THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

DELTA WATER REQUIREMENTS

APPENDIX to BULLETIN No. 76

DELTA WATER FACILITIES

Preliminary Edition

FEBRUARY 1962

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
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STATEMENT OF CLARIFICATION

This preliminary edition presents a comparison of alternative solutions to the Delta problems. This bulletin shows that the Single Purpose Delta Water Project is the essential minimum project for successful operation of the State Water Facilities. This bulletin also presents, for local consideration, optional modifications of the Single Purpose Delta Water Project which would provide additional local benefits.

The evaluation of project accomplishments, benefit-cost ratios, and costs of project services, are intended only to indicate the relative merits of these solutions and should not be considered in terms of absolute values. Benefits related to recreation are evaluated for comparative purposes. Detailed recreation studies, presently in progress, will indicate specific recreation benefits.

Subsequent to local review and public hearings on this preliminary edition, a final edition will be prepared setting forth an adopted plan. The adopted plan will include, in addition to the essential minimum facilities, those justifiable optional modifications requested by local entities.

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FOREWARD

This appendix to Bulletin No. 76, "Delta Water Facilities", is one of six appendices upon which were based the recommendations and conclusions in Bulletin No. 76. Other appendices are entitled:

Economic Aspects

Salinity Incursion and Water Resources

Recreation

Plans, Designs, and Cost Estimates

Channel Hydraulics and Flood Channel Design

Data and analyses contained in this appendix were utilized to determine the physical extent and economic feasibility of all local water supply features proposed in Bulletin No. 76. These proposed features are intended to meet all local water requirements through the year 2020.

Since Bulletin No. 76 is a preliminary draft designed to assist local agencies in evaluating the means by which local Delta problems can be solved within the structure of the State Water Resources Development System, all conclusions presented in this appendix must be considered preliminary. Following local review and public hearings on Bulletin No. 76, a final report will be issued, which will incorporate comments and suggestions pertinent to the appendices as well as the summary report. The final report will describe the essential minimum facilities and those economically justifiable options requested by local interests.

CHAPTER I. INTRODUCTION

The watersheds of the Central Valley of California come together in the Sacramento-San Joaquin Delta. The availability of fresh water in Delta channels depends upon seasonal water supply resulting from precipitation and from melting snow in the Central Valley watersheds. Upstream development during the past 60 years has seen an increase in water use and water storage with a resulting increase in the intensity and area of salinity incursion.

Plate 1, "Areas of Investigation, Sacramento-San Joaquin Delta", shows the boundary of the Delta, as described in Section 12220 of the California Water Code. The area is bounded by the Cities of Antioch, Pittsburg, Tracy, Stockton, Sacramento, and Rio Vista. The plate also shows the overlapping western Delta study area, for which intensive studies of water supplies and requirements have been made. This area, which is partially within the legally defined Delta boundary, extends from the vicinity of Franks Tract to a point approximately 3 miles west of Pittsburg and encompasses channels, Delta lands, shore lands, and lands in the adjacent watershed area.

Intensive studies have been made of the future economic development of lands which could be supplied with water from channels in the western Delta study area, future water needs, and the future supplies available to the Delta. The broad scope of these studies permitted the inclusion of only the most pertinent information and computations in this report. The data collected were considered in formulating the conclusions contained in the summary report, Bulletin No. 76 "Delta Water Facilities". This bulletin, and previous studies, indicate that there are several physically feasible methods of solving water supply and related problems in the Sacramento-San Joaquin Delta and upper San Francisco Bay system.

This report summarizes studies of present development and projected future growth in the Sacramento-San Joaquin Delta. It discusses quantity and quality of water requirements. Design concepts basic to the planning of adequate supply facilities for unhindered regional development are developed. Because projections of economic growth are based upon an assumption of adequate water supply, the adoption of any one of several alternative plans does not alter projections of water requirements. Water quality at specific locations, however, does depend upon the features of a specific plan. Hence, the adoption of any one of the alternative facilities would dictate which supplementary or replacement water supply facilities must be included. Wherever feasible, continued operation of existing water supply facilities was included in the planning. The gross water deliveries for alternative plans might differ, but the projected net requirements would remain independent and unchanged.

Area of Investigation

The area of investigation includes the entire Sacramento-San Joaquin Delta and the overlapping western Delta study area. Agricultural water requirements were determined for each of the portions of the six counties included within the Delta. The evaluation of water quality applies only to the western Delta study area, where present and future salinity concentrations in the water channels reach levels that affect the economy.

Industrial and municipal water requirements were determined only for the western Delta portions of Solano and Contra Costa Counties. Other municipal and industrial areas within the Delta will continue to obtain water from sources other than Delta channels, or will be insured adequate water supplies under all conditions resulting from the construction of the proposed Delta facilities. The Sacramento County portion of the western Delta study area was not considered in detail because major municipal or industrial growth is not anticipated therein.

CHAPTER II. THE ECONOMIC GROWTH OF THE DELTA

During the early stages of development the economic growth of the Delta was centered around the cultivation of the highly fertile swamplands. The cultivating of these swamplands required the reclamation of such areas by the construction of levees to prevent seasonal inundation from flood flows. The present highly prosperous economy, firmly based on irrigated agriculture, annually produces many thousands of tons of food products. A wide variety of food-processing industries have located on the perimeter of the Delta. These industries prepare foods for shipment throughout the world. Seasonally they employ many thousands of workers.

Since 1900 certain natural advantages of the Delta have attracted a wide variety of heavy manufacturing industries. These industries have altered the economic structure of portions of the Delta by shifting them from agricultural to industrial orientation. As a result of this development, population has increased considerably and thousands of acres of Delta farm lands have been withdrawn from agricultural use to be devoted to urban use.

The study of the economic growth patterns of the Delta and the projection of these growth patterns into the future were an integral part of Delta water facility planning. These studies were conducted in terms of two major segments of the Delta economy -- agricultural development and urban development. The latter includes industrial and municipal development.

Past and Present Industrial and Municipal Development

Since 1900, industrial development in California has proceeded at an accelerated pace to serve markets created by the increasing population of the western states. The development of the Delta, hastened by the recognition of its natural industrial sites, reflects this pace. Large employment and population increases have occurred. Large amounts of capital have been invested. Certain areas, including those within or surrounding the Cities of Stockton, Antioch, and Pittsburg, have been converted almost completely from an agricultural to an industrial economy.

The study of municipal and industrial development within the Delta, with the exception of present and future land use, has been limited to the western Delta study area. This area, in general, encompasses those portions of the Delta affected by salinity incursion. The Cities of Stockton, Sacramento, and Tracy, and the County of Yolo, are omitted from the study area, not because their industrial and municipal developments are small factors in the overall Delta economy but because Delta water facility planning will have little, if any, effect upon these areas.

Past industrial growth within the western Delta study area has occurred in or near Pittsburg and Antioch. Table 1 indicates the name and year of establishment of all major manufacturing industries in the Pittsburg-Antioch area.

Since 1950, industrial growth in the western Delta study area has been represented by an average capital investment of over $20,000,000 per year,[1/] either through the establishment of new industries or the

[1/] Includes Pacific Gas and Electric Company generation plants in Pittsburg and Antioch.

TABLE 1

MAJOR MANUFACTURING INDUSTRIES IN THE
WESTERN DELTA STUDY AREA

Industry	Year established
Fibreboard Paper Products Corporation, Antioch Division	1889
Quaker Pioneer Rubber Company	1906
Columbia-Geneva Steel Division, U. S. Steel Company	1910
Dow Chemical Company	1916
Western California Canners Company	1920
Glass Containers Corporation	1920
Johns Manville Products Corporation	1924
Shell Chemical Corporation 1/	1931
Kroehler Manufacturing Company 2/	1940
Hickmott Canning Company	1940
Gladding McBean and Company	1940
Continental Can Company	1948
Fibreboard Paper Products Corporation, San Joaquin Division	1949
E. I. du Pont de Nemours and Company Inc.	1956
Crown Zellerbach Corporation	1956
Kaiser Gypsum Company	1956
Ethyl Corporation	1958
Linde Air Products Company	1959

1/ Located outside the western Delta study area boundary (within the Pittsburg township) but considered to be within the Pittsburg metropolitan area.

2/ Moved to Alameda County in 1958.

expansion or modernization of older industries. The present total market value of the present industrial complex within the western Delta study area is estimated to be over $500,000,000.1/ They presently2/ employ an average of 10,900 employees.

As industry has expanded in the western Delta study area, population has increased. Population increased by 60 percent during the 1940-50 decade, and by 40 percent during the 1950-60 decade. The present2/ population of more than 71,000 is estimated to be increasing at the rate of 2,000 people per year. Present2/ total employment in the western Delta study area is estimated to be more than 26,000 persons.

Population figures obtained from the Bureau of the Census are presented for the western Delta study area in Table 2.

1/ Includes Pacific Gas and Electric Company generation plants in Pittsburg and Antioch.

2/ As of 1960

TABLE 2

POPULATION OF THE WESTERN DELTA STUDY AREA

County and township	April 1, 1930	April 1, 1940	April 1, 1950	July 1, 1960
Contra Costa County				
# 6 (Pittsburg)1/	10,692	11,713	20,992	
# 8 (Antioch)	4,856	6,569	12,403	
# 9 (Brentwood)	1,676	3,237	4,034	
#14 (Byron)	1,092	1,486	1,413	
#17 (Oakley)	2,908	2,945	5,135	
Solano County				
Denverton	134	101	104	
Montezuma	386	316	308	
Rio Vista	4,479	3,748	3,128	
Sacramento County				
Georgiana2/	1,500	1,100	1,000	-------
TOTALS	27,723	31,215	48,817	71,200 3/

1/ Includes population from a small area located west of the western Delta study area boundary (but considered to be within the Pittsburg metropolitan area) which could not be segregated in the census data.

2/ Estimated number of people in Georgiana township living within the limits of the western Delta study area.

3/ Estimated.

Factors Which Have Influenced the Location of Industries In the Western Delta Study Area

Industrial location in the western Delta has generally followed the pattern of industrial growth in California. However, the advantages of certain industrial sites have played an important part in attracting industry to the western Delta study area. These advantages have included an abundant water supply, a large assimilative capacity within the river channels for industrial wastes, readily accessible railroad facilities, location on major highway routes, deep-water transportation facilities, nearness to labor supplies, reasonably close market centers, and the availability of land for future industrial expansion.

Water Supply. Unlimited quantities of water from the channels of the Sacramento and San Joaquin Rivers are readily available to industries located within the western Delta study area. This availability has been of particular advantage to those industries which use vast quantities of water for cooling purposes. However, because of seasonal salinity incursion problems, the river channels are not dependable sources of high quality water. This disadvantage has been largely overcome through construction of the Contra Costa Canal, a facility which is usually able to meet the water needs of the existing industries in the Pittsburg-Antioch metropolitan complex. During certain periods the canal is also affected by salinity incursion and expensive water treatment costs are incurred by the industries in overcoming the problems resulting from water quality deterioration. In spite of these disadvantages, the joint availability of river and canal water supplies has favorably influenced the western Delta study area for industrial site location.

Waste and Heat Disposal. Dissipation of heat and waste products are important factors of site location to many industries. The river channels of the Sacramento and San Joaquin Rivers within the western Delta study area offer excellent dissipation of these wastes. These advantages arise from the high outflows, which usually occur during the winter months, and the increases in assimilative capacity which occur through tidal diffusion. These advantages have been of particular interest to the paper and chemical industries.

Transportation. One of the strongest factors in the development of the western Delta has been the availability of deep water access. Through this access, river barges and ocean-going vessels have been able to service the local, national, and world-wide interests of the established industries. In addition, the Pittsburg-Antioch area is serviced by adequate highways for the commuting of workers and the transport of raw materials and finished products. Two major railroads, the Southern Pacific and the Sante Fe, service the area.

Labor Market. Since the end of World War II there has been an increasing move toward suburban living. Suburban growth in the San Francisco Bay area has extended to the Concord, Walnut Creek, and Martinez areas in Contra Costa County. This suburban growth has placed a portion of the vast San Francisco Bay area labor force within reasonable commuting distance to the western Delta study area. Therefore, industries which have located within the western Delta study area have been able to draw from this steadily increasing skilled and unskilled labor market. Studies of industrial worker commuting indicate that 75 percent of the industrially employed have become permanent residents within the study area.

Proximity to Market Centers. The central location of the western Delta study area has an advantage of nearness to the consumer markets of the San Francisco Bay area and the Central Valley. The existing industries have been able to save transit costs by shipping directly to both market areas.

Land Availability. Historically there has been land available at reasonable prices within the western Delta study area to serve the requirements of industrial location and expansion. Land speculation, however, has resulted in inflated prices of many outstanding industrial tracts. This inflation will probably become more intense as sites with comparable advantages are utilized in the San Francisco Bay area. The land around the Montezuma Hills in Solano County, however, could offer comparable site advantages to the Pittsburg-Antioch area if adequate highways and high quality water supply facilities were constructed. This land will probably be less expensive than that within Contra Costa County since it is nearly completely undeveloped and will tend to remain so for some time in the future.

Future Industrial and Municipal Development

Nearly 75 percent of the existing urban high quality water requirements of the western Delta study area are industrial in nature. This fact clearly indicated that future industrial water requirements would have to be projected separately. It was also concluded that projections of population would not provide an adequate basis upon which to estimate these industrial requirements.

To provide an adequate basis upon which future industrial water requirements could be estimated, detailed projections of manufacturing employment were made for the 1960-1980 period. These trends were continued up to 2020. Total civilian employment, population, and land use projections were concurrently made with the manufacturing employment estimates.

Urban Economic Structure

Before discussing the procedures and assumptions utilized in the development of employment, population, and land use projections, it is useful to review the general aspects of the structure of an urban economy. This structure can usually be divided into two parts, base and service activities. These activities are defined as follows:[1/]

> "Base activities are represented by those activities of an economy which export goods, services, or capital to persons or firms whose source of payment is beyond the predetermined boundaries of the economic community. These are the activities which, through a favorable trade balance with other cities, regions, and nations, enable the community to continue its existence and to pay for the necessities of living and production which it must import."

1/ Richard B. Andrews. "Land Economics", University of Wisconsin. July 1954

". . . service activities do not export but are engaged in caring for local demands for goods, personal services, and capital. Local demands stem from the base itself and its employees, from service establishments and their employees, and from the rest of the population not directly identified in an employment sense with either base or service activities."

In the western Delta study area, the base activities consist of three segments; manufacturing, agriculture, and recreation. Manufacturing is the largest segment. Agriculture, an important segment, will continue to diminish as agricultural lands are withdrawn for urban uses. Recreation is the fastest growing base activity in the area, but at present is the least significant portion of the total economic structure.

Since manufacturing is the largest contributor to the economic activity of the western Delta study area, it was concluded that projection of this segment would provide the most representative picture of future economic development. Several alternative measurements of manufacturing activity were considered as bases for the projections. These included employment, income, value added, value of production, units of production, and the so-called input-output relationship. Employment was selected as the most advantageous measurement since it provided a single yardstick to which population, municipal and industrial water requirements, and land use could be related.

The employment data used in this study were based on wage and salary statistics which were converted to annual average employment figures. This procedure enabled the nonproduction or "white collar employee" employees to be included in the employment data. This is an important consideration since the number of physical production workers in some manufacturing industries has decreased; while both the physical product output and the number of nonproduction workers have steadily increased.

Service activities in the western Delta study area were represented by those employed in activities other than manufacturing or agriculture. Service activities were analyzed only to the extent required to separate total civilian employment and manufacturing employment projections.

Economic Projections

The accuracy of economic projections is directly related to the size of the area for which the projection is made. For this reason it was decided that projections of economic growth of larger geographic areas, of which the western Delta study area is a part, would provide more accurate limits within which the economic growth of the western Delta study area could be projected. The opinions of national, state, and local economic experts were reflected in these projections by utilizing other studies which covered the United States, California, the nine-county San Francisco Bay area, Contra Costa County, Solano County, and the western Delta study area.

The projections for all geographic areas were based upon the following assumptions:

1. That population, economic activity, employment, and movements of goods and people within the United States, California, San Francisco Bay area, Contra Costa County, Solano County, and the western Delta study area will continue to increase.
2. That there will be no devastation by war.

3. That there will be no severe or prolonged economic depression.

4. That there will be no major disaster, epidemic, or catastrophe during the time period of this study.

5. That sources and supplies of energy and fresh water required for future growth in the San Francisco Bay area will be adequate to supply the demand and will be available at costs competitive with other metropolitan areas of the nation.

6. That technological advances will continue and automation and productivity will be expanded and intensified.

7. That long-distance transportation and communication will develop and accelerate future movements of peoples and goods throughout the nation and the world.

8. That world hostilities will not increase, but will either remain at, or retreat from, their present level.

9. That the nation's economy will be operating close to capacity.

10. That the present favorable attitudes of local governments toward the location of major industries will continue.

11. That the same factors which influence national and state economic growth similarly influence local areas.

<u>1960 to 1980 Levels of Economic Development</u>. The projection of future trends in employment in the United States during the 1960 to 1980 period were based upon long-term projections of total civilian

employment, manufacturing employment, and five manufacturing category employments,[1/] as prepared by the Office of Business Economics, United States Department of Commerce, for use in studies of the Delaware River Basin.[2/] Adjustments were made to the Department of Commerce studies to reflect later data, and additional projections were made for the 15 unpublished manufacturing categories.

The total civilian employment, total manufacturing employment, and 20 manufacturing category employments of California for the 1960-1980 period were estimated by analysis and projection of the following measures of employment growth:

1. Historical employment trends in California.
2. California employment, as a percentage of United States employment, for comparable categories.
3. California category employments as percentages of total California employments.

1/ The term "manufacturing categories", as used in this report, represents the two-digit manufacturing categories. These categories retain the same classifications as prescribed in the Standard Industrial Classification Manual. There are 20 categories under the two-digit manufacturing heading; they are: ordinance, food, tobacco, textiles, apparel, lumber and timber, furniture and fixtures, paper, printing, chemicals, petroleum, rubber, leather, stone, clay and glass, primary metals, fabricated metals, machinery (except electrical), electrical machinery, transportation equipment, instruments, and miscellaneous industries.

2/ U. S. Department of Commerce, Office of Business Economics. "Report on the Comprehensive Survey of the Water Resources of the Delaware River Basin, Appendix B, Economic Base Survey", p. 31, 1958. The five manufacturing categories which were projected are the primary metals, paper, chemical, food, and petroleum manufacturing industries, and are referred to as the high water-using industries.

The projections of each of the above measures of employment growth were progressively adjusted and combined to obtain the projections for California listed in this report. The analysis and judgment applied to these projections were to a great degree influenced by the conclusions reached by the Department of Water Resources in planning studies for the Southern California Aqueduct Investigation.1/

Projections of total civilian employment, total manufacturing employment, and manufacturing employment by categories for the nine-county San Francisco Bay area during the 1960-1980 period of development were developed using techniques similar to those used in the projections of employments in California. Geographical relationships for these projections were based upon the percentage of employees in California who were located within the San Francisco Bay area. The analysis and trends of the projections utilized some of the data contained in a report prepared in 1956 by Parsons, Brinckerhoff, Hall, and Macdonald, entitled "Regional Rapid Transit, A Report to the San Francisco Bay Area Rapid Transit Commission".

Procedures similar to those used in the employment projections of California and the San Francisco Bay area were utilized for the employment projections of Contra Costa and Solano Counties, and the western Delta study area during the 1960-1980 period. These employment projections, however, were limited to total manufacturing and major established manufacturing categories in Contra Costa County and the western Delta study area, and to manufacturing employment only in

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1/ State of California, Department of Water Resources. "Investigation of Alternative Aqueduct Systems to Serve Southern California". Bulletin No. 78. "Economic Demand for Imported Water", Appendix D. 1960.

Solano County. Total civilian employment was eliminated from these projections because of the difficulty of establishing historical growth trends and the complications which are presented by commuting labor forces.1/ Manufacturing employments by category were omitted from the Solano County projections because there were no major established categories upon which to base the projections. No major development was assumed to occur in the Solano County portion of the western Delta study area until after 1980.

Summaries of the employment projections of the various geographic areas for 1970 and 1980 are shown in Table 3. The geographical and categorical relationships developed for comparing and analyzing employment growth trends are shown in Plate 2, "Schematic Diagram of Area Employment Relationships".

In order to judge the validity of the population and employment trend developed by the Department of Water Resources, a comparison was made with the work of other economists. The Department of Water Resources work was predicated upon projections of employment, from which total projected population was extrapolated. Most of the comparison sources, however, had made their projections in terms of population estimates. These projections are shown in Table 4. In order to correlate the two sets of results a total civilian labor force was estimated for each geographic area. The number of unemployed, assumed to be 4-3/4 percent of the total civilian labor force, plus military personnel in the area, were added to the total civilian labor force estimates. A

1/ A commuting labor force is defined as people who live outside the boundaries of a geographic area but work within the boundaries.

TABLE 3

SUMMARY OF MANUFACTURING EMPLOYMENT PROJECTIONS
FOR 1970 AND 1980 LEVELS OF
ECONOMIC DEVELOPMENT BY GEOGRAPHIC AREAS

(Employees)

Area and decade	Total wage and salary manufacturing	Manufacturing categories 1/ Primary metals	Paper	Chemicals	Stone, clay and glass	Food
1970						
United States	21,200,000	1,633,000	763,000	1,166,000	700,000	1,781,000
California	2,000,000	94,000	48,000	66,000	64,000	226,000
San Francisco Bay Area	380,000	27,300	17,500	19,000	14,100	68,400
Contra Costa Co.	44,100	8,200	4,300	7,000	1,900	3,500
Solano County	3,800	2/	2/	2/	2/	2/
Western Delta Study Area						
Contra Costa Co. 3/	17,900	7,000	4,100	4,200	1,100	1,100
Solano County	300	2/	2/	2/	2/	2/
1980						
United States	25,100,000	1,908,000	954,000	1,481,000	803,000	2,058,000
California	2,700,000	138,000	73,000	100,000	86,000	289,000
San Francisco Bay Area	508,000	40,800	24,900	25,400	18,600	81,300
Contra Costa Co.	62,500	13,100	6,500	10,200	2,400	3,900
Solano County	6,600	2/	2/	2/	2/	2/
Western Delta Study Area						
Contra Costa Co. 3/	27,200	11,700	5,900	6,100	1,400	1,400
Solano County	700	2/	2/	2/	2/	2/

1/ Includes only those categories which are presently established in the western Delta study area.
2/ No projections were made for specific categories in Solano County.
3/ For continuity of economic statistics this area includes all of Pittsburg township.

TABLE 4

PROJECTIONS OF TOTAL POPULATION BY GEOGRAPHIC AREAS
(Population in thousands)

Geographic area	July 1, 1960	July 1, 1970	July 1, 1980	July 1, 1990	July 1, 2000	July 1, 2010	July 1 2020
United States 1/	180,000	212,000	250,000	292,000	335,000	380,000	425,000
California 2/	15,830	21,700	28,200	35,000	42,000	49,000	56,000
San Francisco Bay Area (Nine-county) 3/	3,730	4,900	6,200	7,600	9,050	10,490	11,900
Contra Costa County 3/	400	570	775	1,020	1,275	1,525	1,765
Solano County 3/	138	200	310	465	650	850	1,060

1/ Projections by V. B. Stanbery based on those in the Bureau of the Census reports series, No. 187, page 25, November 10, 1958.

2/ Projections are the same as those developed by the Los Angeles Office of the State Department of Water Resources in 1958 for the Southern California Aqueduct Investigation.

3/ Latest projections by V. B. Stanbery, February 6, 1960, based on data available, February 6, 1960.

ratio of the total labor force to the total population, or labor force participation rate, was then applied to obtain an estimated total population.

Similar comparisons of trends of economic development from the manufacturing employment projections with those of the population projections, listed in Table 4, were made for Contra Costa and Solano Counties. However, the added step of developing total civilian employment estimates from the manufacturing employment estimates was required for these areas. This step was completed by using relationships developed from multiple correlations of manufacturing employment, commuting labor forces, and total civilian employment shown in the Bay Area Rapid Transit Survey.

The population estimates developed for each geographic area in all cases checked quite closely with those listed in Table 4. The relationships of population, total labor force, unemployment, total civilian employment, and manufacturing employment are indicated on Plate 3, "Schematic Diagram of the Distribution of Area Economy".

1980 to 2020 Levels of Economic Development. Trends of total employment and population for the 1980-2020 period were derived by methods essentially similar to those used to derive the 1960-1980 trends. To obtain total employment estimates, assumed labor force participation rates and a 4-3/4 percent unemployment rate were applied to the population projections.

Manufacturing employment estimates were developed for the United States, California, San Francisco Bay area, Solano and Contra Costa Counties for the 1980 to 2020 period, using the same methods as used for the 1960 to 1980 period. Continuation of similar trends developed for the earlier period was assumed. Checks of the manufacturing employment projections for Solano and Contra Costa Counties with the population projections listed in Table 4 were made with the same procedures as utilized for the 1960 to 1980 period.

Manufacturing employment in the western Delta area was estimated by two related analyses. The first consisted of the relationship of manufacturing employment in the western Delta study area to the combined projected manufacturing employment in Solano and Contra Costa Counties. A second analysis, consisting of the relationship of each county subarea within the western Delta study area to its respective county, was made to reflect an assumption of more rapid development in the Solano County subarea. By means of the two analyses, manufacturing employment projections for the western Delta study area and subareas of Solano and Contra Costa Counties were developed. Results of the manufacturing employment projections for the 1980 to 2020 period for all geographic areas are contained in Table 5.

TABLE 5

SUMMARY OF MANUFACTURING EMPLOYMENT PROJECTIONS, 1980 TO 2020, BY GEOGRAPHIC AREAS
(Thousands of employees)

Year	United States	California	San Francisco Bay area	Contra Costa County	Solano County	Western Delta Study Area	
						Contra Costa County	Solano County
1980	25,100	2,700	508	62.5	6.6	27.2	0.7
1990	30,000	3,470	650	83.2	13.0	38.4	1.5
2000	35,300	4,260	800	105.6	26.4	49.5	6.0
2010	40,900	5,070	950	128.3	49.4	60.8	14.7
2020	45,800	5,830	1,090	149.3	85.0	71.0	29.0

Population Projections For the Western Delta Study Area

The projections of population in the western Delta study area were determined by developing the manufacturing employment projections into total employment estimates, and applying commuting labor force, unemployment, and labor force participation rate factors. Total employment in the western Delta study area was estimated by intensive analyses of the base and service activity factors. Base activity employment was assumed to include all manufacturing employment and a constant, which included agricultural and recreational employments.

An existing ratio of 1:1 of service activity to base activity employment in the western Delta study area was determined for the area from Bureau of the Census data. This ratio was projected to increase to 2.4:1 in the year 2020, on the basis that as the urbanization of an area increases, the area tends to become self-sufficient in terms of service activities. Service activity employment was estimated by applying the projected service to base activity ratios to the base activity employment projections. Total employment was estimated by adding the service activity employment to the base activity employment.

The resident labor force of the Contra Costa and Solano Counties subareas of the western Delta study area was estimated by subtracting the commuting labor force from the total employment estimates and adding unemployment, which was assumed to be 4-3/4 percent of the resident labor force. Commuting labor force rates were estimated to decrease from the present 25 percent in the Contra Costa County subarea to 19 percent in 2020, and to increase from the estimated present and 1980 near-zero percent in Solano County to 40 percent in 2020. The population of the county subareas was determined by applying labor force participation rates to the estimated resident labor forces. It was assumed that the population in the Sacramento County subareas would remain at its present level.

A summary of the population projection for the western Delta study area is contained in Table 6.

TABLE 6

PROJECTIONS OF POPULATION
IN THE WESTERN DELTA STUDY AREA
(Thousands of persons)

County	1970	1980	1990	2000	2010	2020
Contra Costa	102	161	236	325	431	535
Solano	5	8	14	49	102	158
Sacramento	1	1	1	1	1	1
TOTAL	108	170	251	375	534	694

Land Use Projections

Studies of municipal and industrial land uses, and the projection of these uses, were an essential feature of Delta water facility planning. By means of these studies and projections, estimates of future agricultural land withdrawals for urban uses were determined, with the resulting decreases in requirements for agricultural water supply. Applied water requirements for municipal and industrial users were distributed in the western Delta study area on the basis of the land use studies. This distribution of water requirements provided an adequate basis upon which capacities of water supply facilities could be estimated.

Industrial Land Use. Industrial land use in areas of the Delta other than the western Delta, the areas within and around Tracy, and the Yolo Port District, was assumed would increase 20 percent by 1980, and 100 percent by 2020. These projected increases were based on the assumption that the existing food-processing industries in these areas would expand with increased productivity of nearby farms. While this productivity would not be sufficient to justify a 100 percent increase in industrial land use by 2020, certain portions of these lands will also be suitable for the location of other types of industries.

The area within and around Tracy was considered to have greater potential then the above lands for industrial location. Therefore, it was assumed that in the Tracy area 550 acres of new industrial lands would be developed by 1980, and 1,500 total new acres by 2020. The Yolo Port District undoubtedly will develop rapidly as an industrial center with the opening of the Sacramento Deep Water Channel. Therefore, it was assumed that a total of 1,000 acres in this area would be developed by 1980, and 6,000 acres by 2020.

In the western Delta area, developed industrial acreage was determined as a function of the projected manufacturing employment. The analysis of existing land use and employment in this area showed an existing density of 11 employees per acre, although for specific companies this density varied from less than 3 to over 75 employees per developed acre. The existing average density of 11 employees per acre was found to be typical of other areas in the United States and was, therefore, used as a basis for projection of future industrial land requirements.[1/]

An index, using 1960 as a base, was developed to reflect the increasing displacement of production workers by machines and automation, with an anticipated intensification of land use, higher industrial land costs, and increased production per acre. More than a fourfold increase in employee productivity and a threefold increase in production per acre over present levels was projected for the year 2020. Industrial land requirements were determined by multiplying the projected manufacturing employment by the index and base employee per acre ratio. Existing and projected western Delta study area industrial land use is summarized in Table 7. Projected areas devoted to municipal land use in the western Delta study area are summarized in Table 8. Existing and projected total Delta industrial and municipal land use is summarized in Table 9. Present western Delta industrial and municipal land use is illustrated on Plate 4, "Present Land Use, Western Delta Study Area"; 1980 land use on Plate 5, "1980 Land Use, Western Delta Study Area"; and 2020 land use on Plate 6, "2020 Land Use, Western Delta Study Area".

Municipal Land Use. For areas in the Delta outside the western Delta study area it was assumed that municipal land use would increase by 20 percent by 1980, and 100 percent by 2020. In the western Delta study area, it was assumed that low-density municipal areas would have a population of 8 people per acre, and high-density areas 12 people

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1/ Data indicate that the industrial land requirements in various areas of the United States vary from 3.17 to 9.69 acres per hundred persons of total population. In terms of manufacturing employment, these figures indicate typical densities of 7 to 15 employees per acre.

TABLE 7

EXISTING AND PROJECTED INDUSTRIAL LAND USE IN THE WESTERN DELTA STUDY AREA

Year	Index of employees per acre	Manufacturing employees per acre	Contra Costa County: Projected manufacturing employment 1/	Contra Costa County: Developed industrial lands: Manufacturing in acres	Contra Costa County: Developed industrial lands: Other in acres 2/	Contra Costa County: Developed industrial lands: Total in acres 1/	Solano County: Projected manufacturing employment	Solano County: Developed industrial lands in acres	Western Delta study area, developed industrial lands in acres 1/
1960	100	11.15	10,700	960	730	1,690	200	20	1,710
1970	85	9.41	17,900	1,910	780	2,690	300	30	2,720
1980	77	8.56	27,200	3,200	830	4,030	700	80	4,110
1990	72	8.03	38,400	4,790	880	5,670	1,500	190	5,860
2000	68	7.60	49,500	6,510	930	7,440	6,000	790	8,230
2010	65	7.25	60,800	8,390	960	9,350	14,700	2,000	11,350
2020	62	6.94	71,000	10,220	960	11,180	29,000	4,180	15,360

1/ Includes all of Pittsburg township.

2/ Includes steam-electric power plants, electric distribution lines and facilities, and tank farms.

TABLE 8

EXISTING AND PROJECTED MUNICIPAL LAND USE
IN THE WESTERN DELTA STUDY AREA

Year	Area in acres
1960	13,600
1980	27,400
2020	63,200

TABLE 9

EXISTING AND PROJECTED INDUSTRIAL AND MUNICIPAL LAND USE
IN THE SACRAMENTO-SAN JOAQUIN DELTA
(In acres)

Type of land use	Present	1980	2020
Industrial	1,500	5,400	20,300
Municipal 1/	18,600	28,500	47,400
Total municipal and industrial	20,100	33,900	67,700

1/ Includes semiurban areas scattered throughout the Delta.

per acre during the 1980 decade. By 2020 these figures were increased to 12 people per acre for low-density municipal areas, and 16 people per acre for high-density areas. Increased densities are based upon the assumption that as an area urbanizes, land values will increase and larger numbers of multiple family dwellings will be required.

Past and Present Agricultural Development

The stress laid in this report upon the industrial segment of the Delta economy should not minimize the importance of the agricultural segment of the economy. Industry is the major economic factor only in certain areas of the Delta.

Past agricultural development in the Delta has depended upon cultivation of the reclaimed swamplands. Because of the problems of drainage and flood protection, cultivation was slow to develop, even though reclamation took place over a period of several decades. Prior to 1910 the reclaimed areas contained large areas of waste land, water surface, and lands used for the grazing of livestock only.

Land Reclamation in the Delta

The most important federal legislation affecting reclamation of land in the Delta was the "Arkansas Act" of 1850. This act granted title of swamp and overflow land to certain states, on the condition that the proceeds from the sale of such lands to private ownership would be used to assist reclamation. In spite of the federal policy, reclamation in the Delta was complicated by disagreements between state and federal governments. In 1861 the California Legislature created the State Board of Reclamation Commissioners and adopted a formal reclamation policy under which the State assumed responsibility for reclamation.

