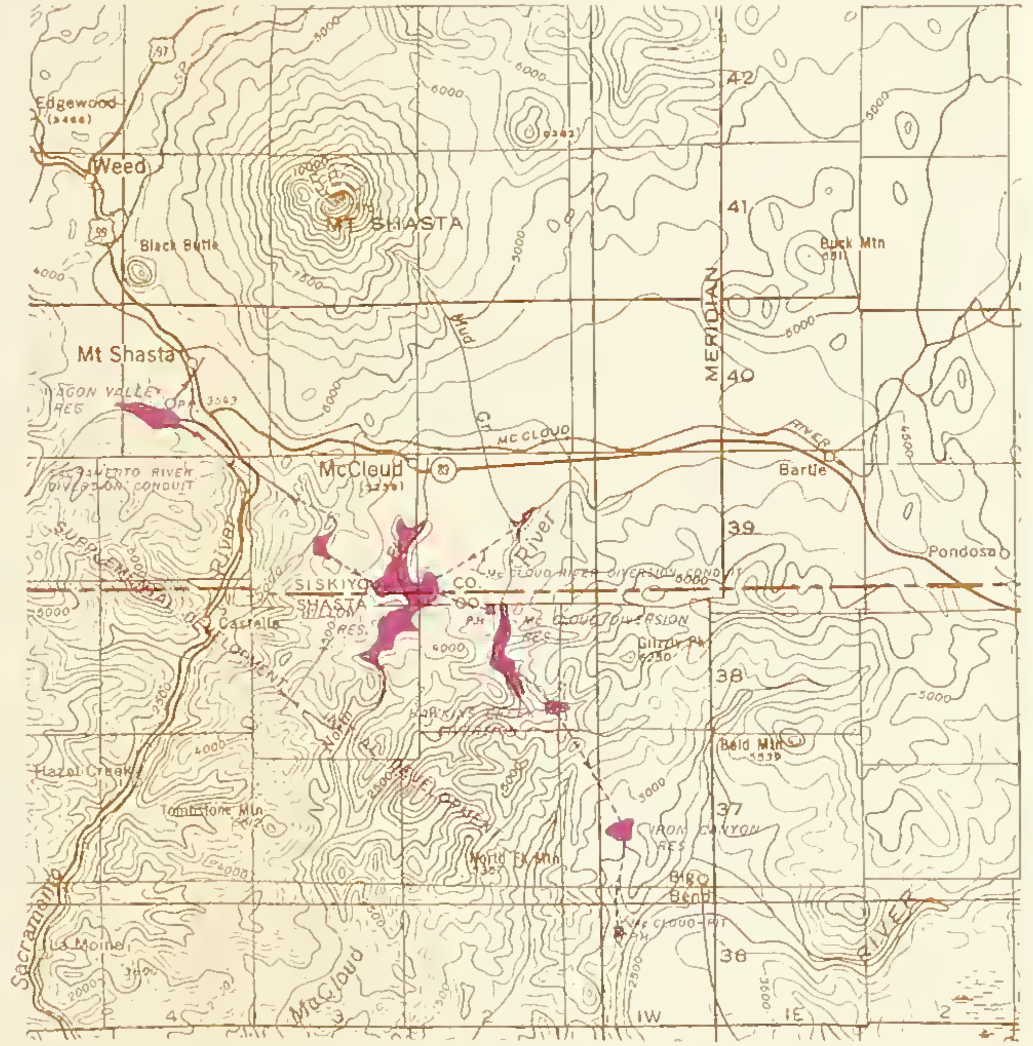
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN







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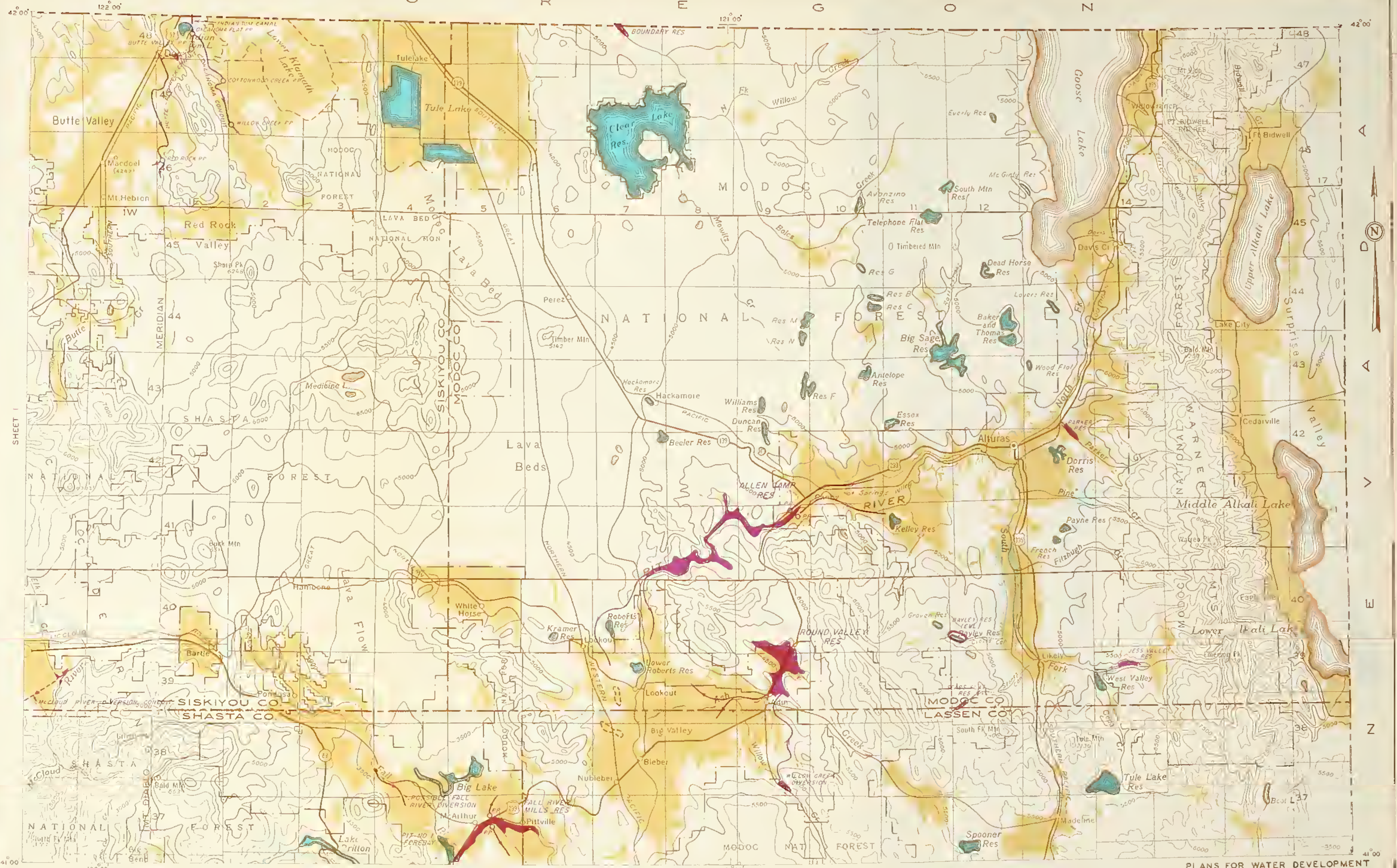

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ALTERNATIVE RESERVOIR						
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TUNNEL						
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PUMPING PLANT			PP	PP	PP	
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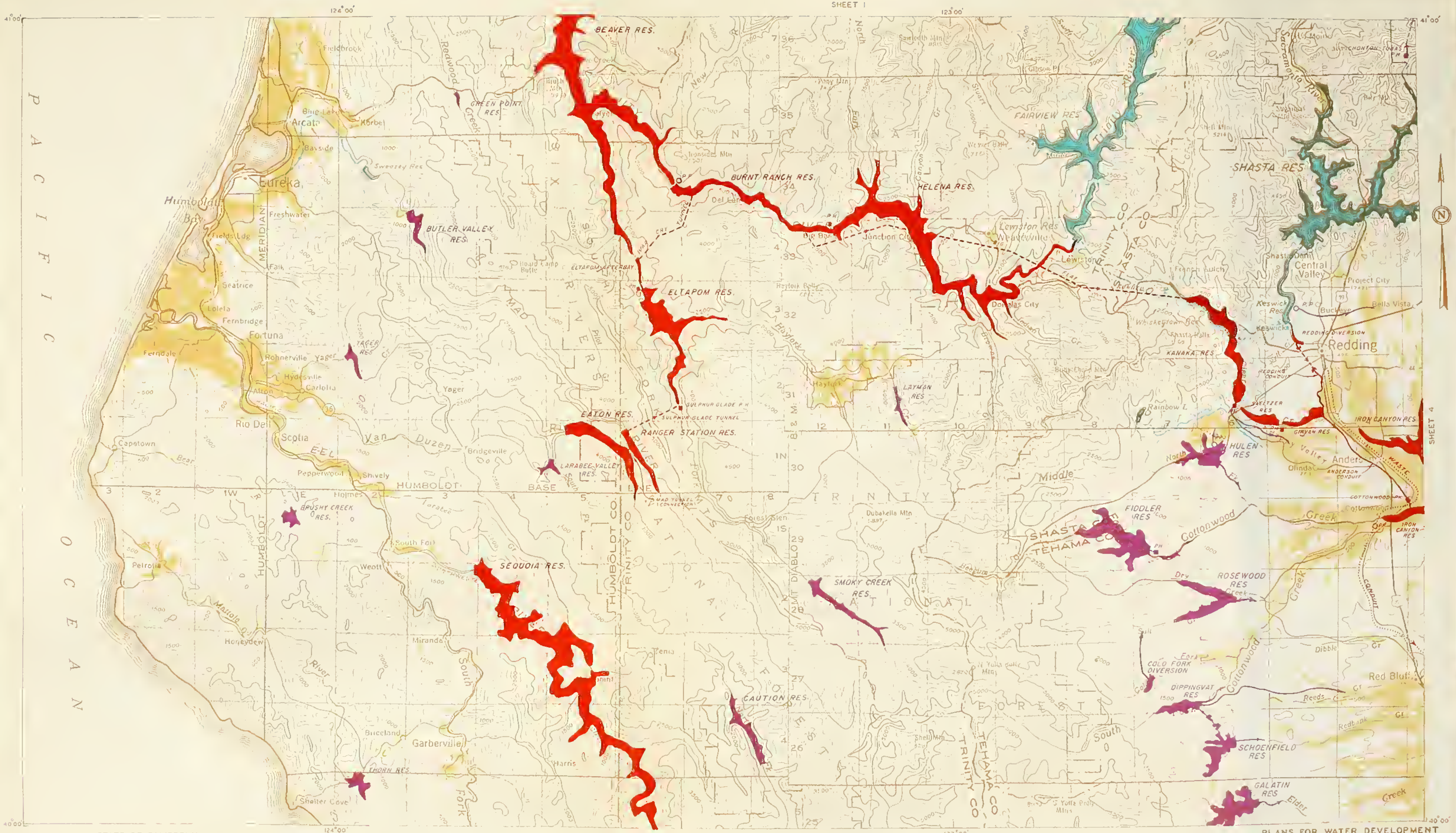

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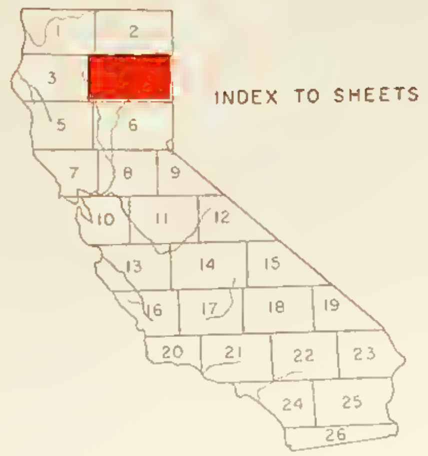

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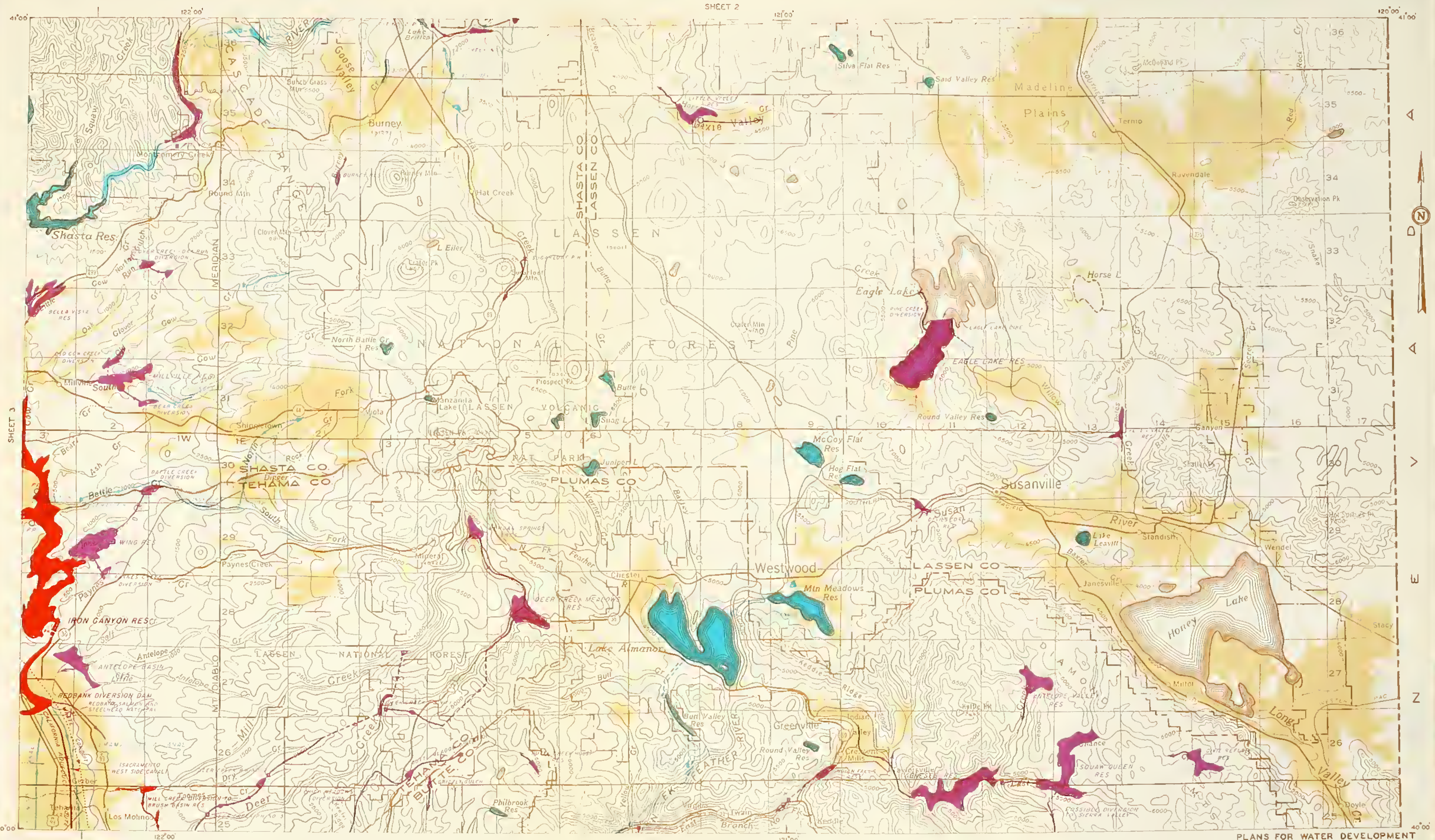
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE			PH	PH	PH	
PUMPING PLANT			PP	PP		
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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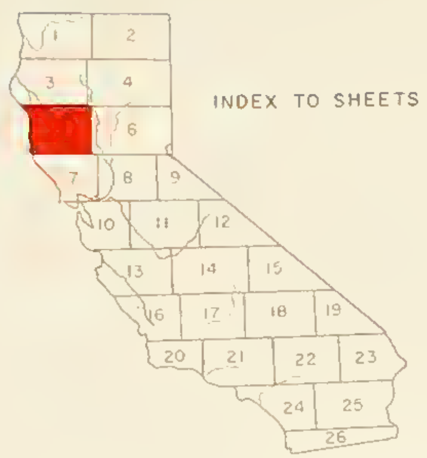