The growth of reclamation in the Delta was reported in Bulletin No. 27, "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay", California Department of Public Works, Division of Water Resources, 1931. This report showed certain areas were subsequently inundated after reclamation. Data in the report were listed according to dates at which reclamation, or the severance from basin flooding effects, were considered to be permanent. Summaries of these data are contained in Table 10.

TABLE 10

GROWTH OF RECLAMATION
IN THE SACRAMENTO-SAN JOAQUIN DELTA 1/
(1860 to 1930)

Decade	Acres reclaimed	Accumulative acres reclaimed
1860-1870	15,000	15,000
1870-1880	92,000	107,000
1880-1890	70,000	177,000
1890-1900	58,000	235,000
1900-1910	88,600	323,600
1910-1920	94,000	417,600
1920-1930	24,000	441,600

1/ California State Department of Public Works, Division of Water Resources. "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay". 1931.

Boundaries of the Sacramento-San Joaquin Delta

Growth of agriculture in the Delta is best measured through periodic land use surveys. Unfortunately, these surveys have not always covered equivalent areas, since the Delta was not legally defined until 1959.

The survey of 1929-1931 reported upon an area totaling 488,000 acres, while land use surveys in 1938 and 1950 included only

448,000 acres. The survey of 1955[1/] was considerably expanded to 674,100 acres, which comprised 467,200 acres in the "lowlands" of the Delta and 206,900 acres in the "uplands".[2/] The Delta, as now legally defined,[3/] includes a gross area of 738,200 acres, of which 49,500 acres are tidal water surfaces.

Boundaries of the 1931 and 1955 land use surveys, the Delta lowlands, and the present legal Delta boundary are shown on Plate 7, "Historical Boundaries of the Sacramento-San Joaquin Delta".[4/] Table 11 indicates the subareas of counties which are now located within the legal boundaries of the Delta.

1/ California State Department of Water Resources. "Report of Sacramento-San Joaquin Water Supervision for 1955". Bulletin No. 23-55. June 1952.

2/ The Sacramento-San Joaquin Delta service area, as defined in the 1955 land use survey, is considered in two parts: (1) the "Delta Lowlands" commonly called the "Delta", consists generally of lands less than 5 feet elevation above mean sea level. These lands, for the most part, consume water derived from Delta channels by subirrigation or surface application not susceptible to direct measurement. The water surface of the lowlands has been assumed to include all water in channels affected by tidal action in both the lowlands and uplands, and up to the lowest gaging stations on streams tributary to the Delta; (2) the "Delta Uplands" lie outside of and adjacent to the "Delta Lowlands" and are served by irrigation water pumped from Delta channels. Lands served by diversions below the lowest gaging stations on streams flowing to the Delta, which lie outside of the Delta lowlands boundary, are also considered as Delta uplands.

3/ Section 12200 of the California Water Code.

4/ The location of the boundary line for the Delta service area, as shown on Plate 1, was determined to include those lands that were (1) historically referred to as the Delta area (as shown in Bulletin No. 27), and in the Sacramento-San Joaquin Water Supervision reports of the Division of Water Resources, (with the exception of Reclamation District 535, just south of Sacramento); (2) within "places of use" or rights to use water from Delta tidal channels designated in appropriative water rights permits and licenses, as delineated in 1952; (3) within organized districts or individual ownerships containing land with elevation less than 4 feet above mean sea level; and (4) served historically with water originating from Delta tidal channels.

TABLE 11

SUBAREAS OF COUNTIES LOCATED IN THE
SACRAMENTO-SAN JOAQUIN DELTA

County	Area in acres
Alameda	4,700
Contra Costa	113,400
Sacramento	118,800
San Joaquin	316,900
Solano	92,400
Yolo	92,000
TOTAL	738,200

Past and Present Agricultural Land Use

Agricultural land use surveys of the Delta have been periodically made since 1924. These surveys indicate that by 1931 the Delta had attained a high level of development. Since that date the acres of land under cultivation within the Delta has increased. This increase is primarily due to the expansion of the boundaries covered by the surveys rather than the cultivation of new lands within the original boundaries. Summaries of agricultural land use during the 1931-1955 period are contained in Tables 12 and 13. A detailed summary of the results compiled during the 1955 land use survey is contained in California State Department of Water Resources Bulletin No. 23-55. Table 219.

TABLE 12

CROPPED AND IRRIGATED AREAS IN THE 1/
SACRAMENTO-SAN JOAQUIN DELTA
(In acres)

Year of survey	Total irrigated area	Total cropped area	Gross area	Percent of area cropped
1931	339,300	355,000	488,000	72.8
1938	335,600	349,900	448,800	78.0
1950	365,800	378,900	448,300	84.5
1955	499,600	518,100	674,100	77.0

1/ California State Department of Water Resources, *op. cit.*

TABLE 13

DISTRIBUTION OF HISTORICAL
AGRICULTURAL LAND USE IN THE
SACRAMENTO-SAN JOAQUIN DELTA

Type of land use	1931 land use survey		1955 land use survey	
	Acres	Percent of total	Acres	Percent of total
Field crops	203,466	46	222,016	35
Forage crops	54,161	12	125,414	20
Truck crops	105,192	24	140,509	22
Fruit and nut crops	10,775	3	22,896	4
Other crops	---	---	6,531	1
Miscellaneous uses	37,008	8	56,125	9
Total agricultural use	410,602 1/	93	573,491	91
Other land uses	28,367	7	57,408	9
Total area	434,909	100	630,899	100

1/ Includes 4,060 acres of double cropping.

1960 agricultural land use was determined by applying certain adjustments to the results of the 1955 survey. These adjustments were made to agricultural land not included in the 1955 survey, and supported by partial land use surveys conducted during 1959 and 1960.

Future Agricultural Development

The intensity of irrigation development and the resultant demand for water in any area will, over a period of time, increase to the limits of the capacity of the area for production of vendible products. The rate of development is closely related to the development of markets and the cost-price relationships involved in the production process. The development of markets for products grown within the Delta is generally related to markets for the entire Central Valley. For this reason, criteria developed for the Central Valley have been adopted for projections of developments within the Delta.

The Delta is in an excellent competitive position. It is endowed with adequate low cost water, has generally excellent soils, and should be in a favorable position to intensify irrigation development at rates initially parallel to nearby service areas. However, irrigation is now available to almost all Delta farm lands. Further agricultural production will result from more intense use of the land, rather than an increase in the area under cultivation.

Future Development Within the Central Valley of California

Two reports defining the future market potential of vendible agricultural products grown in portions of the Central Valley of California have recently been completed.[1/] The first report was prepared to assist in the evaluation of new Central Valley water district water requirements, and to evaluate the extent of future upstream depletion of existing water supplies within the Delta. The second report was proposed to establish water-marketing schedules for State Water Facilities. In both reports detailed studies of future agricultural development, including projections of the acreage devoted to the nine major crops, were completed. Such factors as increased yield, technological changes, irrigation efficiencies, market demands, and shifts in production acreage, were included in the projections. Both reports include future trends of irrigated agriculture, projected from past data. These trends were summarized as:

> California agriculture has been expanding continually, but not at the same rate in all hydrographic areas. California irrigated acreage has increased 66 percent since 1940 with an increase of almost 30 percent in the 5 years between 1945 and 1950. The San Joaquin Valley increased its irrigated acreage by 85 percent between 1940 and 1954 and now has 64 percent of the State's total as compared to 47 percent in 1940. The resource shifts in California agriculture from 1940 to 1954 indicate a gradual shift of importance to the Central Valley with respect to both crop land and irrigated crop land.

Indices of projected irrigation development were derived from each of the two reports. These indices were based on 1955 levels of development and are illustrated on Plate 8, "Projected Indices of Irrigation Development, Sacramento and San Joaquin Valleys".

1/ California State Department of Water Resources. "Increase in Water Demands, Sacramento-San Joaquin River, Delta Drainage Area, 1960-2020". Unpublished. November 1958.

----. "Office Report Supplement to Information and Data on Proposed Program for Financing and Constructing State Water Facilities". May 1960.

Assumptions. In the projection of rates of agricultural development, certain assumptions were required. These were:

1. That population will continue to grow and increase to an estimated 420 million in the United States, 56 million in California, and more than 9 million within the 26 counties of the Sacramento-San Joaquin Delta drainage area by the year 2020.
2. That cost of production and farm products price relationships will resemble those of 1950-1956.
3. That relatively high levels of employment and consumption will prevail during the period 1960-2020.
4. That demand for agricultural crops in California will resemble those developed in the study entitled "Market Outlook Studies for Selected California Crops, 1960-2020, Office Report of August 1958, Department of Water Resources. (Unpublished)
5. That sufficient quantities of water of adequate quality will be available at a cost that will not be restrictive to irrigation development.
6. That world peace will continue.

Future Irrigation Development In the Delta

To project the maximum possible and maximum probable intensities of irrigation development in the Delta, the computation procedure illustrated in Table 14 was utilized. This procedure was based upon data derived from the 1955 land use survey. The maximum possible intensity

TABLE 14

DERIVATION OF POTENTIAL ACRES OF DOUBLE CROPPING
IN THE SACRAMENTO-SAN JOAQUIN DELTA

Summer or major irrigation season crops: Crops classified by land use intensity	Acreage [1/]	Percent of total	Maximum cropable acreage: Perennials and summer crops	Maximum cropable acreage: Other seasons or double crops	Reduction factor for maximum double cropable acreage [2/]	Estimated acreage double cropped
1.0 crops [3/]						
Pasture	63,140					
Alfalfa	62,280					
Rice	5,770					
Asparagus	82,830					
Fruit and nut	22,900					
Grapes	770					
	237,690	45.9	237,690	0	0	0
1.5 crops [4/]						
Sugar beets	34,520					
Potatoes	8,540					
Tomatoes	40,810					
Onions	1,220					
Corn	52,010					
Safflower	5,620					
	142,720	27.6	142,720	71,360	0.30	50,000
2.0 crops [5/]						
Beans	3,910					
Milo	30,150					
Grain and hay	95,710					
Miscellaneous	7,210					
	136,980	26.5	136,980	136,980	0.30	97,000
TOTAL AND AVERAGE	517,390	100.0	517,390	208,340	0.30	147,000

1/ Under 1955 irrigation development conditions.
2/ Estimated allowance for many constraints associated with double cropping practices, such as adverse weather conditions, poor market situations, personal factors, cultural difficulties, etc.
3/ Includes perennial and long-growing season crops which permit growing only one crop per year.
4/ Includes six to nine months growing season crops which permit growing three crops per two years.
5/ Includes less than six months growing crops which permit growing two crops in a given year.

of irrigation development in the Delta was determined through application of the following formula to the values listed in Table 14:

$$I = \frac{A + B + C}{D}$$

Where I = index of development

A = number of acres cropped once each year

B = number of acres cropped three times during each two-year period times 1.5

C = number of acres double cropped times 2.0

D = total number of acres cropped

The same formula was used, with proper adjustments, to develop the maximum probable intensity of irrigation for the double cropable acreage listed in Table 15. The resultant indices were determined to be 1.4 of 1955 development for maximum possible development, and 0.1 less, or 1.3 of 1955 for maximum probable development.

The rate of development in the Delta was determined by assuming initial expansion at a rate parallel to that of the Sacramento Valley, and maximum probable development by 1990. Development in the Delta has been motivated by the same economic factors as in the Sacramento Valley, but is limited in extent by the lack of newly developable lands. The rate of irrigation development is illustrated in terms of an index based upon 1955 levels on Plate 9, "Projected Indices of Irrigation Development for the Sacramento Valley and Sacramento-San Joaquin Delta".

Agricultural Land Use Projections In the Delta

Development of new agricultural lands in the Delta is limited to approximately 12,500 acres. This limitation is a result of the high agricultural development which presently exists, and the high costs which

TABLE 15

PRESENT AND PROJECTED AGRICULTURAL LAND USE IN THE
SACRAMENTO-SAN JOAQUIN DELTA
(In acres)

Year	Total area	Miscellaneous lands 1/ and water surfaces	Municipal and industrial lands	Municipal and industrial lands withdrawn from agriculture 2/	Projections of new agricultural lands 2/	Total agricultural lands
1960	738,200	112,600	20,100	0	0	605,500
1970	738,200	107,400	28,200	4,400	1,500	602,600
1980	738,200	105,100	33,900	9,500	3,200	599,200
1990	738,200	99,600	42,600	14,400	4,900	596,000
2000	738,200	95,200	51,000	20,300	6,800	592,000
2010	738,200	92,000	59,400	28,100	9,400	586,800
2020	738,200	89,800	67,700	37,300	12,500	580,700

1/ Includes tidal water surfaces and undeveloped municipal and industrial lands.

2/ Referenced to 1960.

would be associated with the reclamation of presently undeveloped areas. Those lands which can be expected to be developed are located at elevations considerably above sea level. Since relatively high pumping costs would be associated with irrigation of these lands, development will occur very gradually.

Continued industrial and municipal expansion will continue to affect agricultural land use. Substantial acreages of presently cultivated land can be expected to be withdrawn from agricultural uses by 2020. Summaries of these withdrawals and new land development are also contained in Table 15.

Future crop patterns in the Delta will probably remain similar to the existing patterns shown in Table 14. Hence, for the purposes of determining water requirements, the present crop pattern was assumed to represent future conditions. However, for purposes of determining the feasibility of providing replacement water facilities to the lowland portions of the western Delta study area, crop patterns were projected for conditions that would result from deteriorated channel water quality. Another crop pattern was prepared to reflect the availability of high quality replacement water. These patterns are summarized in Chapter IV of this report.

CHAPTER III. DELTA WATER REQUIREMENTS

The planning of Delta water facilities required analysis of existing and probable future water requirements within the Delta for the following reasons:

Critical water supply problems exist in areas of the Delta. These problems result from a deterioration of water quality caused both by salinity incursion and by drainage from lands within the Delta and upstream from it. Economical solutions to such problems depend upon studies of water requirements in terms of quantity and quality.

The applied and consumptive use of water within the Delta must be considered before establishing operation procedures for proposed Delta water facilities. The determination of such procedures required evaluation of existing and future applied and consumptive use requirements.

An analysis of Delta water requirements helps determine the economic and physical feasibility of alternative Delta water facilities. For example, improvements or detriments to the quality of agricultural water supplies to certain areas of the Delta would influence the feasibility of certain projects. Evaluation of relative magnitude of this feasibility required an analysis of the water requirements.

Legislative directives state that water supply to the Delta by either salinity control or substitute water supply facilities shall be a function of the State Water Resources Development System. The satisfaction of these directives required an extensive study of water requirements of the area. In addition, determination of the economic and physical feasibility of alternative plans for Delta water facilities required consideration of that legislation protecting Delta water users from export water users.

The requirements for water within the Delta have been divided into three categories: industrial, municipal, and agricultural.

Industrial Water Requirements

The present industrial complex of the Delta is centered in two main areas--Stockton and northeast Contra Costa County. Lesser developments occur in Rio Vista, Tracy, and other locations suitable for processing the agricultural products of nearby lands. Future developments probably will occur within eastern Solano County and the Yolo Port District of Yolo County. Stockton and northeast Contra Costa probably will continue to develop, and industry within and around Tracy, to intensify.

Development of these industrial areas depends upon the availability of adequate water supplies. However, only those industrial water requirements within the western Delta study area have significant bearing upon Delta water facility planning. The water supply of remaining industrial areas either is unaffected by the proposed Delta water facilities, or will be met by sources of supply other than from Delta channels (i.e., Folsom South Canal).

Present Industrial Water Requirements

In the spring of 1960, a comprehensive inventory of water use in industrial plants within the western Delta study area was made to establish the present water requirements of area industry in terms of quantity and quality and to provide an adequate picture of the problems faced by industry as salinity incursion increased.

The survey indicated that water quality requirements could be separated into two main classes: (1) high quality water or water with definite quality restrictions; and (2) low quality water or water with quality requirements which could be met from supplies containing wide ranges of dissolved solids. The high quality water classification includes boiler feed water, process water (water that comes in contact with the manufactured product), sanitary and air conditioning water, and water for cooling systems with high quality water requirements. This classification covers a wide range of water quality requirements. However, in this study, the analysis of water quality requirements has been limited to consideration of the dissolved solids. Other factors of quality, such as suspended solids, color, taste, odor, and bacteria count, would not be changed significantly by any of the proposed water facilities in the Delta.

Water Quality Requirements. The present water quality requirements of all major uses within the high and low quality water classes were determined either by the 1960 industrial water use inventory or by a literature survey. The results of these surveys are summarized in the following sections. The sections cover each major industrial use of water in the western Delta study area.

1. Process Water. Process water quality requirements relate to the chemical, food processing, primary metals, paper, stone, clay, and glass industries. Within each industry, wide ranges of quality requirements existed, their limits governed by the specific product produced.

Water, because it is an almost universal solvent, is extremely important to the chemical industry. Water increases the rates of many chemical reactions. Water is used for cleaning, dilution, solution, and transport of raw materials through the intermediate stages of chemical process. Water itself often is a raw material. Impurities in water may produce detrimental chemical reactions. Should such impurities become mixed with the final product, they would reduce the quality of that product. On the other hand, some chemical processes do not require rigid water quality restrictions and are well able to operate with highly saline waters.

Equipment components may also limit use of low quality water by the chemical industry. The metals or alloys which can withstand the highly corrosive action of certain chemical processes may be unable to withstand the corrosive action of low quality water. Certain stainless steels, for example, are not corroded by reducing acids. These same steels are often highly corroded by water with a chloride ion content of greater than 50 parts per million. The present chemical industries in the western Delta study area have quality requirements ranging from 50 to 250 parts per million chlorides, and from 200 to 700 parts per million total dissolved solids.

In the food industry, process water carries the product through the various stages of processing and washing. It may be used to wash the processing equipment. It may be used as a raw material. Because dissolved solids may affect the edibility of the final product, water quality is an important consideration. Table 16 presents limiting values of dissolved constituents for food processing.

TABLE 16

WATER QUALITY TOLERANCES
FOR FOOD PROCESSING

Constituents in the process water	Food to be processed	Range of recommended threshold values/ppm
Hardness ($CaCo_3$), ppm	general	50-85
	peas	200-400
	fruit and vegetables	100-200
	legumes	25-75
Iron, ppm	general	0.2
Manganese, ppm	general	0.2
Iron,and manganese, ppm	general	0.2
pH	general	Not lower than 7.5
Hydrogen sulfide, ppm	general	1.0
Fluoride, ppm	general	1.0

The primary metals industry within the western Delta study area is represented essentially by the steel industry. The primary use of process water in this industry is for contact cooling and cleaning of the final product. Certain dissolved solids in the process water may tarnish or corrode the final product. This factor is particularly critical in the manufacture of tin plate for the canning industry. Water tolerances are difficult to establish, but tentative limits of 175 parts per million chlorides and 40 parts per million hardness have been assumed.

Process water in the paper industry is used to transport the raw materials through the paper-making process, to cook wood chips into paper pulp, and to wash pulpwood, woodpulp, and those machines that handle the pulp. The complete paper making process depends upon the availability of large quantities of water.

The quality requirements of this water vary with the specific products produced and throughout the stages of the paper making process. Waters with a chloride ion content of as high as 1,000 parts per million are tolerable for certain products. Chloride ion concentration, however, is not necessarily the dominating factor even though it can be used as a measure of the desired quality. Specific water quality requirements involve hardness, iron content, and alkalinity as well as chloride ion content.

Excessive hardness is detrimental to paper processing because the mineral salts in hard water react with size, the material added to increase the resistance of paper to liquid penetration. The reaction of mineral salts with size reduces the effectiveness of the size, requires the addition of more size and thus causes higher production costs. Hardness may also cause precipitation of dissolved salts. Such salts form scales on the screens of the Fourdrinier machines, and reduce the efficiency of the machines.

Traces of iron and manganese in process water cause discolorations in the paper processed. Chlorides may cause corrosion of equipment or foaming in the sulfate pulping process. This latter condition causes salt carry-over into the chemical recovery precipitors. Alkalinity, caused by the presence of carbonates or bicarbonates, adds to the cost of paper making by reducing the effectiveness of the alum used to precipitate the size. Salts, in general, cause staining of materials, such as those cans stored in cardboard boxes whose manufacture involved the use of highly saline water.

Table 17 summarizes recommended water quality requirements for the paper industry.

TABLE 17

PROCESS WATER QUALITY TOLERANCES FOR THE MANUFACTURE OF PAPER[1/]

Dissolved constituents in the water (ppm)	Type of paper product				
	Fine paper	Kraft paper		Ground-wood papers	Soda and sulfate pulp
		Bleached	Unbleached		
Total hardness ($CaCo_3$ eq.)	100.0	100.0	200.0	200.0	100.0
Calcium hardness ($CaCo_3$ eq.)	50.0	---	---	---	50.0
Alkalinity ($CaCo_3$ eq.)	75.0	75.0	150.0	150.0	75.0
Iron	0.1	0.2	1.0	0.3	0.1
Manganese	0.05	0.1	0.5	0.1	0.05
Silica (SiO_2 eq.)	20.0	50.0	100.0	50.0	20.0
Total dissolved solids	200.0	300.0	500.0	500.0	250.0
Chlorides	---	200.0	200.0	75.0	75.0
Magnesium hardness (CaCo eq.)	---	---	---	---	50.0

1/ N. S. Chamberlin, and others. "Water Technology in the Pulp and Paper Industry", Tappi Monograph Series, No. 18. Technical Association of the Pulp and Paper Industry. New York. 1957.

The uses of process water in the stone and clay industries generally are limited to making raw materials into final products and, in the glass industry, to contact cooling and washing of products.

Dissolved solids in water may effect the bonding strength of the products of the stone and clay industry. For example, tests have shown that saline waters whose salt concentration is that of sea water or less can reduce the compressive strength of cement from 5 to 20 percent. Such a loss can be compensated for only by the addition of greater quantities of cement. Water quality presents problems to the glass industry because the dissolved minerals may be deposited upon the product in the wash and cooling stages. The 1960 industrial water use survey indicated that waters containing less than 250 parts per million chlorides and less than 50 parts per million hardness are required for the stone, clay, and glass industries.

2. Boiler Feed Water. All industries within the western Delta study area operate boilers to produce steam for processing and power generation. Thermal capacities and operating pressures of these boilers vary widely.

Those industries which obtain boiler feed water solely from river channels experience considerable difficulty during periods of maximum salinity incursion. During these periods, saline waters often render various boiler feed treatment facilities inadequate. They hamper production, cause excessive blowdown, reduce the capacity of boilers, and possibly cause excessive corrosion or scaling. Such corrosion or scaling may result ultimately in boiler failure and complete shutdown of production. Those industries which obtain boiler feed water from a supplementary supply such as that provided by the Contra Costa Canal or the cities of Pittsburg and Antioch face similar problems. Such supplies also are affected by salinity incursion, although to a lesser degree.

To a specific company, the economic detriments caused by a slowdown or shutdown in production can be severe, if not catastrophic.

Even those industries whose treatment equipment is designed to handle relatively high salinities face economic detriments. Such detriments occur because the costs of chemical treatment rise proportionately to the amount of dissolved solids in the water and because water treatment equipment may require higher capital costs.

The problem does not relate to the chloride content of the water, but to the hardness constituents (calcium and magnesium) in the case of low pressure boilers and, more critically, to silica constituents in the case of high pressure boilers. Table 18 illustrates generalized water requirements for boilers as a function of operating pressures in boilers.

TABLE 18

VARIATION IN WATER QUALITY TOLERANCES
OF BOILER FEED WATER FOR VARIOUS BOILER OPERATING PRESSURES[1/]

Dissolved constituents in the water	Boiler operating pressures in pounds/sq. in.			
	0-150	150-250	250-400	over 400
Total hardness ($CaCo_3$), ppm	80	40	10	2
Sulfate-Carbonate ratio (ASME) ($Na_2So_4:Na_2Co_3$)	1:1	2:1	3:1	3:1
Aluminum oxide, ppm	5	0.5	0.05	0.01
Silica, ppm	40	20	5	1
Bicarbonate, ppm	50	30	5	0
Carbonate, ppm	200	100	40	20
Hydroxide, ppm	50	40	30	15
Total Solids, ppm[2/]	3,000-500	2,500-500	1,500-100	50
pH	8.0	8.4	9.0	9.6

1/ From progress report of the Committee on Water Quality Tolerances for Industrial Uses, New England Water Works Association.

2/ Depends on design of boiler.

3. High Quality Cooling Water. In the western Delta, a significant portion of the total demand for cooling water is for high quality water. This requirement results from both physical and economic factors.

The physical factors arise from the effects of scale or corrosion upon the operation of air compressors, diesel power units, bearing cooling devices, and similar equipment. Such equipment cannot operate efficiently under conditions of scaling or corrosion. In the food-canning industry, high quality water is used for cooling the canned product in the retorts after cooking. Low quality water would either rust the cans, or force the use of more expensive materials.

Economic factors leading to the use of high quality cooling water arise from the location of the plant, the disadvantage of maintaining two water systems, and the considerations of heat exchanger tube material. When plant sites lie relatively far from river channels, the potential cost of constructing facilities to bring water from the river plus the added cost of salt resistant cooling equipment may result in the use of the more costly yet closer high quality water supply. The operation of two water supply systems with double capital costs in such facilities as pumps, pipelines, and filtration plants may lead to similar use. Certain processes may dictate the use of material which is highly corroded by saline water. In such cases, bimetal tubes can be employed. One side of such a tube is resistant to the process element; the other, to saline water. To avoid the cost of such tubes, an industry may find the use of more costly high quality water advantageous.

The quantities of water necessary for most high quality cooling combined with much high unit water costs usually dictate that water be recirculated through cooling towers. These towers are relatively inexpensive on a unit basis for large circulation rates. The makeup rates of these towers average only four to six percent of the circulation rates, hence the actual net water input requirement to the system is small.

In the 1960 industrial water use survey, quality requirements for high quality cooling water systems ranged between 50 and 250 parts per million chloride ions.

4. Low Quality Water. The primary use of low quality water is for cooling. In all cases, the industries interviewed in 1960 indicated that their cooling equipment had been adequate for the river channel salinities experienced to date, although problems of maintenance and treatment had arisen on several occasions. Basically however, such problems related to fluctuations in salinities.

The successful use of saline water as a coolant depends, in part, upon treating the water so that it will deposit a small layer of scale upon the heat exchanger tubes. This deposit prevents corrosion. Seasonal changes in salinity often cause either the removal of this deposit or deposition of too much scale. Sometimes considerable difficulties are encountered in maintaining the desired amount of scale.

Low quality water also is used for fire protection, the washing of floors, roadways, and buildings, the dilution of waste effluents, and the transport and washing of certain raw materials.

5. Sanitary and Air Conditioning. Table 25 presents the State of California Public Health Department standards for the quality of drinking water. While these standards are sufficient for safety and health, waters of better quality generally are more drinkable.

Where required, sanitary water of lesser quality can supply uses other than drinking, although high hardness of such water may destroy some of its cleansing power. Since these uses usually are met most economically by the same facility that supplies drinking water, the quality requirements are assumed to be similar.

Makeup water for air conditioning units usually is served by the same facility that serves sanitary uses. This situation occurs because the air conditioning units are located in the same areas as the sanitary units. Quality requirements of this makeup water are less than they are for drinking purposes, but because of the common supply system they have been assumed equal.

Water Quantity Requirements. The present water quantity requirements of the western Delta study area were estimated from data obtained during the 1960 industrial water use survey and from sales records of the several water agencies within the area. These requirements were divided into requirements for high quality water and for low quality water.

The present total high quality water requirement in the western Delta atudy area is estimated to be 31,000 acre-feet a year. To obtain this estimate, average monthly diversions for 1957 and 1958 were adjusted to reflect employment estimates for 1960. Such average monthly diversions were computed from sales to specific companies from the Contra Costa County Water District, the cities of Antioch and Pittsburg, and the Oakley County Water District. For those companies which met part or all of their high quality water requirements from river channels, average monthly diversions were computed by determining the rate of flow through specific processes or from pump capacities. The partial use of nonriver supplies such as well water, plant shutdowns, and the blending of high quality water with river water were taken into account in the computations.

Table 19 shows the amounts of high and low quality water required for each manufacturing industry category within the western Delta. In all cases, the requirements for low quality water were based upon pump or equipment capacities.

TABLE 19

PRESENT INDUSTRIAL WATER REQUIREMENTS
IN THE WESTERN DELTA STUDY AREA[1/]
(Acre-feet per year)

Industry category	High quality water requirements 1958	High quality water requirements 1960	Low quality water requirements 1958-60	Total industrial water requirements 1960
Contra Costa County				
Food and kindred products	1,000	1,200	1,800	3,000
Pulp, paper, and allied products	12,400	15,300	25,200	40,500
Chemicals and allied products	4,200	5,000	30,400	35,400
Primary metals	7,800	8,900	17,900	26,800
Stone, clay, and glass products	300	300	3,600	3,900
Miscellaneous industries	200	300	1,525,600	1,525,900
SUBTOTAL	25,900	31,000	1,604,500	1,635,500
Solano County	---	400	2/	400
TOTAL	25,900	31,400	1,604,500	1,635,900

1/ Includes all of Pittsburg Township
2/ All existing uses in Solano County were assumed to be high quality

Unit water requirements were determined for high quality water, but not for low quality water. Unit requirements of high quality water were computed both on the basis of employment and on that of acreage. Estimated present average annual diversion figures and estimated 1960 average annual employment figures were used to compute the amount of water per employee per year. Estimated present average annual monthly diversions, the results of 1960 land use surveys, and 1957-58 aerial photography surveys supplied figures used to compute the amount of water per acre per year. Table 20 shows present unit water requirements.

TABLE 20

INDUSTRIAL HIGH QUALITY WATER REQUIREMENTS
FOR THE WESTERN DELTA STUDY AREA
1960 TO 1980 LEVELS OF DEVELOPMENT

Year	Item	Contra Costa County industrial categories[1/]: Food and kindred products	Paper and allied products	Chemicals and allied products	Primary metals	Stone clay and glass	Miscellaneous[2/]	Industry total	Solano County industry total	Area industry total
1960	High quality water requirements in acre-feet/year	1,200	15,300	5,000	8,900	300	300	31,000	400	31,400
	Employment	770	2,450	2,400	3,900	850	330	10,700	200	10,900
	Developed industial acreage in acres	---	---	---	---	---	---	1,260[3/]	20	---
	Base unit water requirement in acre-feet employee/year	1.50	6.26	2.08	2.27	0.37	1.00	2.90	1.94	---
	Water duty in acre-feet acre/year	38.70	80.50	11.90	35.80	4.70	0.8	24.6	20.0	---
1970	Employment	1,100	4,100	4,100	7,000	1,100	500	17,900	300	18,200
	Base unit water requirement in acre-feet employee/year	1.50	6.26	2.08	3.65	0.37	1.00	2.90	1.94	---
	Unit water requirement index	1.04	1.11	1.32	1.11	1.12	1.12	1.35	1.23	---
	Computed unit water requirement in acre-feet/employee year	1.56	6.95	2.74	4.05	0.42	1.12	3.92	2.38	---
	High quality water requirement in acre-feet/year	1,700	28,400	11,400	28,400	450	550	70,900	700	71,600
	Developed industrial acreage in acres	---	---	---	---	---	---	2,260[2/]	30	---
	Water duty in acre-feet/year	---	---	---	---	---	---	31.4	23.3	---
1980	Employment	1,400	5,900	6,100	11,700	1,400	700	27,200	700	27,900
	Base unit water requirement in acre-feet/employee/year	1.50	6.26	2.08	4.11	0.37	1.00	2.90	1.94	---
	Unit water requirement index	1.07	1.21	1.61	1.21	1.21	1.21	1.61	1.44	---
	Computed unit water requirement in acre-feet/employee/year	1.60	7.57	3.37	4.97	0.45	1.21	4.67	2.79	---
1980	High quality water requirement in acre-feet/year	2,300	45,000	20,600	58,000	600	800	127,300	2,000	129,300
	Developed industrial acreage in acres	---	---	---	---	---	---	3,600[2/]	80	---
	Water duty in acre-feet acre/year	---	---	---	---	---	---	35.4	25.0	---

1/ Includes all of Pittsburg township
2/ Includes high quality water requirements of steam electric plants
3/ Excludes tank farms

Future Industrial Water Requirements

An estimate of future industrial water requirements in the western Delta study area was important to the comparison of the economic feasibility of alternative Delta water facilities, and to the sizing of water supply features of such facilities. Adequate quantities of water of sufficient quality were assumed to be available for industrial growth.

Future water quality requirements are expected to increase because the effects of intense industrial competition, both foreign and domestic, will lead to continued improvement of product qualities. Undoubtedly, higher water quality requirements will accompany these improvements. The ability of local water supplies to meet all of these requirements is limited. Nevertheless, because of the high cost incurred in the treatment of industrial water to meet these requirements, any attempt made to maintain or improve existing and future water supplies should prove fruitful.

Industries involved in the manufacture of products different from those presently produced may locate in the western Delta study area. Table 21 indicates suggested water quality limits for some of these products.

The increasing costs of obtaining high quality water supplies and the interest of industry in water conservation should result in the discovery of new and more effective ways of using saline waters. Trends in increasing use of saline water already are in evidence throughout the world. Recent articles in a leading paper industry journal,[1/]

1/ John C. W. Evans. "Unique Sulphite-Soda Pulping and Recovery System Used at Rauna". Paper Trade Journal. September 14, 1959.

Ibid. "How French Firm Uses Ocean Water in Manufacture of Sulphite Pulp".

TABLE 21

WATER QUALITY REQUIREMENTS OF POTENTIAL INDUSTRIES
IN THE WESTERN DELTA STUDY AREA
(In parts per million)

Constituents of the process water	Product					
	Light beer	Dark beer	Sugar	Ice	Rayon	Plastics
Hardness (as $CaCo_3$)				70.0	8	
Alkalinity	75	150		30-50	50	
Total Solids	500	1,000		300	100	200
Calcium	100-200	200-500	20			
Iron	0.1	0.1	0.1	0.2	0.05	0.02
Manganese	0.1	0.1		0.2	0.03	0.02
Calcium Sulphate	100-200	200-500		300		
Sodium Chloride	275	275		300		
Silicate	50	50		10	25	
Chloride			20			
Magnesium			10			
Bicarbonate			100			
Sulfate			20			

indicate that brackish water supplies suit certain paper processes up to their final stages, at which point a high quality water supply is required. Other articles indicate that the chemical industry in the Gulf Coast area of the United States has found many uses for highly saline waters. The power industry in California also has made significant progress in using saline water supplies by economically evaporating sea water for use as boiler feed water.

Continued research and development by the Office of Saline Water of the U. S. Department of Interior, the University of California, and the Department of Water Resources, undoubtedly will lead to more economical ways of converting saline water supplies to usable water. Plastics and other new materials probably will be developed to resist the corrosive attack of saline waters. New forms of treatment also will be developed. The rapidly advancing science of metallurgy will define more exactly the many causes and means of prevention of corrosion.

Such predicted progress cannot completely be overlooked in a study of water requirements. In the western Delta study area, however, the economic advantages of such advances in the use of brackish water as compared to the use of high quality water probably will be marginal, if not nonexistent. This condition exists because the cost of transporting high quality water from the Delta to the area of use is relatively small.

High Quality Water Requirements. Estimates of the quantity of future industrial high quality water relate directly to those manufacturing employment projections discussed in Chapter II.

Although what is probably the best measure of unit industrial high quality water requirements is based on unit of production, a review of national data indicates a wide variance in water required per unit of production. This variance results from the reuse of industrial water, engineering economics, product quality, and the availability of water. Analysis of such factors in the western Delta study area, projections of present production and predictions of production of new products were beyond the resources of this study. Other measures of unit industrial high quality water requirements such as value added by manufacture were found to present similar difficulties.

Projections of land use were used to distribute industrial water requirements and to determine the necessary capacities of water supply facilities. Projections of the total industrial high quality water requirement on the basis of land use was considered inadvisable since insufficient data on automation, water reuse and land efficiencies hindered accurate projections of industrial trends in water use per unit of land.

Projections by other agencies were considered. Data upon national trends in unit high quality water use per manufacturing employee are available from the Department of Commerce[1/]. Long term projections of these trends have been made for each major water-using industry both by the Business and Defense Services Administration of the Department of Commerce, and by Resources for the Future, Incorporated. This latter organization is a private research group involved in long-range planning of the resources of the nation.

The following plates show, for those manufacturing industries using vast quantities of high quality water, the projected indices of water use per employee per year in the United States: Plate 10, "Food Products Industry, ..."; Plate 11, "Pulp and Paper Industry, ..."; Plate 12, "Chemical Industry, ..."; and Plate 13, "Primary Metal Industries, ...". These projections are those of the Department of Commerce and Resources for the Future, Incorporated. For certain industries, as shown on the plates, the indices projected by these two agencies differ. In such cases, the Department of Water Resources prepared a median index, also shown on the plates, to be used in studies in the western Delta.

Plate 41, "Total Manufacturing, ...", summarizes the indices presented in Plates 10 through 13.

The calculation of high quality water requirements through 1980 for the chemical, food products and pulp and paper industries in the Contra Costa County portion of the western Delta study area, required multiplication of their projected employments by the appropriate index of water use per employee per year and then by the appropriate figure for water use per employee

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1/ Select Committee on National Water Resources, United States Senate. "Water Resources Activities in the United States, Future Water Requirements of Principal Water Using Industries". Senate Resolution 48, 86th Congress. 1960.

per year in 1960. The calculation of water requirments through 1980 for the stone, clay, glass and miscellaneous industries employed a similar method, but used the total manufacturing water use index.

Projections of the high quality water requirements of the primary metals industry were treated similarly but took into consideration an increasing base unit requirement adopted to reflect the assumed future location of an integrated steel mill, the unit high quality water requirements of which would be considerably greater than those of the existing mill. The unit high quality water requirements of this integrated mill were assumed to be similar to those of the Bethlehem Steel Plant at Sparrows Point, Maryland. This plant was considered ideal for comparison. It lies on a tidal water basin and produces products similar to those of the steel industry in the Delta area. The unit high quality water requirement of the Sparrows Point plant is 5.04 acre-feet per employee per year. The base unit high quality water requirements of the Delta steel industry for 1970 were determined by averaging the present unit requirements of the Delta steel industry with those of the Sparrows Point plant. To determine such requirements for 1980, this average was weighted on a basis of 2:1 (Sparrows Point:Delta). The projected indices then were applied to the developed bases to determine total high quality water requirements for the primary metals category.

For the period 1980-2020, a somewhat different projection procedure was used. An average index of water per employee per year for total manufacturing in the Delta study area was determined for 1960,1970, and 1980. This index was plotted against the projected composite national index for total manufacturing in these years (Plate 14). The differences in the two projections arise from different employment distributions and different unit high quality water requirements. The national index as shown on Plate 14 was extrapolated from 2000 to 2020. The resulting 2020 index in the United States was assumed to equal that of the Delta. A correlation curve was completed for the intermediate years 1990, 2000, and 2010. Plate 15, "Western Delta Index Versus United States Index, Unit Water Requirements for Total Manufacturing" shows this curve. Plate 16 "Manufacturing Industries, Index of Water Use per Employee in the Western Delta Study Area", shows the resulting indices for the western Delta. Total industrial high quality water requirments were determined by applying both the projected indices and the total manufacturing employments to the 1960 composite unit high quality water requirements.

Projections for the Solano County portion of the study area used the total manufacturing index shown on Plate 16. However, the base water per employee per year requirement was assumed to be two-thirds that of Contra Costa County. The basis for this assumption is the possibility that the industries locating in Solano County might represent a wider industrial cross section and include fabrication-type mills which generally consume comparatively little water. Further support for this assumption lies in the fact that no major industries presently exist in Solano County. Future industries will be of the latest design and will incorporate the most modern and efficient water using machinery.

The national total manufacturing index indicates that by the year 2020 there will be an average increase in employee productivity of 440 percent and an average increase in industrial water efficiencies of 200 percent. In other words, less than one-fourth of the present man hours and one-half the present high quality water will be required to produce a commodity in 2020.

It is difficult to imagine that productivity can continue to grow at the suggested rates. Such an objection undoubtedly would have been raised in 1900, yet such a sustained increase in productivity actually has occurred since that time. Technological improvements are advancing at an accelerated pace. No reason exists to assume that these rates will decline. Similar reasoning applies to water efficiencies. The introduction of automatic control equipment, the recovery of raw materials from waste effluents, the heavy investments in water treatment equipment, and the general interest of industry in water conservation certainly will affect the industrial water consumption within the Delta.

Plate 15 shows that, until 1980, total manufacturing water indices of the western Delta study area rise more rapidly than those for the United States, and that after 1980 they decelerate to reach the national index in 2020. The increase is influenced partially by the assumed location of an integrated steel mill; the decrease results partially from the secondary effects of such a mill. Such effects would include the formation of the fabricated metal products industry, an industry which uses less water than the primary metals industry. The location of satelite industries for the chemical, and paper industries would produce a similar deceleration effect. A comparison with other areas supports this prediction. Since the beginning of postwar operations of the Geneva Steel Plant in Provo, Utah, for example, steel fabricating and allied manufacturing has increased sevenfold in the Provo-Salt Lake City-Odgen areas. The Boeing Airplane Company in Seattle is served by as many as 5,000 subcontractors in the Seattle-Tacoma area. In the Gulf Coast area of the United States, the growth of the plastics component of the chemical industry has resulted in tremendous expansion in plastic fabrication plants. Because of such examples, the projection of water requirements in the western Delta study area recognizes the possible influx of satellite industries.

The combined indices of employee per acre ratios and high quality water per employee per year requirements lead to an increasing unit water duty per acre. The assumed increasing industrial land efficiencies shown in Table 7 explain this increase. The adoption of higher speed machinery, increasing land costs and the adoption of production line processing, assembly and finishing, make this trend appear feasible.

Table 20 shows projected high quality water requirements from 1960 to 1980 and Table 22, from 1990 to 2020.

TABLE 22

INDUSTRIAL HIGH QUALITY WATER REQUIREMENTS
FOR THE WESTERN DELTA STUDY AREA
1990-2020 LEVELS OF DEVELOPMENT

	Year			
	1990	2000	2010	2020
Contra Costa County[1/]				
Employment	38,400	49,500	60,800	71,000
Base unit water requirement in acre-feet/employee year	2.90	2.90	2.90	2.90
Unit water requirements index	1.79	1.94	2.08	2.21
Computed unit water requirement in acre-feet/employee year	5.19	5.62	6.03	6.41
High quality water requirement in acre-feet/year	199,100	278,100	366,100	455,000
Developed acreage in acres[2/]	5,240	7,010	8,920	10,750
Water duty in acre-feet/ acre/year	38.1	39.7	41.1	42.4
Solano County				
Employment	1,500	6,000	14,700	29,000
Base unit water requirement in acre-feet/employee year	1.94	1.94	1.94	1.94
Unit water requirement index	1.63	1.83	2.02	2.21
Computed unit water requirement in acre-feet/employee year	3.16	3.55	3.92	4.29
High quality water requirement in acre-feet/year	4,700	21,300	57,600	124,200
Developed acreage in acres[2/]	190	790	2,000	4,180
Water duty in acre-feet/ acre/year	24.8	27.0	28.8	29.8
TOTAL high quality water requirement in acre-feet/year	203,800	299,400	423,700	579,200

1/ Includes Pittsburg township.
2/ Excludes tank farms.

Low Quality Water Requirements. Future industrial low quality water requirements for the western Delta study area were determined on the basis of their ratio to high quality water requirements. This ratio was decreased from 2.5:1 in 1960 to 2.0:1 in 2020. The decrease resulted from the fact that some of the potential industrial lands would be located sufficiently far from river channels to merit the use of cooling towers and recirculation units. The Pacific Gas and Electric Company provided estimates of future cooling water requirements for steam-electric power generation. Such estimates were added to the industrial low quality requirements determined from projections developed in this study. Table 23 summarizes industrial low quality water requirements in the area.

TABLE 23

INDUSTRIAL LOW QUALITY WATER REQUIREMENTS
FOR THE WESTERN DELTA STUDY AREA[1/]
1960-2020 LEVELS OF DEVELOPMENT

Year	High quality industrial water requirements in acre-feet/yr.	Ratio of low quality to high quality	Low quality industrial water requirements in acre-feet/year	Steam-electric plant cooling water in acre feet per year	Total low quality water requirements in acre-feet/yr.
1960	31,400	2.53:1	79,500	1,525,000	1,604,500
1970	71,600	2.41:1	173,000	2,000,000	2,173,000
1980	129,300	2.31:1	299,000	2,475,000	2,774,000
1990	203,800	2.23:1	454,000	2,475,000	2,929,000
2000	299,400	2.15:1	644,000	2,475,000	3,119,000
2010	423,700	2.07:1	877,000	2,475,000	3,352,000
2020	579,200	2.00:1	1,158,000	2,475,000	3,633,000

1/ Includes all of Pittsburg township.

Verification of Industrial Water Requirements. The proposal that high quality water requirements will increase nearly twentyfold in the western Delta study area and fifteenfold in the Contra Costa County portion is startling. However, the unit water requirement projections listed in Tables 20, 22 and 23 are well supported both by U. S. Department of Commerce data and by the existing requirements of industries in other parts of the nation. The Chambers Works of The E. I. DuPont Chemical Company in Delaware, for example, produces over 2,000 different chemicals and has a unit annual requirement of 75 acre-feet of high quality water per developed acre. In the area encompassed by these studies only the requirements at the paper industry exceed this figure. Verification of total high quality water requirement projections also was made by comparisons with projections made by the Business and Defense Services Administration of the Department of Commerce. These projections indicate a fivefold increase in Northern California steel production, an eightfold increase in chemical production, and a tenfold increase in paper production by the year 2000.

Studies of the assumptions regarding low quality cooling water under the salinity conditions proposed by the Delta Water Project revealed that the increase in the duration of peak salinity waters resulting from operation of the project would not harm existing industries because the major problem has been a seasonal transition from low to high salinity rather than the duration of peak salinity. Studies of the effects of an increased degree of salinity on heat exchange materials indicated that, under conditions created by the Delta Water Project, the same tube materials would be used as are used at present. In other words, an increase in salinity of 2,000 parts per million chlorides would not change the design criteria in the selection of material for heat exchangers. Table 24 supports this conclusion. The table depicts heat exchanger material selections throughout the United States as a function of water quality. This table also shows that, because of the use of the same materials, decreases in salinites such as might occur with either the construction of the Chipps Island barrier or the maintenance of a high Delta outflow would not necessarily be a significant design benefit.

While Table 24 supports conclusions that increased capital costs would not be required because of salinity increase, it does not consider annual costs. Consequently, the Department of Water Resources surveyed the literature concerning corrosion rates and their causes. This survey indicated that corrosion of these materials generally is caused by substances found--not in sea water--but in polluted waters which often result from wastes discharged by nearby industries. The contention that increased sea water incursion would cause such corrision would be very difficult to prove.

In some cases, the materials listed in Table 24 are not suited to certain heat exchange processes. In such cases, ferrous materials usually are substituted. In the presence of little or no dissolved oxygen or carbon dioxide saline waters do not corrode most ferrous materials. Evidence indicates that such materials might be effected by increased salinities should no reduction be made in the content of dissolved oxygen and carbon dioxide. Existing and future industries, therefore, actually would benefit by the installation of deaeration equipment.

TABLE 24

HEAT EXCHANGER TUBE MATERIAL
SELECTIONS FOR VARIOUS SALINE WATERS

Company	Location	Date of installation	Water source	Tube material	Chlorides-ppm Range	Chlorides-ppm Average
Philadelphia Electric Co., Richmond Station	Philadelphia, Pa.	1950	Delaware River	Admiralty	2-168	14
Philadelphia Electric Co., Delaware Station	Philadelphia, Pa.	1952	Delaware River	Admiralty	2-168	14
Savannah Electric and Power Company	Port Wentworth, Georgia	1958	Savannah River	Admiralty		30
Virginia Electric and Power Co., Possum Pt.	Dumfries, Va.	1955	Potomac River	Admiralty	1-700	50
Carbide and Carbon Chemical Company	Texas City, Texas	1952	San Jacinto River	Admiralty	20-230	82
Gaylord Container Corp.	Bogalusa, La.	1954	Pearl River	Admiralty		100
Scott Paper Company	Chester, Pa.	1954	Delaware River	Admiralty	4-1,920	188
Central Hudson Gas and Electric Company	Roseton, N. Y.	1951	Hudson River	Admiralty		898
Jos. Bancroft and Sons Company	Wilmington, Delaware	1948	Delaware River	Admiralty	14-3,100	915
Alabama Power Company	Chickasaw, Ala.	1951	Mobile River	Admiralty		5,500
Gilman Paper Company	St. Marys, Ga.	1954	St. Marys River	Admiralty		5,500
St. Mary's Kraft Corp.	St. Marys, Ga.	1955	St. Marys River	Admiralty		5,500
Colgate-Palmolive-Peet Company	Jersey City, New Jersey	1948	Hudson River	Admiralty	3,300- 14,400-	7,000
St. Joe Paper Company	Port St. Joe, Florida		Gulf of Mexico	Admiralty		14,400
Atlantic Wire Company	Branford, Conn.	1941	Long Is.Sound	Admiralty		16,000
Philadelphia Electric Company	Philadelphia, Pa.	1957	Delaware River	Admiralty	2-168	14
Philadelphia Electric Company	Eddystone, Pa.	1958	Delaware River	Admiralty Inhibited	4-809	80
Delaware Power and Light Company, Edge Moor	Wilmington, Delaware	1954	Delaware River	Admiralty Inhibited	14-3,100	915
Atlantic City Elec. Co. - Deepwater	Penns Grove, New Jersey	1958	Delaware River	Admiralty Inhibited	14-3,100	915
Northern Chemical Ind., Inc.	Searsport, Maine	1956	Penobscot Bay	Admiralty Inhibited		16,600
New Orleans Public Service, Inc.	New Orleans, La.	1954	Mississippi River	Alum.-Brass	11-64	25
Florida Power & Light Company	Ft. Myers, Florida	1958	Caloosahatchee R.	Alum.-Brass	26-43	33
Dow Chemical Company	Freeport, Texas	1953	Brazos River	Alum-Brass	18-370	154
Dow Chemical Company	Pittsburg, California	1952	San Joaquin	Alum.-Brass	8-1,525	179
Pacific Gas & Electric Company	Pittsburg, California	1954	San Joaquin River	Alum.-Brass	8-1,525	179
Crown Zellerbach Corp.	Antioch, California	1956	San Joaquin River	Alum.-Brass	8-1,525	179
California & Hawaiian Sugar Ref. Corp.	Crockett, California	1958	San Pablo Bay	Alum.-Brass	540-11,100	
Connecticut Light & Power Company	Montville, Conn.	1954	Thames River	Aluminum - Brass	2,800 - 11,100	
Central Maine Power Company	Yarmouth, Me.	1957	Royal River	Aluminum - Brass	5,500 - 14,000	
South Carolina Electric & Gas Company	Charleston, S. C.	1951	Black River	Aluminum - Brass	7,800 - 15,500	
St. Regis Paper Company	Eastport, Florida	1955	St. Johns River	Aluminum - Brass	1,700 - 15,000	9,000
Gulf Power Company	Pensacola, Florida	1952	Gulf of Mexico	Aluminum - Brass	6,000 - 13,300	9,500
Consolidated Edison Company of New York	New York, N. Y.	1955	East River	Aluminum-Brass		11,000
Mississippi Power Company	Gulfport, Miss.	1957	Gulf of Mexico	Alum.-Brass		11,000
International Paper Company	Panama City, Florida	1949	Gulf of Mexico	Alum.-Brass	7,800 - 14,400	12,000

TABLE 24 (Continued)

HEAT EXCHANGER TUBE MATERIAL
SELECTIONS FOR VARIOUS SALINE WATERS

Company	Location	Date of installation	Water source	Tube material	Chlorides-ppm Range	Chlorides-ppm Average
Public Service Company of N. H.-Schiller	Portsmouth, N. H.	1957	Piscataqua River	Alum.-Brass	11,000-16,600	14,900
Florida Power Corporation	St. Petersburg, Florida	1949	Gulf of Mexico	Aluminum - Brass	13,300 16,600	15,000
United Illuminating Company	New Haven, Conn.	1953	Long Island Sound	Aluminum-Brass	---	16,000
United Illuminating Company	Bridgeport, Conn.	1957	Long Island Sound	Alum.-Brass	---	16,000
Pacific Gas & Electric Company	Eureka, California	1958	Pacific Ocean	Alum.-Brass	---	16,600
Pacific Gas & Electric Co., Hunters Point	San Francisco	1958	San Francisco Bay	Alum.-Brass	---	16,600
New England Power Company	Salem, Mass.	1958	Atlantic Ocean	Alum.-Brass	14,400-17,700	17,200
Cambridge Electric Light Company	Cambridge, Mass.	1950	Boston Bay	Alum.-Brass	---	17,670
Southern California Edison Company	Oxnard, California	----	Pacific Ocean	Alum.- Brass	---	18,600
San Diego Gas & Elec. Co., Silvergate Station	San Diego, California	1950	Pacific Ocean	Alum.- Brass	---	18,600
Pacific Gas & Electric Company	Moss Landing, California	1952	Pacific Ocean	Alum.- Brass	---	18,600
San Diego Gas & Electric Company	San Diego, California	1952	Pacific Ocean	Alum.-Brass	---	18,600
Southern California Edison Company	Huntington Beach, Calif.	---	Pacific Ocean	Alum.-Brass	---	18,700
San Diego Gas & Electric Company	Carlsbad, California	1954	Pacific Ocean	Alum.-Brass	---	18,700
Pacific Gas & Electric Company	Morro Bay, California	1955	Pacific Ocean	Alum.-Brass	---	18,700
San Diego Gas & Electric Company	Carlsbad, California	1956	Pacific Ocean	Alum.-Brass	---	18,700
Florida Power & Light Company	Miami, Florida	1952	Atlantic Ocean	Alum.-Brass	---	19,400
St. Mary's Kraft Corp.	St. Mary's, Ga.	1941	St. Mary's River	Alum.- Bronze	---	5,500
Boston Edison Company	N. Weymouth, Mass.	1954	Boston Bay	Alum.- Bronze	13,800-17,700	16,000
Southern California Edison Company	Alamitos Bay, California	1956	Pacific Ocean	Ars. Alum.-Brass		18,600
Southern California Edison Company	El Segundo, California	1956	Pacific Ocean	Ars. Alum.-Brass		18,600
Southern California Edison Company	Redondo Beach, California	1957	Pacific Ocean	Ars. Alum.-Brass		18,600
Union Bag and Paper Corp.	Savannah, Ga.	1945	Savannah River	Ars. Copper	300-2,800	--
Baltimore Gas and Electric Company	Anne Arunde City, Maryland (Wagner Sta.)	1959	Patapsco R.	Ars. Alum.-Brass	3,600-6,700	2,900
Charles Pfizer and Company	Groton, Conn.	1953	Thames River	Cop. Nickel	6,700-15,500	--
Narragansett Electric Company	Providence, R.I.	1953	Providence R.	Copper-Nickel	8,300-16,600	--
Carolina Power and Light Company	Wilmington, N.C.	1955	Cape Fear River	Cupro - Nickel	4.5-1,450	242
Virginia Electric and Power Company	Portsmouth, Va.	1959	James River	Cupro - Nickel		11,000
Virginia Electric and Power Company	Yorktown, Va.	195[illegible]	York River	Cupro - Nickel	8,700-14,000	11,000
Tampa Electric Company	Tampa, Florida	1957	Tampa Bay	Cupro - Nickel	12,200-16,600	14,400
Key West Utility Board	Key West, Florida	1957	Gulf of Mexico	Cupro - Nickel		19,900
St. Croix Paper Company	Woodland, Maine	1951	St. Croix R.	Muntz Metal		--
Florida Pulp and Paper Company	Pensacola, Florida	1941	Gulf of Mexico	Muntz Metal	6,100-12,700	9,700
Narragansett Brewing Company	Cranston, R. I.	1947	Narragansett Bay	Muntz Metal	8,300-16,600	--
Boston Naval Shipyard	Boston, Mass.	----	Boston Bay	Adm. - Copper-Nickel	14,400-17,200	16,000

Following such installation, no additional corrosion of ferrous materials would occur with an increase in salinities. Several industries in the area presently are studying the advantages of such an installation.

Studies indicated that, while the provision of high quality water for cooling is of benefit, the degree of benefit falls far behind that of domestic, agricultural, or industrial process use, particularly in view of the unlimited quantities of low quality water available within the river channels.

Municipal Water Requirements

Municipal water supplies of the western Delta in general are affected by the same factors as industrial water supplies. For reasons similar to those given in the case of industrial water requirements studies of municipal water requirements were limited to the western Delta study area. Furthermore, municipal water supplies outside of the western Delta either are presently satisfactory or will come from sources other than the Delta channels.

Municipal Water Quality Requirements

In general, the water quality standards of any municipal supply should be maintained at as high a level as possible not only to ensure the safety of the supply, but also to ensure its potability and cleansing power

Table 25 indicates the minimum safe standards adopted by the United States Public Health Service. While these standards are adequate, considerable improvements in drinkability can be attained through a lower content of total dissolved solids. The cleansing power of water depends on the degree of hardness. Water of low hardness improves the effect of soap and detergents and thus permits the consumer to economize on such cleansing agents.

Past Municipal Water Requirements

Table 26 shows past municipal use of water in the western Delta study area. Plate 17, "Historic and Projected Water Use Per Capita for the Cities of Pittsburg and Antioch", shows trends in unit water use for specific communities.

TABLE 25

MUNICIPAL WATER QUALITY STANDARDS OF THE UNITED STATES PUBLIC HEALTH SERVICE

Constituent	Parts per million
Mandatory Maximum	
Lead	0.05
Fluoride	3.40
Arsenic	0.05
Selenium	0.01
Hexavalent chromium	0.05
Silver	0.05
Barium	1.00
Cadmium	0.01
Cyanide	0.20
Recommended Maximum	
Iron	0.3
Copper	1.0
Manganese	0.05
Chloride	250.0
Sulfate	250.0
Nitrate	45.0
Total Dissolved Solids	500.0

TABLE 26

MUNICIPAL WATER SALES IN THE WESTERN DELTA STUDY AREA (In millions of gallons per year)

Year	Antioch	Pittsburg	Rio Vista1/
1950	332	695	
1955	587	765	202
1956	632	844	148
1957	724	847	
1958	729		200
1959	782		267

1/ Fiscal year.

Future-Municipal Water Requirements

Population and per capita water use forecasts were combined to project future municipal water requirements in the western Delta study area. The method used the population forecasts shown in Chapter II.

The influence of income seems most to dominate per capita water requirements. As personal income rises, standards of living rise proportionately. Larger lawns, more complete sanitary facilities, a larger number of water-using appliances, and more swimming pools, become the rule rather than the exception. In the western Delta study area per capita water use is affected by personal income. Personal income in the area undoubtedly will follow national, state, and Bay area trends, all of which probably will sustain significant increases during the next 60 years. These increases will lead to higher per capita water use demands.

Land use can influence per capita water consumption. In certain area, a large portion of the municipal use of water results from irrigation of lawns and gardens during summer months. As population density increases, housing lots become smaller, apartment houses more prevalent, and steeper land slopes more thoroughly used. As a result, lawn and garden irrigation decreases and seasonal water demands become more uniform. A lower yearly per capita water requirement usually results.

In the western Delta study area, per capita water use is affected directly by land use. The effects of land use changes upon per capita water demands will vary for any specific community within the area.

For the study area as a whole, the present one percent per year increase in per capita water demands may be anticipated to decrease to one-half percent per year by 2020. Table 27 shows the per capita and total municipal demands which will result from these rates of increase.

TABLE 27

MUNICIPAL WATER REQUIREMENTS
AND PER CAPITA WATER CONSUMPTION IN THE
WESTERN DELTA STUDY AREA1/
1960 to 2020 LEVELS OF DEVELOPMENT

Year	Per capita water consumption in gallons per capita per day	Population	Total municipal water requirement in acre-feet per year
1960	135	70,150	10,600
1970	150	107,000	18,000
1980	160	169,000	30,300
1990	170	250,000	47,600
2000	180	374,000	75,500
2010	190	533,000	113,700
2020	200	693,000	155,400

1/ Excludes Sacramento County.

The influence of price on per capita water consumption is somewhat confusing. As the price of metered water increase, the per capita water usage of water immediately decrease. With time, however, such per capita usage gradually increases. Eventually, it becomes greater than that which existed before the time of the price increase. In areas where the price of water is excessively high, however, the per capita use of water is low and tends to remain so.

In the western Delta study area, price was assumed to remain constant throughout the study period. Price would not, therefore, contribute to changes in demands for water.

Climate affects per capita water demands. Per capita water use in the Central Valley of California cannot be related to that of the San Francisco Bay area without consideration of the temperature and humidity differences between the two areas. Higher temperatures in the Central Valley result in more lawn sprinkling, greater use of bathing facilities, and overall higher water demands. Climate like price, will remain constant in the western Delta study area and therefore will not contribute to changes in demands for water.

The following assumptions regarding the year 2020 population densities and water requirements for specific communities in the portion of Contra Costa County within the western Delta study area were made: Pittsburg would attain the greatest population density; its water requirements would be 180 gallons per capita per day. Antioch, with a lower population density, would develop water requirements reaching 190 gallons per capita per day. The Oakley area, with a still lower population density, would require 195 gallons per capita per day. Lone Tree Valley, with the lowest population density, would develop the highest per capita use of water: 200 gallons per day.

In Solano County, Rio Vista was the only community in the western Delta study area for which the existing unit water per capita requirements could be determined. Because the existing population of Rio Vista is small, a projection based upon these requirements could not be justified. Therefore, development similar to that of Lone Tree Valley in Contra Costa County was assumed for Rio Rista per capita water requirements were assumed to be identical with those of Lone Tree Valley. Such requirements are similar to the existing and projected per capita water requirements for Fairfield in Solano County.1/

1/ Karrer and Stoddard. "Solano County, Water Resources and Requirements". December 1959.

The average unit water per capita requirements shown in Table 27 were applied to all other communities in the western Delta study area.

A typical ratio of high quality industrial water requirements to municipal water requirments might help in the projection of future requirements or at least help check those projections which are developed from different methods. Table 28 shows such ratios for the western Delta study area.

TABLE 28

RATIO OF INDUSTRIAL AND MUNICIPAL WATER REQUIREMENTS IN THE WESTERN DELTA STUDY AREA

Year	Industrial high quality water requirements in acre-feet/year	Municipal water requirements in acre-feet/year	Ratio of industrial to municipal water requirements
1960	31,400	10,600	2.96:1
1970	71,600	18,000	3.98:1
1980	129,300	30,300	4.28:1
1990	203,800	47,600	4.26:1
2000	299,400	75,500	3.96:1
2010	423,700	113,700	3.73:1
2020	579,200	155,400	3.72:1

The projected increase in these ratios from 1960 to 1980 depends on the establishment of an integrated steel mill. The location of the so-called satellite industries in the 1980-2020 period gradually counteract this increase. Factors related to base-service activity ratios discussed in Chapter II have a similar effect. A ratio of 3.7:1 would seem to be directly applicable to the western Delta study area.

Table 29 gives such ratios for similar areas in the United States and shows that the ratio of 3.7:1 compares favorably. The ratio computed for the western Delta study area ratio is less than those computed for more fully developed areas on the East Coast of the United States. Differences in climate explain this variation: the climate of the East Coast requires the residents to make less use of lawn sprinkling and air conditioning than do those of the West Coast.

TABLE 29

RATIOS OF INDUSTRIAL TO
MUNICIPAL WATER REQUIREMENTS IN
VARIOUS REGIONS OF THE UNITED STATES

Region	Ratios of industrial to municipal water requirements
Sacramento-San Joaquin River Delta	3.7:1
North Atlantic	5.1:1
Upper Hudson River	5.1:1
Lower Hudson River and coastal area	3.6:1
Chesapeake Bay	4.3:1
Eastern Great Lakes and St. Lawrence River	5.9:1
Delaware River	6.7:1

Agricultural Water Requirements

This report analyzed agricultural water requirements throughout the Sacramento-San Joaquin Delta. A proper estimate of the depletions of water from channels within the Delta, required an analysis of this extent. Such an estimate was important to the analysis of all proposed Delta water facilities. Furthermore, certain proposed facilities will affect the agricultural water supplies of nearly all the Delta lands. The design of works to alleviate these effects required extensive analysis of agricultural water requirements and irrigation practices.

Such analyses considered those factors of water quality which influence agricultural water quantity requirements, crop patterns, crop yields and other economic aspects. The system of works to supply high quality water to the lowlands within the western Delta study area, included in all alternative of the Delta Water Project, was based upon these economic aspects.

Irrigation Practices in the Delta

Prior to 1870, little irrigation was practiced on the 15,000 reclaimed acres of Delta land. Normal precipitation in conjunction with some ground water provided adequate water for the crops planted in time to benefit from the rainy season. As reclamation progressed, lowland portions of the Delta were irrigated by water piped from surrounding channels through innumerable siphons, or by that supplied, in a few locations, by pumping plants.

In those few locations of the Delta where soil type and uniformity of land surface permit, such surface irrigation continues to be practiced. The diversion rates vary with the elevation of the tidal channels. The sprinkler method of irrigation is used where special problems exist.

Increased seepage influenced the change to present water management practices. Such seepage is the result of subsidence and a decrease in peaty soil depths. The application of water to the land continues to be by surface contour or strip check methods or by subirrigation through a network of narrow, deep ditches. Consideration of drainage, however, has become an increasingly important factor.

Where subirrigation is employed in the Delta, water circulated through the network of ditches is held to a sufficiently high level to promote horizontal water movement and the subsequent capillary movement upward to the root zone. Because the duration of saturation of the complete root zone is critical to most crops,1/ a minimum of water is withdrawn from surrounding channels to attain the desired soil wetting. Excess water is returned to main island drains and then, by means of drainage pumping plants, pumped over the levee to the channels. Appropriate spacing of drain ditches controls subirrigation of these lands by controlling the elevation of the water table. Because of the high water table, some crops and some nonagricultural areas consume percolated water from Delta channels even though no diversions are made from them.

Water Quality Standards for Delta Agriculture

Water quality standards should serve as guides in selecting or evaluating a source of irrigation water. It should be possible to use such standards to evaluate in economic terms the chemical and physical effects of water on crop production. The effects of a lower quality water can result in a reduced agricultural crop yield, an increased quantity of water required to maintain salt balance, and an increased cost because of additional irrigation practices associated with salinity or permeability.

The following discussion will set forth certain basic principles related to the measurement of the physical and economic effects of water quality upon agriculture in the Delta.

1/ Byron T. Shaw, (Editor). "Soil Physical Conditions and Plant Growth", Agronomy Vol. 2. 1932.

James N. Luthin, (Editor). "Drainage of Agricultural Lands", Agronomy Vol. 7. 1957.

Water Quality Standards. A review of quality standards shows that in the past such standards stressed only the constituents of water. Later standards included the relation of water quality to plant tolerance and drainage conditions, and still later standards stressed the percentage ratio of key constituents such as sodium. Authorities on water quality recently have collaborated on a new set of irrigation water quality standards. These new standards consider three aspects of quality: (1) the effect of irrigation water on soil permeability; (2) the accumulation of salines in the soil profile; and (3) substances toxic to various plant species. These standards more realistically classify water used on the highly organic soils found in the Delta.