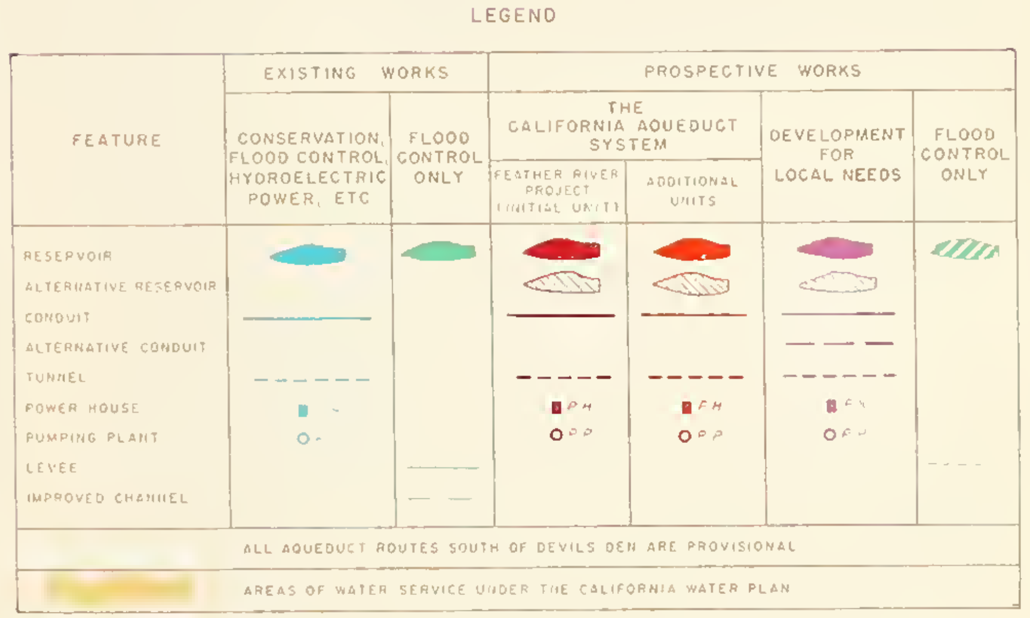

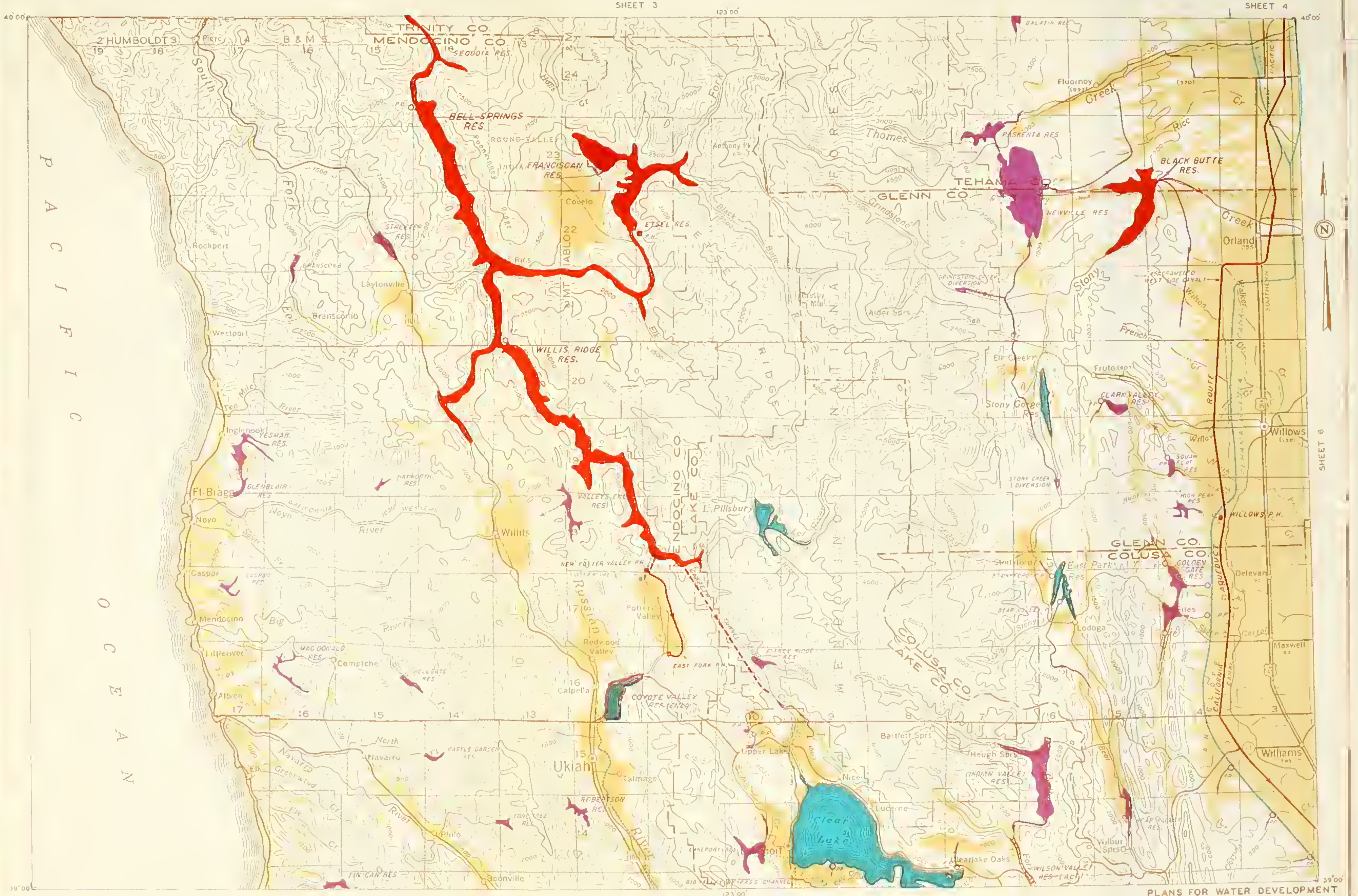

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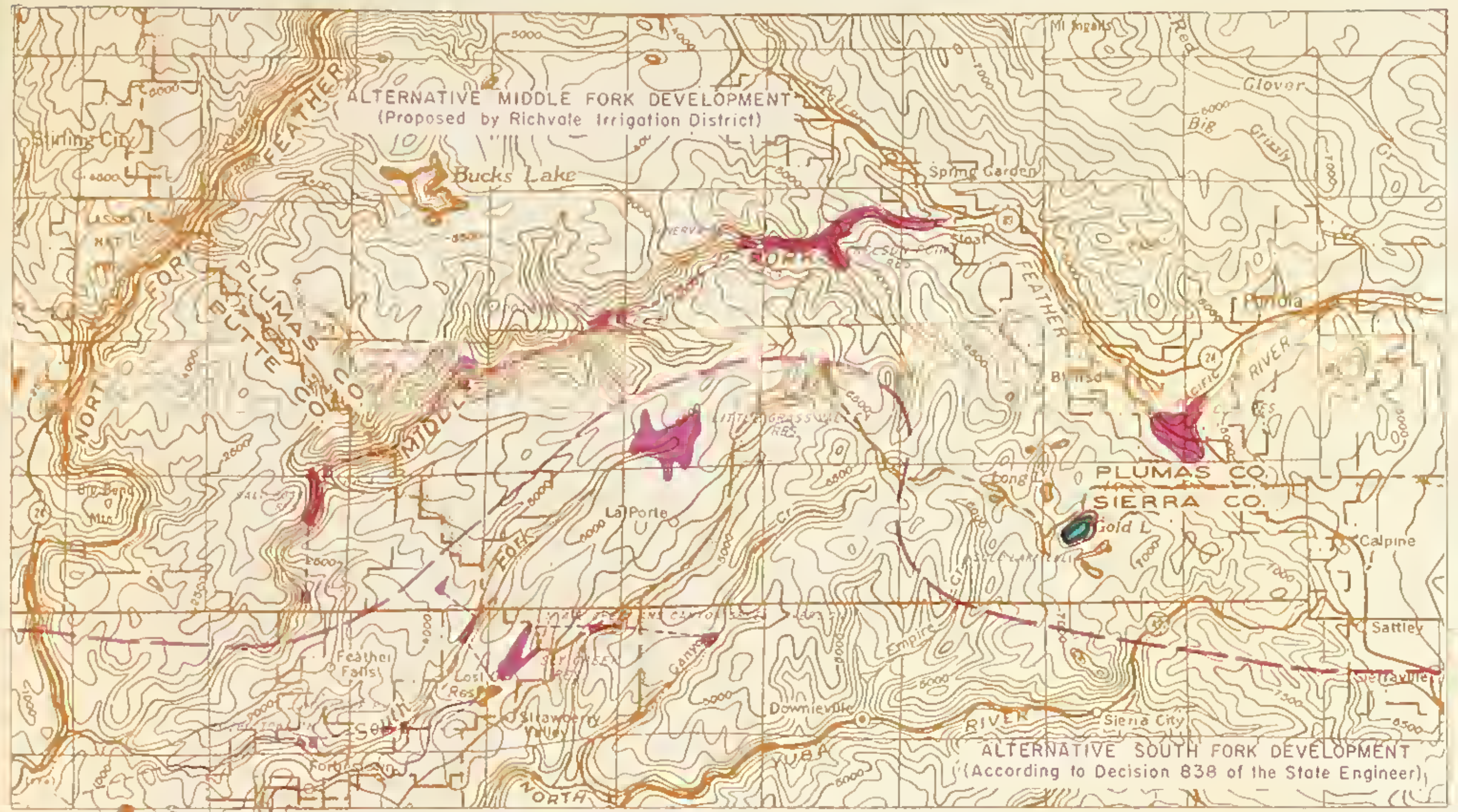
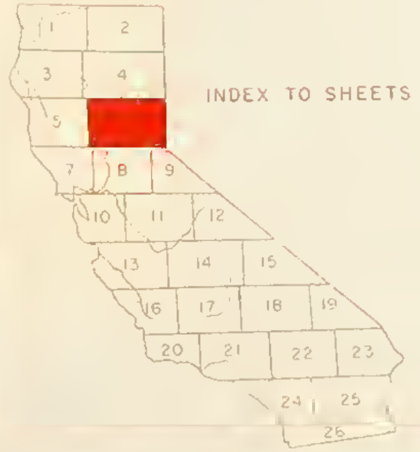


ALTERNATIVE PLANS FOR FEATHER RIVER DEVELOPMENT



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FEATURE	EXISTING WORKS: CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC.	EXISTING WORKS: FLOOD CONTROL ONLY	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	PROSPECTIVE WORKS: DEVELOPMENT FOR LOCAL NEEDS	PROSPECTIVE WORKS: FLOOD CONTROL ONLY
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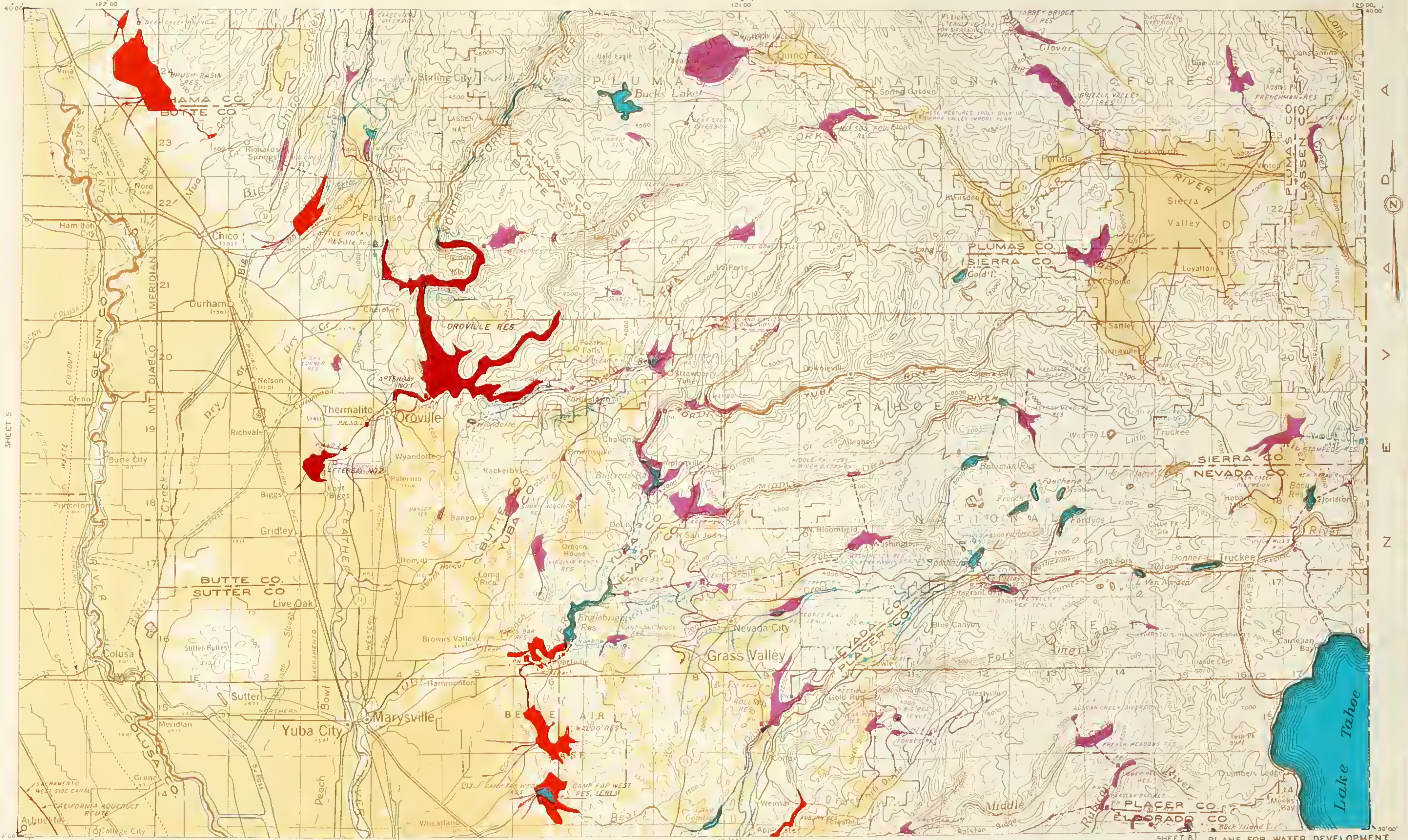
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE	PH		PH	PH	PH	
PUMPING PLANT	PP		PP	PP	PP	
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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PUMPING PLANT			PP	PP		
LEVEE						
IMPROVED CHANNEL						

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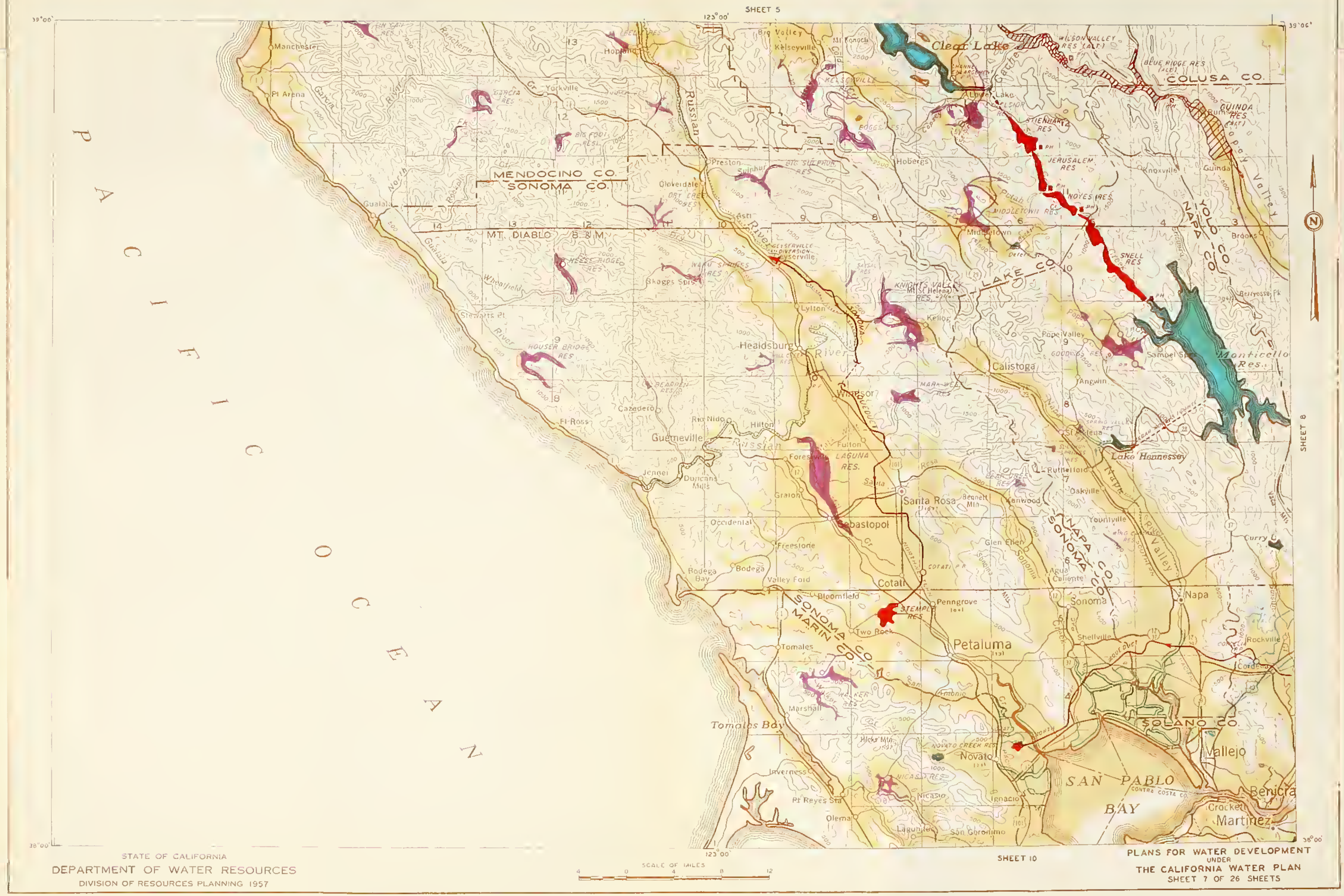
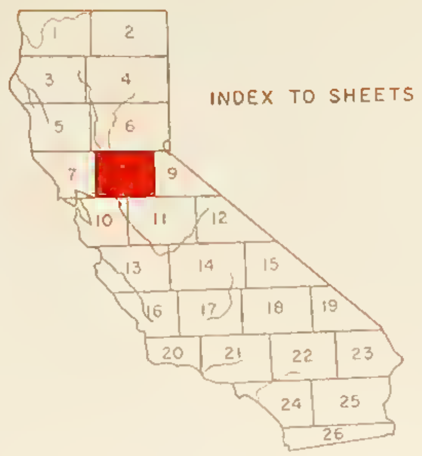
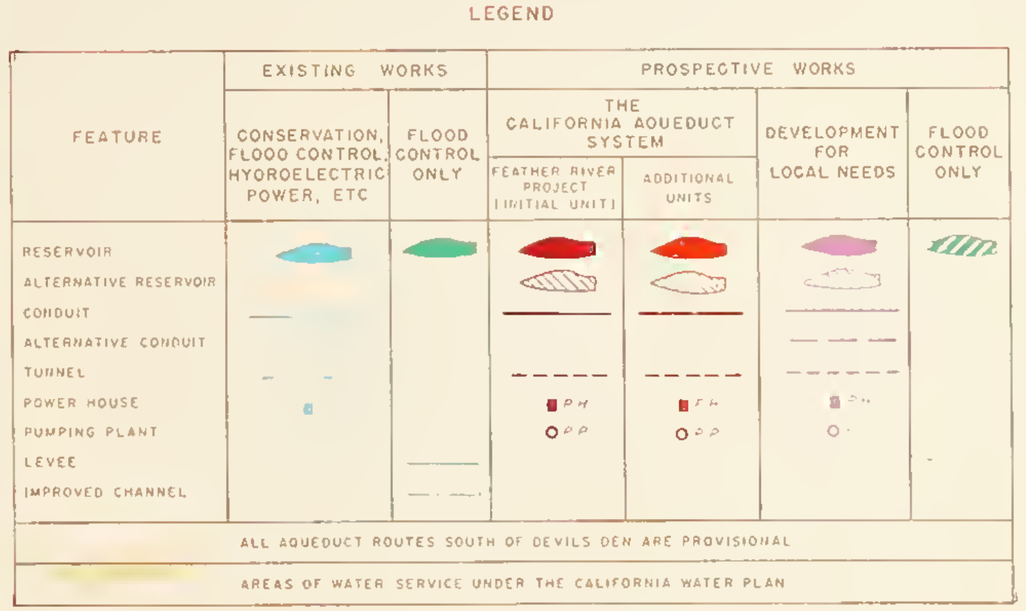
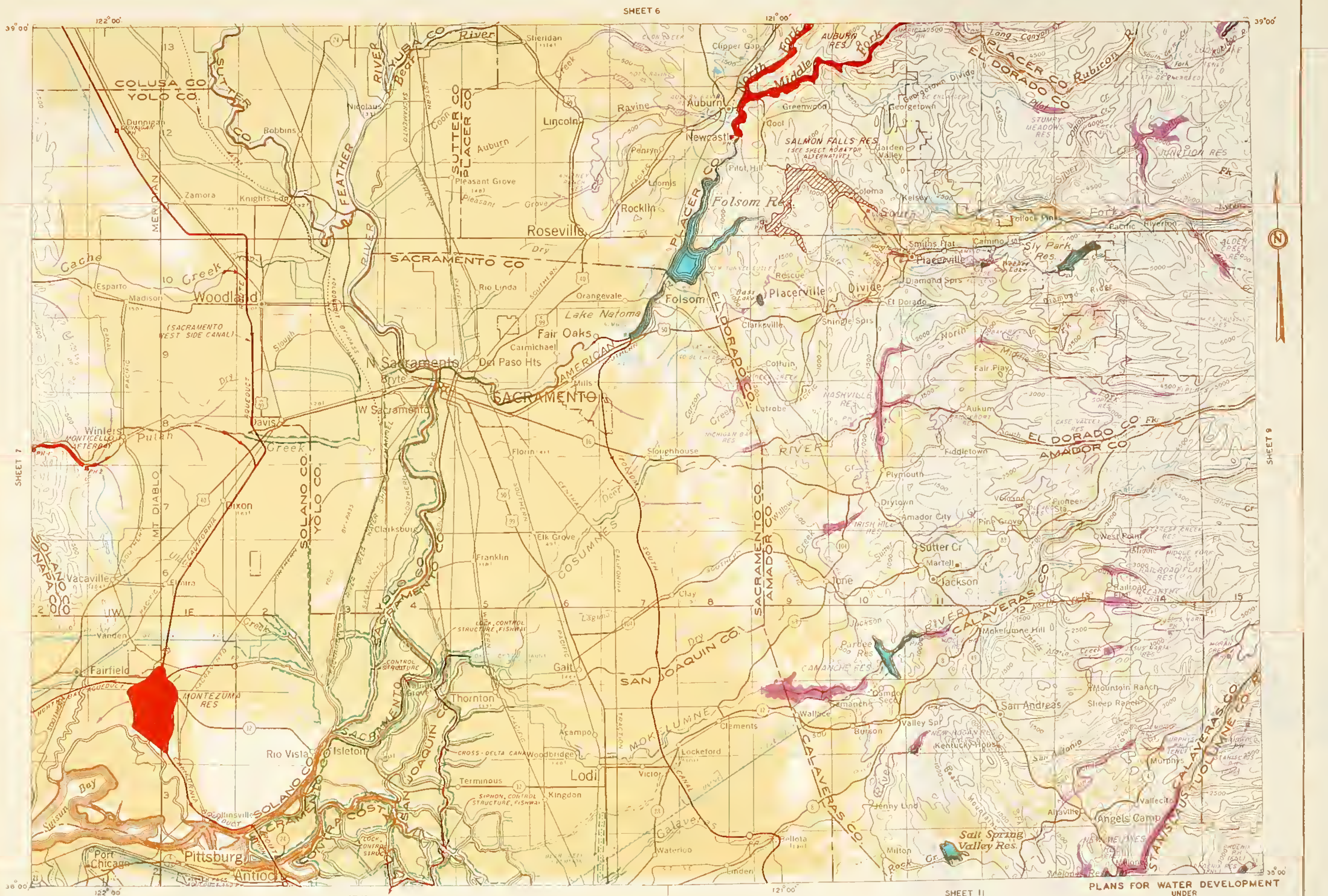
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN









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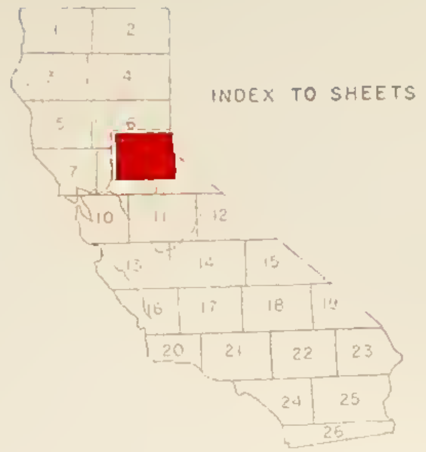

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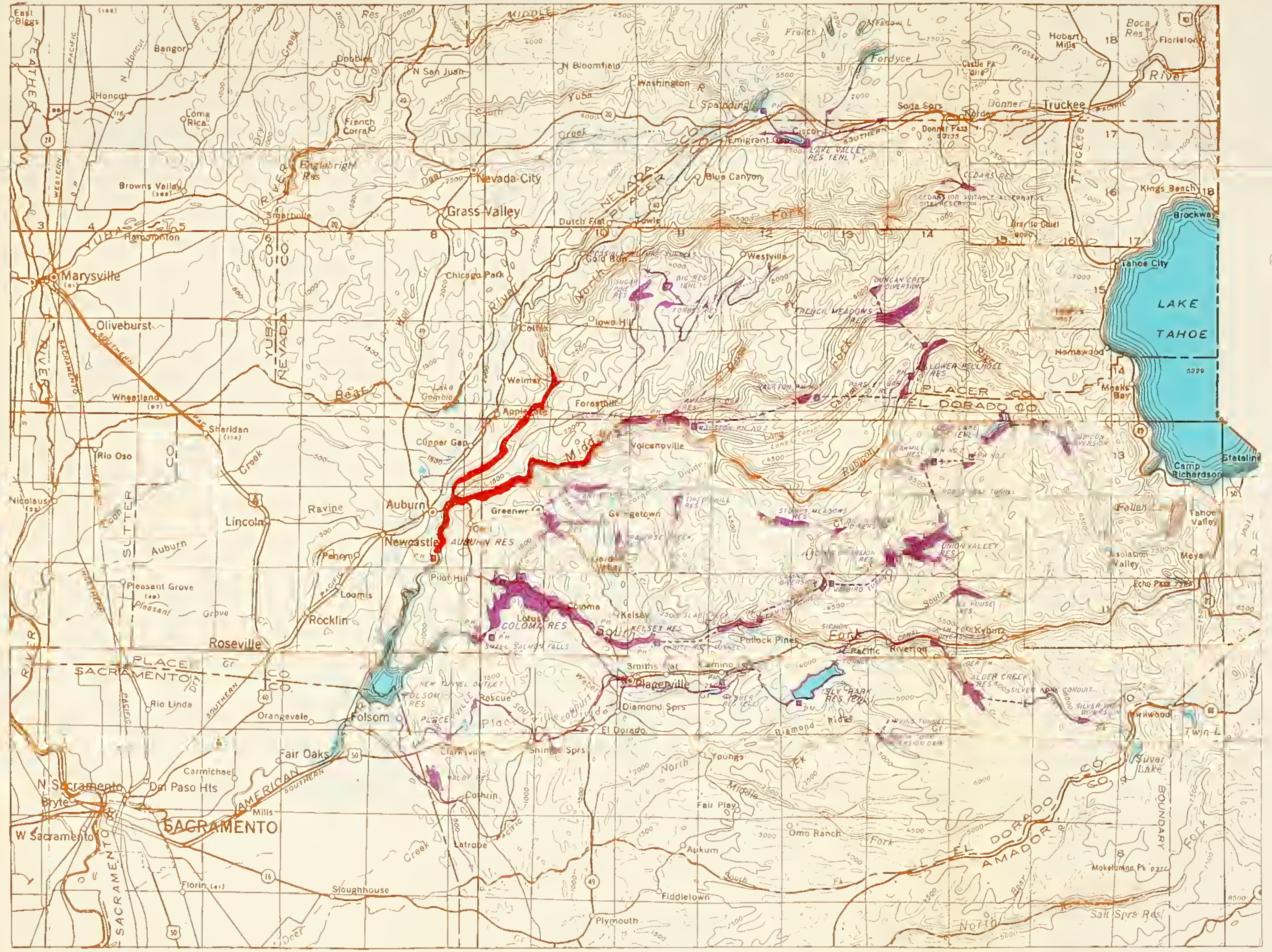
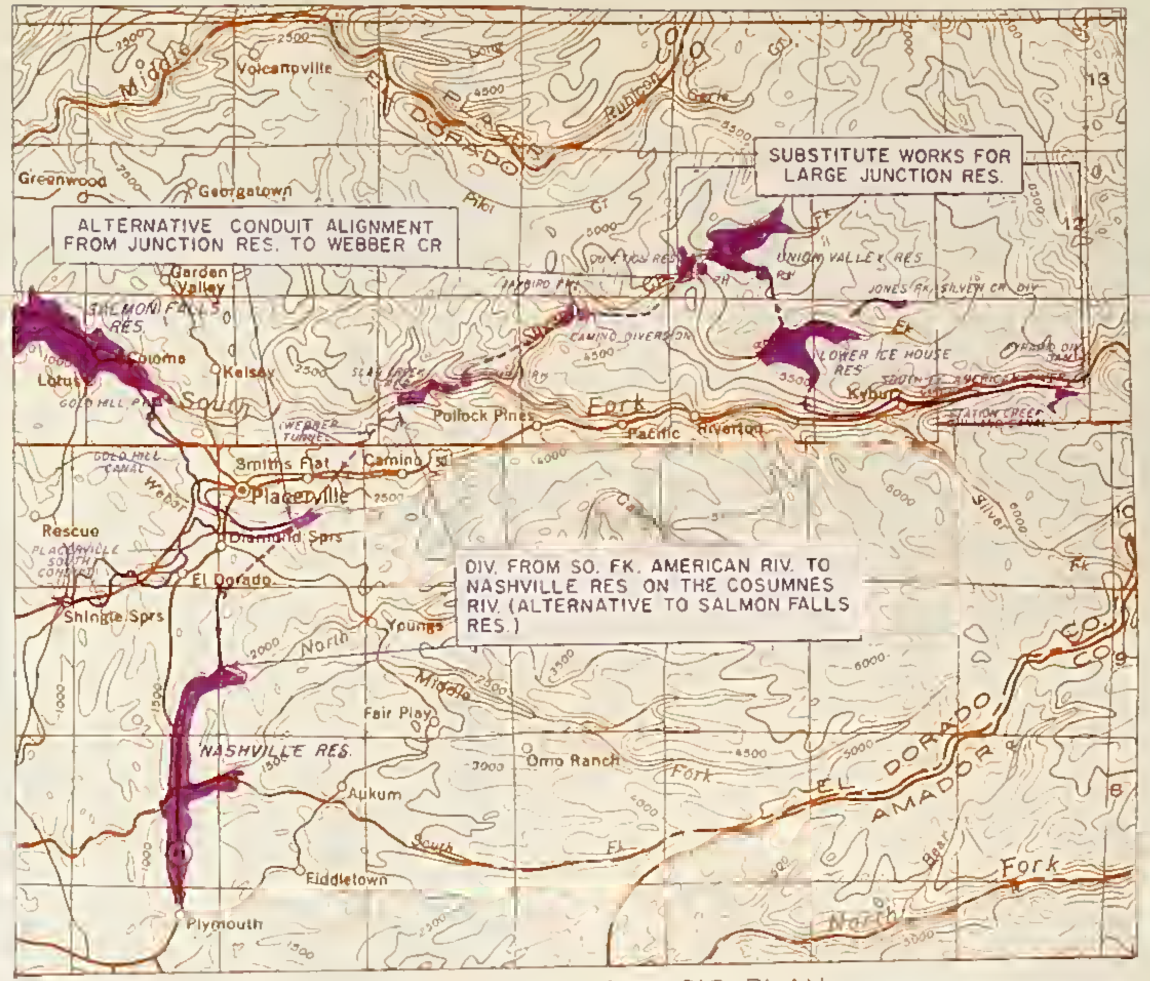


MODIFIED PLAN FOR THE AMERICAN RIVER BASIN DEVELOPMENT
AS PROPOSED BY THE SACRAMENTO MUNICIPAL UTILITY DISTRICT

SCALE OF MILES



ALTERNATIVES TO BASIC PLAN
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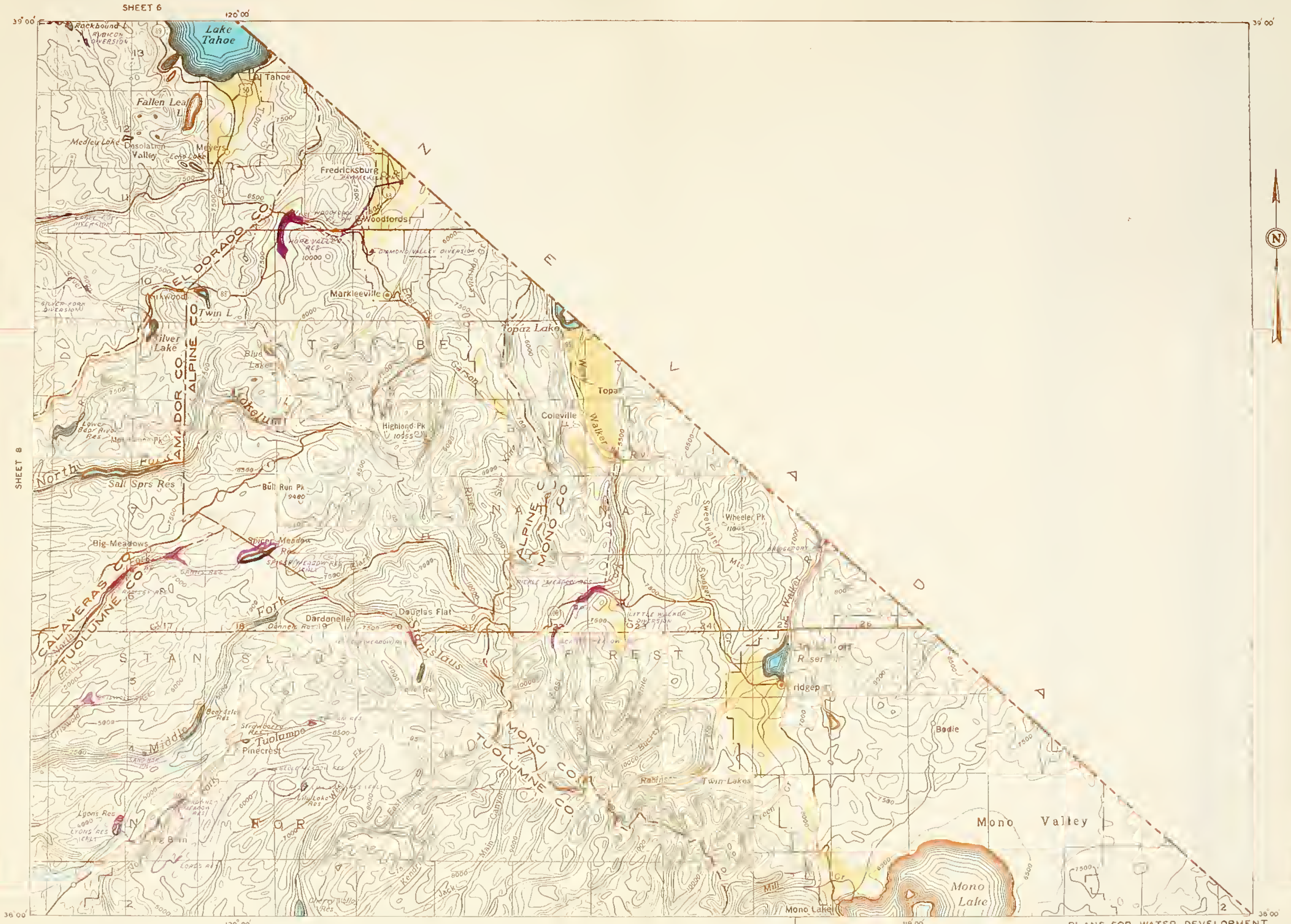
ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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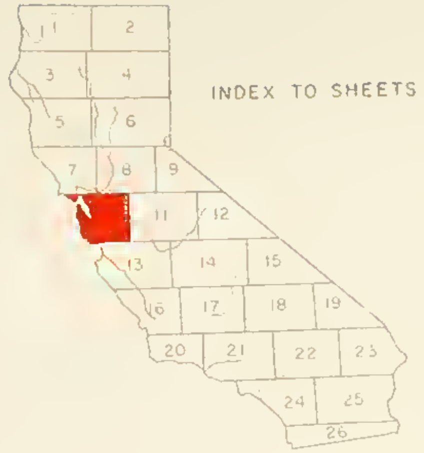