Influence of Water Quality on Delta Agriculture. In all seasons of the year, large flows of water are conveyed across the Delta from north to south. This present condition will continue into the future. Through dilution, these flows eliminate critical agricultural water quality problems from all but the southeastern and western portions of the Delta.

A water quality problem has arisen because of the use and reuse of San Joaquin River water before this water enters the southeastern portion of the Delta. Although this problem does not originate in the Delta, it does affect those Delta upland areas to which the water is diverted. Proposed Delta water facilities will not aggravate this problem. On the contrary, the facilities will alleviate the problem in varying degrees, depending upon the alternative project selected.

In the western portion of the Delta, the present salinity incursion from the upper San Francisco Bay system creates water quality problems which have resulted in decreased agricultural incomes, and necessitated changes in crop patterns. The physical and economic effect of these problems in the lowlands is, and will continue to be, different from the effect on the uplands. This difference occurs because the higher elevation of the uplands affords more effective drainage and because the water diverted for upland use contains less salt. Furthermore, the water supply for the western Delta uplands is diverted from natural channels upstream from the area of use. Such upstream diversion reduces the effect of salinity incursion on agriculture more than does diversion to an area of use at channel-side.

The Effects of Salinity Incursion on Delta Upland Water Requirements. The application of water specifically for leaching is not practiced generally within the upland portion of the study area. In areas where indications of salinity exist, an excess application of irrigation water has remedied the problem. Areas where salinity accumulation has proved difficult to remedy are associated generally with local drainage characteristics or inadequate drainage.1/

In some water service districts, measurement has been made of the combined amount of water used for normal and excess irrigation. Some of these districts purposely pump from ground water to control the water level and to effect satisfactory drainage. In 1958, East Contra Costa Irrigation District, for example, diverted 26,000 acre-feet from Delta channels to serve 15,800 acres. The district also pumped an additional 3,200 acre-feet from ground water. Considered on the basis of the total area of the Delta, excess application of water does not change the water requirements. Nevertheless, salts leached in the process do affect the quality of supply to other lands. Except

1/ California State Department of Water Resources. "Lower San Joaquin Valley Water Quality Investigation", Bulletin No. 89, December 1959.

from organized districts, relatively little information is available concerning the quantities of applied water. The gross diversion for the upland area computed for 1955 was 398,000 acre-feet. The portion of this intended for excess application is unknown.

Plate 18, "Irrigation Water Quality and Leaching Requirements Relationship", shows the relationship of excess or leaching water to quality of irrigation water[1/] and permissable soil salinity. This relationship is fundamental and can, within drainage limitations, be applied to any area. For the sake of simplicity, the chemical reaction which ignores base exchange between constitutents is ignored. Under present conditions in the uplands of the western Delta study area, the estimated quantity of water which should be applied for leaching does not exceed ten percent.

Effects of Salinity Incursion on Delta Lowland Water Requirements. Delta lowland farm operators and county farm advisors state that the application of sufficient excess water to maintain a favorable salt balance during the growing season seldom is practical in the western Delta lowlands. Too frequent excess application results in excess root zone saturation. Under Delta conditions of high water table and slow soil moisture movement such excess saturation results in a partial crop loss. Consequently, farm operators leach annually during months of no crops--generally December or January--when such leaching does not interfere with crop rotation. Neither published literature nor conferences with cooperating agencies and farm operators involved in the western Delta indicate a well-established method to determine the relationship of the salinity of irrigation waters to that of soils, leaching requirements, or leaching effectiveness on Delta lowlands. The decision to leach or

1/ California State Department of Water Resources, "Lower San Joaquin Valley Water Quality Investigation", Bulletin No. 89, December 1959.

not to leach has been a matter of judgment, guided by the observance of the farm operator of the yield of his previous crop. A year of exceptionally high rainfall may change the planned sequence of leaching.

At the beginning of studies in 1957, the acceptable salinity concentration of water used to irrigate crops in the western Delta lowlands without detrimental effects could not be clearly defined. Representatives of federal and state agencies and consultants on water quality were not in full accord. Lacking information, farm operators and diverters did not accept fully any recommendations. The following published statements indicate the opinions at that time of representatives of public entities involved in evaluating water quality effects on Delta agriculture.

1. California State Department of Public Works, Division of Water Resources

A. "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay". Bulletin No. 27, pg. 55. 1931:

> "Although it is difficult to set an exact limit, it has been assumed for average conditions in the delta that water having in excess of 100 parts of chlorine per 100,000 parts of water" (1,000 parts per million) "is not suitable for irrigation use."

B. "Water Quality and Waste Disposal, Appendix F of Report to the Water Project Authority of the State of California on Feasibility of Construction by the State of Barriers in the San Francisco Bay System." Page 13. June 1955:

> "Qualitative classifications of irrigation waters ... injurious to unsatisfactory ... over 355 parts per million chlorides."

2. U. S. Department of the Interior, Bureau of Reclamation

A. "Central Valley Project Studies". Page 3. 1947:

> "For agricultural use with average conditions and crops in the Delta, it has been assumed that water having a salinity of over 100 parts of more of chlorine per 100,000 parts of water" (1,000 parts per million) "would not be suitable for irrigation."

3. Sacramento-San Joaquin River Problems Conference, 1924

Mr. Thomas L. Means, Consulting Engineer of San Francisco and an authority on saline conditions:

"Under average conditions such as exist over the Delta and upper Bay region generally, water containing less than 100 parts saline matter per 100,000 parts" (1,000 parts per million) "of water is safe for use, ... above 200 parts" (per 100,000) "its use is unsafe."

4. Sherman Island, Sacramento County, California

Mr. Rossini, Reclamation District 341: 1955:

"Irrigation is generally stopped when the chloride content of the irrigation water reaches 500 parts per million parts water. Delta experiments with 1,000 parts per million water resulted in detrimental effect on the following year's crop."

5. Jersey Island, Contra Costa County

Mr. Halsey, Owner-operator, 1955:

"... irrigation water with more than 500 ppm chlorides will cause excessive salt conditions in the soil."

The lack of accord on usable salinity concentrations apparently resulted from failure to establish a basis for comparison. Areas long and successfully engaged in irrigation practices have used water with salinities higher than those suggested as feasible for the western Delta. Conversely, other areas using irrigation water with salinities lower than those suggested for the study area are having severe problems. The hydraulic conductivity of the soil and the ability to provide sufficient drainage to remove excess water are inseparable parts of the problem. The effects of salinity usually are recognized and measured by plant response and crop yields. Chapter IV presents salinity and crop yield relationships.

Present Agricultural Water Quantity Requirements

Tabulations of water use and water requirements, presented in the "Report of Sacramento-San Joaquin Water Supervision" for 1955, for all irrigated areas within the Central Valley of California except the Delta, appear as diverted quantities. For the Delta the use is tabulated as consumptive use. Such consumptive use is derived by multiplying the estimated acreages of specific crops by the appropriate unit consumptive use. Irrigation practices and the geologic complexities of the Delta subsoils have made it impossible--within the scope of this investigation--to determine water utilization directly from diversion measurements except in the case of a few scattered locations on the perimeter of the Delta.

Unit Consumptive Use Factors for the Delta. Table 30 presents the monthly units of consumptive use in acre-feet per acre for crops, vegetation, and evaporation from water surfaces in the Delta. Such units of consumptive use represent the amounts of water consumed, irrespective of source, and include amounts consumed from rainfall. The unit consumptive use factors presented in Table 30 were developed from extensive experimental investigations conducted in the Delta in 1924. They are essentially the same as those appearing in the Division of Water Resources Bulletin No. 27, and in numerous subsequent reports. For the period following 1924, the unit values have been updated to include data from several reports. These reports include "Rates of Evaporation and Consumptive Use in the San Franciso Bay and Adjacent Areas" by Dean C. Muckel and Harry F. Blaney of the U. S. Agricultural Research Service, 1938, and "Determining Water Requirements in Irrigated Areas from Climatological Data" by Harry F. Blaney and Wayne D. Criddle, U. S. Department of Agriculture, 1950. The figures shown apply to the Delta. They do not

TABLE 30

UNIT CONSUMPTIVE USE OF WATER [1/]
IN THE
SACRAMENTO-SAN JOAQUIN DELTA

In acre-feet per acre

Classification	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Pasture													
Sudan	.05	.05	.10	.10	.15	.30	.30	.25	.20	.10	.10	.10	1.8
Miscellaneous	.05	.10	.15	.40	.50	.65	.70	.70	.50	.20	.10	.10	4.2
Alfalfa	.06	.08	.10	.30	.40	.50	.65	.55	.50	.20	.10	.07	3.51
Rice	.05	.05	.10	.15	.90	1.15	1.25	1.20	.35	.09	.10	.10	5.49
Field Crops													
Beans	.06	.08	.08	.16	.20	.14	.24	.58	.37	.09	.07	.05	2.12
Corn and Milo	.04	.04	.04	.08	.10	.24	.70	.60	.40	.10	.10	.07	2.51
Grain and Hay	.04	.04	.07	.40	.60	.30	.14	.23	.21	.14	.07	.05	2.29
Peas	.10	.10	.20	.30	.10	.05	.14	.13	.11	.09	.10	.10	1.47
Safflower	.05	.05	.10	.30	.40	.50	.20	.13	.11	.09	.10	.10	2.13
Sunflower	.05	.05	.10	.30	.40	.50	.20	.13	.11	.09	.10	.10	2.13
Sugar Beets	.06	.08	.08	.13	.32	.51	.61	.53	.20	.13	.10	.07	2.82
Truck Crops													
Asparagas	.05	.05	.05	.05	.08	.14	.40	.68	.55	.42	.12	.10	2.69
Celery	.04	.04	.04	.08	.10	.10	.10	.20	.25	.30	.20	.05	1.50
Onions	.04	.04	.08	.13	.27	.49	.43	.20	.16	.13	.10	.07	2.14
Potatoes	.06	.08	.08	.16	.15	.38	.52	.30	.15	.09	.07	.05	2.09
Tomatoes	.05	.05	.10	.10	.10	.25	.35	.60	.45	.35	.10	.10	2.60
Seed and Misc	.06	.08	.08	.10	.25	.50	.50	.50	.35	.10	.10	.07	2.69
Fruit and Nuts	.04	.04	.04	.18	.32	.50	.57	.40	.23	.07	.07	.05	2.51
Grapes	.04	.09	.04	.09	.20	.35	.50	.35	.22	.05	.07	.05	2.05
Native Vegetation													
Lush	.12	.14	.21	.31	.40	.59	.68	.57	.39	.29	.20	.12	4.02
Medium	.12	.16	.22	.28	.31	.40	.45	.38	.28	.24	.19	.13	3.16
Dry	.13	.17	.23	.24	.22	.21	.22	.20	.17	.18	.18	.14	2.29
Fallow and Bare	.04	.04	.04	.08	.10	.13	.14	.13	.11	.09	.07	.05	1.02
Idle Crop Land	.06	.08	.08	.16	.20	.26	.28	.24	.16	.13	.10	.07	1.82
Duck Ponds	.05	.05	.10	.10	.10	.05	.14	.13	.60	.60	.30	.10	2.27
Urban	.06	.08	.08	.16	.20	.20	.21	.20	.16	.13	.07	.05	1.65
Tule and Swamp	.13	.18	.34	.51	.70	.79	.87	.77	.64	.49	.27	.13	5.84
Levee and Berm	.10	.10	.15	.20	.25	.30	.35	.35	.30	.20	.10	.10	2.50
Water Surface	.06	.10	.20	.33	.50	.58	.65	.57	.44	.27	.12	.06	3.88

1/ Copied from Department of Water Resources Bulletin: "Sacramento River and Sacramento-San Joaquin Delta, Trial Water Distribution, 1955". January 1956.

necessarily agree with unit consumptive use factors determined for other areas in the Central Valley. Unit consumptive use may vary from year to year for the same crop. Such variance results from conditions of temperature, precipitation, humidity, wind, soil, topography, sunlight, availability of water, and farming and irrigation practices. The unit consumptive use factors in Table 30 are those which occur under average Delta conditions.

Present Consumptive Use of Agricultural Water in the Delta. The present consumptive use of agricultural water in the Delta, regardless of source, is based upon estimated agricultural land use discussed in Chapter II. Table 31 presents a summary of consumptive use for each of the seven Delta counties. The average unit consumptive use for the agricultural lands of the entire Delta is 3.06 acre-feet per acre per year.

Evaluation of Channel Diversion For Delta Agriculture. It has not been possible to measure the quantities of water diverted from the Delta channels through the numerous pumps and siphons. Even if such quantities were measured, however, the true channel diversions would not be known because such diversions are composed of relatively unmeasurable subsurface inflow (seepage) as well as those diversions controlled by man.

Computed consumptive use, adjusted for effective precipitation, provides an acceptable evaluation of the net channel diversions for the entire Delta on an annual basis. When an island or island-group of the Delta is considered separately, however, all of the following factors must be considered: (1) irrigation efficiency; (2) effective precipitation; (3) applied irrigation water; and (4) subsurface inflow. Periods less than one year require consideration also of the factors of soil moisture change and drainage disposal. In addition, adequate consideration of the differences in irrigation practies between the upland and lowland portions of the Delta must be made.

TABLE 31

COMPUTED CONSUMPTIVE USE OF AGRICULTURAL WATER IN THE SACRAMENTO-SAN JOAQUIN DELTA[1/]
1960

County	Consumptive Use in Acre-Feet
Alameda	13,000
Contra Costa	237,000
Sacramento	294,000
San Joaquin	840,000
Solano	230,000
Stanislaus	nil
Yolo	244,000
TOTAL	1,858,000

1/ Values include effective precipitation and **evapotranspiration** use of subsurface inflow from natural channels. Uses by urban areas and 310,000 acre-feet by nonagricultural waste land or water surface areas located throughout the Delta are excluded.

1. Irrigation Efficiency of the Delta. The natural channels of the Delta are used almost universally both for supply and for drainage. The opportunity for repeated use of the water flowing through such channels results in a very high irrigation efficiency for the Delta as a unit. In fact, when surplus flows are small, the efficiency approaches 100 percent. Considered separately, the Delta upland service area does not have the same high degree of irrigation efficiency as the Delta lowland. In 1955, as reported in the Sacramento-San Joaquin Water Supervision, Delta upland diversions were 398,000 acre-feet, while the computed consumptive use for the same area was 441,000 acre-feet.

The area in question contained about 180,000 acres of agricultural land. If the effective precipitation in that portion of the Delta was 0.9 acre-feet per acre per year and the subsurface inflow was assumed to be zero, the computed irrigation efficiency would be 80 percent.

When island-groups within the Delta are considered separately, as proposed in variations of the Delta Water Project, quality limits and the opportunity for use and reuse must be considered. In the Delta, the term "irrigation efficiency" does not possess the significance it has when applied to other standard water service projects.

2. Effective Precipitation. Effective precipitation is that portion of precipitation that is available for **evapotranspiration**. It is numerically equal to the reduction in applied water necessary to meet the consumptive needs of a specific crop. Because effective precipitation is based upon total annual precipitation, monthly distribution, specific crops grown, and water-holding capacity of the soil, the value varies from one portion of the Delta to another. The "Factual Report for the Solano Irrigation District", prepared by the U. S. Bureau of Reclamation in 1950, contains a derived weighted mean effective precipitation of 0.6 feet of depth. The report on "Solano County Water Resources" by Stoddard and Karrer and dated December 1959 derived a weighted mean effective precipitation of 0.67 feet of depth. The U. S. Bureau of Reclamation feasibility report on "Folsom South Unit" dated January 1959, indicates effective precipitation of about 0.9 feet of depth. The California State Department of Water Resources Bulletin No. 2, "Water Utilization and Requirements of California", dated June 1955, reports a value of 0.9- to 1.1 feet of depth for effective precipitation for the Sacramento-San Joaquin Delta.

The Delta encompasses in area having a long-term mean annual precipitation ranging from approximately 9 inches in the southern portion to 18 inches in the northern portion, and having a weighted mean of about 15 inches. A weighted mean effective precipitation for the several precipitation zones could be derived under the present crop pattern criteria.

The projected intensity of land use to year 2020 (Plate 9) will increase the opportunity for greater use of precipitation. For the purposes of the studies encompassed in this report, an effective depth of precipitation of one foot was used for the entire Delta.

3. Applied Irrigation Water. The results of an investigation conducted by the Department of Water Resources within the Delta area in 1954-55 are contained in the report entitled "Quantity and Quality of Water Applied to and Drained from Delta Lowlands". In this investigation, the weighted mean diversions for each of the eight major crops of the Delta were derived indirectly by measurement of drain pump discharges, precipitation, consumptive use, and periodic diversion measurements at selected representative fields. Variations in diversions of greater than 100 percent were encountered for the same crop under conditions of varying location and management. Table 32, reproduced from the above report, contains the mean values of applied water for eight major crops on three soil classes under Delta field conditions. Statistics used in the preparation of Table 32 were collected under conditions which reflected changes in the volume of applied water which resulted from variations in seepage or capillary moisture rather than from the effects of salinity incursion.

4. Subsurface Inflow. The variation in subsurface inflow from island to island contributes greatly to the wide variation in the application of irrigation water practiced in the Delta. Differences in subsoils and soil

TABLE 32

IRRIGATION SEASONAL USE OF APPLIED WATER - DELTA LOWLANDS - 1954 1/

Crop	Irrigated Area in Acres				Seasonal Applied Water Acre-feet/acre			Seasonal Applied Water Acre-feet			
	North Mineral Soils	Middle Organic Soils	South Mineral Soils	Total	North Mineral Soils	Middle Organic Soils	South Mineral Soils	North Mineral Soils	Middle Organic Soils	South Mineral Soils	Total for Delta & Lowlands
Asparagus	6,878	53,096	20,351	80,325	0.7	1.4	0.7	4,820	74,330	14,250	93,400
Corn	13,681	30,342	3,534	47,557	1.5	3.6	1.5	20,520	109,230	5,300	135,050
Alfalfa	14,081	9,478	10,922	34,481	2.3	2.3	4.2	32,390	21,800	45.870	100,060
Sugar Beets	20,514	8,573	1,094	30,181	1.9	3.3	3.7	38,980	28,290	4,050	71,320
Tomatoes	13,284	9,899	6,916	30,099	2.5	3.4	2.6	33,210	33,660	17,980	84,850
Pasture	13,266	2,887	6,844	22,997	3.9	3.9	4.8	51,740	11,260	32,850	95,850
Milo	8,189	10,194	2,589	20,972	1.0	1.0	1.0	8,190	10,190	2,590	20,970
All other crops	17,403	5,041	2,611	25,055	2.1	2.3	2.4	36,550	11,590	6,270	54,410
Total	107,296	129,510	54,861	291,667				226,400	300,350	129,160	655,910
Weighted average acre-feet per acre								2.11	2.32	2.35	2.25

1/ Copied from Department of Water Resources Bulletin: "Investigation of the Sacramento-San Joaquin Delta Report No. 4, Quantity and Quality of Waters Applied To and Drained From the Delta Lowlands".

profiles influence the quantity of subsurface inflow from natural channels into land surfaces below sea level. Large tracts of certain islands within the Delta, for example, depend entirely upon subsurface inflows to supply even the high summer water requirements of corn. Preliminary studies based upon limited data collected in 1954 and 1955 show that subsurface inflows among 15 islands in the central portion of the Delta varied from 1.4 to 6.3 acre-feet per acre per year.

Regardless of which variation of the Delta Water Project is adopted, the increase in basin development and water use will result in a somewhat greater degree of saline incursion than presently experienced in the natural channels of the western Delta. The presence of more saline waters in these channels has prompted consideration of supplemental water supply facilities to replace present water supplies obtained from subsurface inflow and direct diversion. Subsurface inflow of relatively higher saline waters will continue under proposed project operation. The effect of such inflow upon agriculture should be evaluated. The problem prompted a study under the auspices of the Water Resources Center, University of California and directed by Dr. David Todd of the university and Dr. Gerard de Josselin de Jong of the Delta Soils Laboratories in The Netherlands. The initial study, of a theoretical nature, developed the concept of flow patterns resulting from dual liquid systems--saline subsurface inflow and nonsaline applied surface water--in typical Delta substratas. Dr. de Jong reported on this subject in "Vortex Theory of Multiple Phase Flow Through Porous Media", September 1959. The analysis method could not be adopted easily to the solution of the field problem because of the lack of information concerning the nonhomogeneous substrata of the Delta.

In "Flow Problems Connected with Irrigation and Drainage", a paper dealing with a similar problem in other areas, Dr. J. J. Van Deemter of The

Netherlands developed a solution which showed graphically the flow lines representative of typical Delta lowland conditions. Plate19, "Schematic Flow Diagram of Irrigation and Subsurface Inflow Under Delta Field Conditions", is from this source. Plate19 contributes toward the understanding of the problem. The nonhomogenous nature of Delta soil profiles and lack of adequate data, however, limit the usefulness of this approach to theoretical analysis.

"River Seepage Investigations", September 1959, a report by David K. Todd, authorized by the Water Resources Center, University of California, analyzes seepage conditions in the Delta. This report evaluates potential flows through 56 typical cross sections of channels and adjacent lands. An electric analog program aided the quantitiative analysis. The model cross sections are typical of those found in the northern half of the Delta lowlands and much of the perimeter uplands.

Information concerning "Land Drainage in Relation to Soils and Crops" appears in the book, Drainage of Agricultural Lands published in 1957 by the American Society of Agromony. James N. Luthin edited this book. The book discusses the many factors pertinent to irrigation practices which Delta conditions require. Such factors lie beyond the scope of this office report. They are used, however, in determining certain water quality and quantity limitations which appear in this report.

The Department of Water Resources currently is measuring all quantities of water supply and disposal on Twitchell Island. All diversions, drain discharges, crop patterns and ground coverage, precipitation and weather factors, and changes in soil moisture in the root zone are beingrecorded. The extensively instrumented measurements should aid in refining (1) the subsurface inflow quantities; (2) the unit consumptive use factors; (3) the regimen of seasonal soil moisture changes; and (4) applied water requirements for major Delta crops. The results will aid in theoretical analyses and in correlating the presently available limited measurements for the total Delta. Both computations will improve materially the computations for future Delta water requirements.

Future Intensity of Irrigation

The projected intensity of Delta irrigation requirements, developed in Chapter II, is shown on Plate 10. The demand for land and water use are based upon the projected demand for agricultural products. The acreages of specific crops needed relative to production demand are adjusted for factors of yield and technology. The water requirement of some crops grown in rotation practices under more intensive cropping might be less than that for growing a single crop in one year. However, less of the effective precipitation would be available for any one crop. Thus the unit consumptive use factors derived for single crops are considered applicable for use in the Delta under future conditions. Technological advances are assumed to cope with problems of seepage associated with continued land subsidence which might otherwise modify intensity of cropping in the Delta. For ease of computation, intensity has been expressed as an index varying from 1.0 in 1955, to 1.3 in 1990, and continuing constant to 2020. Table 33 shows this index.

TABLE 33

PROJECTED UNIT CONSUMPTIVE USE
OF AGRICULTURAL WATER
IN THE SACRAMENTO-SAN JOAQUIN DELTA

Year	Intensity Index	Annual consumptive use, acre-feet/acre
1955	1.00	2.81 1/
1960	1.09	3.06
1970	1.22	3.43
1980	1.27	3.57
1990	1.30	3.65
2000	1.30	3.65
2010	1.30	3.65
2020	1.30	3.65

1/ Derived from agricultural consumptive use in the Delta as presented in Department of Water Resources Bulletin No. 23-55, "Report of Sacramento-San Joaquin Water Supervision for 1955"

Future Delta Crop Acreages

Future crop acreages and specific crops were assumed generally to follow the present pattern, although replacement water facilities in the western Delta will alleviate the adverse effects of salinity incursion and will allow a change to less salt-tolerant crops. However, only five to ten percent of the total Delta area would be influenced by this change. Table 34 shows the percentage of each type of crop in the Delta under future conditions.

TABLE 34

PROJECTED FUTURE DISTRIBUTION OF AGRICULTURAL CROPS
IN THE SACRAMENTO-SAN JOAQUIN DELTA

Type of Crop	Percentage of total Delta agricultural land
Field	39
Forage	22
Truck	24
Fruit and nut	4
Miscellaneous and other crops	11
TOTAL	100

Future Consumptive Use of Agricultural Water in the Delta. The projected annual consumptive use of water by agriculture will bear a direct relation to the intensity of agricultural cropping. A significant change in unit consumptive use of the crops within the projected crop pattern is not expected. Technological advances in equipment and in methods of irrigation will improve irrigation efficiency but would not affect the basic consumptive use.1/ The average annual consumptive use in acre-feet per acre of agricultural water for the Delta was derived from data compiled in the Sacramento-San Joaquin Water Supervision report for 1955. Future values were based upon the 1955 values and were directly related to the intensity of irrigation as shown in Table 33. The projected unit annual consumptive use was multiplied by the lands remaining in agriculture and adjusted for effective precipitation to derive the values shown in Table 35.

1/ California State Department of Water Resources, Engineering Service Branch, Economics Unit. "Increase in Water Demands, Sacramento-San Joaquin River Delta Drainage Area, 1960-2020". November 1958.

TABLE 35

PROJECTED ANNUAL CONSUMPTIVE USE
OF APPLIED AGRICULTURAL WATER
IN THE SACRAMENTO-SAN JOAQUIN DELTA
(Thousands of acre-feet/year)

Year	Delta Lowland	Delta Upland	Total
1960	798	454	1,250
1970	939	528	1,467
1980	993	549	1,542
1990	1,025	559	1,584
2000	1,025	550	1,575
2010	1,025	535	1,560
2020	1,025	518	1,543

The values exclude effective precipitation and subsurface inflow from natural channels. The consumptive use of 310,000 acre-feet of water by vegetation on levees, berms or similar areas and evaporation from water surfaces interspersed among agricultural lands has been also excluded.

Future Delta Channel Diversions

The future increase in net channel diversions is assumed to be in proportion to the annual increase in consumptive use of agricultural water for the Delta. The diversions for the western Delta study area may occur at locations upstream from the point of use. Such diversions may occur in greater quantities because of moderate salinity and leaching requirements, but will not influence net annual diversions because the excess will be returned to the natural channels. The existing monthly distribution is shown in Table 36.

TABLE 36

PRESENT MONTHLY DISTRIBUTION OF CONSUMPTIVE USE OF AGRICULTURAL WATER IN THE SACRAMENTO-SAN JOAQUIN DELTA

Month	Percent of Annual
January	2.0
February	2.4
March	3.2
April	7.7
May	10.8
June	12.5
July	16.7
August	17.8
September	13.1
October	7.2
November	3.7
December	2.9
TOTAL	100.0

CHAPTER IV. WATER SUPPLIES OF THE DELTA

The problems of water supply in the Delta generally are related to quality. Adequate quantities of water always have been available but because of salinity incursion, upstream water quality deterioration, and insufficient channel flushing during periods of low outflows, the quality of these supplies has often deteriorated. For these reasons, all discussions of Delta water supply must be considered in terms of quality as well as quantity.

The solution of water quality problems in the Delta always has depended upon the construction of supplemental water supply facilities. These facilities include reservoirs upstream from the Delta which store winter runoff for release during the summer and fall months, and supplemental supply facilities which divert water from channels with high quality supplies to serve areas within the western Delta. Future solution of water quality problems in the Delta depends upon construction of additional facilities, regardless of the manner in which State Water Facilities are operated. The justification for additional water supply facilities in the Delta depends to a large degree upon the economical aspects of water quality in terms of industrial and agricultural water utilization. This chapter discusses ways to measure such economic aspects.

Delta Water Supplies--Past, Present, and Future

The water supplies available to the Delta derive from precipitation, ground water, and surface water. The latter provides the most important source of supply. Precipitation is also of importance, particularly to agriculture. The importance of ground water is diminishing because of its deterioration in quality.

Precipitation

Precipitation in the Delta approaches a long-term average of nearly one million acre-feet per year. The effective use of this water, however, is limited primarily to agriculture. Precipitation makes small contributions to ground water basins, but the use of such water is limited. Delta topography renders impractical any overall collection of runoff from local precipitation, although such runoff is used in scattered areas.

Most precipitation falls on the Delta when it is least needed to satisfy the requirements of agriculture. Therefore, only that precipitation which can be stored in the soil long enough for plant use can be considered to be effective. The remaining precipitation either cannot be so stored or falls upon open water surfaces. Such precipitation contributes only to an increased outflow from the Delta. The value of this increased outflow as an aid to the flushing and control of saline waters is not significant under present conditions. Under future conditions of long-term minimum outflows (proposed by certain Delta projects) this water may provide significant salinity protection.

Table 37 shows the average monthly precipitation during a 20-year period for several representative Delta stations.

Ground Water

In the past, surface water and ground water in the Delta lowlands comprised one continuous body of water. In more recent times, the exclusion of surface water by levees has allowed reclamation of the Delta swamp lands. Land subsidence has accompanied such reclamation. Together, reclamation and land subsidence have created a geography in which most Delta lowland areas require continuous control of ground water seepage to prevent inundation.

TABLE 37

PRECIPITATION RECORDS IN THE VICINITY OF THE SACRAMENTO-SAN JOAQUIN DELTA
(20-year average)

Month	Inches of precipitation at station locations			
	Sacramento	Stockton	Rio Vista	Brentwood
July	0.00	0.01	0.00	0.01
August	0.02	0.01	0.01	0.01
September	0.22	0.21	0.18	0.16
October	0.79	0.60	0.60	0.47
November	1.67	1.31	1.40	1.10
December	3.48	2.68	2.97	2.60
January	3.87	3.04	3.29	2.62
February	3.31	2.34	2.69	2.08
March	2.59	2.11	2.19	1.62
April	1.32	1.00	1.03	0.74
May	0.59	0.53	0.43	0.33
June	0.19	0.12	0.14	0.13
TOTAL	18.05	13.96	14.93	11.87

Under such conditions the extraction of water for agricultural purposes is neither necessary nor extensively practiced in the Delta lowlands. Limited extraction is practiced in the Delta uplands. Records, compiled in 1955, indicate that 1.4 percent of the Delta agricultural lands were irrigated by water extracted from wells.

In many areas of the Delta, domestic wells drilled to depths of 200 to 400 feet have continuously extracted water containing less than 50 parts per million chloride ions. The importance of these wells in meeting the domestic water requirements of the agriculture economy should not be overlooked.

In addition, certain municipalities on the perimeter of the Delta continue to use wells. Municipalities which are using ground water include: Rio Vista, Isleton, Tracy, Walnut Grove, and Stockton. In most cases the ground waters in these areas require neither filtration nor chlorination. In the western Delta, however, Pittsburg and Antioch have limited the extraction of ground water because of intrusion of saline water from offshore channels. Other areas in the western Delta are also affected by quality deterioration of ground water supplies.

Table 38 shows the typical quality of ground water supplies in certain areas of the Delta.

TABLE 38

QUALITY OF GROUND WATER SUPPLIES IN THE DELTA
(Concentration in parts per million)

Constituent	Tracy	Antioch	Pittsburg
Bicarbonate	224	333	338
Calcium	84	34	80
Chloride	190	243	267
Magnesium	32	80	59
Sulfate	143	134	148
Total Hardness	340	416	444
Boron	0.59	0.56	0.63
Total Dissolved Solids	730	907	974
Date of Sample	July 18, 1958	July 8, 1959	July 8, 1959

Surface Water

The Sacramento-San Joaquin River system is the primary source of surface water for most areas of the Delta. Surface water resulting from local runoff is limited and does not present extensive opportunity for use because of the lack of suitable reservoir storage sites.

Prior to upstream developments, surface water flowed through the Delta in vast quantities. These flows, however, were highly seasonal and not to be depended upon. When the natural flows of the Sacramento and San Joaquin Rivers were small, the quality of water within the Delta was reduced by the incursion of sea water from San Francisco Bay. Plate 20, "Present and Future Salinity Conditions in the Western Sacramento-San Joaquin Delta", shows the monthly distributions of the availability of quality water in the western Delta under natural conditions. These distributions are based upon data contained in the appendix report to Bulletin No. 76, "Salinity Incursion and Water Resources"

The development of areas upstream from the Delta depleted the water supplies which under natural conditions flowed through the Delta. As such depletions increased, the degree of saline water incursion into the Delta also increased and the quality of the water supply in the natural channels of the Delta degenerated. Plate 21, "Historical Salinity Incursion, Sacramento-San Joaquin Delta", shows the extent of such incursion on specific dates.

In 1943, operation began of the Central Valley Project of the U.S. Bureau of Reclamation. This project altered considerably the regimen of the water supply of the Delta. Upstream storage of the projects Shasta, Folsom, and Friant Reservoirs and the diversion of water from the Sacramento and

San Joaquin River Basins to project service areas reduces natural outflows from the Delta during certain times of the year. The Central Valley Project does provide a degree of salinity control to a large portion of the Delta, however. This control occurs during periods when the natural outflow from the Delta would be relatively small. At such times releases from project storage are required to maintain satisfactory water quality at the diversion pumping plants of the Central Valley Project.

Net results of such changes in Delta water supply are difficult to measure. Operation of the Central Valley Project has reduced the threat of salinity incursion to a large portion of the Delta. Plate 21 shows that the extent of maximum salinity incursion has decreased since 1943. Since 1943, however, increasing demands on the Central Valley Project have reduced the availability to the Delta of the surplus waters the project provides. The satisfaction of such increasing demands has reduced the availability of quality waters at Antioch to nearly pre-1943 levels.

Under present conditions, water quality problems affect limited areas of the Delta. Some of these problems result from pollution and insufficient dilution of irrigation drainage water. Insufficient dilution of **drainage waters affects Delta water supplies throughout the southern and western portion o**f the Delta. In the San Joaquin River, for example, reduced outflows caused by upstream storage and diversions often are insufficient to dilute adequately the waste waters which drain into the San Joaquin River. Other water quality problems directly or indirectly relate to salinity incursion. Direct effects of salinity incursion are apparent in the western Delta study area. Here, such incursion has reduced the quality of river channel waters to the extent that municipalities and certain industries utilize supplemental water supply systems. Salinity incursions have reduced crop yields or have forced farmers to switch to more salt-tolerant but lower net income crops. Salinity incursion affects the quality of Contra Costa Canal water supplies during the transfer of water from the Sacramento River system through the Delta to the Tracy Pumping Plant. Such quality deterioration occurs through mixture with saline waters.

Three factors will affect future surface water supply in the Delta: upstream depletions, the Central Valley Project, and proposed State Water Facilities. A discussion of these factors follows.

Additional storage reservoirs in the Sacramento River basin, operated to meet diversions in the reservoir service areas, will continue to cause depletions of the Delta surface water supply and will tend to reduce the availability of quality water in the western Delta. Such depletions probably will more than double by the year 2020. Plate 20 illustrates the magnitude of this effect in terms of monthly availability.

Future operations of the Central Valley Project also will cause additional depletions to the Delta surface water supply. Increased demands upon the project, only partially met by importations from river basins beyond the Central Valley, will reduce the availability of quality water to the western Delta. Despite such depletions, the Central Valley Project would in the absence of State Water Facilities continue to provide a high degree of protection from salinity incursion to the portions of the Delta presently protected. However, continued degradation of the quality of water supplies in the southern half of the Delta could be anticipated to result from inadequate dilution of Delta and San Joaquin River drainage water and mixture with saline waters in the course of transfer through the Delta.

Operation of the State Water Facilities also will affect western Delta surface water supplies detrimentally. One such detriment will be the decreased availability of quality water in the river channels of the western Delta. This decrease will be caused by upstream regulation and diversions from the Delta to the San Luis Reservoir, and the Southern California aqueduct system. Another detriment will be the increased salinity incursion which will result from decreases in salinity control outflows. The construction and operation of replacement water supply facilities, however, will compensate for all such detrimental effects. Such facilities are designed to provide all areas of the Delta affected by salinity incursion with high quality water in sufficient quantity to meet foreseeable demands. Such replacemnt water supply facilities also will overcome the detrimental effects caused by increased upstream depletions and Central Valley operations. Chapter V describes these replacement water supply facilities in detail.

Surface water quality in the channels of the southern portion of the Delta also will improve considerably as a result of construction of the Delta Water Project and the operation of State Water Facilities. Drainage waters will be routed so that they are more adequately diluted by the high quality water transported through the Delta and the quality of this transported water will be better protected from salinity incursion. Also, construction of the San Joaquin Valley drain will reduce drainage problems occurring on the San Joaquin River.

Studies were made to assess physical responsibility for detriments to the Delta water supply created by increased upstream consumptive uses and operation of the Central Valley Project and State Water Facilities. A companion office report, "Economic Aspects", summarizes these studies. Tables 39 and 40 summarize the results of these studies.

TABLE 39

NET ANNUAL DEPLETIONS OF THE DELTA WATER SUPPLY[1/]

(Millions of acre-feet per year)

Level of development	State	Federal	Upstream depletions	Total
Natural	0.0	0.0	0.0	0.0
1900	0.0	0.0	1.1	1.1
1920	0.0	0.0	3.1	3.1
1940	0.0	0.0	5.8	5.8
1960	0.0	5.4	3.6[2/]	9.0
1980	2.5	6.8	5.6	14.9
2000	1.6	8.7	6.8	17.1
2020	3.1	8.8	8.3	20.2

1/ Yield minus import to the basin.
2/ Decrease from 1940 due to incorporation of areas into Central Valley Project service area. Demands are therefore included in the "Federal" column.

Water Quality Considerations

Water quality is a critical factor in evaluating the relative merits of water supplies and water supply facilities. Delta water facility planning included a detailed evaluation of the physical and economic advantages of the present and future quality of water supplies of certain Delta areas. The evaluation was made in terms of the two major uses of water in the Delta--agricultural, and industrial. Because of difficulties in relating economic advantages to individual consumer habits no numeric evaluation was made in terms of municipal water use.

TABLE 40

PHYSICAL RESPONSIBILITY FOR SALINITY INCURSION AT ANTIOCH

(Units = shortage of quality water at Antioch in percent of time)

Level of Development	State		Federal		Upstream depletions		Natural deficiency		Total	
	350 ppm	1,000 ppm	350 ppm	1,000 ppm	350 ppm	1,000 ppm	350 ppm	1,000 ppm	350 ppm	1,000 ppm
Natural	0.0	0	0.0	0	0.0	0.0	12	3	12.0	3.0
1900	0.0	0	0.0	0	6.0	6.5	12	3	18.0	9.5
1920	0.0	0	0.0	0	16.0	19.0	12	3	28.0	22.0
1940	0.0	0	0.0	0	27.0	32.0	12	3	39.0	35.0
1960	0.0	0	23.0	28	15.5	18.0	12	3	50.5	49.0
1980	10.0	11	26.0	29	21.0	24.0	12	3	69.0	67.0
2000	6.0	7	32.0	36	25.0	27.0	12	3	75.0	73.0
2020	10.5	12	30.5	34	29.0	32.0	12	3	82.0	81.0

Industrial Water Supplies

Chapter III emphasized that many industries require water of high quality. The ability of a public water supply system to meet such quality standards is limited by the quality of available supplies and the wide range of requirements. In many areas the industries must make use of expensive water treatment facilities to satisfy their requirements.

In the service area of the Contra Costa Canal, for example, industries have been forced to construct and operate expensive water treatment facilities because of continuing degradation of water qualities within the river channels and the Contra Costa Canal. This degradation is related to factors already discussed.

Construction of facilities to insure water quality within the Delta will permit existing and future industries to save money as a result of reduced capital investment for water treatment facilities and reduced operating costs.

The measurement of these savings was related to two types of water treatment processes--water softening, and water demineralization. Sheppard T. Powell, industrial water-use consultant to the western Delta studies, developed a way to measure these savings. A companion office report, "Economic Aspects", illustrates the derivation of such savings and shows their relationship to future water demands. Table 41 shows the improvement in water quality resulting from the operation of State Water Facilities.

Agricultural Water Supplies

To justify replacement water supply facilities and the cost allocation for such facilities, economic aspects of the quality of alternative agricultural water supplies were measured in terms of the effects of the use

TABLE 41

AVERAGE MONTHLY SALT CONCENTRATIONS IN OLD RIVER 1/
WITH AND WITHOUT STATE WATER FACILITIES

(Concentrations in parts per million)

Month	Nonproject conditions						Project conditions					
	TDS	Cl	HCO_3 2/	Na	SO_4	Total hardness 2/	TDS	Cl	HCO_3 2/	Na	SO_4	Total hardness
January	440	113	82	165	111	179	228	46	48	72	23	119
February	520	138	106	193	119	214	216	45	41	72	23	106
March	435	118	87	161	96	185	177	31	54	48	17	81
April	245	62	70	67	48	104	143	25	41	39	11	84
May	205	48	68	63	37	71	159	30	35	48	16	87
June	236	50	80	72	40	99	138	23	39	37	13	74
July	520	214	85	268	52	143	104	13	41	22	9	55
August	550	225	78	294	62	157	94	10	46	15	8	54
September	350	102	88	152	53	116	114	14	46	24	9	68
October	270	59	94	96	40	102	147	20	56	33	11	81
November	280	59	101	91	44	108	182	29	63	46	14	94
December	340	79	109	109	56	144	255	53	50	83	26	131

1/ Source of Contra Costa Canal water supply.
2/ $CACO_3$ eq.

of saline water and the costs resulting from this use. In certain industries, the use of low quality water for short periods may destroy the quality of the manufactured product. The economics of agricultural water quality differ considerably from those of industrial water because soil moisture storage capacity permits a somewhat greater degree of tolerance to low quality water for a short period of time. Although previous studies have often asserted fixed limits for the quality of water applied to crops, the salinity of irrigation water is a secondary factor in the preservation of an agricultural economy. A primary factor controlling crop yields is the concentration of soil salinity. This factor dictates the amount, and therefore the cost, of excess water application, leaching, and drainage.

Soil salinity analyses for the soluble salts usually include Co_3, HCo_3, Cl, SO_4, Ca, Mg, K, and Na in the saturation extract of the soil paste. A saturated paste is made by adding sufficient water to a dry soil to saturate it, after which the soil is stirred to a pasty consistency. Some of the solution from the soil paste is removed by suction. This solution is termed the "saturation extract". This technique is the most recent evolved for the estimation of soil salinity, and has also been suggested by the U. S. Salinity Laboratory as a method for estimating sodium percentage (of the cation exchange).

Electrical conductivity in millimhos/cm (Ec x 10^3) is a standard measurement of the electrical conductivity for salt solutions. Conductivity in millimhos (Ec x 10^3) may be converted to conductivity in micromhos (Ec x 10^6) by multiplying the figures given by 1,000. The measurement is an excellent and rapid method for obtaining an estimate of the total salt content of the saturation extract, but does not give the individual salts or ions that may predominate. Because the predomination of such ions also may be a factor important in judging the effects of salinity on soil structure and plant growth, some detailed analyses for the cations and anions listed above should be run.

Salinity of a soil is estimated by the electrical conductivity of the saturation extract (Ec x 10^3). The salinity by this method has been correlated with plant growth as follows:

$Ec \times 10^3$	Crop Response
0 - 4	All crops thrive
4 - 8	Yields of many crops restricted
8 - 16	Only tolerant crops yield satisfactorily
16 +	Only a few very tolerant crops yield satisfactorily

Recent developments indicate salt concentrations somewhat below 4 millimhos may be injurious to sensitive **plants.**

Sodium percentage (% Na) is the proportion of this element to the total cations when the analysis is expressed in milliequivalents per liter. This relationship is indicated by the following formula:

$$\frac{Na \times 100}{Ca + Mg + K + Na}$$

Studies by the University of California. In the course of Delta water facility planning, the University of California and the Department of Water Resources conducted an extensive study of the physical factors related to the quality of agricultural water supplies and the Delta peat soils.

Dr. L. D. Doneen of the University of California at Davis directed this study.

The major objectives of the study were:

1. To determine the relationship of salinity accumulation in the root zone of peaty soils to salinity variations in the irrigation waters applied to those soils under conditions duplicating those found in the Delta.

2. To determine, for peaty soils, the soil salinity concentrations which can be tolerated by some of the major Delta crops and to correlate findings with published data on mineral soils.

3. To determine the effectiveness of leaching practices which use moderately saline waters.

4. To analyze the laboratory and lysimeter investigation results and to relate the findings to conditions in the Delta and to Delta soil samples.

Soil salinity accumulation rates were evaluated in extensive laboratory, greenhouse, and lysimeter tests as integral parts of the research. Plate 22, "Salination of Delta Soils Versus Salinity of the Irrigation Water, Sacramento-San Joaquin Delta", graphically shows the relationships of soil and water salinities under conditions duplicating the peaty soils and subsurface irrigation practices of the Delta. The curves depicted on this plate represent the composite of many tests. Curves for higher quantities of applied water include a period of more than one crop-year. The initial electrical conductivity of the soil extract, prior to any water application, represents the salinity concentrations found in the best of Delta soils.

Plate 23, "Salt Accumulation in Delta Soils", shows soil salinity typical in the Delta following conventional irrigation practices. The soil columns used in the research were representative of the root depths found in the Delta and the irrigation method duplicated those occurring under Delta conditions.

Extensive tests with controlled leaching aided evaluation of the removal of salts in the soil. The leaching tests were conducted in full scale soil columns under greenhouse conditions. The tests were repeated with lysimeter tanks exposed to field condtions. Such tests duplicated the Delta conditions of high water table and subsurface irrigation. Plate 24, "The Effectiveness of Leaching Peaty Soils in the Sacramento-San Joaquin Delta', presents a composite of numerous leaching tests. The relatively minor difference in the removal of salts resulting from leaching with 250 and 500 parts per million chloride water indicates that within this range the quality of leaching water in not critical. Tests show that even after the application of large quantities of distilled water, the salinity of peaty Delta soils does not decline below an electrical conductivity of about 2 x 10^3. This fact indicates that a residual of constituents other than chlorides remains and that this residual is not readily leached.

Plate 25, "Electrical Conductivity of Saturated Soil Extract Versus Salinity of Western Delta Area Soils", shows the relationship of the electrical conductivity of the saturated soil extract as an indicator of chloride concentration.

Physical Effects of Salinity on the Delta Agricultural Economy.

The effects of water quality deterioration on the upland areas of the Delta have been relatively small and do not appear to have changed crop patterns **significantly.** Such effects have been limited to the application of excess water and little such water need be applied in order to maintain control of salinity. Waters diverted for such purposes are obtained under riparian or appropriative rights and the cost of diversion is limited to small pumping costs. Therefore, an improvement in water quality would provide only small economic advantages to the uplands. However, the replacement of channel water by high quality supplies will offer a considerable economic advantage to those parts of the Delta lowlands which are or will be affected by salinity incursion. These advantages will arise primarily from increased crop yields and from changes in crop patterns from low income, salt-tolerant crops to higher income crops. The reduction in leaching and cultural costs are of a lesser magnitude but should not be overlooked.

1. Crop Yield. Decreased crop yields correlate reasonably consistently with increased soil salinity, according to soil scientists of state and federal agencies. The Bureau of Reclamation[1/], the U. S. Corps of Engineers[2/], the U.S. Regional Salinity and Rubidaux Laboratories (in 1959), the Department of Irrigation and Soil Sciences, the University of California, Los Angeles[3/], other research agencies[4/] and consultants[5/], have reported positive correlations between crop yields and soil salinities. Some of their reports have been based upon steady, carefully controlled temperatures and salinities, from seed planting to harvest; other studies have permitted an increased salinity, and varying temperatures with advancing maturity.

Salinity conditions in Delta fields show that current winter leaching practices followed by moderate precipitation provide relatively low soil salinity near the surface when seedlings are starting. Salinity increases as the crops develop. Temperatures[6/] during the growing season affect the degree of soil salinity that plants will tolerate. Plants tolerate less salinity as temperatures increase. The adjustment of planting dates and types of crops planted in the Delta partially compensate for such effects. Consideration was given to all known factors in developing the relationship shown on

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1/ U. S. Department of Interior, Bureau of Reclamation, Region II. Delta District, Appendix to "Salinity Investigation Report of Lower Sacramento-San Joaquin Delta", January 1950.

2/ U. S. Department of Agriculture. "Suitability of Reclaimed Marsh, Tide, and Submerged Lands in the San Francisco Bay Area for Agriculture". Prepared for U. S. Army Engineer District, San Francisco, Corps of Engineers. December 1959.

3/ O. R. Lunt. "Plant Responses to Salinity as Influenced by Environmental Conditions". Department of Irrigation and Soils, University of California, Los Angeles. September 1, 1960.

4/ Patricio Broussain Carmona. "Salt Tolerance of Plants". University of Chile. (Thesis for Master of Science Degree in Irrigation). 1955.

5/ Dr. Milton Fireman, (presented by). "Growth of Various Crops as Related to Salinity of the Saturation Extract". Exhibit No. 6103A, Arizona, vs. California et al Water Suit.

6/ O. R. Lunt. Op cit.

Plate 26, "Reduction of Crop Yield Versus Soil Salination". The soil salinity values in this plate are based upon average soil salinity accumulation throughout the depth of the root zone at time of crop maturity. These conditions, duplicating those found in the Delta fields, show a somewhat different reduction in specific crop yields for the same soil salinities than do some of the reports based upon laboratory studies by other agencies where soil salinities are maintained at the same level from the time the seed is planted until maturity. However, the method of study used by such agencies differs in that the soil salinities reported in their research were those at the bottom of the root zone. Such a measurement of salinity is not feasible in the Delta because of subsurface inflow and a subirrigation method which tends to maintain the level of salinity at the bottom of the root zone at about the level of the salinity of the water supply.

2. Changes in Crop Patterns. Because of seasonal salinity incur- into the lowlands of the western Delta, certain areas have been forced ow salt-tolerant crops among their other crops. Such salt-tolerant crops ally provide low income. The replacement of saline channel waters by quality waters, as proposed by the Delta Water Project, will undoubtedly in the western Delta, to crop patterns which provide a higher income.

Table 42 shows projected changes in crop patterns with and without roject. Such projected crop patterns help evaluate the economic benefit e area through replacement of channel water with high quality supplies.

3. Effectiveness of Delta Leaching Practices. The effectiveness of nt Delta leaching practices in reducing accumulated soil salinity was ied by determining the salinity of soil samples taken before and after ching operation on Sherman Island. The samples came from a field repre- tive of many which were leached during December 1959 and January 1960. rical conductivities of the saturated soil extracts from 72 field samples determined at the Irrigation Laboratory of the University of California vis. During the growing season prior to leaching, corn had been grown e field from which the samples were taken; sugar beets were to be planted ollowing year. The leaching was accomplished with water containing en 500 and 600 parts per million of chlorides.

By means of electrical conductivity values, Table 43 shows average salinity at each depth, before any leaching occurred. After water had ponded on the soil surface for approximately 30 days and then allowed to off, new average salinities were found. The electrical conductivity s indicate that the salts in the soil had been displaced slightly down- out that the total quantity of salt had not changed significantly.

TABLE 42

PROJECTED CROP PATTERNS
IN THE YEAR 1990 FOR THE
DELTA AREA SUBJECT TO SALINITY
INCURSION1/

Agricultural Crop	Cropped acres: Project conditions	Cropped acres: Nonproject conditions
Alfalfa	600	400
Asparagus	1,000	700
Barley	7,200	9,500
Corn (Grain)	5,600	3,600
Corn (Silage)	2,200	1,500
Grain hay	3,100	4,300
Milo	3,300	2,700
Miscellaneous	200	200
Pasture	3,500	7,400
Safflower and Sunflower	600	300
Sugar Beets	2,300	1,100
Tomatoes	2,800	700
TOTAL	32,400	32,400

1/ Projections made on the basis of project and nonproject conditions. Under project conditions, damaging salinity will be prevented. Under nonproject conditions, salinity will become progressively worse.

Samples taken 90 days later, after the soil profile had drained, showed the leaching to have been effective in reducing salinity to a level acceptable for beginning another crop cycle. Within the lowlands, displaced salts are prevented from entering the lower ground water areas because of the piezometric subsurface pressures. Thus, the leached salts generally move horizontally to the drain ditches and must then be pumped over the island levee to the natural channels. In contrast to upland areas, the Delta lowlands usually have less salinity near the bottom of the root zones.

TABLE 43

CHANGES IN SALINITY CONCENTRATIONS OF PEATY SOILS RESULTING FROM TYPICAL LEACHING PRACTICES IN THE WESTERN DELTA STUDY AREA[1/]

Soil sample depth, in inches	Saturated soil extract, electrical conductivity $Ec \times 10^3$		
	Before leaching: 12/17/59	Ten days after leaching, 1/28/60	Ninety days after leaching 4/28/60
6 - 12	7.28	6.62	2.97
18 - 24	3.34	5.19	2.51
30 - 36	2.39	2.60	1.91
Averages	4.34	4.80	2.46

1/ Walter W. Weir. "Soils of Sacramento County, California." University of California, Division of Soils. April 1950. Peat soils are defined as containing approximately 50 percent organic matter.

Estimates from field observations indicate that the quantities of water applied specifically for leaching in the Delta lowlands range approximately from three to four acre-feet per acre. Leaching as a separate practice generally is confined to the westerly portion of the Delta lowlands. Such leaching is practiced on an intermittent basis dependent upon the salinity of the water applied during the previous year, precipitation, and the tolerance to salinity of the crop to be grown. Presently, an estimated 40,000 acre-feet of water is used annually for leaching in the lowlands. Current measurements of water used on Twitchell Island for leaching purposes probably will provide, by July 1962, a basis for a more accurate estimate of present conditions.

4. Effect of Historic Use of Saline Water on the Properties of Typical Soils of the Western Delta. Measurements of existing field conditions were made to evaluate the adverse properties of typical Delta soils which have resulted from the application of saline irrigation water. This report limits itself to the two most important soil properties affected by such application-salinity accumulation and hydraulic conductivity. Measurements were made in the Delta lowlands in an area adjacent to Montezuma Slough. This area lies in the vicinity of Birds Landing, Solano County. Soil types[1/] in the area are essentially the same as those found four miles upriver on Sherman and Twitchell Islands. Although these lands lie west of the Delta boundaries, they are in the western Delta study area. In the past, these lands were tilled intensively and irrigated with water of relatively high salinity. Salinity concentrations generally exceeded those at Sherman Island.

The present accumulated salinity of these predominately peat and muck soils was determined from soil samples taken from depths representative of crop root zones. Table 44 summarizes salinities of the measured saturated soil extracts. The lands from which these samples were collected currently experience somewhat less intensive tilling and leaching than do the lands of Sherman and Twitchell Islands.

1/ U. S. Department of Agriculture in Cooperation with the University of California Agricultural Experiment Station. "Soil Survey of the Suisun Area, California". 1930.
University of California, Division of Soil. "Soils of Sacramento County, California". April 1950.

TABLE 44

EXISTING SOIL SALINITY OF WESTERN DELTA LANDS
Saturated Soil Extract Salinity Concentrations
Reported as Electrical Conductivity Ec x 10^3

Depth of Soil Sample, in inches	Location	
	Meins Landing Farm	McDougal Farm
6 - 12	6.3	4.2
18 - 24	8.5	7.0
30 - 36	8.3	7.3

The importance of drainage to a continually irrigated agricultural economy cannot be overly stressed. A study of drainage considers the internal drainage characteristics of the soil as well as the drainage facilities for the area as a whole.

The permeability of some fine-textured agricultural soils has been changed as a result of the application of irrigation water with a high sodium content[1/]. In mineral soils in which chemical and structural changes occurred, permeability has decreased. The degree to which this phenomenon would occur in the highly organic soils of the Delta has not been firmly established. However, a comparison of suggested standards for good agricultural soils with those soils found in the Delta provides a basis for classification.

The coefficients of soil permeability shown in Table 45 have been derived from a broad range of field conditions and soil types and are intended for comparative purposes only.

1/ United States Department of Agriculture. "Diagnosis and Improvement of Saline and Alkali Soils". Agricultural Handbook No. 60.

TABLE 45

SUGGESTED STANDARDS FOR CLASSIFICATION OF AGRICULTURAL SOILS ACCORDING TO COEFFICIENTS OF PERMEABILITY 1/

Permeability rating	Soil moisture movement rate ($cm^3/cm^2/hour$)
High	Over 360
Medium	360 to 3.6
Low	3.6 to 0.036
Very low	0.036 to 0.00036
Practically impermeable	Less than 0.00036

1/ Roe and Ayres. "Engineering For Agricultural Drainage". McGraw-Hill. 1954.

Terzaghe and Peck. "Soil Mechanics in Engineering Practice".

Table 46 shows hydraulic conductivities of western Delta soils. Such conductivities were derived from numerous tests conducted on 6-inch by 42-inch core samples of undisturbed soil samples 1/ obtained from the same location as the salinity samples reported in Tables 43 and 44. Comparison of test results with the permeability standards suggested in Table 45 indicates that the western Delta study area has an acceptable soil permeability, considering the high sodium salts to which the area has been subjected repeatedly.

1/ There are limitations to the validity of hydraulic conductivity values determined from soil samples taken from the field to the laboratory, even those as large as 6 inches by 42 inches. However, the high water table conditions in the Delta are not conductive to in-place field measurement of hydraulic conductivity. Furthermore, the values of hydraulic conductivity are used for comparison only and are not used beyond this purpose.

TABLE 46

HYDRAULIC CONDUCTIVITY OF SOIL
IN THE WESTERN DELTA STUDY AREA

Location		Percent of Island Area		
County	Area	Medium Permeability	Low Permeability	Very Low Permeability
Sacramento	Twitchell Island	50	50	0
Sacramento	Sherman Island	25	67	8
Solano	Montezuma Slough (McDougal Farm)	50	50	0
Solano	Montezuma Slough (Meins Landing Farm)	13	60	27

EXISTING SUPPLEMENTAL WATER SUPPLY FACILITIES IN THE WESTERN DELTA STUDY AREA

Certain supplemental water supply facilities have been constructed within the Delta to overcome water quality problems. These facilities include the Contra Costa Canal and works on Sherman Island. During the planning of Delta water facilities, close examination was given to water quality at the diversion location and the capacity of the facilities to meet present and future water requirements in their respective service areas. Determination of the best solution to future water supply problems within the western Delta assumed the use of existing facilities as far as possible.

Contra Costa Canal

The Contra Costa Canal, an integral feature of the Central Valley Project, was constructed to offset the effects of salinity incursion within northeast Contra Costa County. Rock Slough, a minor natural channel paralleling the San Joaquin River system, is the source of water for the canal. Plate 27, "Contra Costa Water District Location Map", shows the alignment and service area of the canal.

As the availability of high quality river waters along the northern shores of Contra Costa County has decreased, the users in the area have constructed or contracted for the use of laterals to obtain water from the canal. At present, all municipalities and nearly all industries in the area have such facilities. Despite the fact that these water users are equipped to meet all their high quality water requirements from the canal, they continue to use river diversion facilities when the river water quality is acceptable. This continued use of river diversion facilities is related to two major factors.

The first factor is the very low cost of river water. Even when high quality water is available from the river only 20 percent of the time, the combined amortized capital and power cost of diversion remains less than the cost of canal water to most of the industrial and municipal users. The 1960 industrial water survey indicated that seven major industrial water users as well as the City of Antioch divert from the river when the quality of river water permits. More than half of the high quality water requirements of area industry are satisfied by river water at such times. Plate 28, "Cost of Self-Supplied Industrial Water from the Sacramento-San Joaquin River in the Pittsburg-Antioch Area", details the cost advantages to industry of river diversion as compared with the cost of water at the canal. The plates give such costs for waters annually available 20, 40, 60, and 100 percent of the time.

The second factor connected with continued river diversions is water quality. During the fall and winter months, the outflows from the main river channels of the Delta generally are sufficient to flush and repel the inflow of sea water. However, such flushing in the lesser channels of the Delta network lags behind the flushing in the main channels by as much as several weeks. This lag is particularly evident in the southern half of the Delta, including Rock Slough. Because of this lag, the water in the Contra Costa Canal occasionally is more saline than in the tidal channels along the northeast shore of Contra Costa County. Consequently, through use of the river supply, industries and municipalities gain a considerable temporary economic advantage in terms of water treatment costs.

Existing supplemental water supply facilities within the Delta will play an important role in satisfying future water requirements. Determination of the most economical way to integrate proposed additional facilities with existing facilities required an extensive analysis of the capacities and deliverabilities of each facility and the quality of water available to each facility. Furthermore, general plans regarding future service areas and administration of the proposed additional facilities required a review of the various water-serving entities within the Delta.

Sherman Island Salinity Alleviation Works

Landowners of the central portion of Sherman Island have cooperated in developing a canal system to convey water from a diversion point near Decker Island to lands downriver which are subject to higher salinity if diversion is made directly from the natural channels. About 18,000 lineal feet of unlined canal are now in service. A 5,000-foot extension for the purpose of incorporating Mayberry Slough is being studied. Should the extension be completed, some of the most westerly areas of Sherman Island will have access to a water supply of a quality comparable to that available at Emmaton.

Water Service Agencies in the Western Delta Study Area

A complete study of water supply in the western Delta study area requires an analysis of the various water supplying agencies, their rights, obligations, and facilities. These agencies include the Contra Costa Water District, East Contra Costa Irrigation District, Byron-Bethany Irrigation District, Oakley County Water District, California Water Service Company, the Cities of Pittsburg, Antioch, and Rio Vista, and several smaller cities, irrigation districts, and reclamation districts.

Contra Costa County Water District

The Contra Costa County Water District was formed primarily to administer the distribution of water from the Contra Costa Canal to the various users. In a sense, the district is the intermediate agency between the users and the U. S. Bureau of Reclamation.

The present ability of the district to serve water is adequately summarized in the following paragraph taken from the report of the Contra Costa County Department of Public Works, May 1957, entitled "Preliminary Report on General Plans for Ultimate Water Service in Contra Costa County".

> "Contra Costa County Water District does not have any right to a specific flow of water in any stream in the State of California. The District's right is to water service from the Central Valley Project of the Bureau of Reclamation as delivered to the District by the Bureau of Reclamation in

the Contra Costa Canal. The right arose and exists by the contract between the United States and the County Water District dated September 18, 1951, and identified by the symbol 175r-3401. This right may be summarized as follows:

"'(1) The United States will furnish 10,000 acre feet of water for agricultural water each year through December 31, 1991.

"'(2) At any time prior to March 1, 1967, upon six months' written notice to the United States, the District may increase the amount of agricultural water to be furnished by the United States to the District each year thereafter through December 31, 1991, up to a maximum of 33,000 acre feet.

"'(3) Any water furnished to the District for agricultural purposes may at the discretion of the District be used for municipal, industrial or domestic uses.

'"(4) The United States will furnish to the District each year through December 31, 1991, the quantity of water requested by the District for municipal and industrial uses (with certain specified minimum annual amounts) up to a maximum of 53,000 acre feet."

The boundaries of the district follow those of the service area of the Contra Costa Canal (defined on Plate 27).

Recent months have seen two major annexations to the District: the area serviced by the California Water Service Company (including purchase of its facilities) and the Lone Tree-Deer Valley Area. The annexation of these areas undoubtedly will lead to greater seasonal and annual demands upon the Contra Costa Canal.

City of Antioch

The City of Antioch presently obtains its water supply from two sources: the San Joaquin River and the Contra Costa Canal. The river supply is utilized only when the water quality is acceptable to California Department of Public Health standards, or better than the quality in the Contra

Costa Canal. When the river water quality is unacceptable, the water supply is obtained from Contra Costa Canal. In conjunction with river diversions, a small reservoir of 720 acre-feet is operated to meet some of the demands during months when waters cannot be diverted from the river. This reservoir also collects a small amount of local runoff from the adjacent watershed of 2.2 square miles.

The diversion of river water is supported by a riparian right, however, this right placed no limit upon the quality of water which the city can divert. Canal water is obtained by contract with the U. S. Bureau of Reclamation. This contract is negotiated in January of each year.

City of Pittsburg

The City of Pittsburg presently has one source of water supply: the Contra Costa Canal. Pittsburg has used the canal since 1939. At that time the last city well was shut down. Canal water is obtained by annual contract with the Contra Costa Water District. Pittsburg has no established right to the use of river water, and has not diverted from the river for many years.

Oakley County Water District

Oakley County Water District was organized in 1955 to serve filtered and treated water to the Town of Oakley and surrounding areas. This district obtains its supply, under annual contract, from the Contra Costa Canal. A large portion of the treated water served by the district is used as process water by the I. E. DuPont Chemical Plant located near Oakley. Prior to 1955, wells were used as a source of supply in the district.

City of Rio Vista

The City of Rio Vista obtains its water from deep wells fed by the surrounding hills and possibly from the Sacramento River. Because of the low-suspended solids content of this water, the water is not filtered, but fed directly into the city water system.

East Contra Costa Irrigation District

The East Contra Costa Irrigation District encompasses a gross area of 20,000 acres in eastern Contra Costa County. Approximately 17,000 acres are considered irrigable and are served with a multiple-lift pump and canal distribution system. Present operations are limited to serving agricultural water during a seven to eight-month summer irrigation season of each year.

The water supply of the district is obtained by ground water pumping and by diversions from the natural delta channel of Indian Slough. This slough has been extended approximately one mile by dredging. The ground water pumping helps control ground water levels in those areas where such levels have tended to rise as the use of diverted water has increased. The quality of the diverted Delta water tends to be protected from the full influence of salinity incursion by the location of the diversion point. Records indicate that less than 300 parts per million chlorides have prevailed during the last 20 years. Ground water contains excessive concentrations of boron and its use has been limited generally to situations which permit its mixture with surface waters. The right of the district to divert water is defined by an appropriation permit of 200 second-feet.

Byron-Bethany Irrigation District

The Byron-Bethany Irrigation District encompasses a gross area of about 17,600 acres, of which about 10,000 are currently irrigated. The service area includes a portion of southeastern Contra Costa County and extends into Alameda County. The distribution of agricultural water by the district is confined to the summer months. The water supply is diverted from the Delta channel, which has been extended to a location suited to the pumping plant. Diversion is under appropriation permit. Additional pumping plant capacity installed in 1959 provides a total of 150 second-feet, and a water duty of 65 acres per second-feet.

Reclamation Districts.

Practically all irrigated lands in the western Delta not included in the irrigation districts fall within the fifteen reclamation districts. Reclamation districts provide a degree of flood control through levee maintenance, drainage pumping facilities, and operation. In addition to their powers of taxation and eminent domain, reclamation districts may provide for the distribution and sale of water. However, the lower Delta reclamation districts thus far have confined their function to flood control and drainage.

Plate No. 29, "Irrigation and Reclamation Districts within the Sacramento-San Joaquin Delta", shows the location of all Delta irrigation and reclamation districts, including those within western Delta study area. Because some overlapping of boundaries may exist and certain boundary changes may have occurred which were not reported, Plate 29 should be used only as an indication of approximate district boundaries.

CHAPTER V. FUTURE WESTERN DELTA WATER SUPPLY

A primary objective of all proposed Delta Water Facilities is to ensure the Delta a water supply sufficient in quantity and quality to meet foreseeable demands. The extent of work necessary to attain this objective will depend upon the specific facilities constructed and their proposed conditions of operation. Only the lands within the Western Delta study area, however, are affected directly by changes in water supply resulting from the operation of any of the proposed facilities. With the exception of changes created by the Chipps Island Barrier Project, Chapter IV has discussed such changes.