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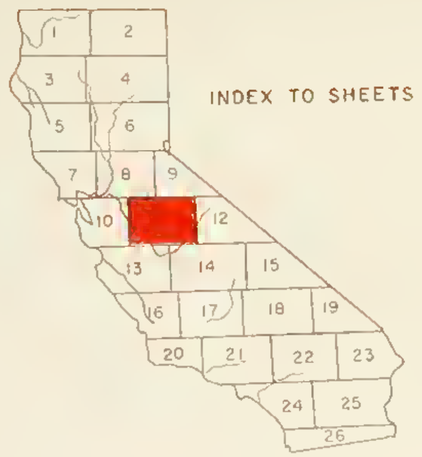

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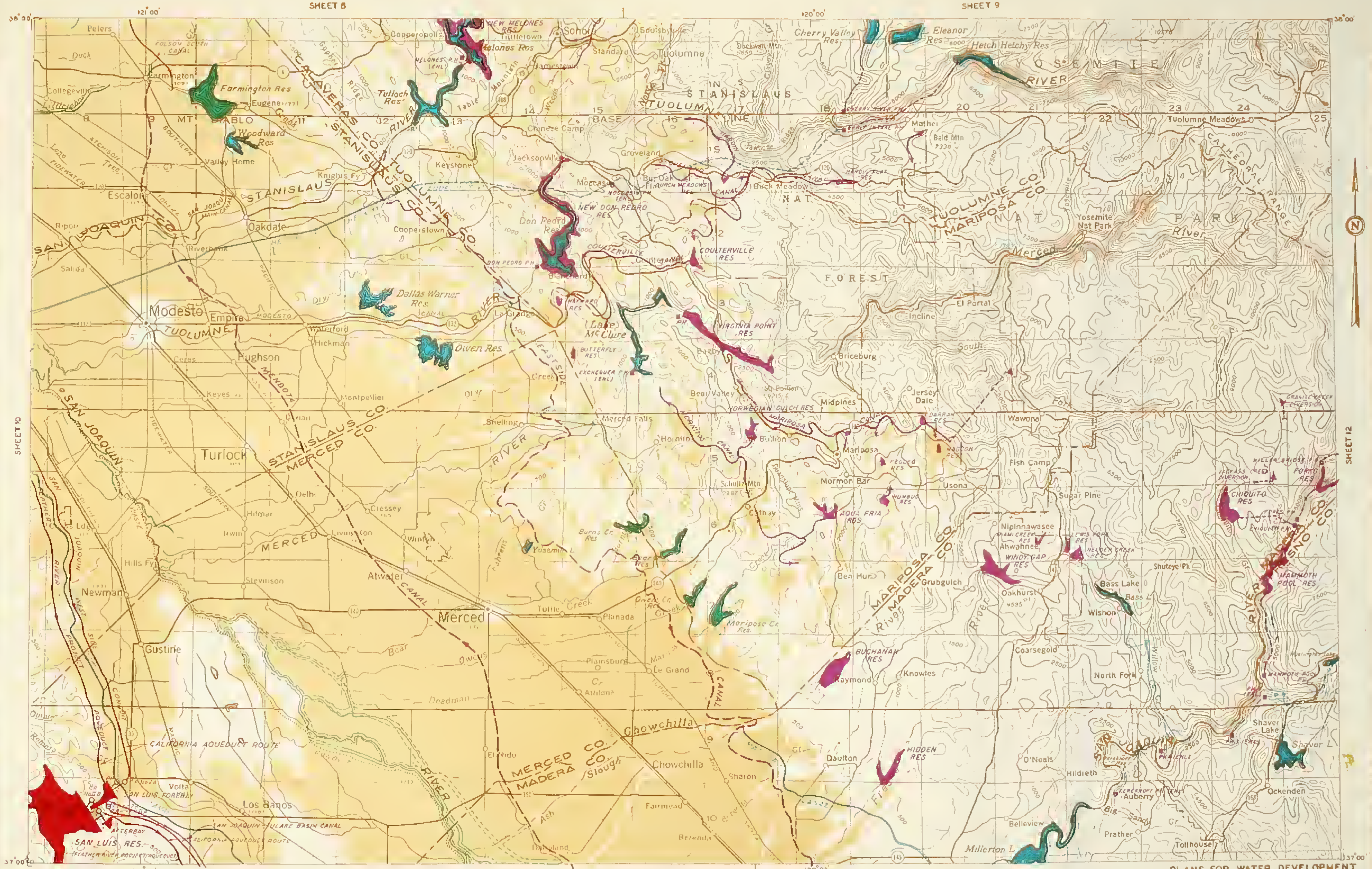

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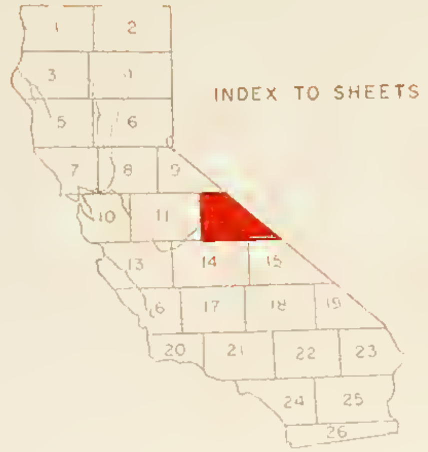

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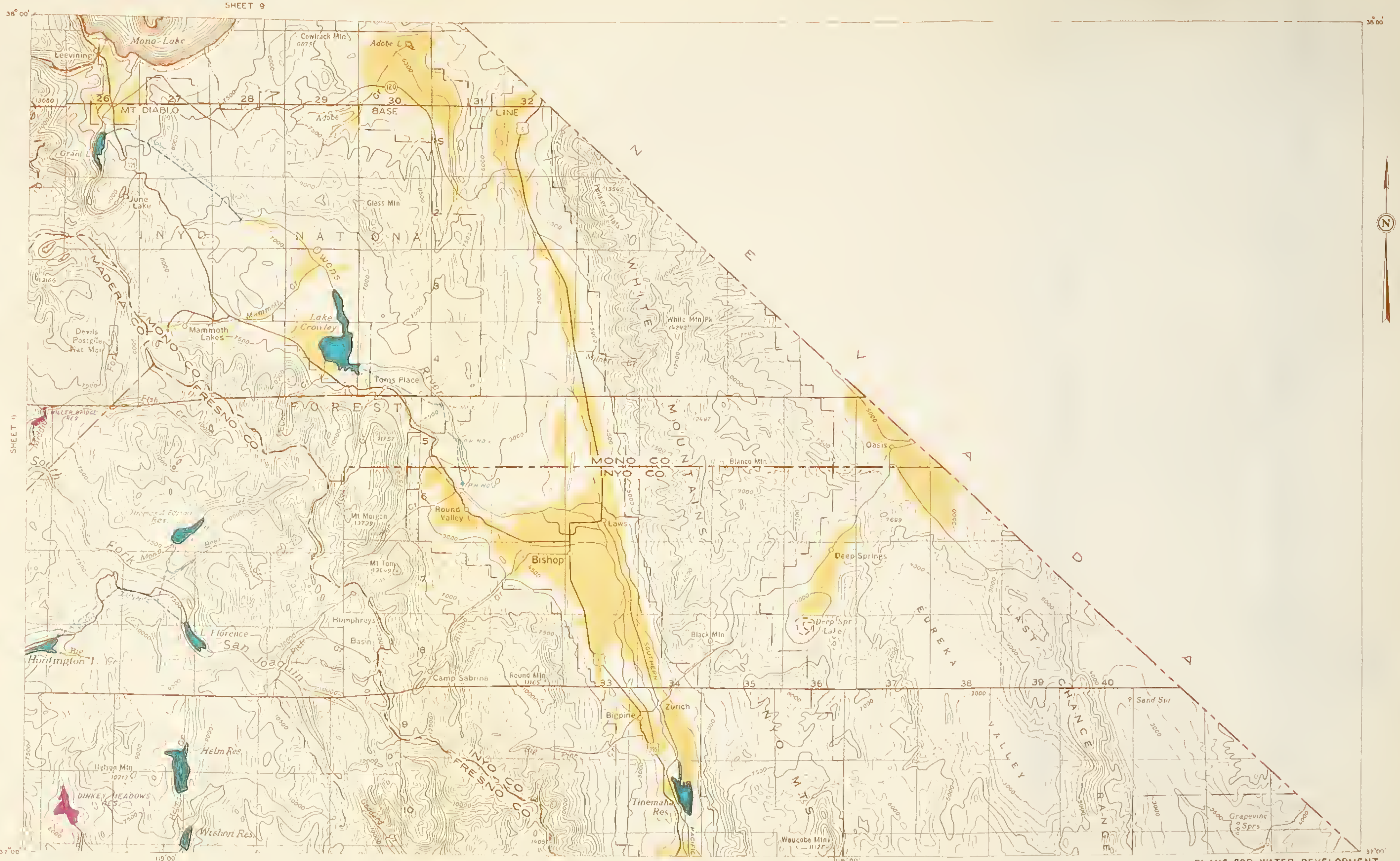
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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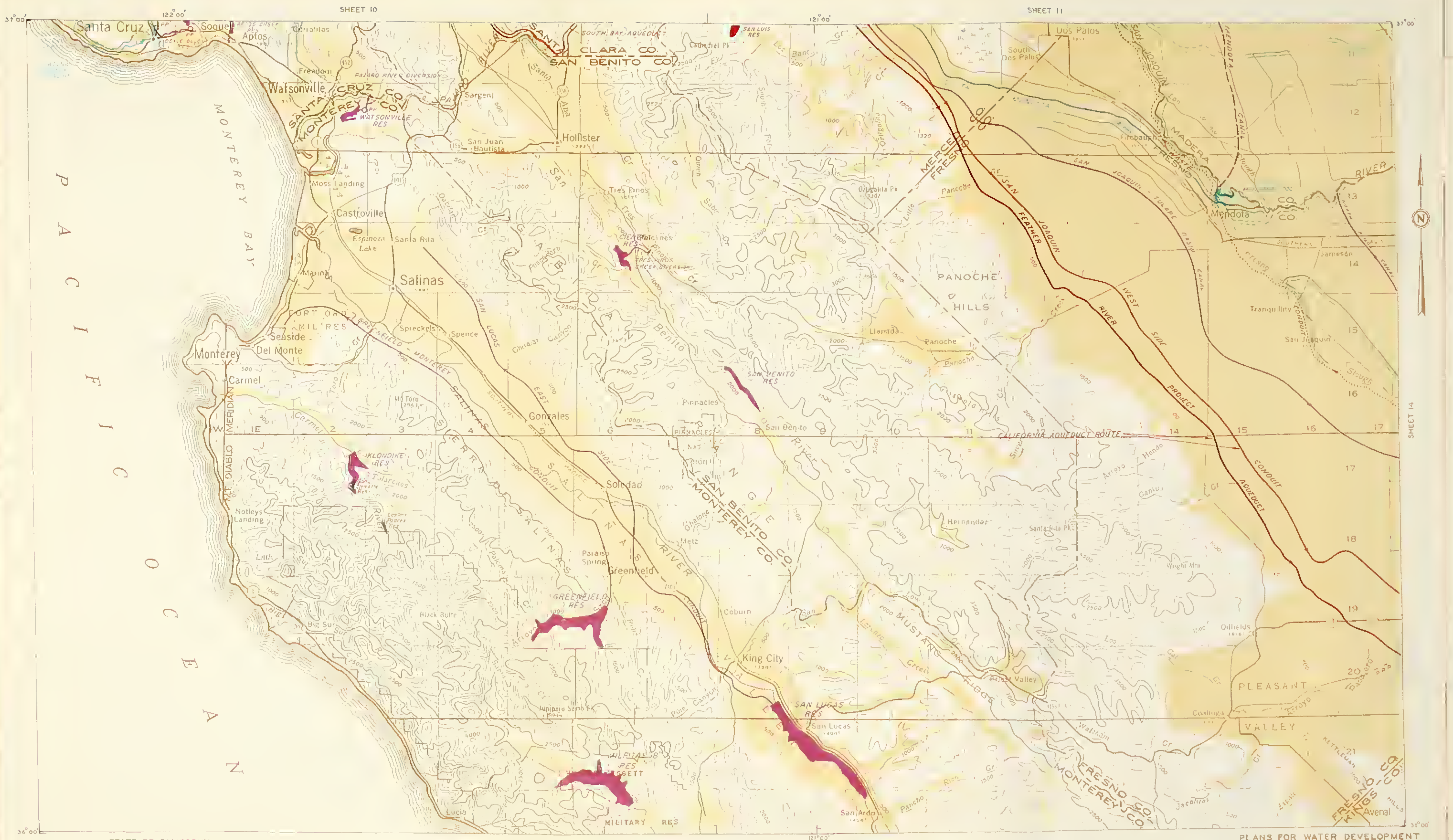
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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CONDUIT						
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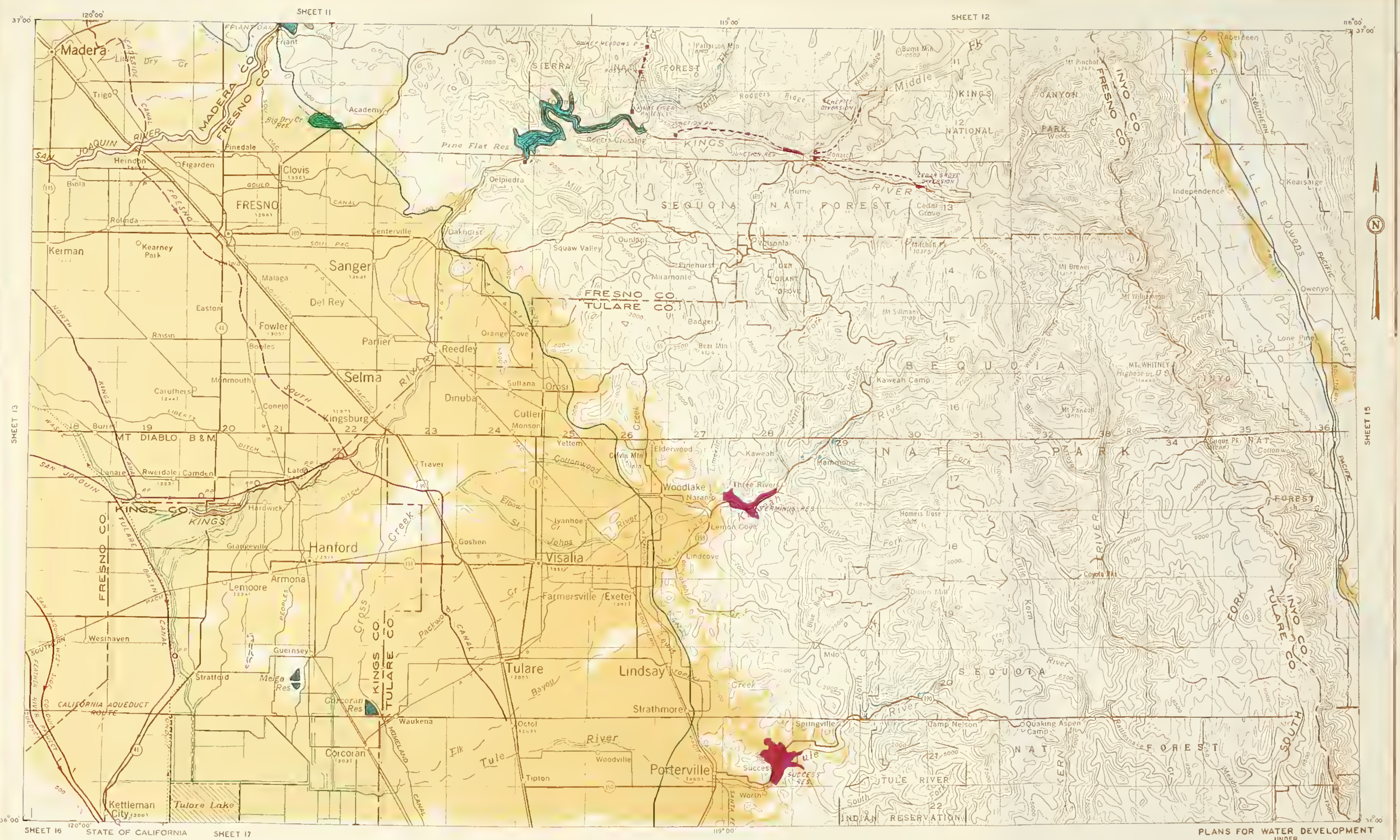
TUNNEL						
POWER HOUSE			P.H.	P.H.	P.H.	
PUMPING PLANT			P.P.	P.P.	P.P.	
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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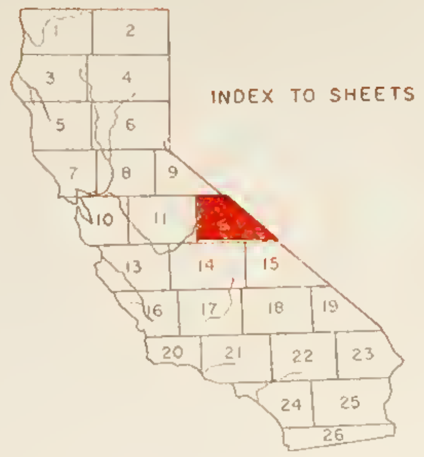