Future Western Delta Water Requirements

Chapter III has defined the future water requirements of the Western Delta study area. Determination of the design and method of operation of replacement and supplementary water supply facilities required knowledge of the local requirements of subareas of the Western Delta study area. Total future water requirements, therefore, were distributed according to the projected land use indicated on Plates 4, 5, and 6, the high quality water requirements set forth in Chapter III, and the existing unit water requirements in each subarea. Table 47 indicates the results of this distribution for municipal and industrial uses. Table 48 shows the projected consumptive use of agricultural water by counties within the entire Delta service area. This projection was based on consumptive use by decade, as shown in Table 33 and estimates of the amount of agricultural land cultivated in the future.

TABLE 47

PROJECTED ANNUAL MUNICIPAL AND INDUSTRIAL WATER REQUIREMENTS 1/
BY SUBAREAS IN WESTERN DELTA
(Acre-feet per year)

Subarea	1960	1970	1980	1990	2000	2010	2020
Solano County							
Municipal Water							
Rio Vista	650	900	1,400	2,600	8,300	17,600	25,400
Denverton-Collinsville	0	0	0	100	1,700	4,200	10,000
Total Municipal Water	650	900	1,400	2,700	10,000	21,800	35,400
Industrial Water							
Rio Vista	400	700	2,000	3,300	5,000	6,800	8,900
Denverton-Collinsville	0	0	0	1,400	16,300	50,800	115,300
Total Industrial Water	400	700	2,000	4,700	21,300	57,600	124,200
TOTAL SOLANO COUNTY	1,050	1,600	3,400	7,400	31,300	79,400	159,600
Contra Costa County							
Municipal Water							
Antioch	2,900	4,600	6,800	9,400	12,400	15,800	19,800
Pittsburg-Shore acres 2/	3,550	5,300	7,400	9,700	12,300	15,100	18,000
Lone Tree-Deer Valley	0	1,200	3,700	6,200	6,900	11,800	14,700
Oakley-Sand Hill	300	1,900	3,100	4,100	4,800	5,300	5,700
Brentwood-Byron	3,200	4,100	7,900	15,500	27,100	43,900	61,600
Total Municipal Water	9,950	17,100	28,900	44,900	65,500	91,900	119,800
Industrial Water							
Pittsburg west 2/	1,300	5,400	9,900	17,600	31,200	43,800	52,500
Pittsburg-Antioch	18,800	45,000	79,100	110,400	132,600	146,300	156,800
Antioch-Oakley	10,900	20,500	36,300	61,600	84,800	105,200	120,500
Oakley east	0	0	2,000	2,900	6,500	10,700	14,000
Brentwood-Byron	0	0	0	6,600	23,000	60,100	111,200
Total Industrial Water	31,000	70,900	127,300	199,100	278,100	366,100	455,000
TOTAL CONTRA COSTA CO.	40,950	88,000	156,200	244,000	343,600	458,000	574,800
TOTAL WESTERN DELTA	42,000	89,600	159,600	251,400	374,900	537,400	734,400

1/ Industrial requirements reflect uses with quality limitations.

TABLE 48

PROJECTED ANNUAL AGRICULTURAL WATER REQUIREMENTS 1/
IN THE SACRAMENTO-SAN JOAQUIN DELTA

(In thousands of acre-feet per year)

Area	1960	1970	1980	1990	2000	2010	2020
Solano County	30	255	264	269	267	265	262
Contra Costa County	237	263	273	278	276	273	270
Sacramento County	294	328	340	346	344	340	337
San Joaquin County	840	936	968	986	980	971	961
Alameda County	13	14	15	15	15	15	15
Yolo County	244	273	282	287	286	283	280
TOTAL	1,858	2,069	2,142	2,181	2,168	2,147	2,125

1/ Values include effective precipitation and subsurface inflow from Delta channels.

Western Delta Water Supply--Chipps Island Barrier Project

Under the conditions proposed by the Chipps Island Barrier Plan, diversions from either the barrier pool or upstream channels could meet all water requirements of the western Delta. Such diversions, therefore, would meet the requirements of the major industries, municipalities and water districts, as well as those of agriculture, although the Contra Costa Canal would continue to supply small amounts of water to the western Delta. The administration of local diversions from the barrier pool would be an obligation of the local water users. This obligation might logically become the responsibility of the Contra Costa Water Agency in Contra Costa County, and a similar agency in Solano County.

Extreme care would be required to prevent pollution of the water supply from the Chipps Island Barrier pool. The barrier would prevent tidal dissipation of temperatures, and tidal dilution and assimilation of chemical, organic, or biological wastes. Such temperatures and pollutions might detract considerably from the usefulness of pool waters for local, domestic, and industrial uses. Prevention of excessive pollution would require a large system of waste disposal conduits discharging downstream from the barrier site. Such conduits would have to be a capacity to discharge 80 percent of the high quality water required by industry in the western Delta and 50 percent of that required by municipalities. These are the amounts of water which would become polluted, during use, with industrial and municipal wastes, and which, therefore, should not be emptied into the barrier pool for reuse.

The return of 20 percent of the high quality industrial demands (Table 47) and nearly all of the low quality demands (Chapter III) to the barrier pool for reuse could be anticipated. The present return flow of agricultural drainage water is computed to be near 1,000 cubic feet per second during the critical summer months. Future conditions in the Delta and the development of the Solano Project, as well as the Folsom South Service Area, may increase this figure.

Under conditions of adequate pollution control, the quality of water available from the barrier pool probably would equal that listed in Table 41. The reduced cost of water treatment would be a project benefit. The use of certain materials for heat exchange tubes might reduce the cost of cooling equipment and produce a minor project benefit not evaluated in the course of these studies.

Plate No. 30, "Chipps Island Barrier Project", shows the location of the major features and related channel works required to produce a physical salinity barrier.

Western Delta Water Supply--Delta Water Project

All alternatives of the Delta Water Project propose a system of replacement and supplementary water supply facilities of sufficient capacity to meet all future demands of agriculture and all future high quality demands of industries and municipalities. Such facilities would be able to provide high quality replacement water during periods of reduced availability of high quality water in the river channels. They would minimize detriments to the Western Delta water supply caused by future Central Valley Project operations, increasing upstream consumptive use, and natural deficiencies.

Plate No. 31, "Single Purpose Delta Water Project", shows the locations of the minimum project facilities required. Plate 32, "Typical Alternative Delta Water Project", shows the extent and location of the principal feature of a possible multipurpose project incorporating limited flood control protection with water quality and water transfer features. Plate No. 33, "Comprehensive Delta Water Project", shows the locations of features of a multipurpose project which provides maximum benefits, including those of salinity, flood and seepage control, transportation and recreation.

Industrial and Municipal Water Supply Facilities

In the future, areas of the Western Delta will require additional municipal and industrial water supply facilities. These areas extend from Oakley to Pittsburg in Contra Costa County, and from Collinsville to the vicinity of Lindsay Slough in Solano County. Other areas would be ensured adequate quantities and qualities of water within adjacent channels under all alternatives of the Delta Water Projects. Such areas include Rio Vista in Solano County and Brentwood and Byron in Contra Costa County.

Several alternative plans to meet the industrial and municipal requirements of the deficient areas were considered. Six of these plans proved to be a feasible part of the Delta Water Project facilities. These six plans propose construction of:

1. An additional canal near the existing Contra Costa Canal alignment.

2. The Northeast Contra Costa aqueduct, an underground pipeline extending from Oakeley through Antioch to the Contra Costa Canal outfall between Antioch and Pittsburg, and connected to Rock Slough by an open canal.

3. The Montezuma Aqueduct, a canal passing along the western edge of the Montezuma Hills and extending from the North Bay Aqueduct in Solano County to Pittsburg in Contra Costa County and crossing under the Sacramento River in the vicinity of Pittsburg.

4. A canal along an alignment similar to that proposed for the Montezuma Aqueduct, but with capacity sufficient to meet only the demands of Solano County and extending only as far as Collinsville.

5. An offside storage reservoir to increase deliverability of the Contra Costa Canal or any of the above alternatives.

6. A high-line canal beginning near the Tracy Pumping Plant and passing through the foothills west of Byron and Brentwood to intersect the Contra Costa Canal slightly west of Antioch.

Certain other alternative plans considered were found to be economically unfeasible. These were:

1. A plan for a subaqueous pipeline parallel to the north side shore of Contra Costa County and extending upriver beyond the salinity incursion zone.

2. A plan for saline water conversion plants.

Other plans proposed alternatives which more logically could be constructed and operated by local agencies. Such plans proposed:

1. A plan for enlargement of the Contra Costa Canal.

2. Sewage reclamation facilities which may, in future years, prove to be a low cost, reliable and satisfactory means of providing water for certain industrial uses.

The plan for the Montezuma Aqueduct best solves Western Delta industrial and municipal water supply problems. This plan not only provides for maximum use of the Contra Costa Canal and meets all foreseeable demands of the Solano and Contra Costa County areas of deficiency; it also provides for a canal with an alignment which falls along relatively inexpensive right of way and supplies water of a quality at least as good as that of the water within or west of Rock Slough. Despite the physical advantages of the Montezuma Aqueduct, however, the economic differential between feasible plans was less than ten percent. Such a slight differential indicates that advanced planning studies may lead to the selection of an alternative plan as the most feasible solution if any change in the design, operation and economic criteria assumed in the studies of alternative facilities occurs.

Plate 34, "Montezuma Aqueduct", indicates the alignment and capacity of each part of the aqueduct.

Facility Capacity Determination. It was assumed that the combined operation of the Montezuma Aqueduct and the Contra Costa Canal would meet, by 2020, the peak monthly demands of that part of the Contra Costa County Water District within the Western Delta study area. This assumption determined the design capacity of the Montezuma Aqueduct.

Canal-side reservoir storage did not receive consideration in the determination of design capacities. In addition, it was assumed that 225 second feet of water from the Contra Costa Canal would be utilized in the service area west of the Western Delta study area. Plate 35, "Contra Costa Canal Operation Demand Schedule", shows the schedule utilized to distribute annual municipal and industrial water requirements for determination of monthly peak demands.

Montezuma Aqueduct Operations. Future high quality water supplies to the portion of the Western Delta study area within the Contra Costa County Water District would be obtained by offshore diversions from the Sacramento-San Joaquin Rivers, the Contra Costa Canal, and the Montezuma Aqueduct. A projected operation schedule for the Montezuma Aqueduct required an extensive operation study to determine the quantities of water which each of these sources should supply.

1. River Diversions. River diversions will probably continue when the quality of available river water is sufficient to meet the specific application. At present, when their quality is acceptable, river diversions can meet more than 55 percent of the industrial high quality water requirements as well as the municipal requirements of the City of Antioch. Future diversions are likely to increase and to meet up to 85 percent of the industrial requirements, because most of the available industrial lands are owned by companies which presently maintain diversion facilities. For purposes of the operation study, 85 percent of the industrial high quality water requirements of each subarea were assumed to be met by river water whenever its quality was better than 250 parts per million of chlorides. Antioch was assumed

to divert river water when its quality was better than 100 parts per million of chlorides. To determine the projected average amount of water diverted from the river for each projected level of development, average salinity conditions as shown on Plate 20, were considered along with the monthly water requirements within each subarea. Table 49 summarizes projected municipal and industrial river diversions.

2. Contra Costa Canal Deliveries. Operation of the Contra Costa Canal, combined with that of the Montezuma Aqueduct, could take various forms. Studies indicated, however, that the canal should be operated at nearly peak capacity throughout the year because of the cheaper power available to the canal pumping plants. Under such conditions, the Montezuma Aqueduct could be operated as a peaking facility. Operation in this manner allows the canal to serve Antioch and all lands eastward and Pittsburg and all lands westward. The Montezuma Aqueduct would serve the industrial lands between Antioch and Pittsburg as well as refill the Contra Costa Canal to the extent necessary to meet the demands west of Pittsburg. Deliveries to the Western Delta study area from the Contra Costa Canal under this type operation scheme are also indicated in Table 49.

3. Montezuma Aqueduct Deliveries. Deliveries from the Montezuma Aqueduct to Contra Costa County would commence in 1971. Initial service would consist of deliveries to the industrial area between Antioch and Pittsburg. By 1980, all industries in this area probably would be receiving water from the Montezuma Aqueduct. In 1980, the aqueduct would also commence deliveries to the Contra Costa Canal to overcome canal capacity deficiencies caused by increased demands in

the area east of Antioch. Deliveries from the Montezuma Aqueduct to Solano County would commence after 1980.

Deliveries by the Montezuma Aqueduct would include both replacement and supplemental waters to Contra Costa County and supplemental waters to Solano County. Replacement water is that water which could be diverted from river channels if State Water Facilities were not constructed and operated. Estimates of the amount of replacement water were obtained by the projected decreases of availability of quality water caused by operation of the State Water Facilities. These decreases would approximate 5 percent during all periods of operation of the State Water Facilities system. Therefore, computation of the amount of replacement water used a factor of 5 percent. Supplemental water is defined as all other water delivered by the Montezuma Aqueduct. Table 49 presents estimates of supplemental and replacement water deliveries to Contra Costa County. Table 50 presents estimates of supplemental water deliveries to Solano County.

Agricultural Water Supply Facilities

Areas of the western Delta which, because of salinity incursion, require supplementary water supply facilities include all of the irrigated lands extending from the vicinity of Antioch to Rio Vista on the Sacramento River, and extending upriver to the vicinity of Franks Tract on the San Joaquin River. All other areas of the Delta would be ensured adequate quantities and qualities of irrigation water within adjacent canals either by through-Delta flows or by project provisions for dilution in localized areas of extensive reuse.

TABLE 49

DISTRIBUTION OF WATER SUPPLY TO PORTION OF WESTERN DELTA STUDY AREA
SERVED BY THE CONTRA COSTA COUNTY WATER DISTRICT
(Acre-feet/year)

Year	River diversions	Contra Costa Canal		Montezuma Aqueduct		Total area demands
		Deliveries	Refill from Montezuma Aqueduct 1/	Replacement water deliveries 2/	Supplementary water deliveries 1/	
1970	38,200	45,700	0	0	0	83,900
1980	33,700	54,600	700	7,400	51,300	146,300
1990	39,900	96,800	17,500	11,100	91,600	221,900
2000	43,900	143,200	44,000	14,700	135,700	293,500
2010	46,300	186,700	72,100	17,700	175,400	354,000
2020	43,000	222,800	96,000	20,100	212,100	402,000

1/ Supplementary water deliveries from the Montezuma Aqueduct include the quantity of water used to refill the Contra Costa Canal.

2/ Replacement water quantities are based upon average water supply conditions.

TABLE 50

SUPPLEMENTAL WATER DELIVERIES
TO SOLANO COUNTY
(Acre-feet/year)

Year	Delivery from Montezuma Aqueduct
1980	0
1990	1,500
2000	18,000
2010	55,000
2020	130,100

Because agricultural water quantity requirements are highly seasonal and because quality limitations are a function both of duration and of constituent concentrations, alternative facility plans required a combination of features which optimize these factors. In each of the three Delta Water Project proposals, different water supply and drainage facilities are required to operate without **interference** to flood and seepage control features.

Facility Service Area and Capacity Criteria. The location of facilities to serve the agricultural areas of the Delta fall within either of two categories. These two categories are: (1) areas which must be served through a new distribution system because the natural channels will become too saline to permit channel-side diversion and irrigation, and (2) areas which would require facilities to continue present irrigation procedures after project flood control and water transfer features, including levees and channel closures, are constructed.

The design capacity criteria for the western Delta area is based upon a duty of 1 second-foot per 60 irrigated acres. For all other areas where project channel supply facilities would be required, the design capacity is based upon the combined July consumptive use and drain pump discharge quantities. An allowance for an increase of 25 percent in consumptive use was incorporated. This criteria appears conservative because the presently undetermined supply from subsurface inflow and effective precipitation has not been subtracted from the total requirements.

The service area of the replacement water facilities included in each of the proposed Delta Water Projects will consist of all of the Delta lowlands within the western Delta study area which are or would be affected by salinity incursion. This area includes all of Sherman, Twitchell, Bradford, and Jersey Islands, Bethel and Hotchkiss Tracts, and portions of Brannan Island, and Holland and Webb Tracts.

Operation of Replacement Water Facilities. The facilities are planned to provide a water supply at all times within the entire service area. The duty of 60 acres per second-foot is adequate for the month of maximum use and was used to facilitate preliminary design. The projected intensity of irrigated agriculture probably will tend to extend the present irrigation season both earlier in the spring and later in the fall, as well as to increase the summer peak. Diversions for leaching purposes are assumed to pass through the distribution system even though the salinity of the water in the natural channels may be low enough to be acceptable for leaching during certain abundant supply years. The alignment of the distribution canals at the toe of the levee permits the maintenance of a water surface level for gravity flow from headgate turnouts in practically all locations. The existing system of drainage and supply canals located away from the levee perimeter probably will continue to be operated and maintained under private ownership. Most efficient operation and maintenance of Jackson and Rock Slough canal systems probably could be obtained under master districts which would include the several islands served.

The probable future distribution of monthly water demands with projected irrigation intensity for 1990 is indicated in Table 50. The projected increased irrigation intensity is reflected in the extended irrigation season as compared to that shown in Table 36.

TABLE 51

PROBABLE FUTURE DISTRIBUTION OF MONTHLY WATER DEMANDS
SACRAMENTO-SAN JOAQUIN DELTA
(In percent of seasonal total)

Month	Irrigation demand in percent	Leaching demand in percent
October	12.2	
November	4.6	20
December	0.8	40
January	0	30
February	0.8	10
March	1.3	
April	2.6	
May	8.8	
June	17.9	
July	18.4	
August	17.4	
September	15.2	
TOTAL	100.0	100

Reductions in channel salinity and in salt in the soil profile would alter leaching demand in the winter months. The variation in drain water returned to Delta channels arising from diversions through the facilities will be in approximately the same proportions as the monthly demand percentages.

1. Agricultural Replacement Water Features in the Single Purpose Delta Water Project. The major features of the agricultural replacemnt water facilities associated with the Single Purpose Delta Water Project are shown on Plate 36, "Principal Irrigation Features of the Single Purpose Delta Water Project". The attached table indicates the capacity of each of the features. The Delta area where facilities are not shown is not subject to salinity incursion and would retain and operate the existing irrigation and drainage facilities now held in private ownership. Even in the western Delta area that is served with replacement water, drainage pumps and facilities probably would remain under existing ownerships and operation.

The agricultural replacement water facilities are of such a nature that stage construction, to provide service to the areas most severely affected by salinity incursion, is physically and financially feasible. Service to areas presently less affected by salinity incursion could be provided, as needed, at a later time. The probable ultimate development would result in the facilities shown in Plate 36. Under such developments the major points of diversion of water would be from Georgiania Slough in the north sector, and from Rock Slough in the south sector. The distribution canal system routing would provide new water to most of the existing points of diversion from natural and man-made channels which have become increasingly saline. A minimum of "on-the-farm-relocation" of irrigation facilities have been incorporated in the plan.

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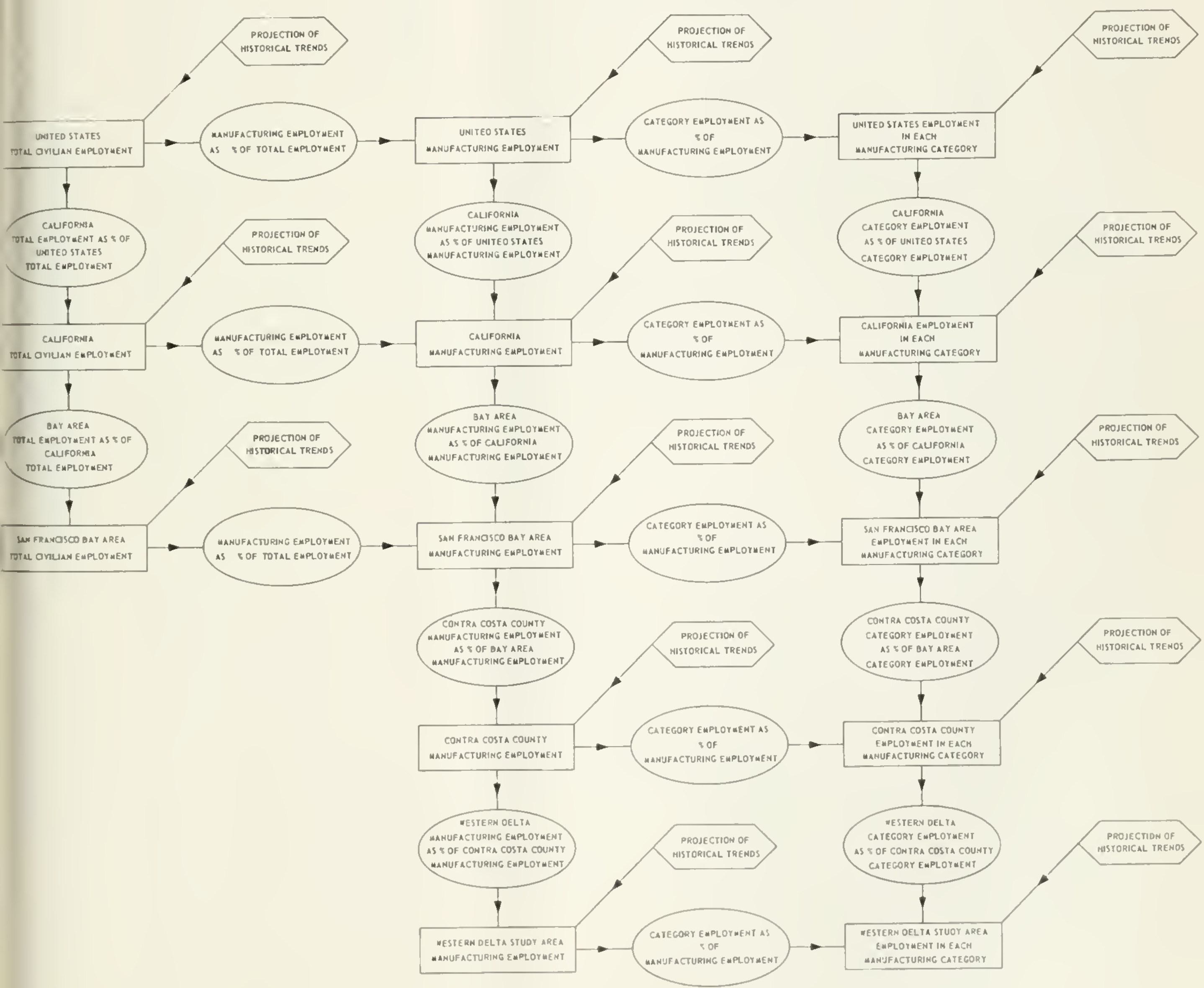
SCHEMATIC DIAGRAM OF

AREA EMPLOYMENT RELATIONSHIPS

FEBRUARY 1962



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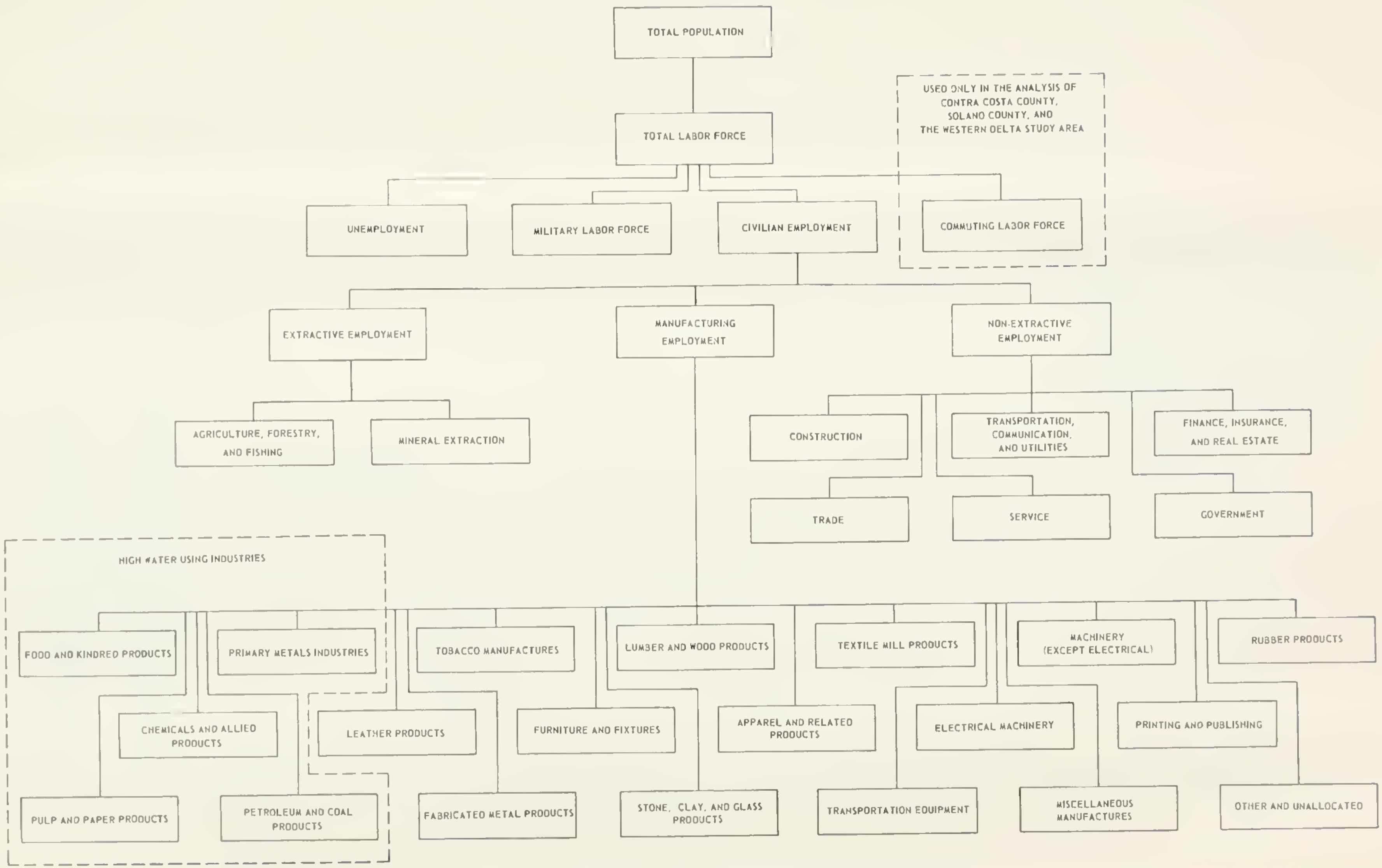
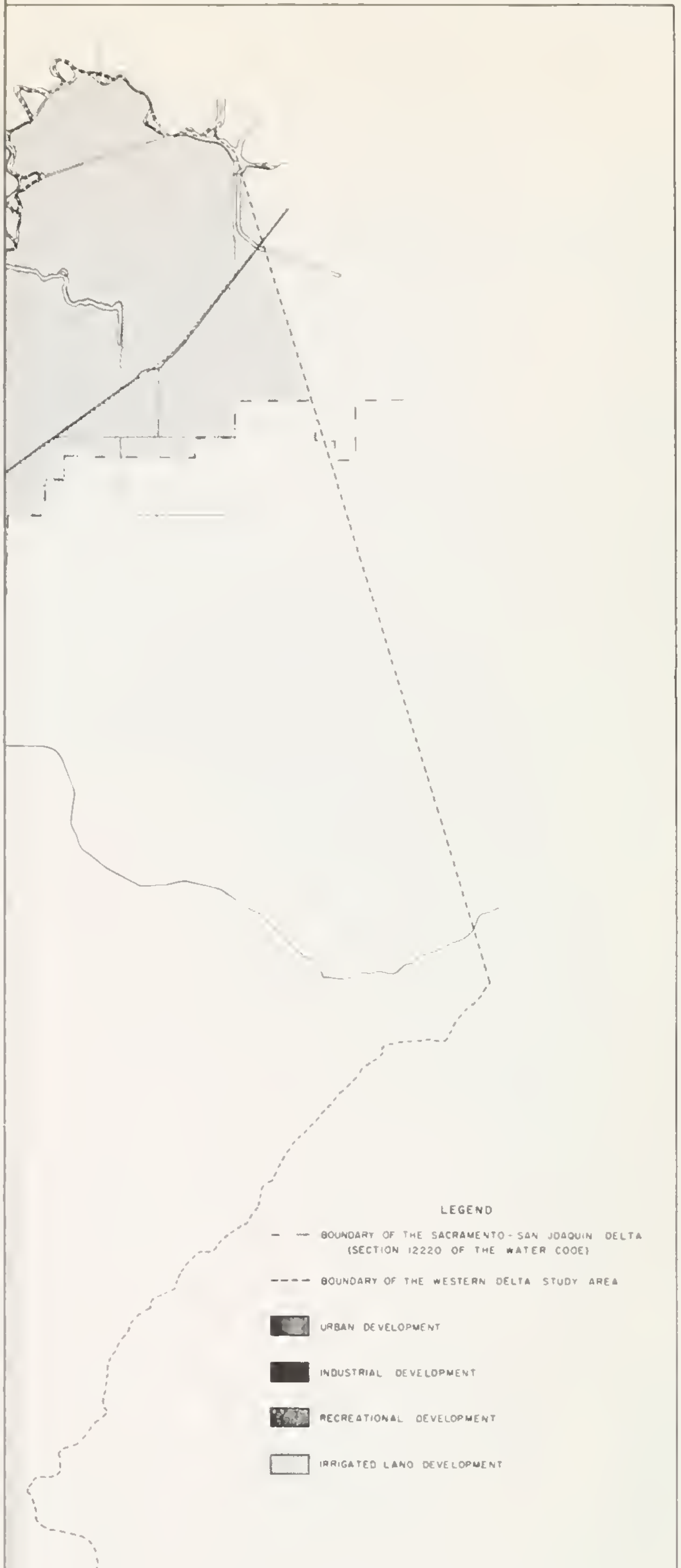
SCHEMATIC DIAGRAM OF

THE DISTRIBUTION OF AREA ECONOMY

FEBRUARY 1962





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PRESENT LAND USE
WESTERN DELTA STUDY AREA
FEBRUARY 1962

SCALE OF MILES
1 0 2 3


SACRAMENTO RIVER
SAN JOAQUIN
RIVER
LEGEND
BOUNDARY OF THE SACRAMENTO - SAN JOAQUIN DELTA (SECTION 12220 OF THE WATER CODE)
BOUNDARY OF THE WESTERN DELTA STUDY AREA
URBAN DEVELOPMENT
INDUSTRIAL DEVELOPMENT
RECREATIONAL DEVELOPMENT
IRRIGATED LAND DEVELOPMENT
STATE OF CALIFORNIA
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DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
PRESENT LAND USE
WESTERN DELTA STUDY AREA
FEBRUARY 1962
SCALE OF MILES
0 1 2 3


RIVER
SAN JOAQUIN
RIVER
SACRAMENTO
LEGEND
BOUNDARY OF THE SACRAMENTO SAN JOAQUIN DEL
(SECTION 12220 OF THE WATER CODE)
BOUNDARY OF THE WESTERN DELTA STUDY AREA
URBAN DEVELOPMENT
INDUSTRIAL DEVELOPMENT
RECREATIONAL DEVELOPMENT
IRRIGATED LAND DEVELOPMENT
STATE OF CALIFORNIA
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DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
1980 LAND USE
WESTERN DELTA STUDY AREA
FEBRUARY 1962
SCALE OF MILES
1 0 1 2 3

RIVER
SAN JOAQUIN
RIVER
SACRAMENTO
LEGEND
BOUNDARY OF THE SACRAMENTO-SAN JOAQUIN DELTA (SECTION 12220 OF THE WATER CODE)
BOUNDARY OF THE WESTERN DELTA STUDY AREA
URBAN DEVELOPMENT
INDUSTRIAL DEVELOPMENT
RECREATIONAL DEVELOPMENT
IRRIGATED LAND DEVELOPMENT
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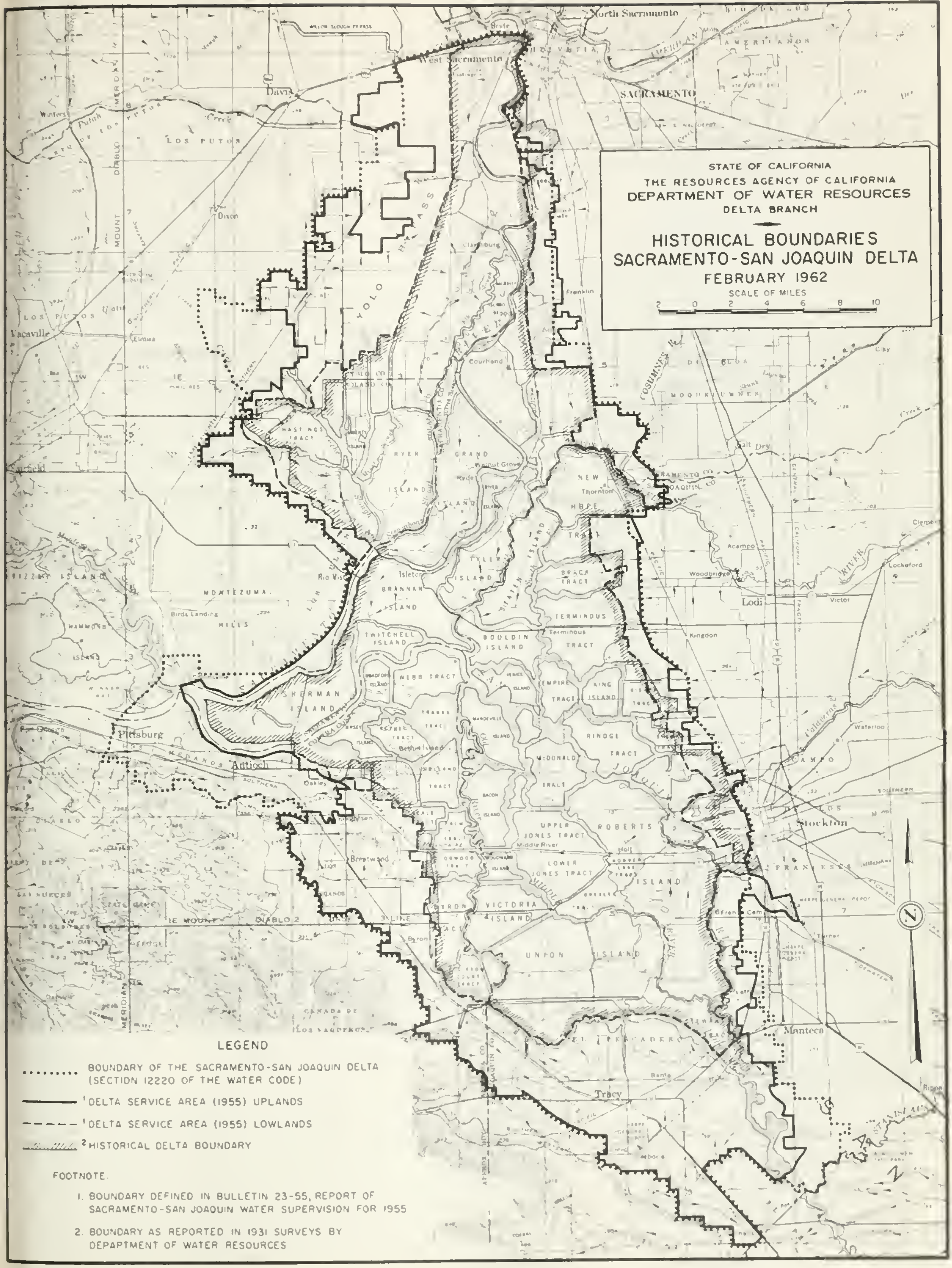
2020 LAND USE
WESTERN DELTA STUDY AREA
FEBRUARY 1962
SCALE OF MILES
1 0 1 2 3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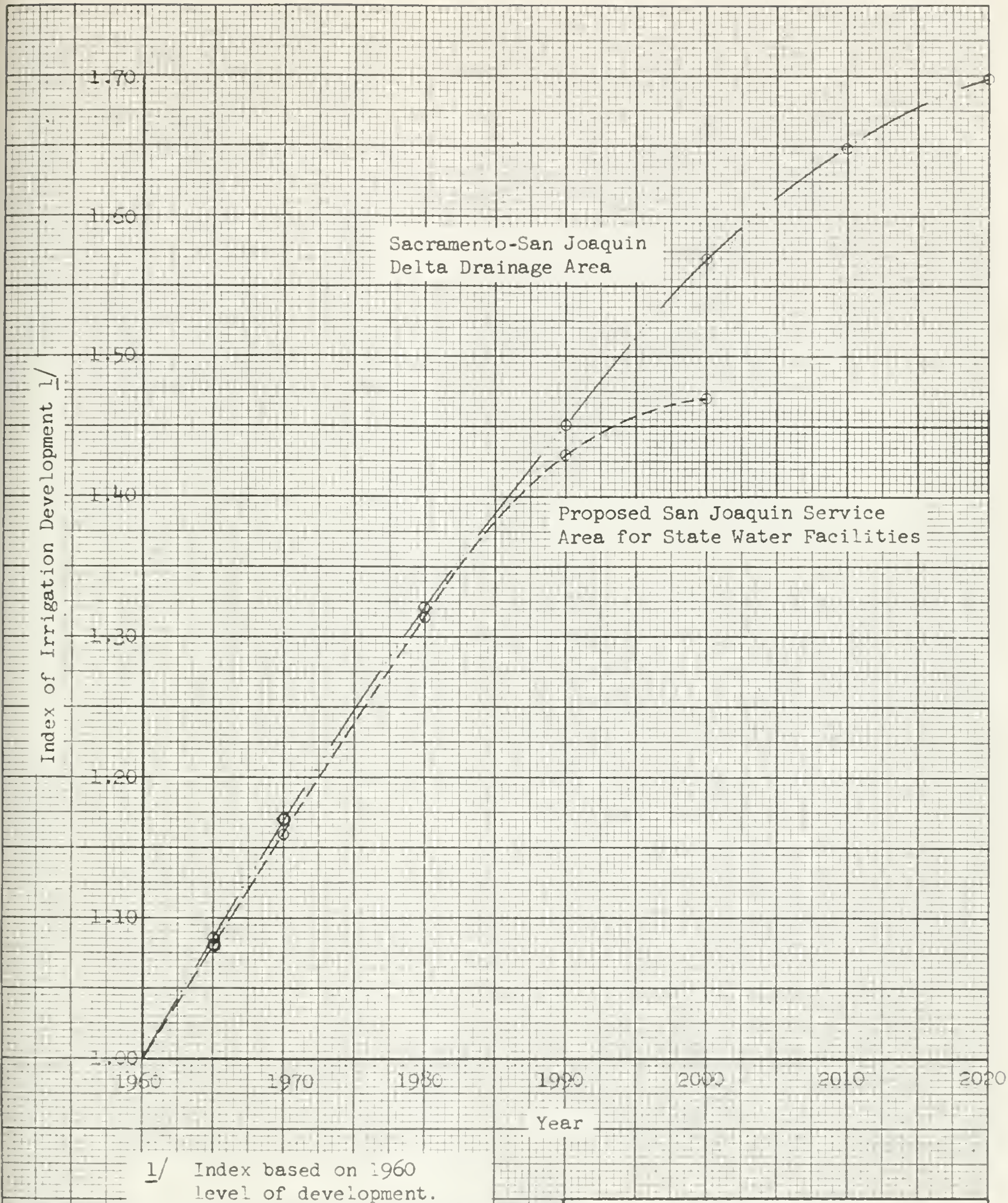
DELTA BRANCH
HISTORICAL BOUNDARIES
SACRAMENTO-SAN JOAQUIN DELTA
FEBRUARY 1962
SCALE OF MILES
2 0 2 4 6 8 10
LEGEND
BOUNDARY OF THE SACRAMENTO-SAN JOAQUIN DELTA (SECTION 12220 OF THE WATER CODE)
1 DELTA SERVICE AREA (1955) UPLANDS
1 DELTA SERVICE AREA (1955) LOWLANDS
2 HISTORICAL DELTA BOUNDARY
FOOTNOTE
1. BOUNDARY DEFINED IN BULLETIN 23-55, REPORT OF SACRAMENTO-SAN JOAQUIN WATER SUPERVISION FOR 1955
2. BOUNDARY AS REPORTED IN 1931 SURVEYS BY DEPAPTMENT OF WATER RESOURCES
North Sacramento
West Sacramento
SACRAMENTO
Davis
Dixon
Vacaville
Fairfield
Clarksburg
Courtland
Franklin
Walnut Grove
Ryde
Isleton
Rio Vista
Pittsburg
Antioch
Oakley
Brentwood
Byron
Lodi
Woodbridge
Acampo
Lockeford
Victor
Kingdon
Thornton
Stockton
Holt
Middle River
Tracy
Manteca
YOLO BYPASS
LOS PUTOS
MONTEZUMA HILLS
HASTINGS TRACT
RYER ISLAND
GRAND ISLAND
TYLER ISLAND
BRANNAN ISLAND
NEW HOPE TRACT
STATEN ISLAND
BRACK TRACT
TERMINOUS TRACT
TWITCHELL ISLAND
BOULDIN ISLAND
SHERMAN ISLAND
WEBB TRACT
EMPIRE TRACT
KING ISLAND
RINDGE TRACT
McDONALD TRACT
UPPER JONES TRACT
LOWER JONES TRACT
ROBERTS ISLAND
VICTORIA ISLAND
UNION ISLAND



1/ Index based on 1960 level of development.

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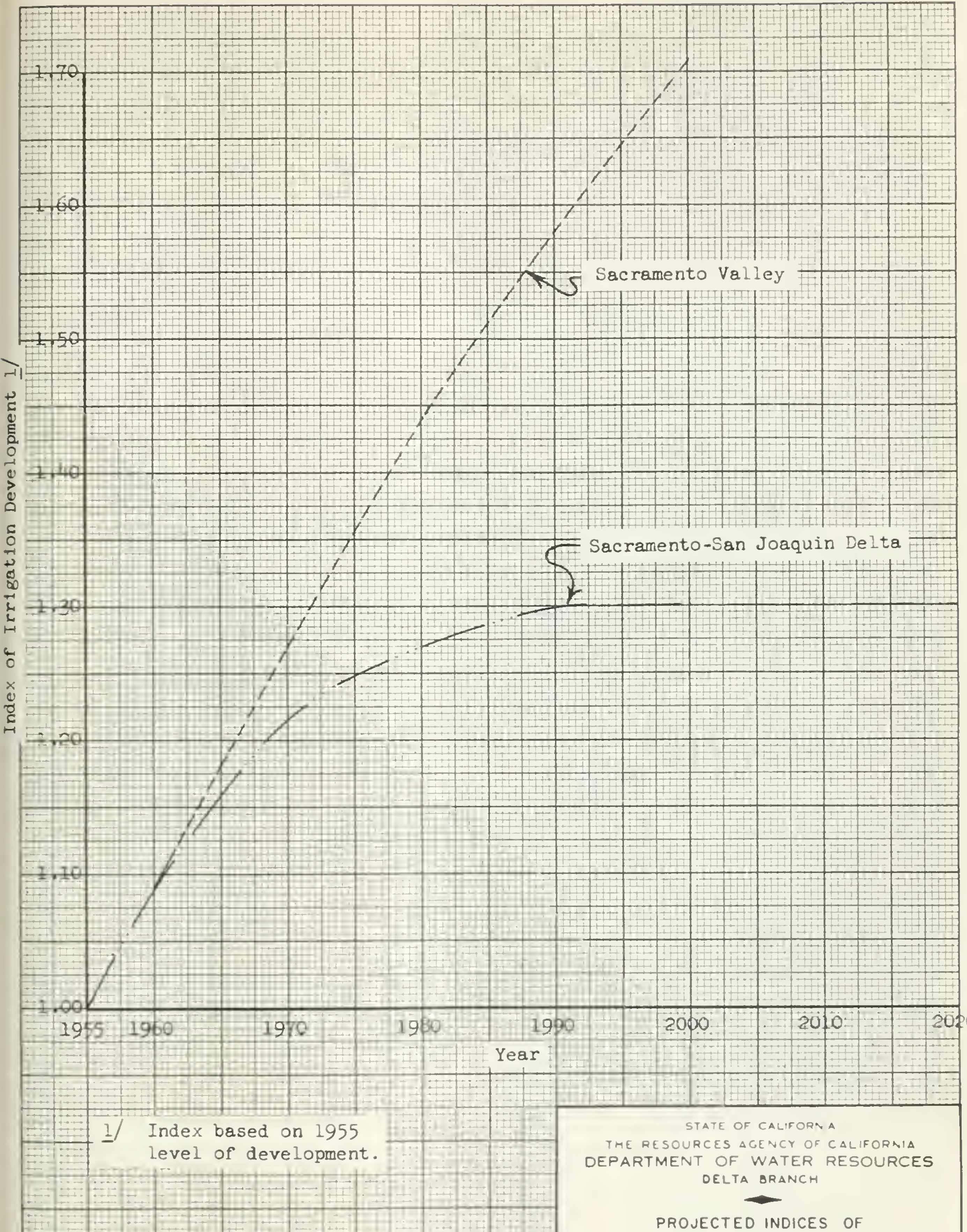
PROJECTED INDICES
OF IRRIGATION DEVELOPMENT
SACRAMENTO AND SAN JOAQUIN VALLEYS

FEBRUARY 1962



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THE RESOURCES AGENCY OF CALIFORNIA
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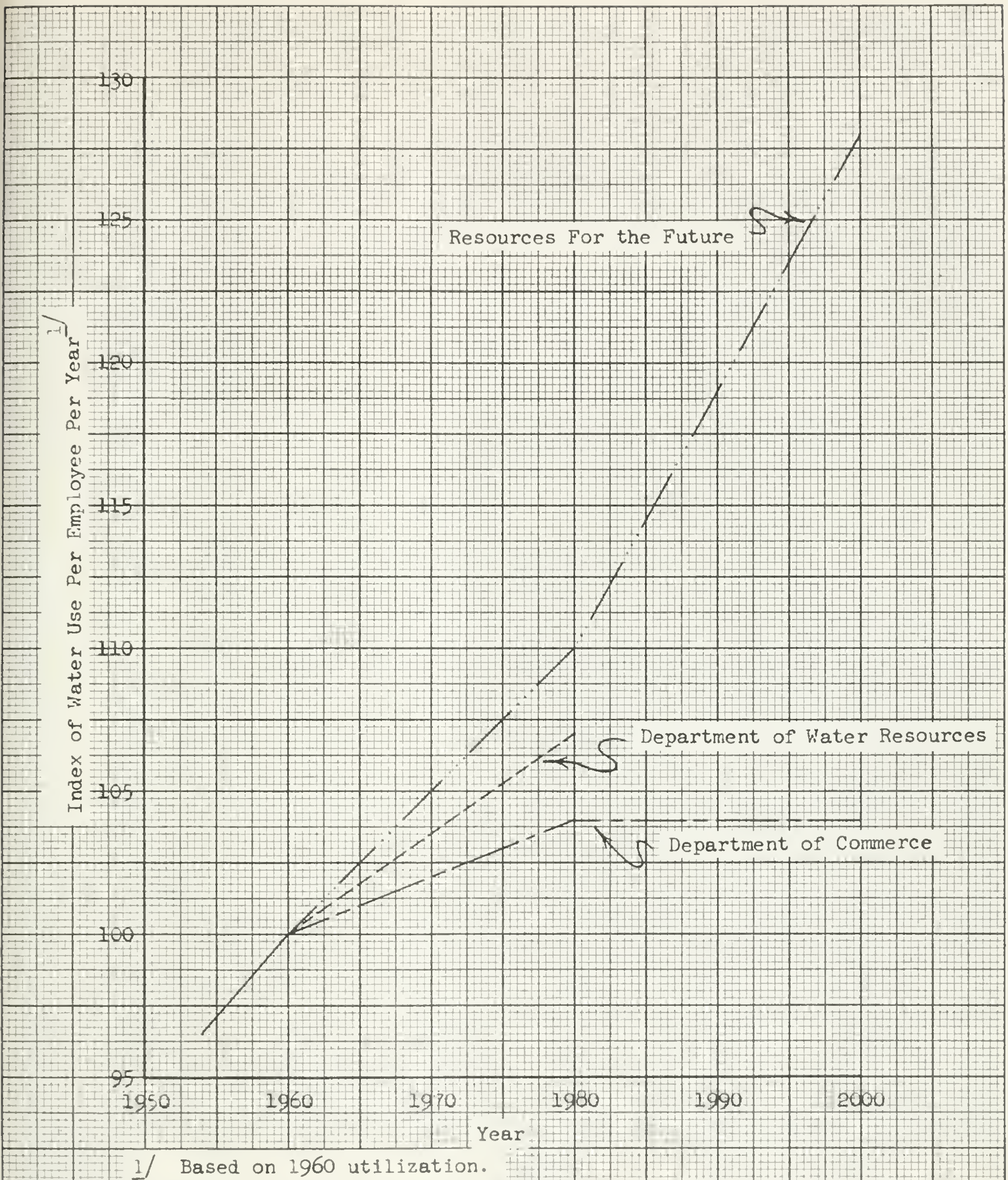
DELTA BRANCH

PROJECTED INDICES OF IRRIGATION DEVELOPMENT FOR THE SACRAMENTO VALLEY AND THE SACRAMENTO-SAN JOAQUIN DELTA

FEBRUARY 1962



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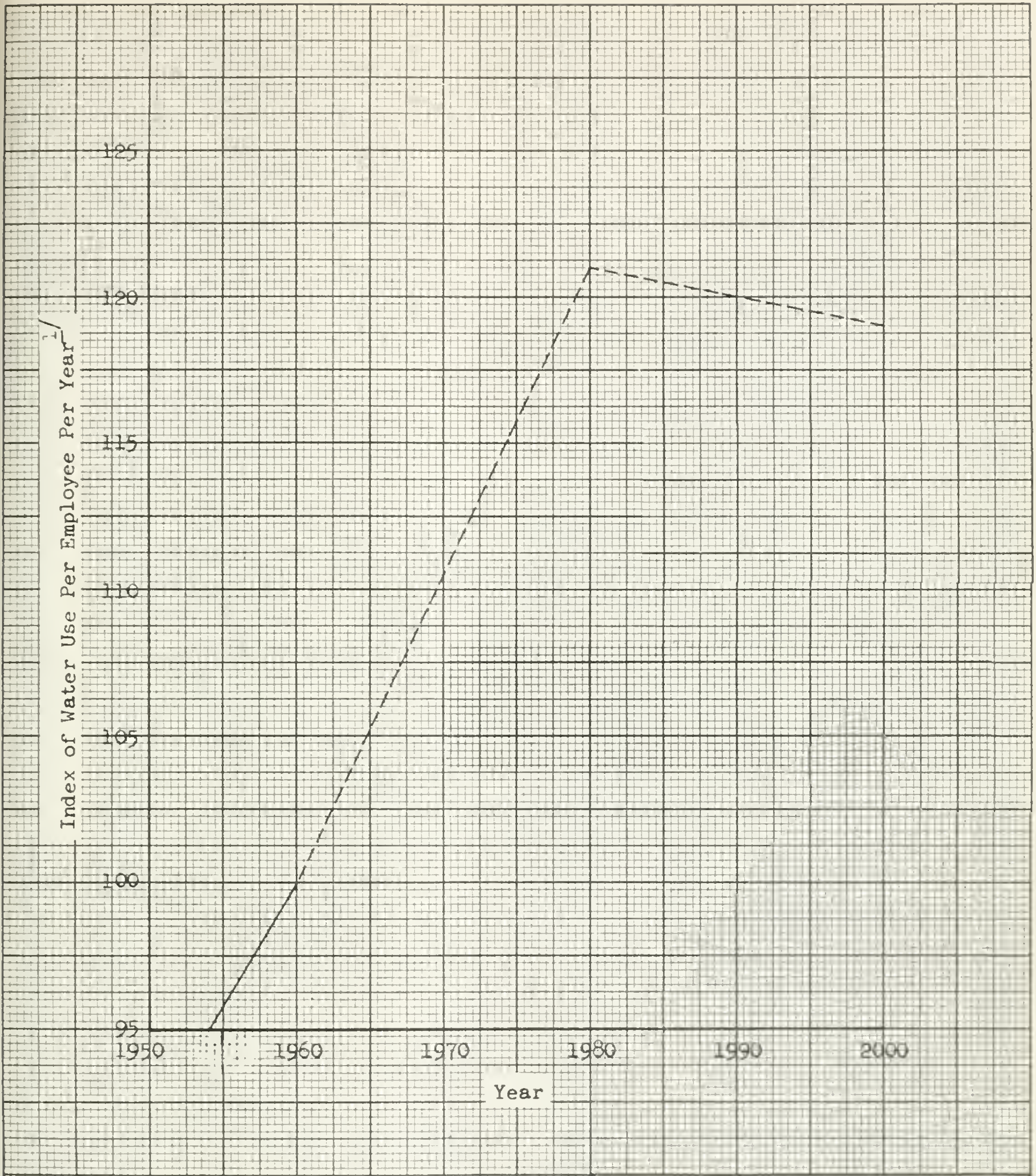
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

FOOD PRODUCTS INDUSTRY
PROJECTED INDICES OF
WATER USE PER EMPLOYEE
IN THE UNITED STATES

FEBRUARY 1962



1/ Based on 1960 utilization.

NOTE: The projections prepared for "Resources For the Future", "Department of Commerce", and "Department of Water Resources" are identical for the period 1960 to 2000.

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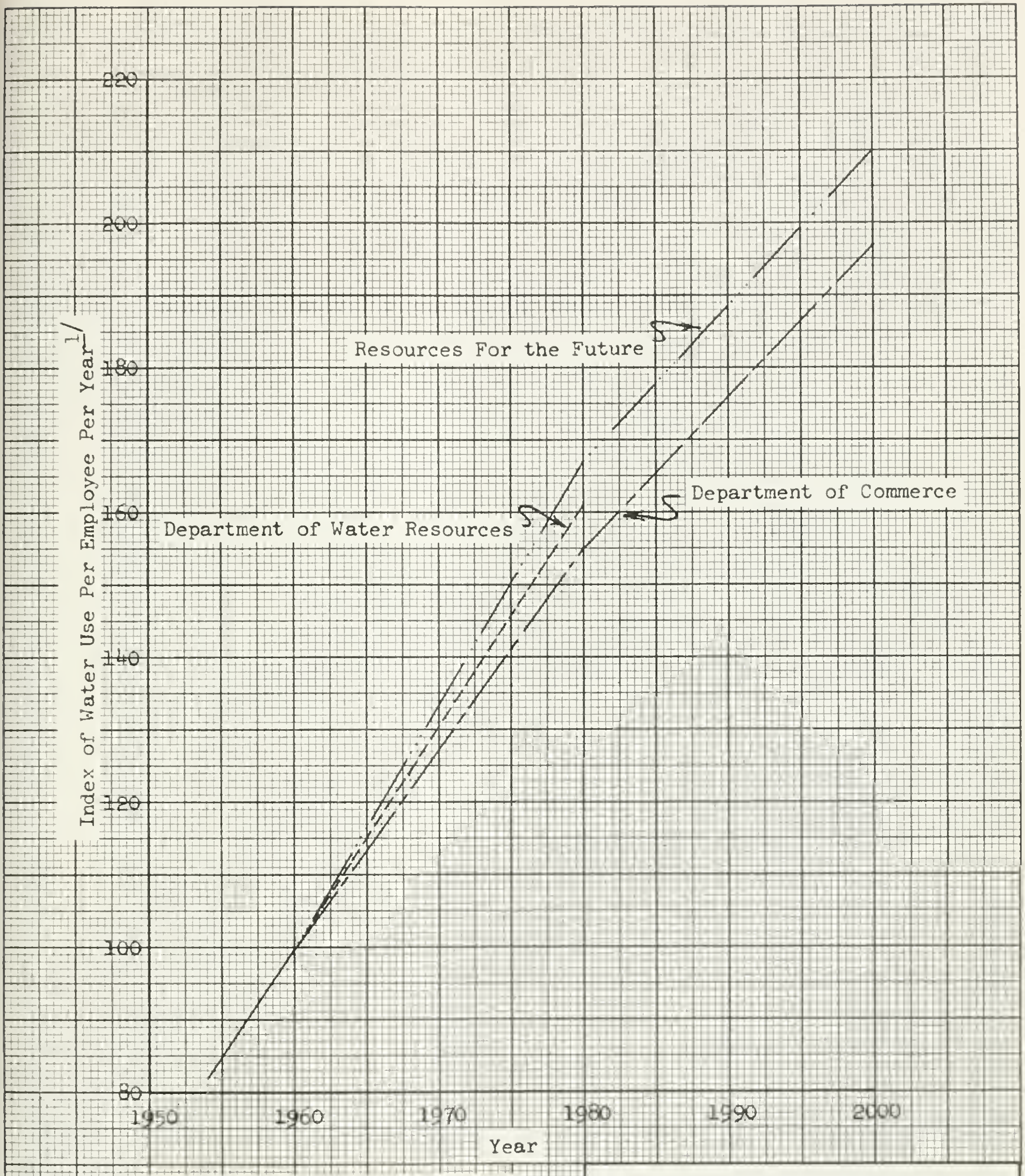
DELTA BRANCH

PULP AND PAPER INDUSTRY
PROJECTED INDICES OF
WATER USE PER EMPLOYEE
IN THE UNITED STATES

FEBRUARY 1962



1/ Based on 1960 utilization.

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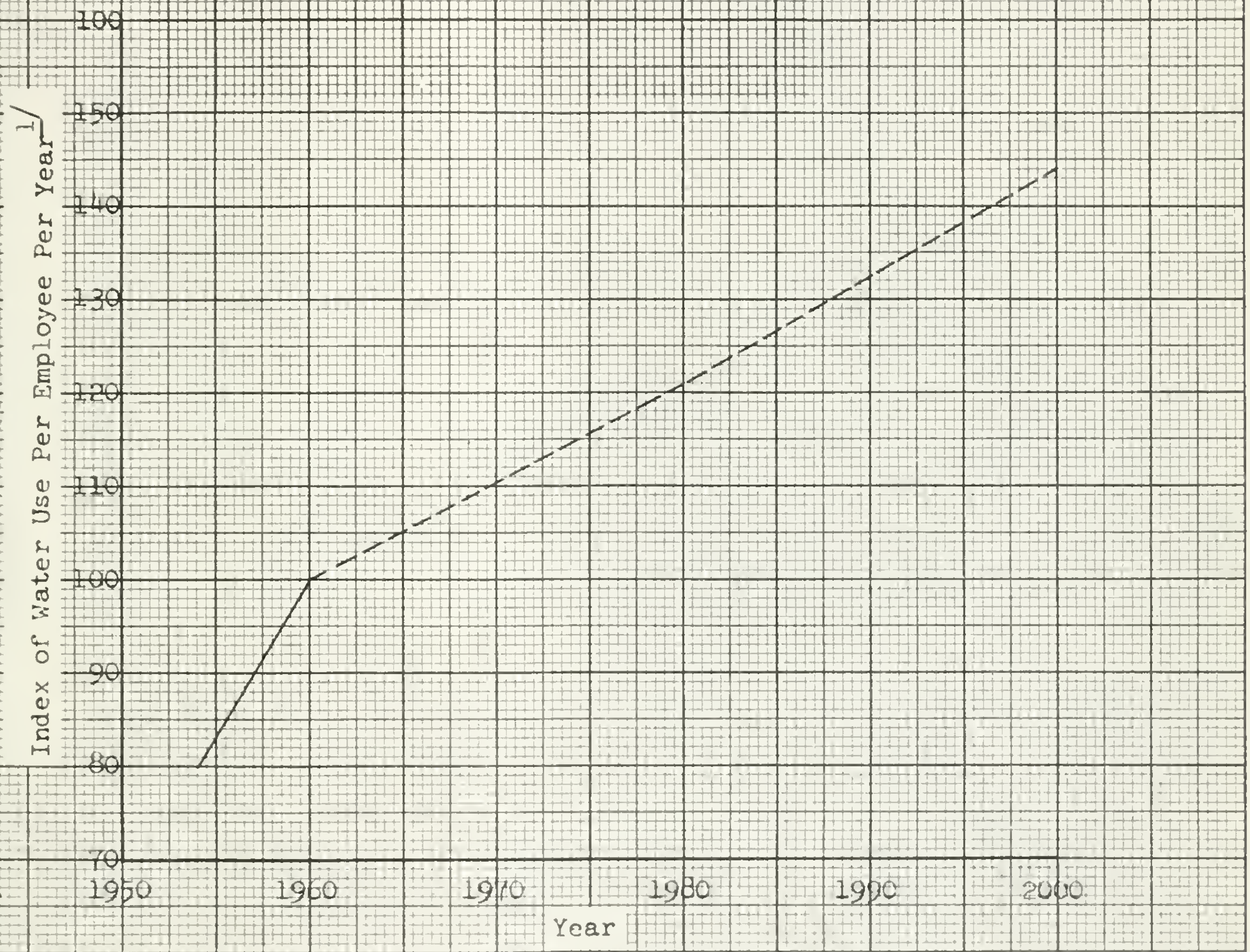
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

CHEMICAL INDUSTRY
PROJECTED INDICES OF
WATER USE PER EMPLOYEE
IN THE UNITED STATES

FEBRUARY 1962



1/ Based on 1960 utilization.

NOTE: The projections prepared for "Resources For the Future", "Department of Commerce", and "Department of Water Resources" are identical for the period 1960 to 2000.

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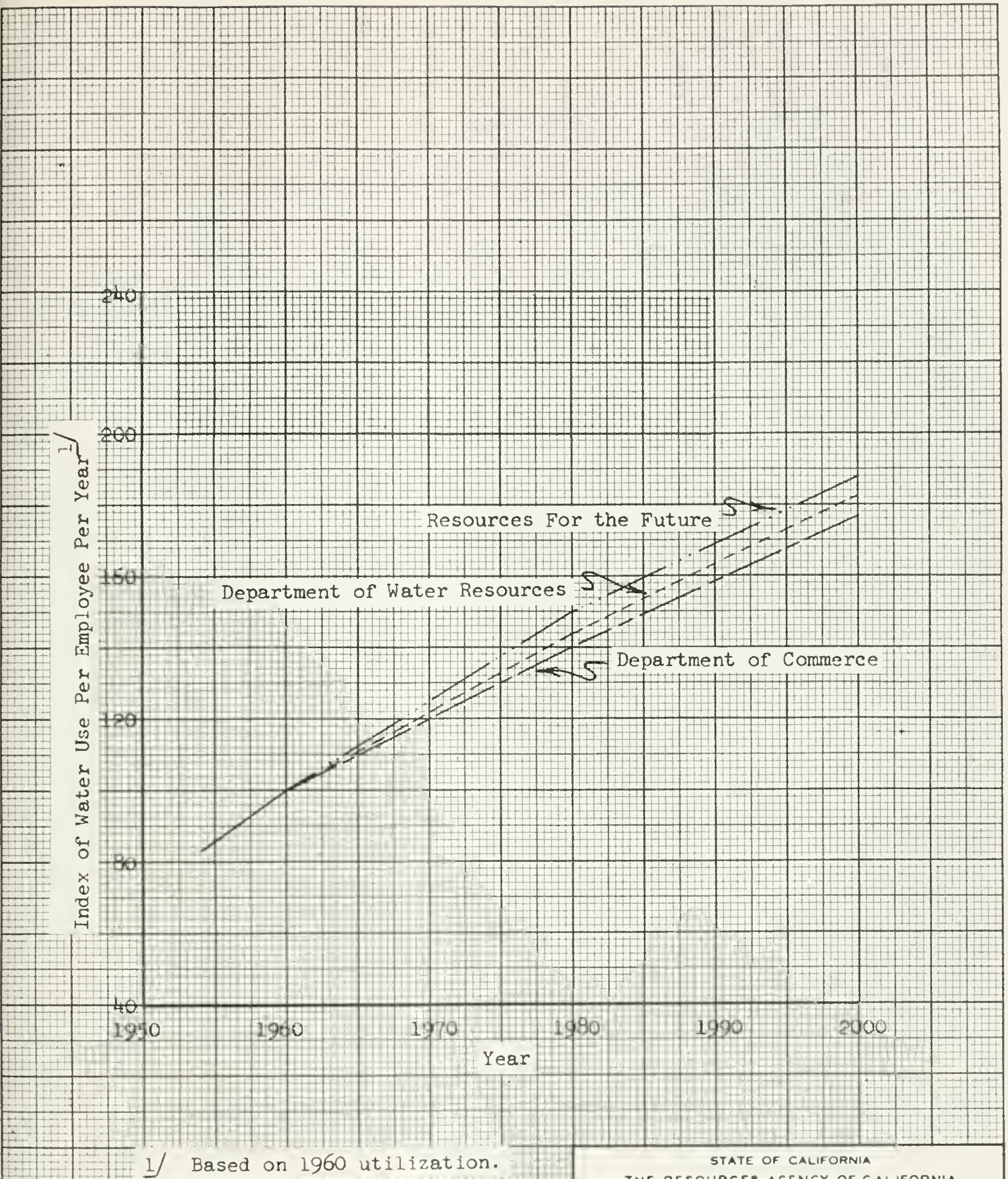
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