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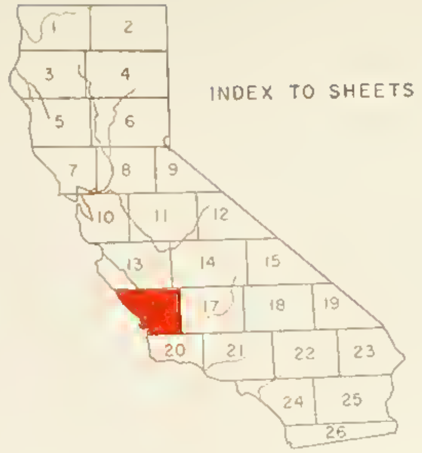

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LEVEE						
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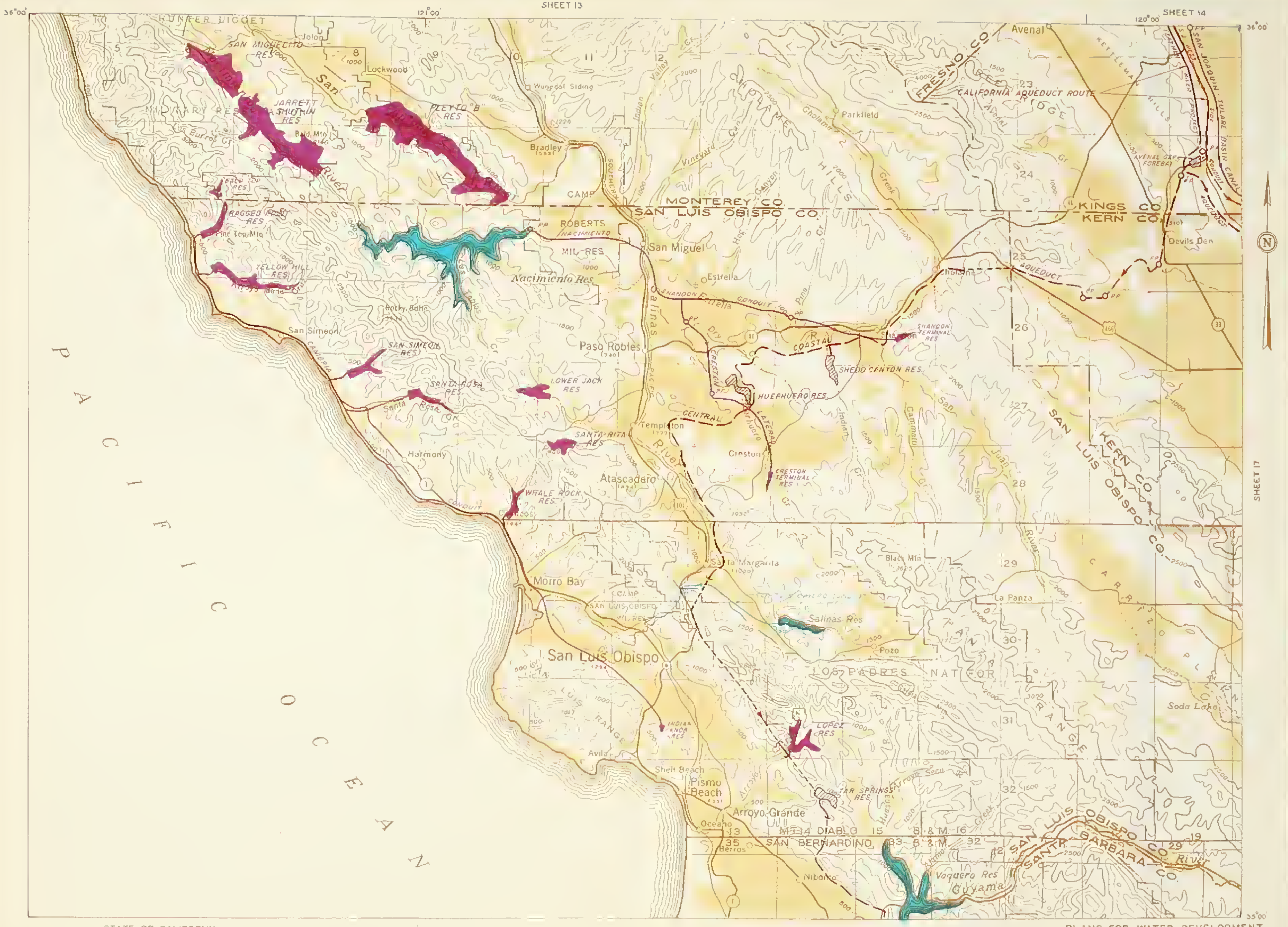

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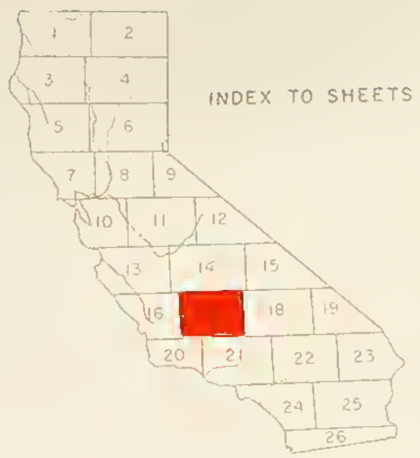

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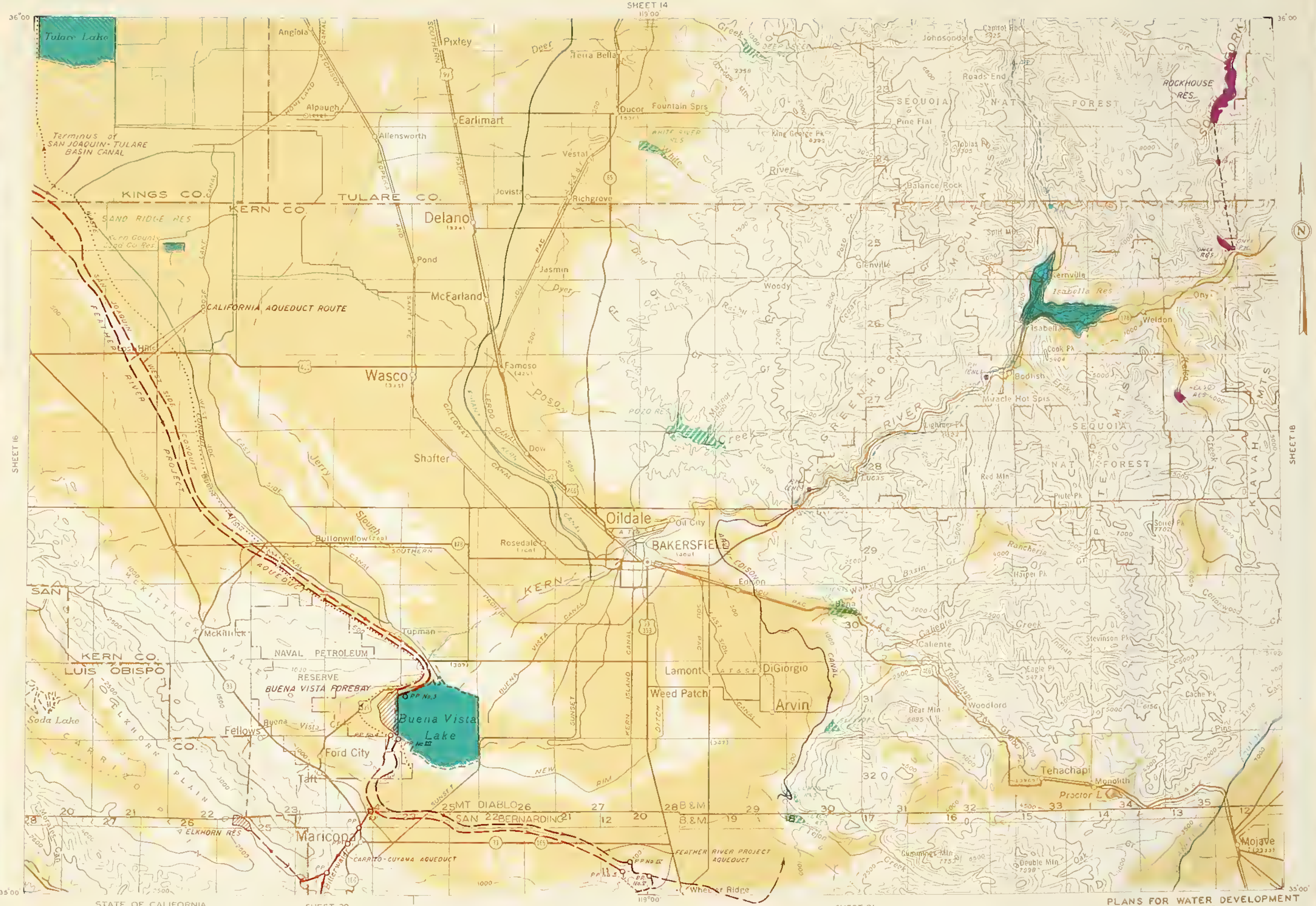
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



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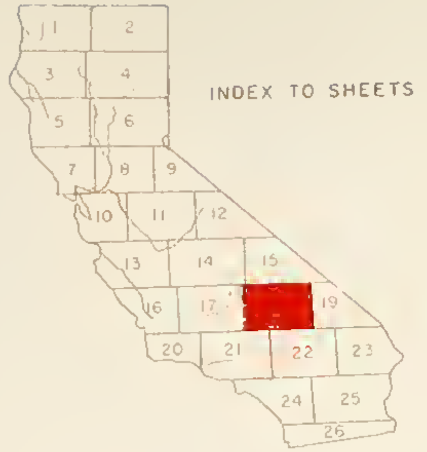
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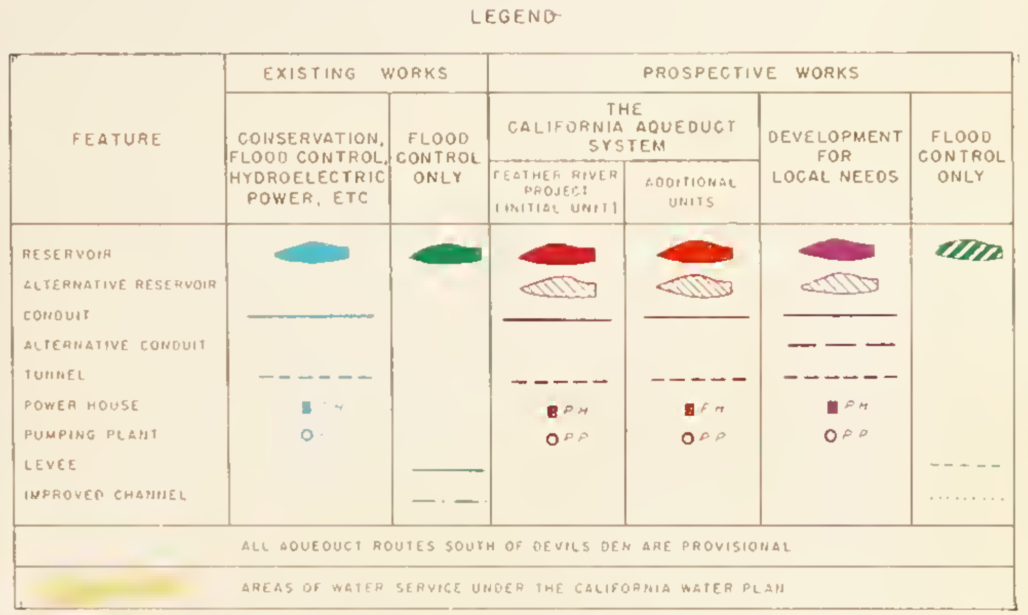
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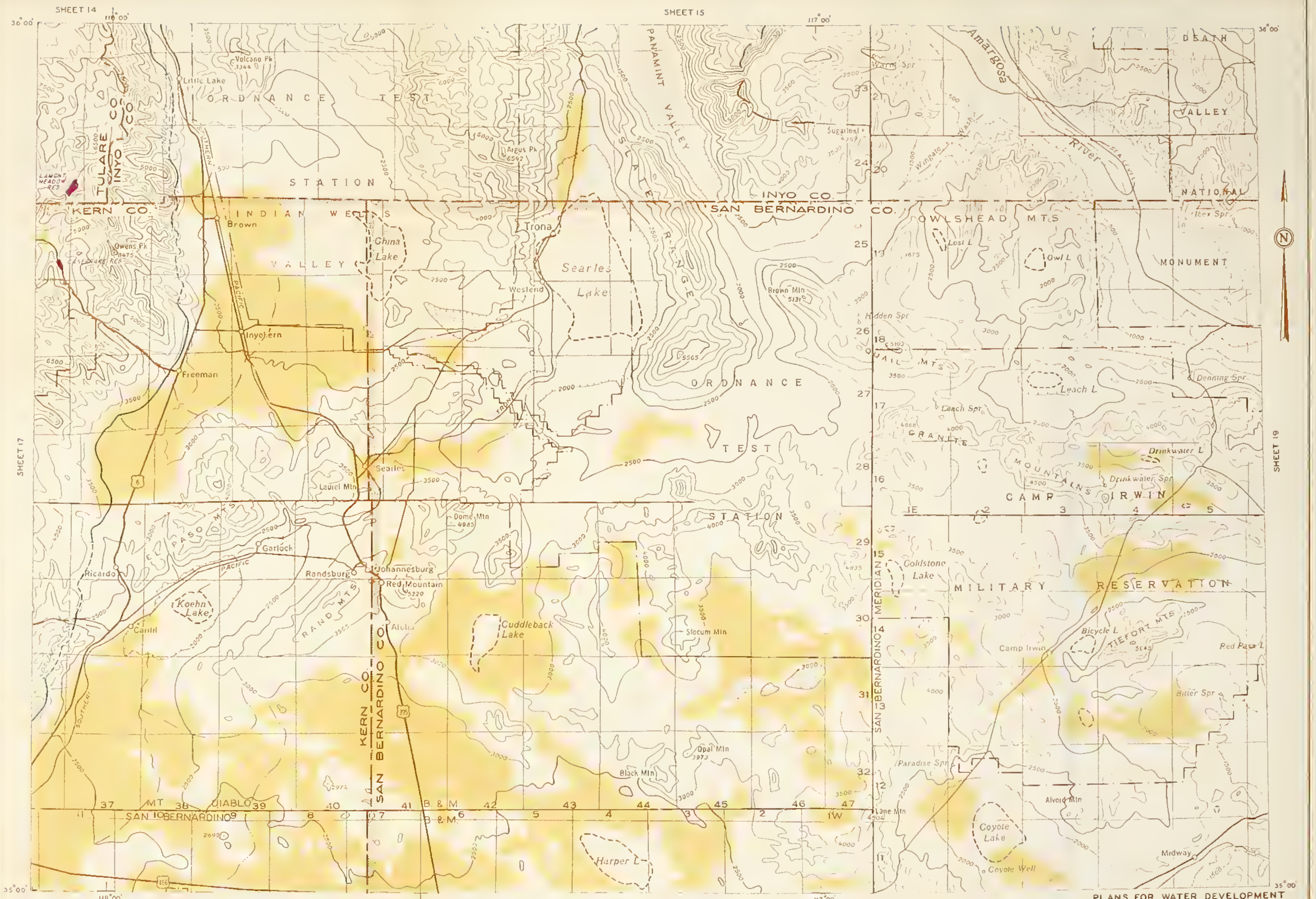
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TULARE CO
INYO CO
KERN CO.
SAN BERNARDINO CO.
ORDNANCE TEST STATION
INDIAN WELLS VALLEY
PANAMINT VALLEY
SLATE RANGE
Searles Lake
Trona
Westend
China Lake
Brown
Inyokern
Freeman
Little Lake
Volcano Pk
Argus Pk
Owens Pk
Searles
Laurel Mtn
Garlock
Ricardo
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Johannesburg
Red Mountain
Atolia
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EL PASO MTS
RAND MTS
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Slocum Mtn
Opal Mtn
Black Mtn
Harper L
Brown Mtn
Sugarloaf
OWLSHEAD MTS
Lost L
Owl L
Hidden Spr
AVAWATZ MTS
Leach L
Coach Spr
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MILITARY RESERVATION
Goldstone Lake
Camp Irwin
Bicycle L
TIEFORT MTS
Red Pass L
Bitter Spr
Paradise Spr
Lane Mtn
Alvord Mtn
Coyote Lake
Coyote Well
Midway
Amargosa River
DEATH VALLEY NATIONAL MONUMENT
Owens Spr
Denning Spr
Wingate Wash
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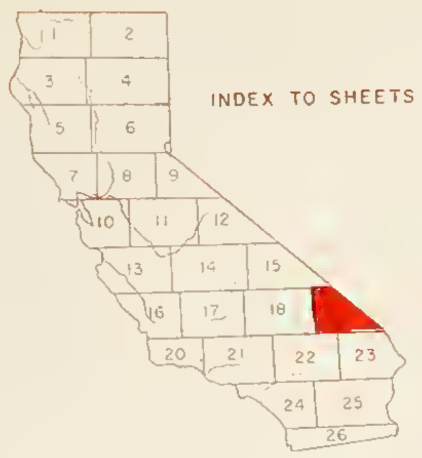
MT DIABLO
SAN BERNARDINO B & M
SCALE OF MILES



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			FEATHER RIVER PROJECT (INITIAL UNIT)	ADDITIONAL UNITS		
RESERVOIR ALTERNATIVE RESERVOIR CONDUIT ALTERNATIVE CONDUIT TUNNEL POWER HOUSE PUMPING PLANT LEVEE IMPROVED CHANNEL	NO EXISTING OR PROSPECTIVE WORKS ON THIS SHEET					
ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL						
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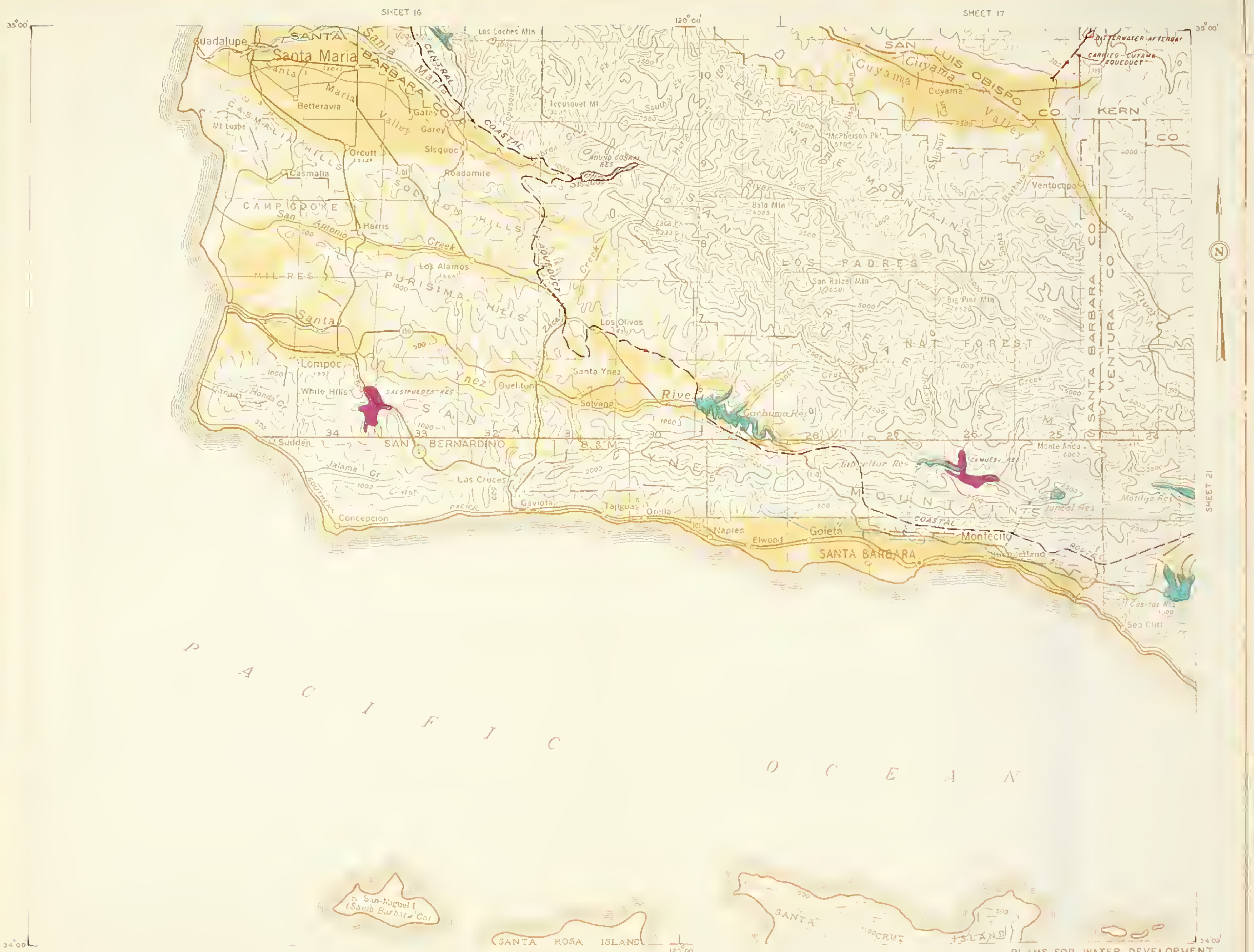
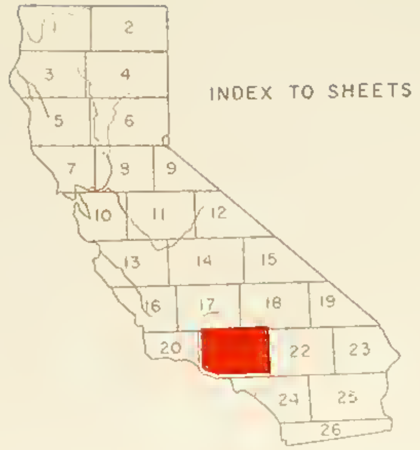
ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING 1957

PLANS FOR WATER DEVELOPMENT
UNDER
THE CALIFORNIA WATER PLAN
SHEET 20 OF 26 SHEETS

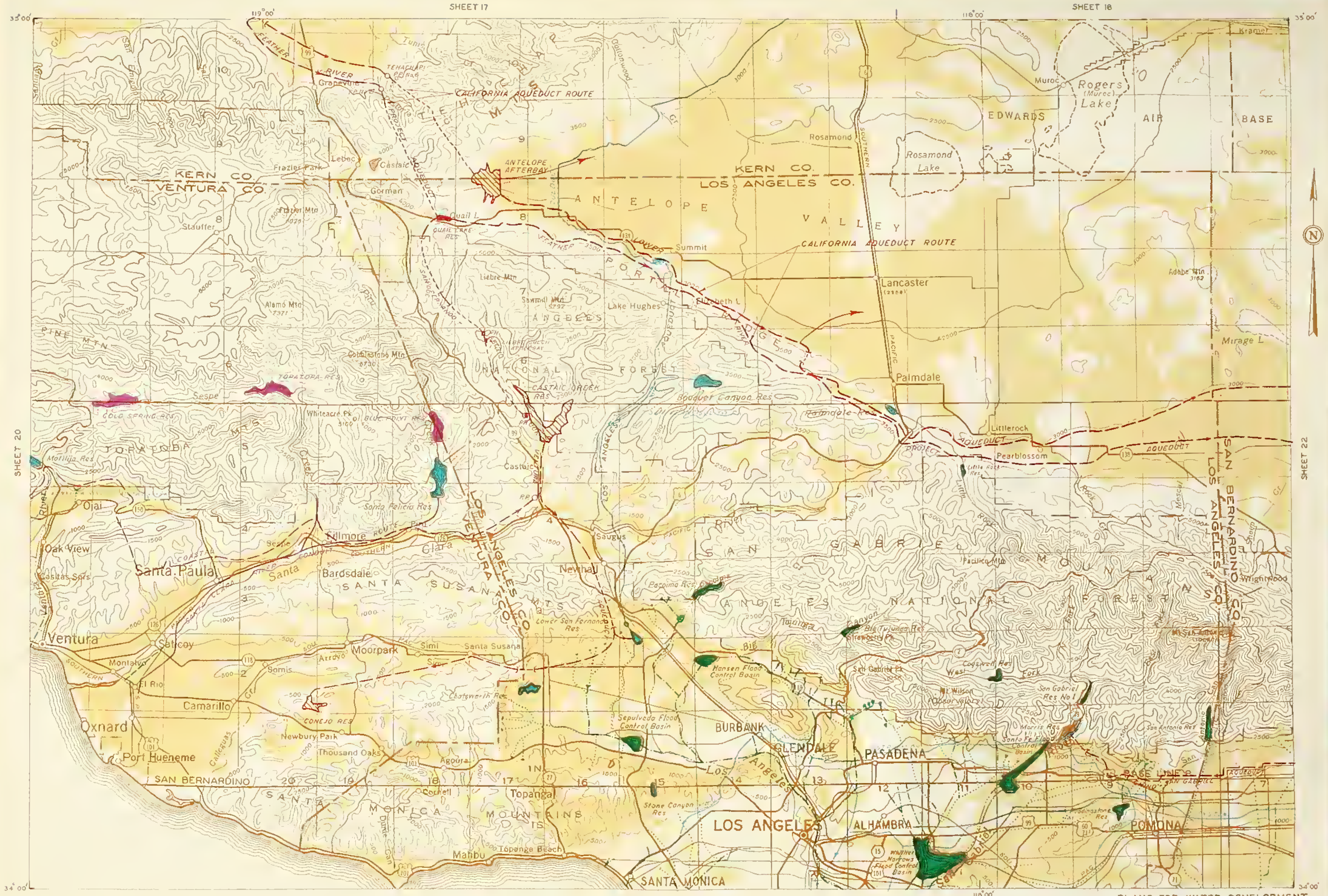


LEGEND

FEATURE	EXISTING WORKS: CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC.	EXISTING WORKS: FLOOD CONTROL ONLY	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	PROSPECTIVE WORKS: DEVELOPMENT FOR LOCAL NEEDS	PROSPECTIVE WORKS: FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE			PH	PH	PH	
PUMPING PLANT			PP	PP	PP	
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

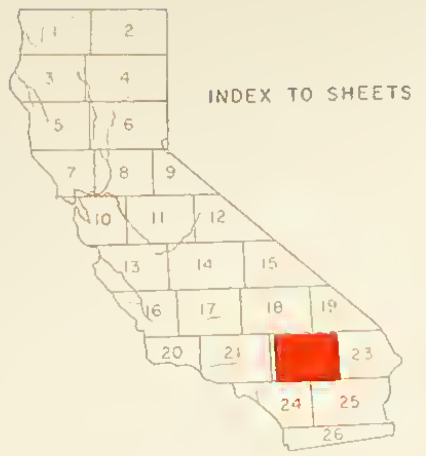
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING 1957

SCALE OF MILES
4 0 4 8 12

PLANS FOR WATER DEVELOPMENT UNDER THE CALIFORNIA WATER PLAN
SHEET 21 OF 26 SHEETS

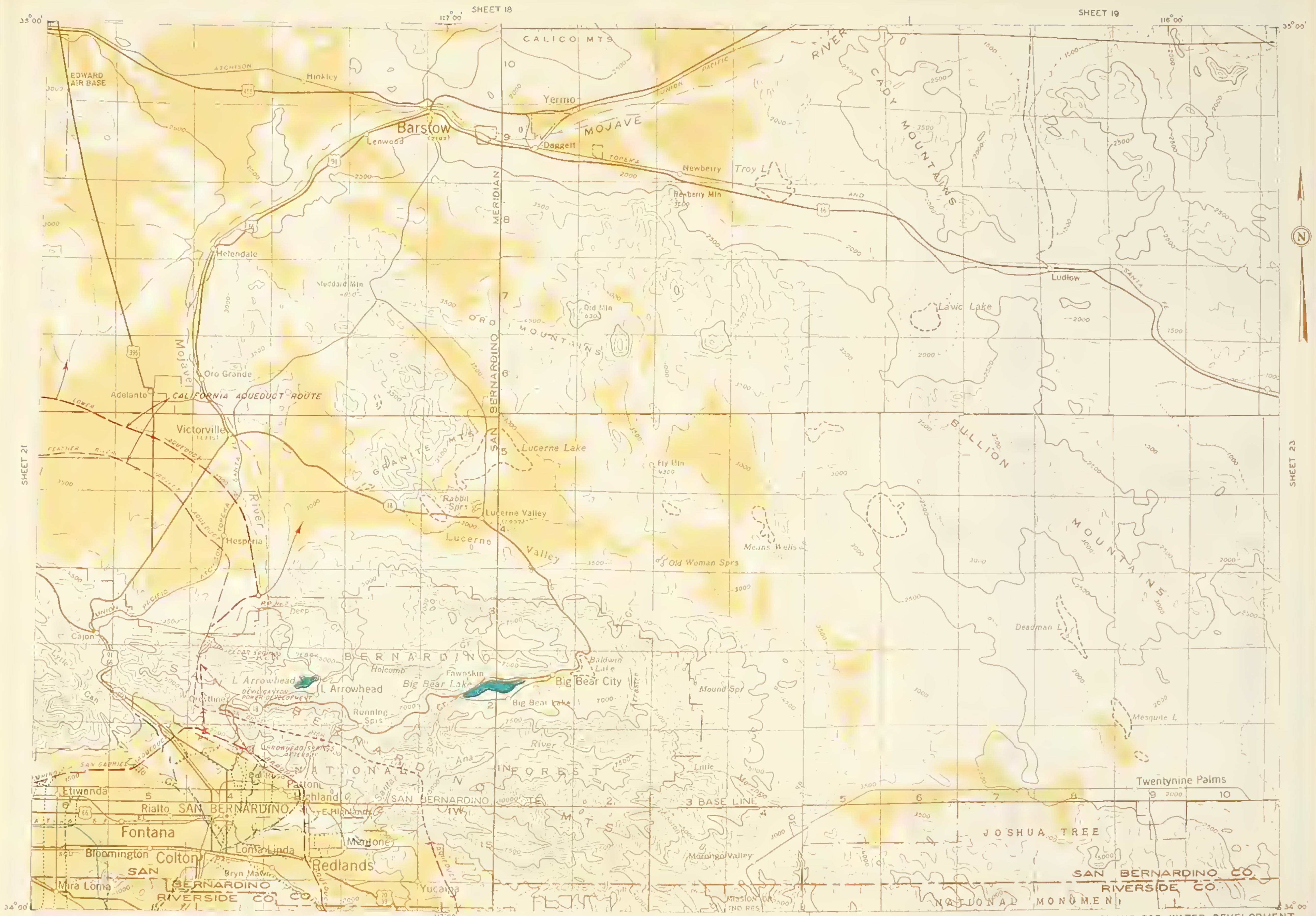


LEGEND

FEATURE	EXISTING WORKS		PROSPECTIVE WORKS			
	CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC	FLOOD CONTROL ONLY	THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	DEVELOPMENT FOR LOCAL NEEDS	FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE			PH	PH	PH	
PUMPING PLANT			PP	PP	PP	
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING 1957

PLANS FOR WATER DEVELOPMENT
UNDER
THE CALIFORNIA WATER PLAN
SHEET 22 OF 26 SHEETS

INDEX TO SHEETS

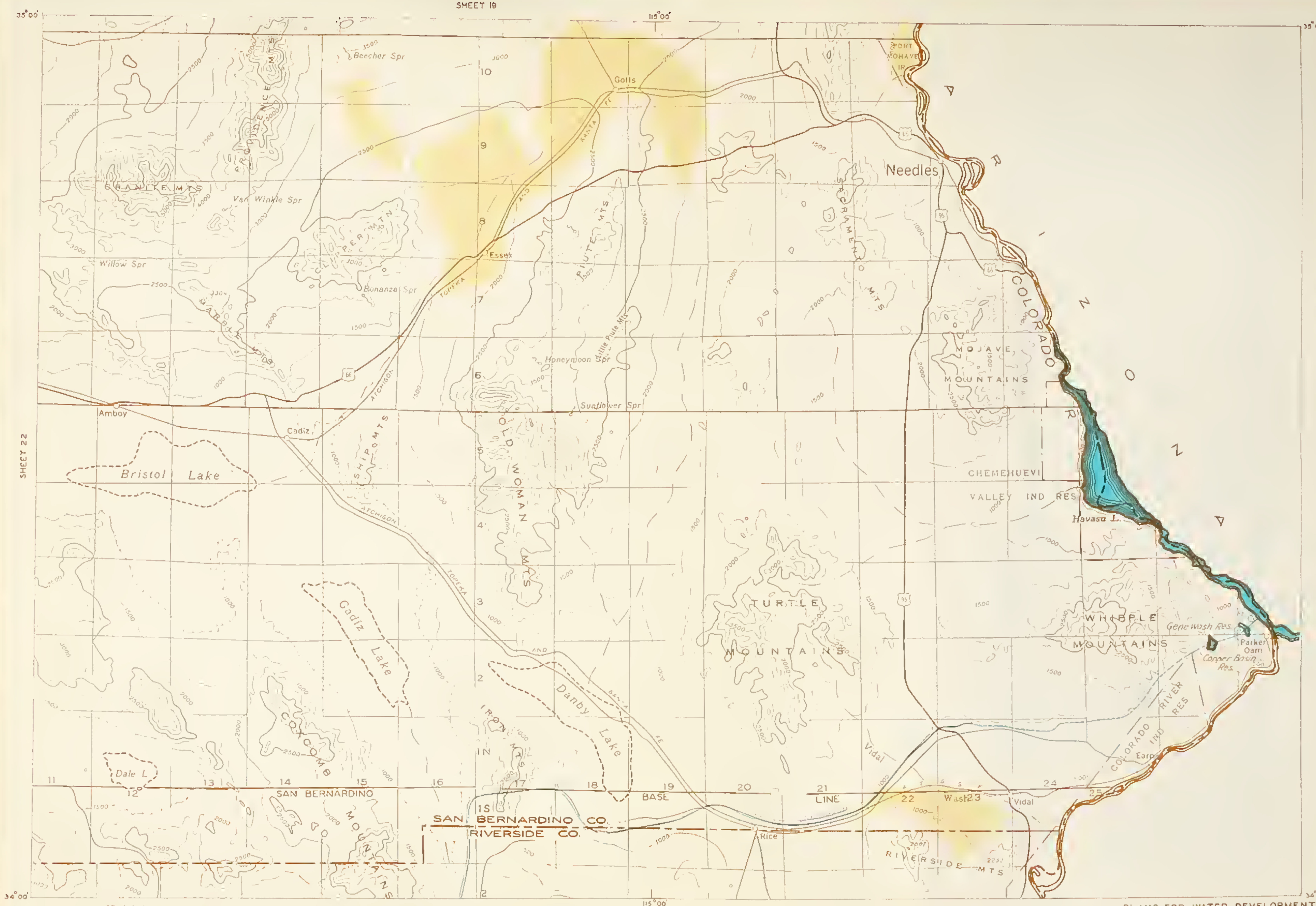
LEGEND

FEATURE	EXISTING WORKS: CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC	EXISTING WORKS: FLOOD CONTROL ONLY	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	PROSPECTIVE WORKS: DEVELOPMENT FOR LOCAL NEEDS	PROSPECTIVE WORKS: FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE			PH	PH	PH	
PUMPING PLANT			PP	PP	PP	
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN

SHEET 19



SHEET 22

SHEET 25

SCALE OF MILES
4 0 4 8 12

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING 1957

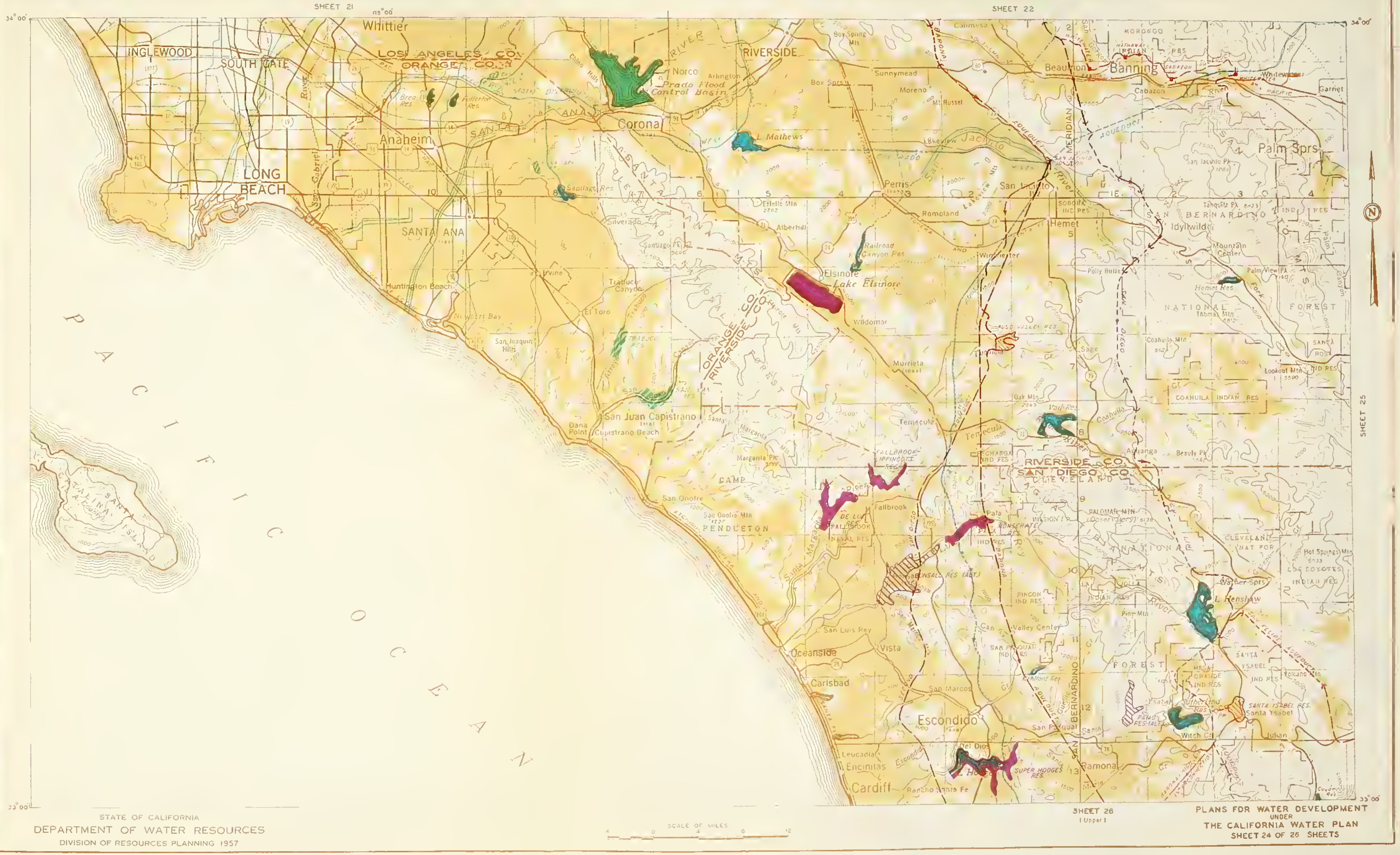
PLANS FOR WATER DEVELOPMENT
UNDER
THE CALIFORNIA WATER PLAN

LEGEND

FEATURE	EXISTING WORKS		PROSPECTIVE WORKS			
	CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC.	FLOOD CONTROL ONLY	THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	DEVELOPMENT FOR LOCAL NEEDS	FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE						
PUMPING PLANT						
LEVEE						
IMPROVED CHANNEL						

ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN



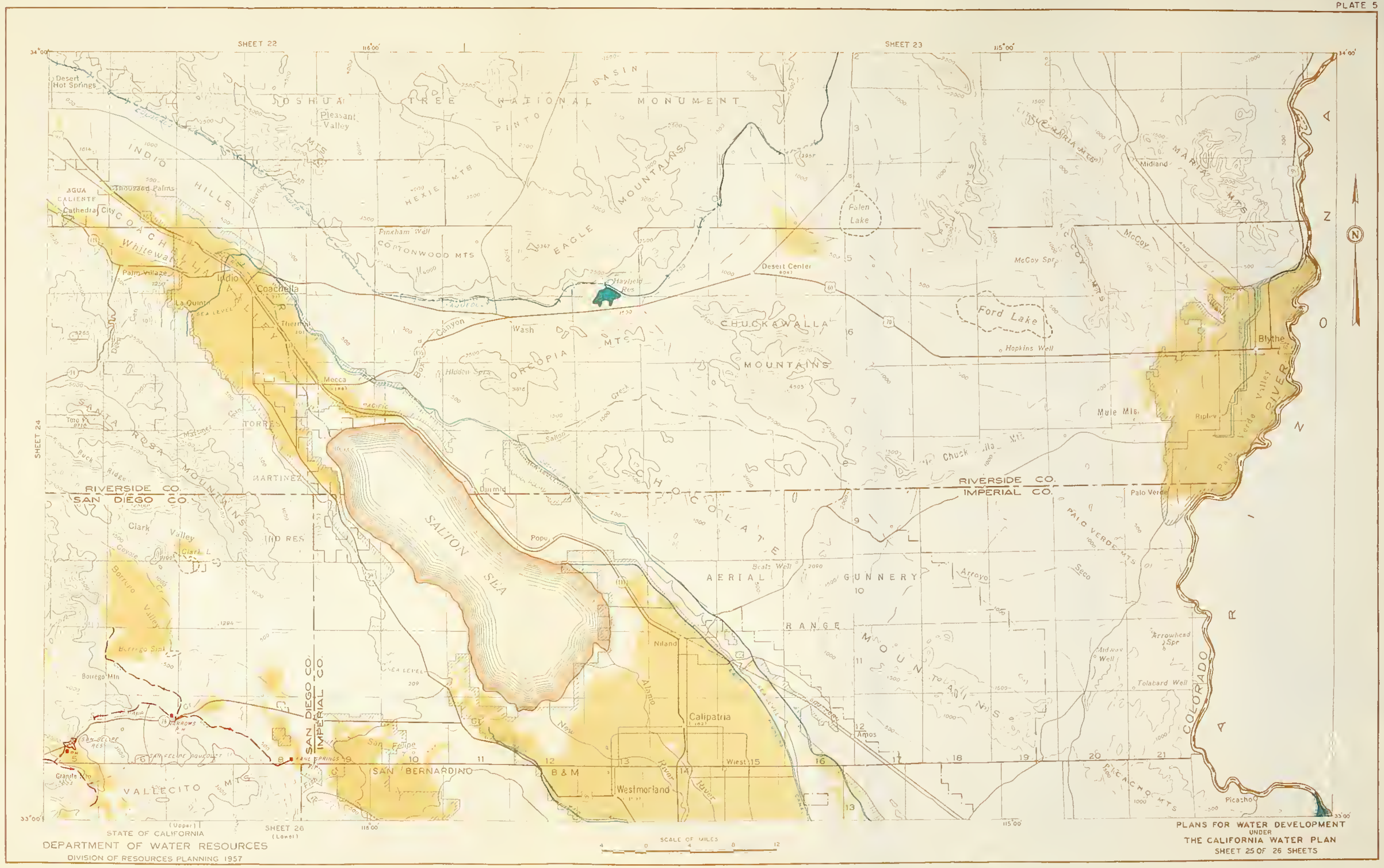
LEGEND

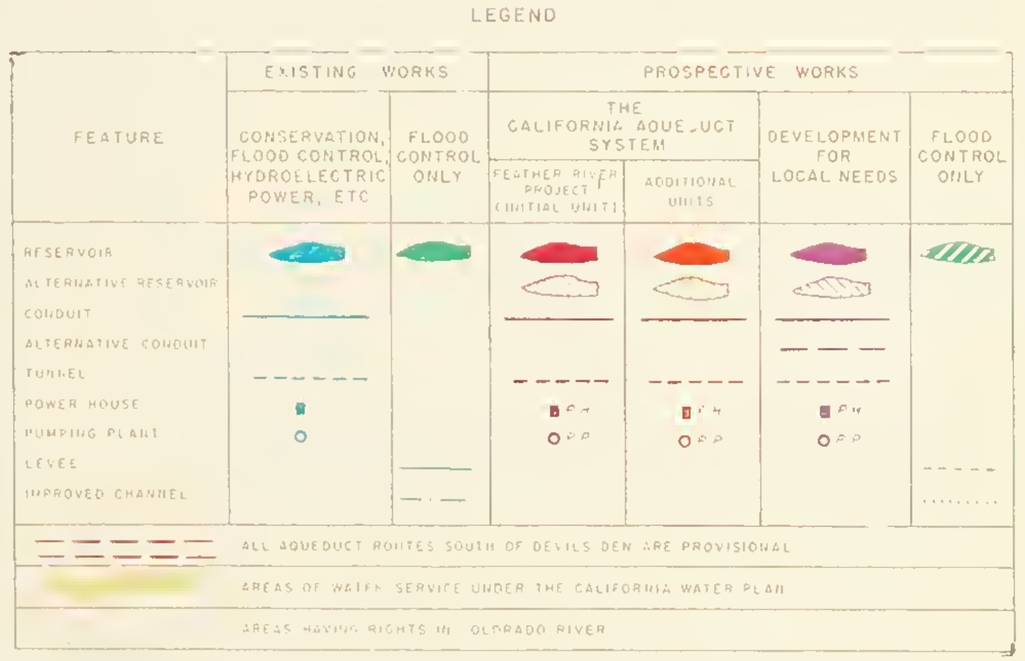
FEATURE	EXISTING WORKS: CONSERVATION, FLOOD CONTROL, HYDROELECTRIC POWER, ETC.	EXISTING WORKS: FLOOD CONTROL ONLY	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: FEATHER RIVER PROJECT (INITIAL UNIT)	PROSPECTIVE WORKS: THE CALIFORNIA AQUEDUCT SYSTEM: ADDITIONAL UNITS	PROSPECTIVE WORKS: DEVELOPMENT FOR LOCAL NEEDS	PROSPECTIVE WORKS: FLOOD CONTROL ONLY
RESERVOIR						
ALTERNATIVE RESERVOIR						
CONDUIT						
ALTERNATIVE CONDUIT						
TUNNEL						
POWER HOUSE	P.H.		P.H.	P.H.	P.H.	
PUMPING PLANT	P.P.		P.P.	P.P.	P.P.	
LEVEE						
IMPROVED CHANNEL						

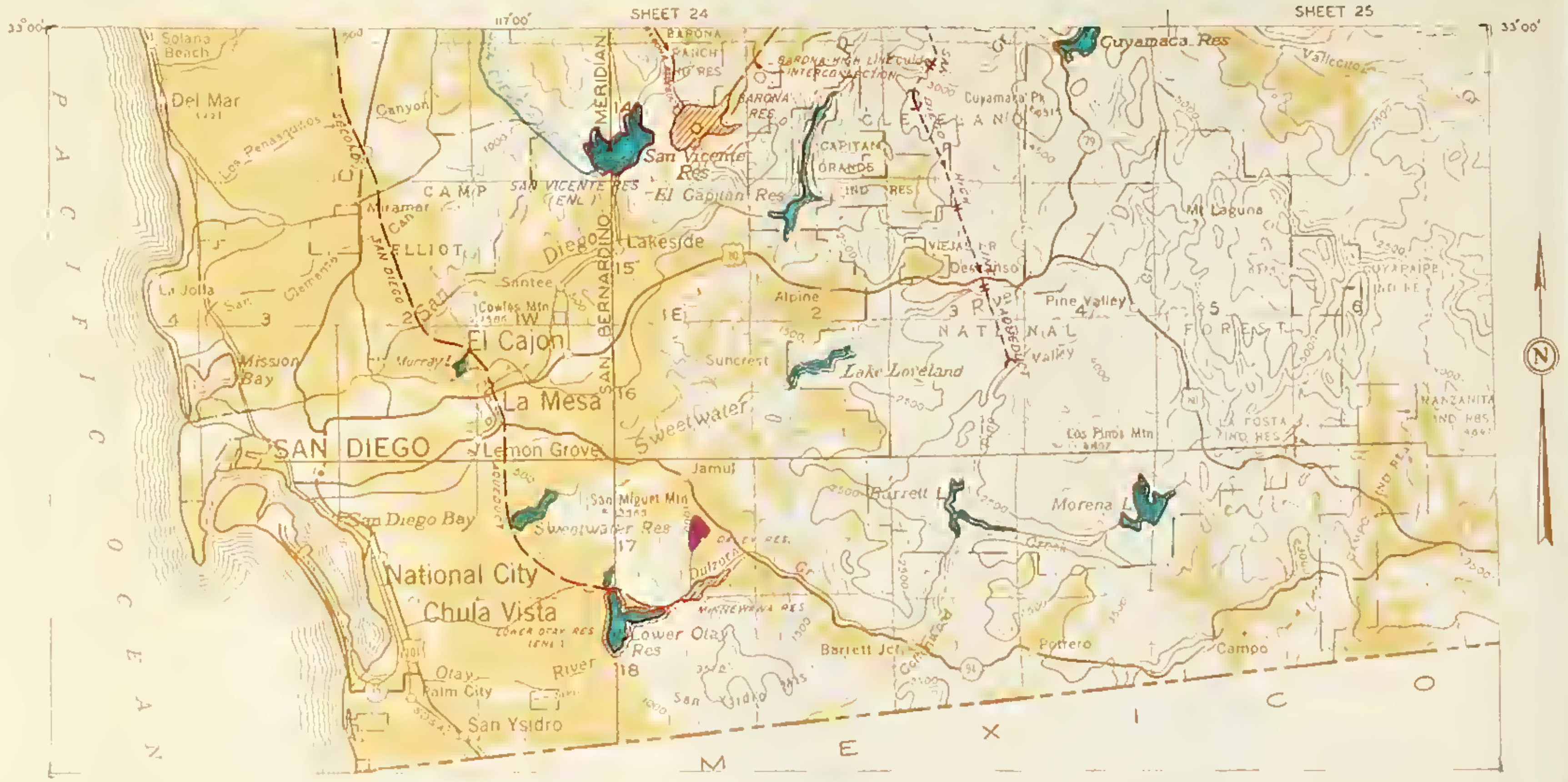
ALL AQUEDUCT ROUTES SOUTH OF DEVILS DEN ARE PROVISIONAL

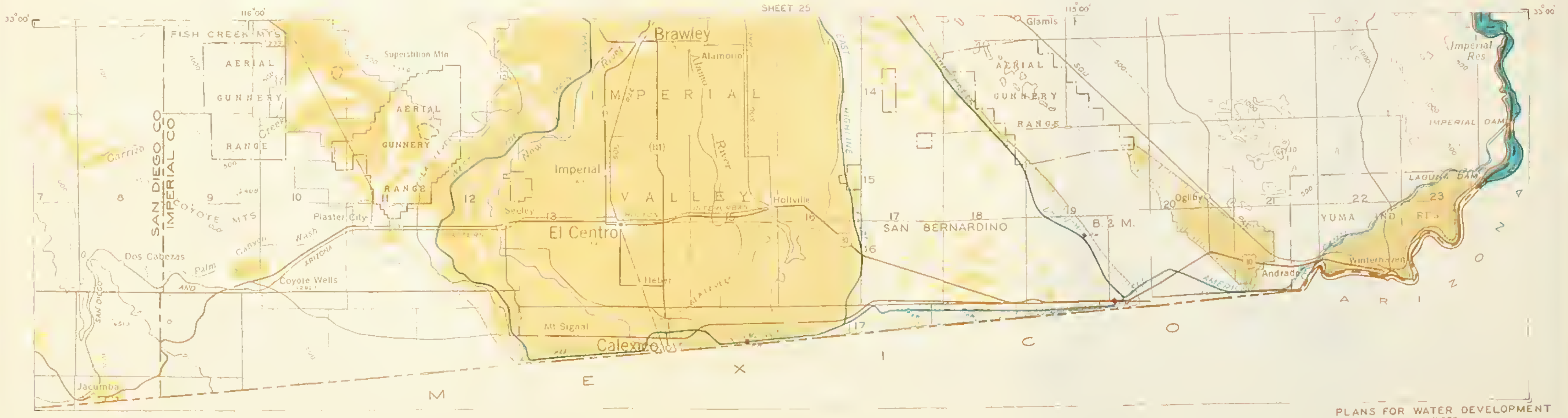
AREAS OF WATER SERVICE UNDER THE CALIFORNIA WATER PLAN

AREAS HAVING RIGHTS IN COLORADO RIVER





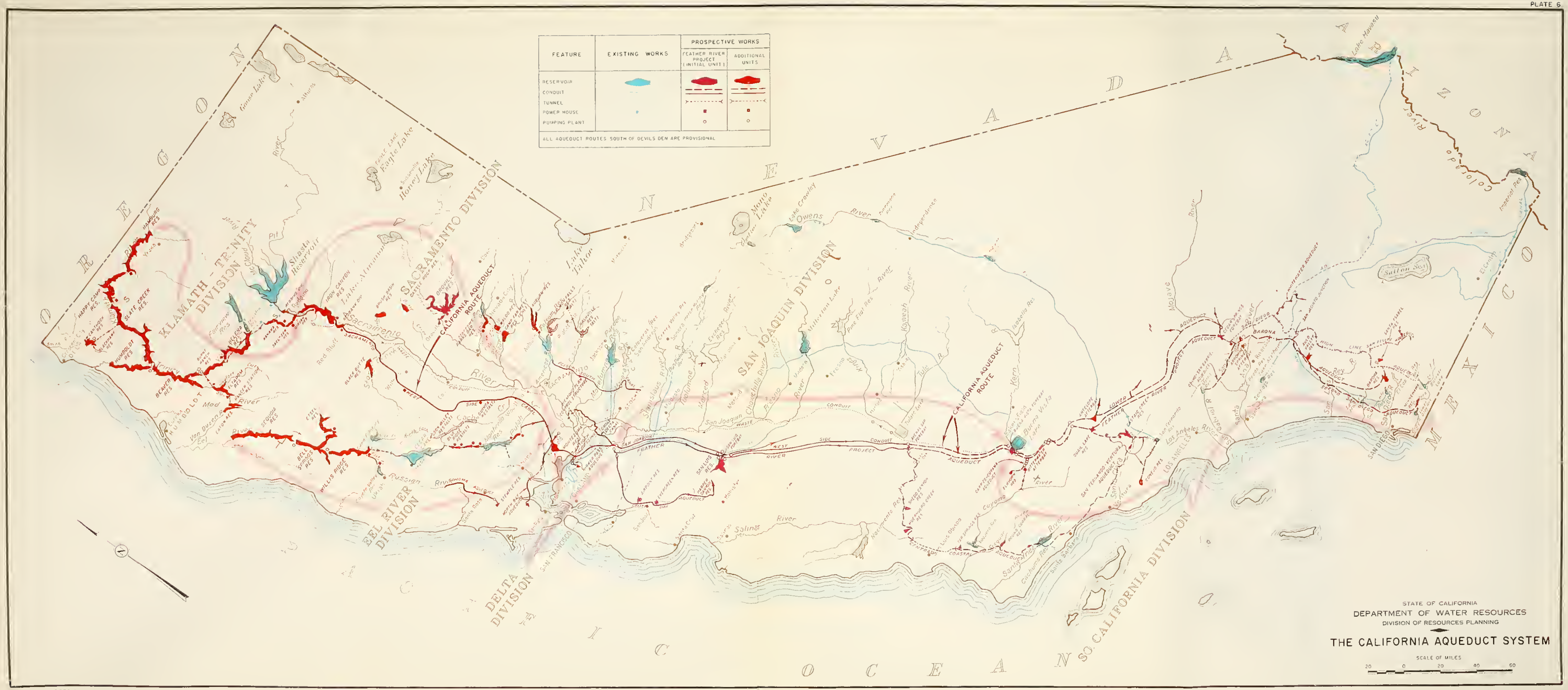




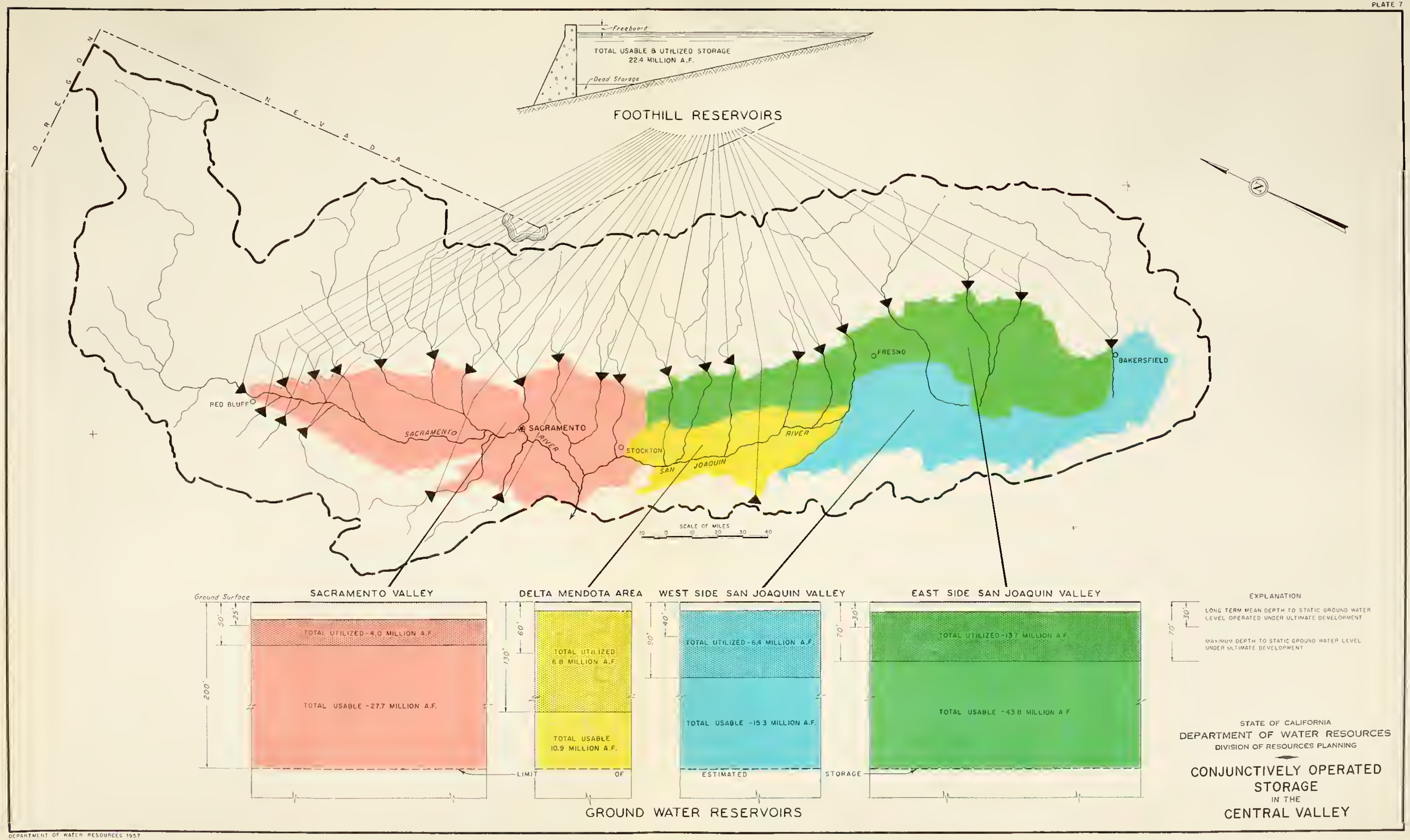
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING 1957

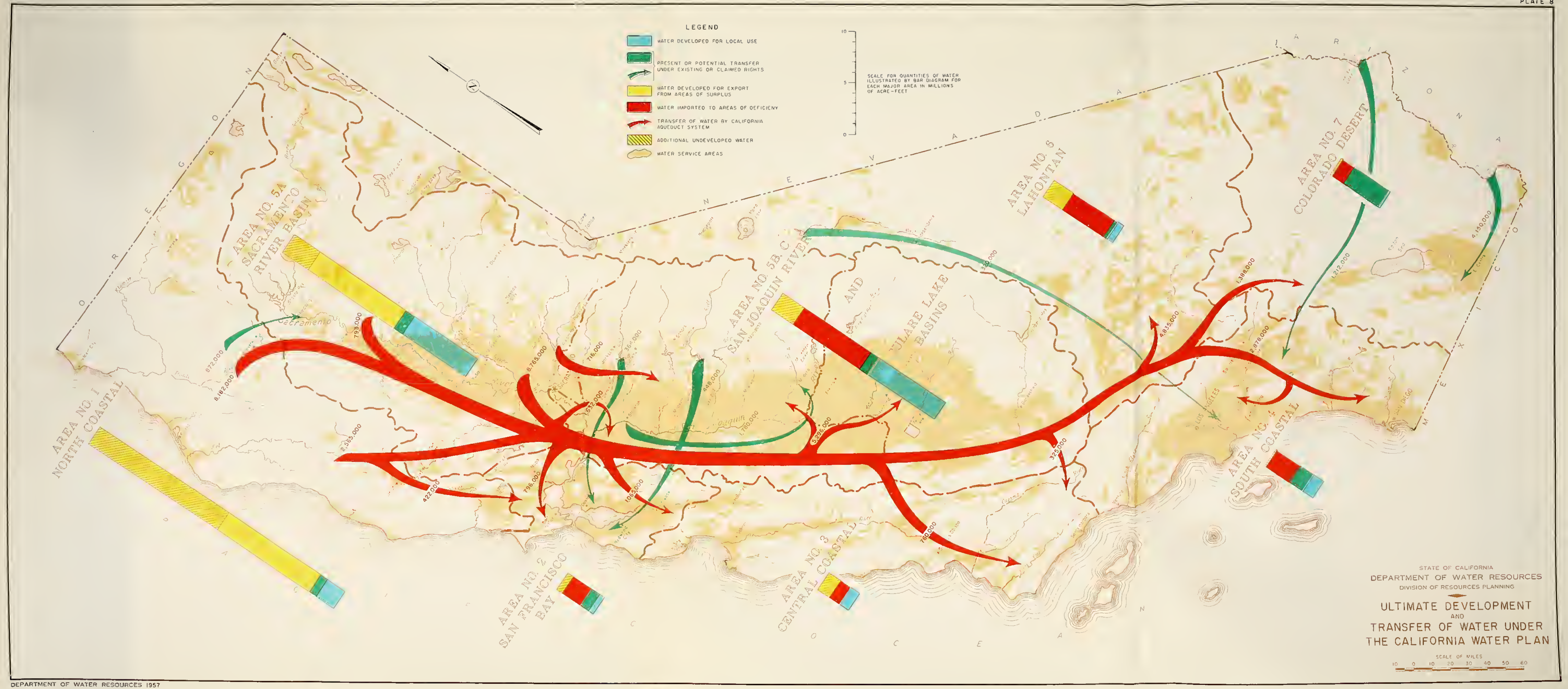
SCALE OF MILES

PLANS FOR WATER DEVELOPMENT
UNDER
THE CALIFORNIA WATER PLAN
SHEET 26 OF 26 SHEETS



DIVISION OF RESOURCES PLANNING 1957


Freeboard
TOTAL USABLE & UTILIZED STORAGE 22.4 MILLION A.F.
Dead Storage
FOOTHILL RESERVOIRS
OREGON
NEVADA
RED BLUFF
SACRAMENTO
SACRAMENTO RIVER
STOCKTON
SAN JOAQUIN RIVER
FRESNO
BAKERSFIELD
SCALE OF MILES
10 0 10 20 30 40
SACRAMENTO VALLEY
DELTA MENDOTA AREA
WEST SIDE SAN JOAQUIN VALLEY
EAST SIDE SAN JOAQUIN VALLEY
Ground Surface
25'
50'
200'
TOTAL UTILIZED-4.0 MILLION A.F.
TOTAL USABLE -27.7 MILLION A.F.
60'
130'
TOTAL UTILIZED 6.8 MILLION A.F.
TOTAL USABLE 10.9 MILLION A.F.
40'
90'
TOTAL UTILIZED-6.4 MILLION A.F.
TOTAL USABLE -15.3 MILLION A.F.
30'
70'
TOTAL UTILIZED-13.7 MILLION A.F.
TOTAL USABLE -43.8 MILLION A.F.
LIMIT OF ESTIMATED STORAGE
GROUND WATER RESERVOIRS
EXPLANATION
LONG TERM MEAN DEPTH TO STATIC GROUND WATER LEVEL OPERATED UNDER ULTIMATE DEVELOPMENT
MAXIMUM DEPTH TO STATIC GROUND WATER LEVEL UNDER ULTIMATE DEVELOPMENT
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
CONJUNCTIVELY OPERATED STORAGE IN THE CENTRAL VALLEY


LEGEND
WATER DEVELOPED FOR LOCAL USE
PRESENT OR POTENTIAL TRANSFER UNDER EXISTING OR CLAIMED RIGHTS
WATER DEVELOPED FOR EXPORT FROM AREAS OF SURPLUS
WATER IMPORTED TO AREAS OF DEFICIENY
TRANSFER OF WATER BY CALIFORNIA AQUEDUCT SYSTEM
ADDITIONAL UNDEVELOPED WATER
WATER SERVICE AREAS
10
5
0
SCALE FOR QUANTITIES OF WATER ILLUSTRATED BY BAR DIAGRAM FOR EACH MAJOR AREA IN MILLIONS OF ACRE-FEET
AREA NO. 1 NORTH COASTAL
AREA NO. 2 SAN FRANCISCO BAY
AREA NO. 3 CENTRAL COASTAL
AREA NO. 4 SOUTH COASTAL
AREA NO. 5A SACRAMENTO RIVER BASIN
AREA NO. 5B, C SAN JOAQUIN RIVER AND TULARE LAKE BASINS
AREA NO. 6 LAHONTAN
AREA NO. 7 COLORADO DESERT
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
872,000
8,182,000
793,000
8,765,000
716,000
2,335,000
422,000
796,000
1,065,000
5,296,000
780,000
325,000
4,835,000
1,388,000
2,878,000
1,212,000
4,150,000
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
ULTIMATE DEVELOPMENT AND TRANSFER OF WATER UNDER THE CALIFORNIA WATER PLAN
SCALE OF MILES
10 0 10 20 30 40 50 60