PRIMARY METAL INDUSTRIES
PROJECTED INDICES OF
WATER USE PER EMPLOYEE
IN THE UNITED STATES

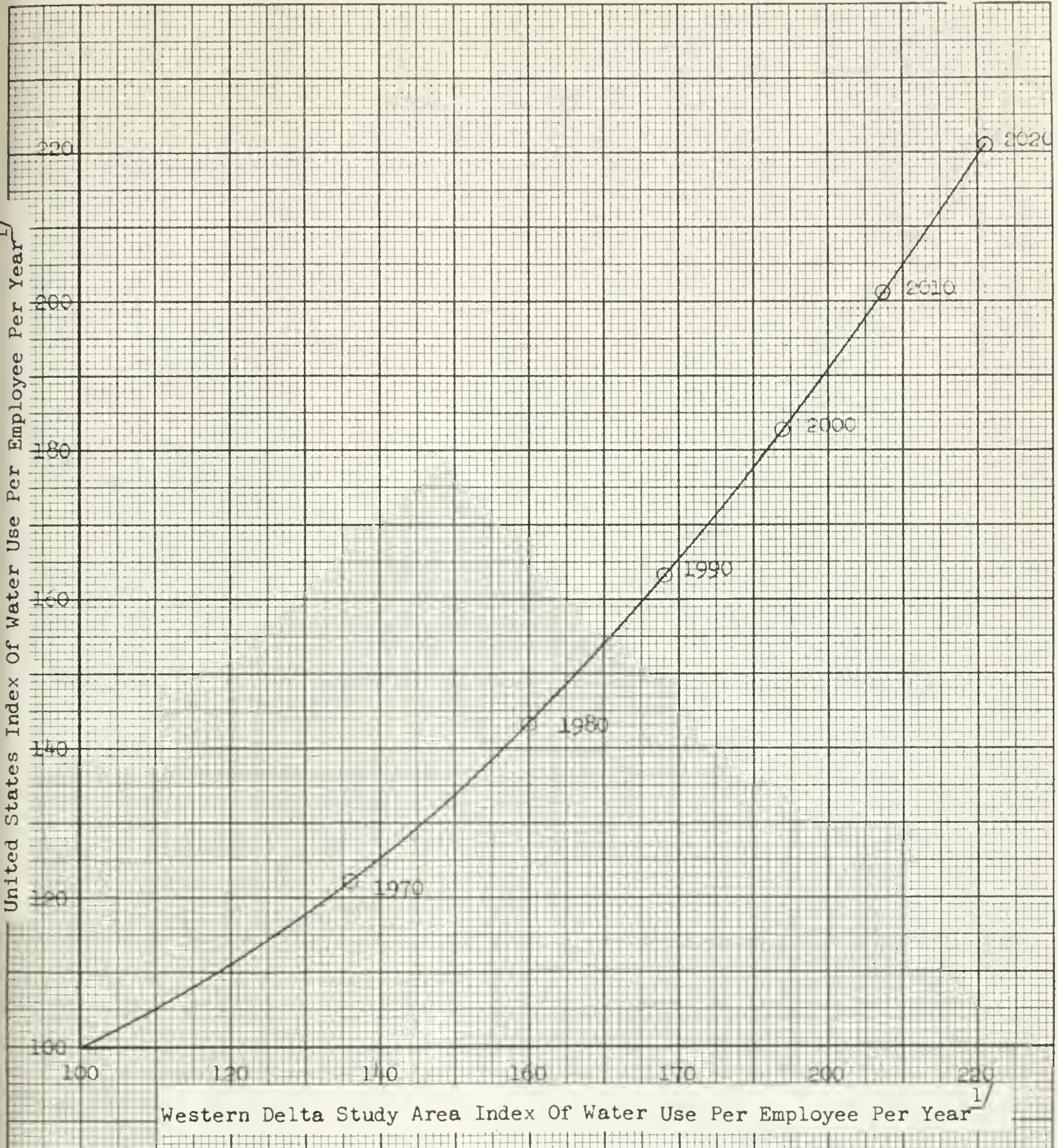
FEBRUARY 1962



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

TOTAL MANUFACTURING
PROJECTED INDICES OF
WATER USE PER EMPLOYEE
IN THE UNITED STATES

FEBRUARY 1962

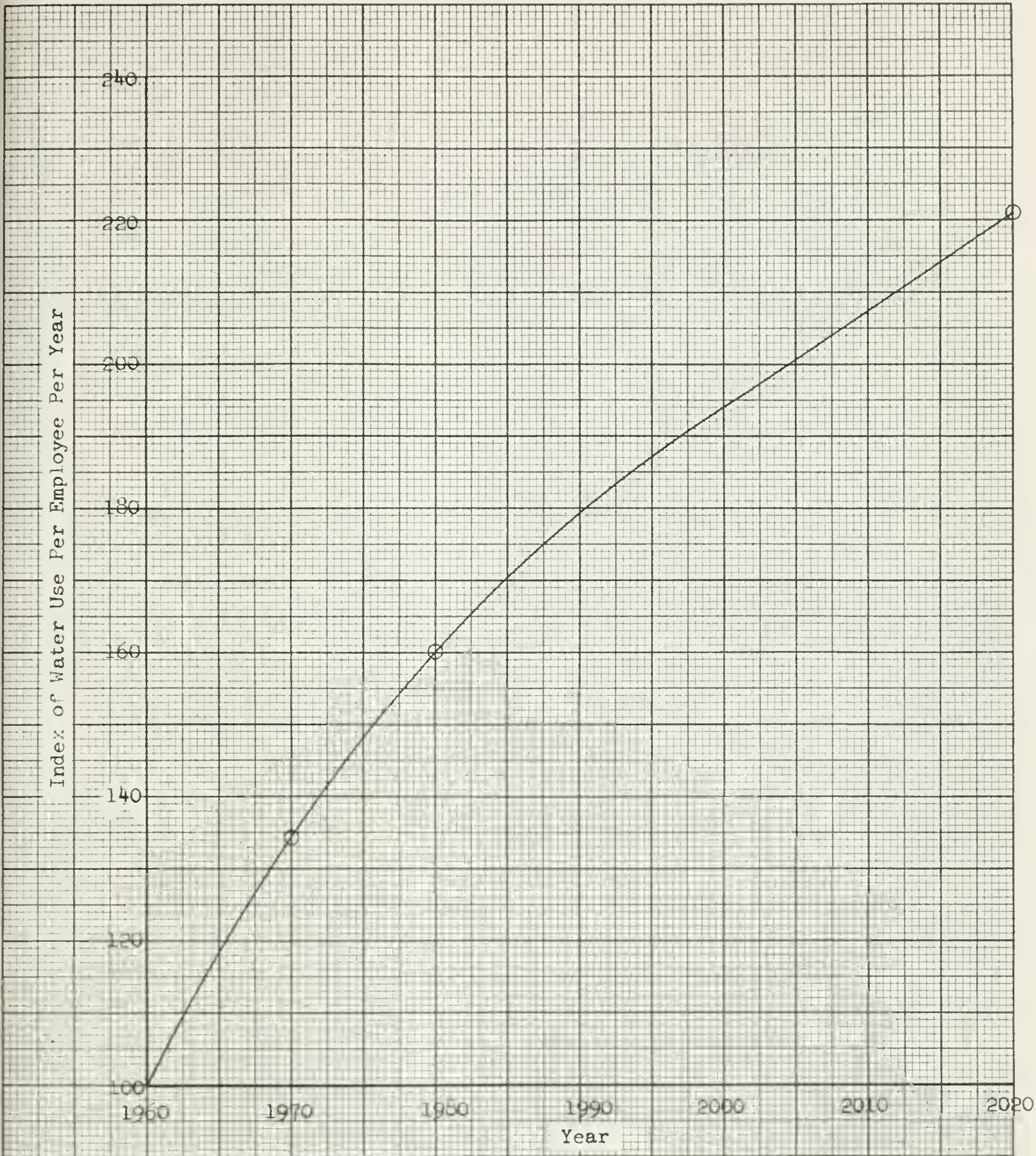


1/ Based on 1960 utilization.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

WESTERN DELTA INDEX
VERSUS
UNITED STATES INDEX
UNIT WATER REQUIREMENTS
FOR TOTAL MANUFACTURING

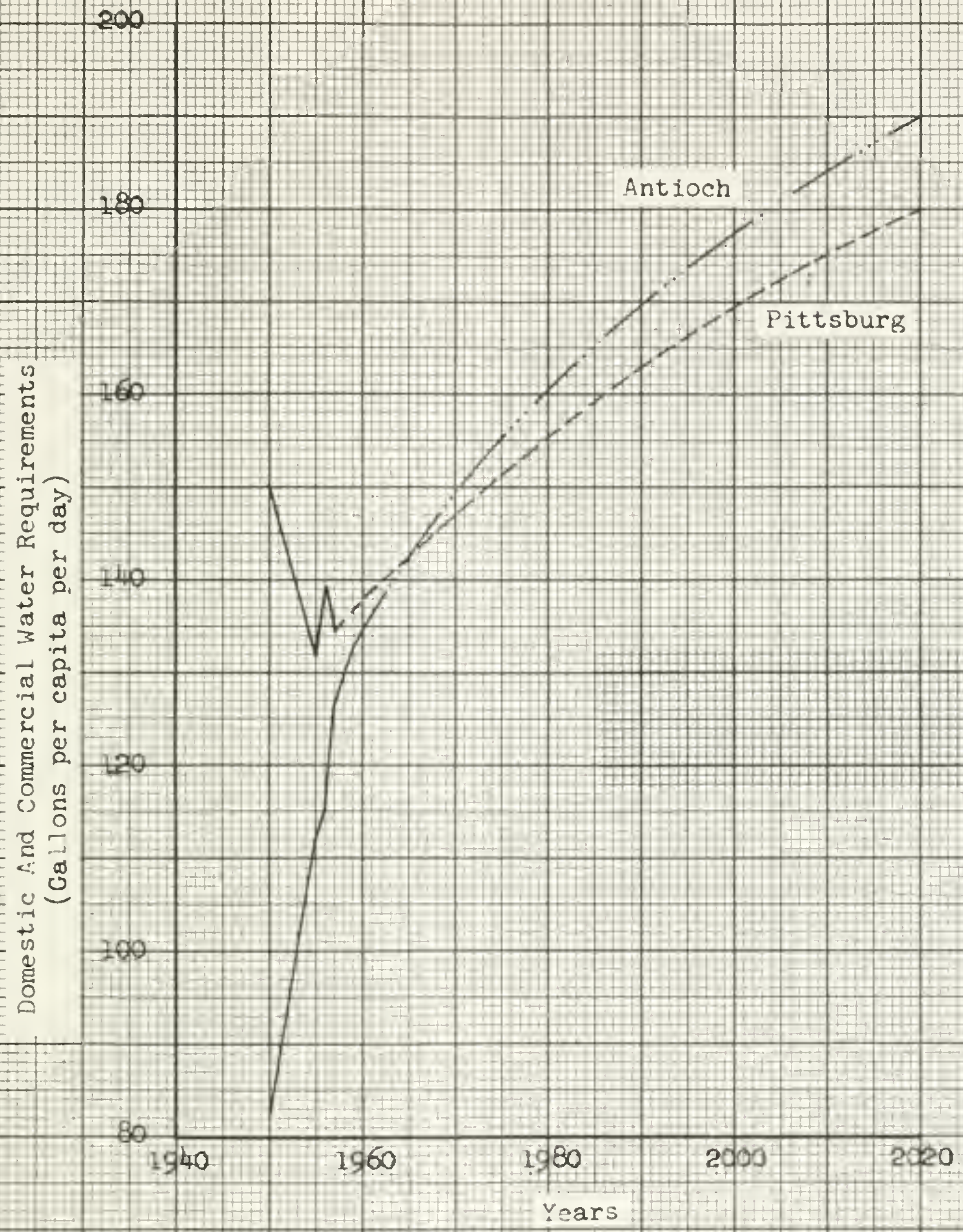
FEBRUARY 1962



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

MANUFACTURING INDUSTRIES
INDEX OF WATER USE
PER EMPLOYEE IN THE
WESTERN DELTA STUDY AREA

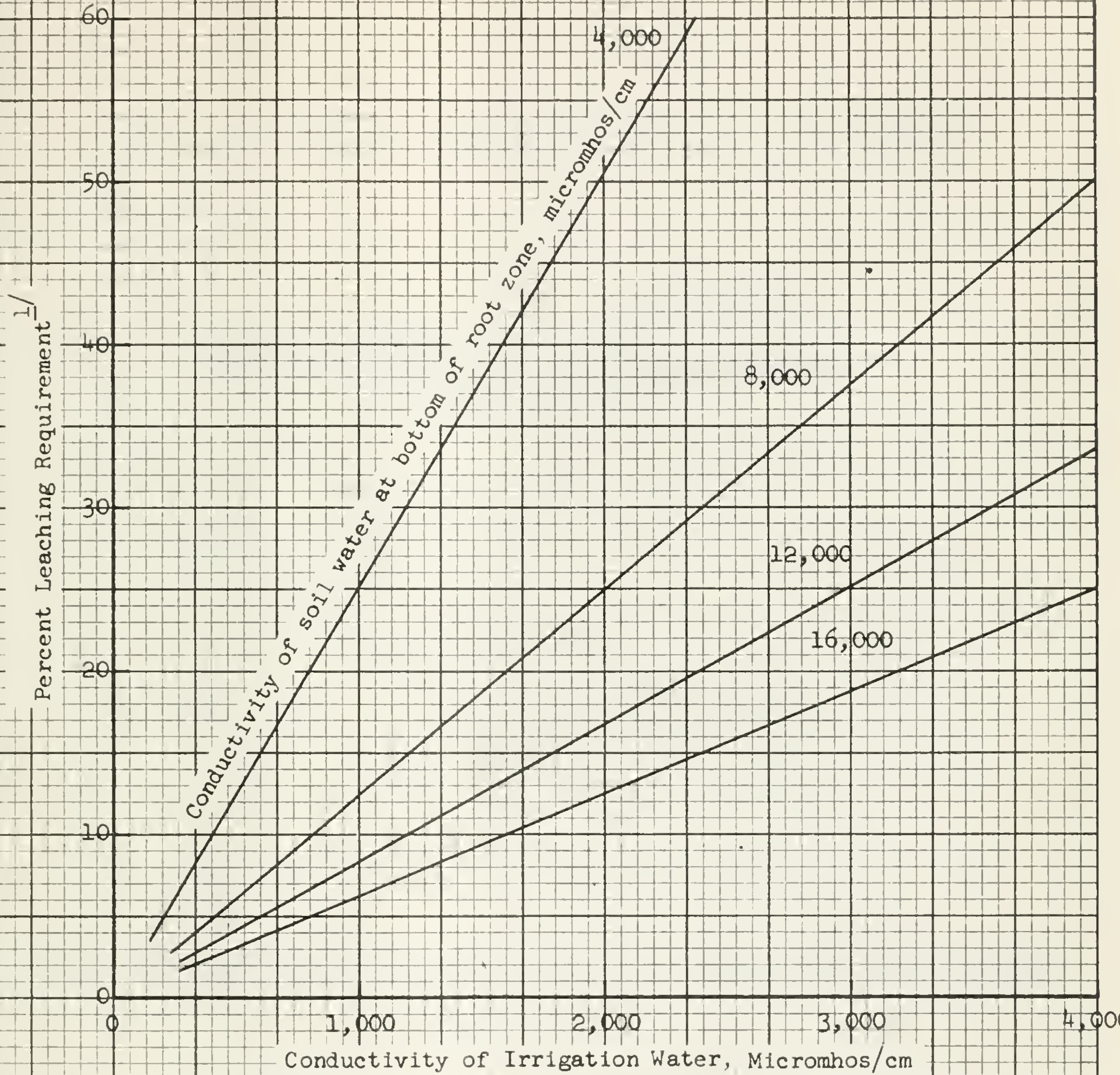
FEBRUARY 1962



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

HISTORIC AND PROJECTED WATER USE PER CAPITA FOR THE CITIES OF PITTSBURG AND ANTIOCH

FEBRUARY 1962



1/ Leaching water requirement in percent of irrigation water requirement.

NOTE: Reproduced from Agricultural Circular No. 969, U. S. Department of Agriculture.

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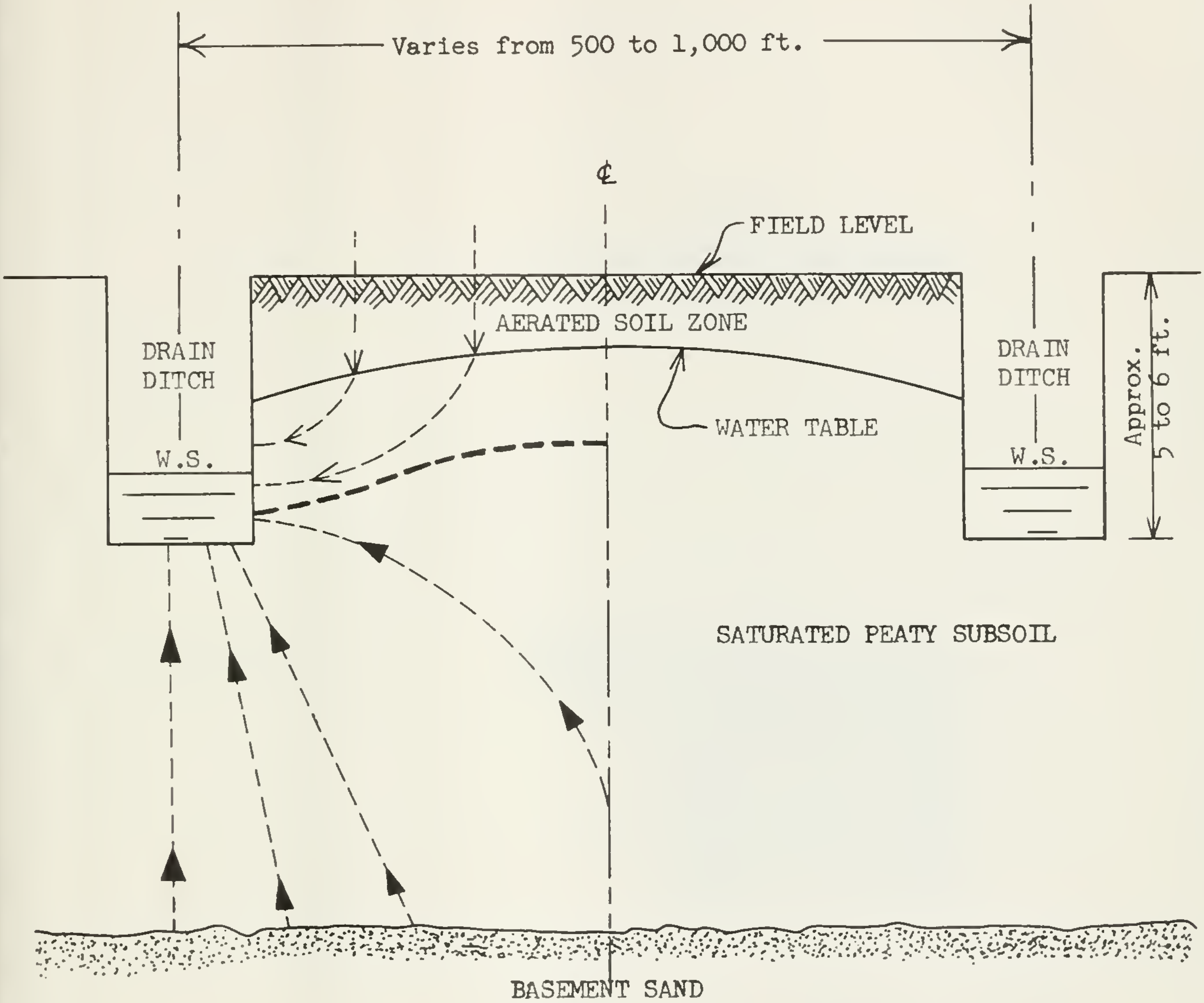
IRRIGATION WATER QUALITY AND LEACHING REQUIREMENT RELATIONSHIP

FEBRUARY 1962



LEGEND

NOTE: NOT TO SCALE

↓ Direction of flow of applied irrigation water and/or precipitation.

▲ Direction of flow of subsurface inflow or seepage from basement sands connected to Delta channels.

– – – – Interface of the two water sources.

STATE OF CALIFORNIA
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DELTA BRANCH

SCHEMATIC FLOW DIAGRAM OF
IRRIGATION AND SUBSURFACE
INFLOW WATER UNDER
DELTA FIELD CONDITIONS

FEBRUARY 1962

LEGEND

AVERAGE MONTHLY SALINITY LESS THAN 150 PPM

AVERAGE MONTHLY SALINITY LESS THAN 350 PP.M

AVERAGE MONTHLY SALINITY LESS THAN 1000 PPM

SALINITY REPRESENTS MEAN TIDAL CYCLE SURFACE ZONE SALINITY EXPRESSED AS PARTS CHLORIDES PER MILLION PARTS WATER BY WEIGHT. (PPM)

SALINITY BASED UPON ESTIMATED OUTFLOWS FROM THE SACRAMENTO–SAN JOAQUIN DELTA WITH 1922–41 WATER SUPPLY CONDITIONS, FOR THE FOLLOWING CONDITIONS OF DEVELOPMENT IN THE CENTRAL VALLEY·

NATURAL:	BEFORE ANY SIGNIFICANT DEVELOPMENT.
PRESENT:	WITH EXISTING CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE CENTRAL VALLEY PROJECT WITH IMPORTS OF WATER FROM THE TRINITY RIVER AND WITH A MINIMUM OUTFLOW OF 1,500 SECOND-FEET.
1990:	WITH 1990 CONDITIONS OF UPSTREAM DEVELOPMENT, OPERATION OF THE CENTRAL VALLEY PROJECT, FEATHER RIVER PROJECT, DELTA DIVERSION PROJECT, DELTA WATER PROJECT AND IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET.
2020:	WITH 2020 CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE SAME PROJECTS AS LISTED FOR 1990 PLUS ADDITIONAL IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET.

STATE OF CALIFORNIA
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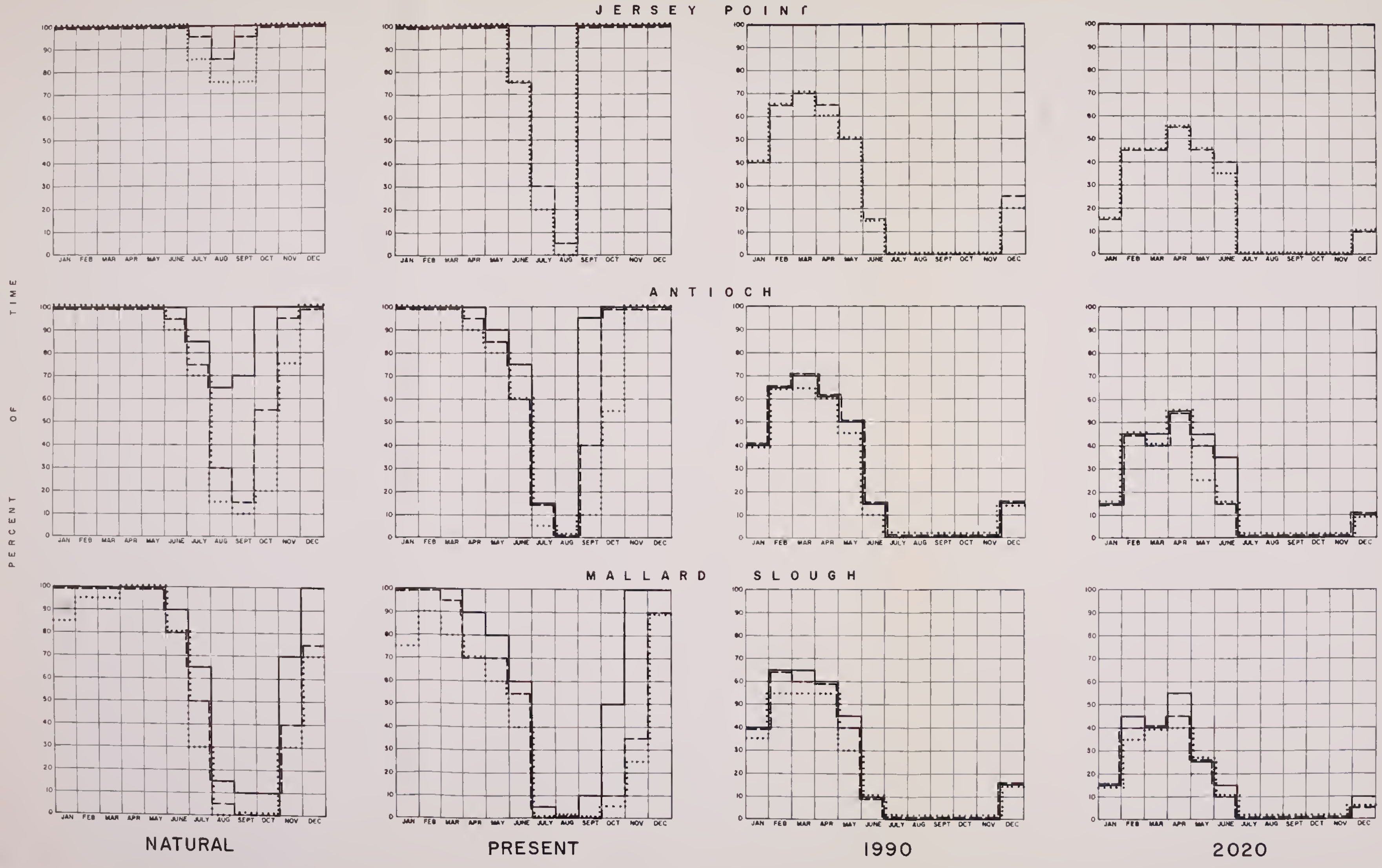
DELTA BRANCH

TURAL, PRESENT AND FUTURE SALINITY CONDITIONS IN WESTERN SACRAMENTO-SAN JOAQUIN DELTA

FEBRUARY 1962



LEGEND

- .... AVERAGE MONTHLY SALINITY LESS THAN 150 PPM
- — — — AVERAGE MONTHLY SALINITY LESS THAN 350 PPM
- ——— AVERAGE MONTHLY SALINITY LESS THAN 1000 PPM

SALINITY REPRESENTS MEAN TIDAL CYCLE SURFACE ZONE SALINITY EXPRESSED AS PARTS CHLORIDES PER MILLION PARTS WATER BY WEIGHT (PPM)

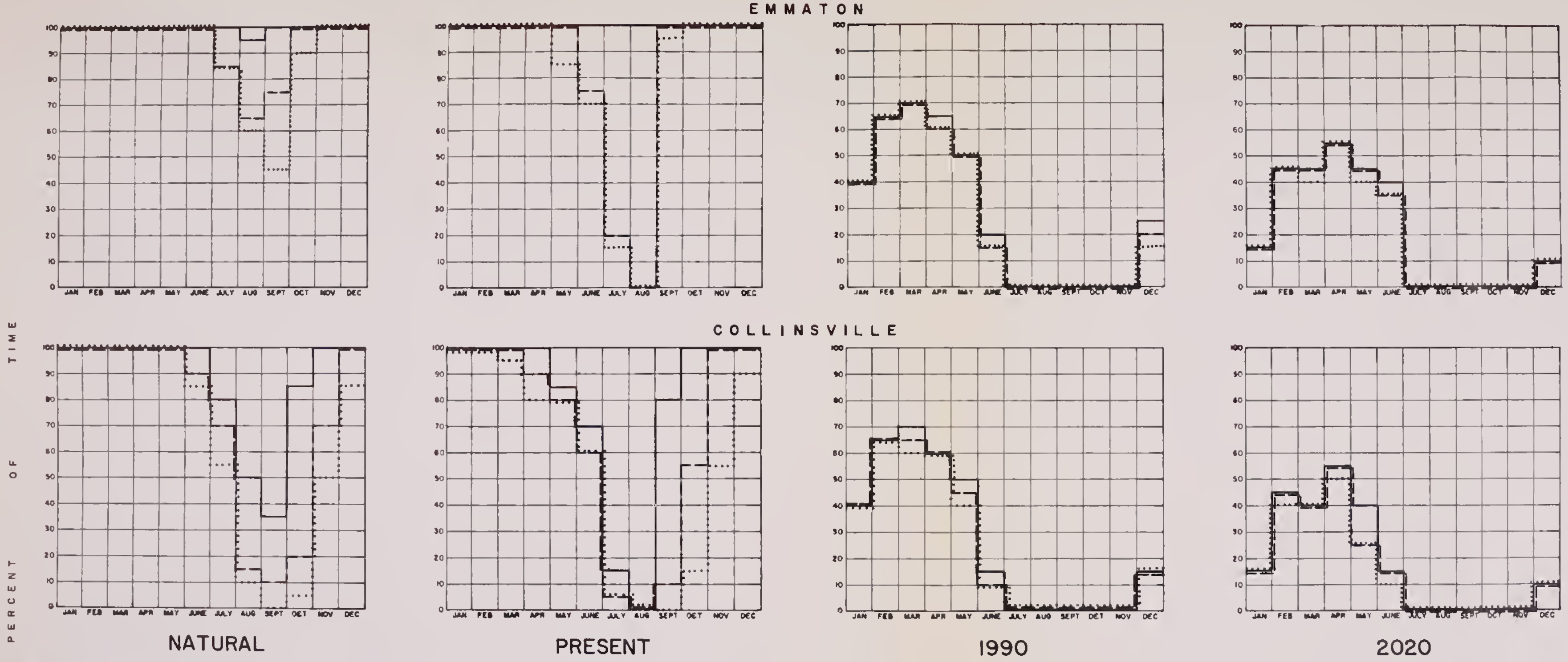
SALINITY BASED UPON ESTIMATED OUTFLOWS FROM THE SACRAMENTO-SAN JOAQUIN DELTA WITH 1922-41 WATER SUPPLY CONDITIONS, FOR THE FOLLOWING CONDITIONS OF DEVELOPMENT IN THE CENTRAL VALLEY

NATURAL	BEFORE ANY SIGNIFICANT DEVELOPMENT
PRESENT	WITH EXISTING CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE CENTRAL VALLEY PROJECT WITH IMPORTS OF WATER FROM THE TRINITY RIVER AND WITH A MINIMUM OUTFLOW OF 1,500 SECOND FEET
1990	WITH 1990 CONDITIONS OF UPSTREAM DEVELOPMENT, OPERATION OF THE CENTRAL VALLEY PROJECT, FEATHER RIVER PROJECT, DELTA DIVERSION PROJECT, DELTA WATER PROJECT AND IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET
2020	WITH 2020 CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE SAME PROJECTS AS LISTED FOR 1990 PLUS ADDITIONAL IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

NATURAL, PRESENT AND FUTURE SALINITY CONDITIONS IN WESTERN SACRAMENTO-SAN JOAQUIN DELTA

FEBRUARY 1962



LEGEND

- · · · · · · AVERAGE MONTHLY SALINITY LESS THAN 150 PPM
- — — AVERAGE MONTHLY SALINITY LESS THAN 350 PPM
- ——— AVERAGE MONTHLY SALINITY LESS THAN 1000 PPM

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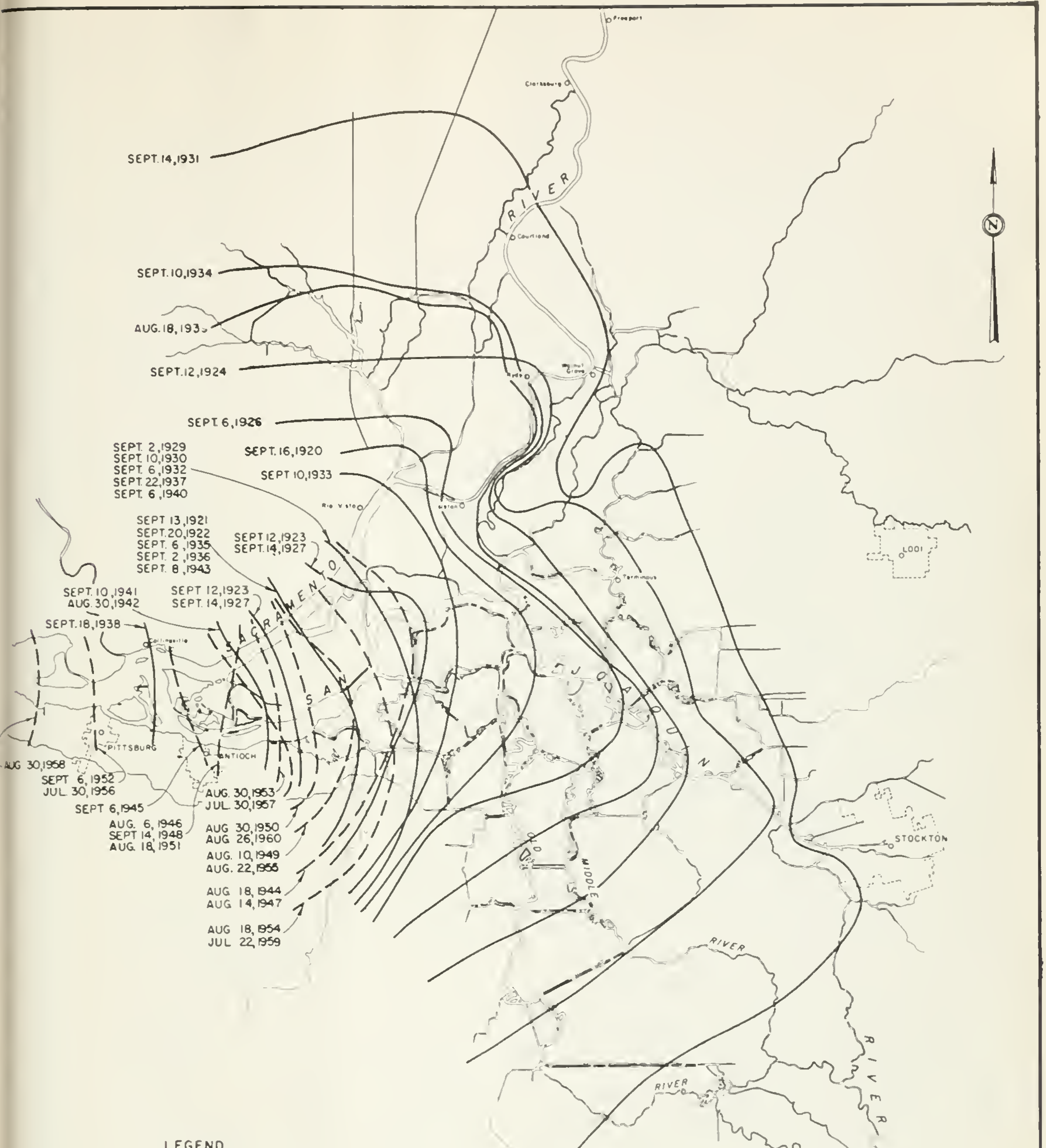
NATURAL	BEFORE ANY SIGNIFICANT DEVELOPMENT
PRESENT	WITH EXISTING CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE CENTRAL VALLEY PROJECT WITH IMPORTS OF WATER FROM THE TRINITY RIVER AND WITH A MINIMUM OUTFLOW OF 1,500 SECOND FEET
1990:	WITH 1990 CONDITIONS OF UPSTREAM DEVELOPMENT, OPERATION OF THE CENTRAL VALLEY PROJECT, FEATHER RIVER PROJECT, DELTA DIVERSION PROJECT, DELTA WATER PROJECT AND IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET
2020:	WITH 2020 CONDITIONS OF UPSTREAM DEVELOPMENT AND OPERATION OF THE SAME PROJECTS AS LISTED FOR 1990 PLUS ADDITIONAL IMPORTS OF WATER FROM THE NORTH COAST AND WITH A MINIMUM OUTFLOW OF 1,000 SECOND-FEET

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

NATURAL, PRESENT AND FUTURE SALINITY CONDITIONS IN WESTERN SACRAMENTO-SAN JOAQUIN DELTA
FEBRUARY 1962



LEGEND

LIMIT OF MAXIMUM INCURSION OF SALINITY OF 1,000 PARTS OF CHLORIDES PER MILLION PARTS OF WATER

——— PRIOR TO OPERATION OF SHASTA RESERVOIR OF THE CENTRAL VALLEY PROJECT

— — — SUBSEQUENT TO OPERATION OF SHASTA RESERVOIR OF THE CENTRAL VALLEY PROJECT

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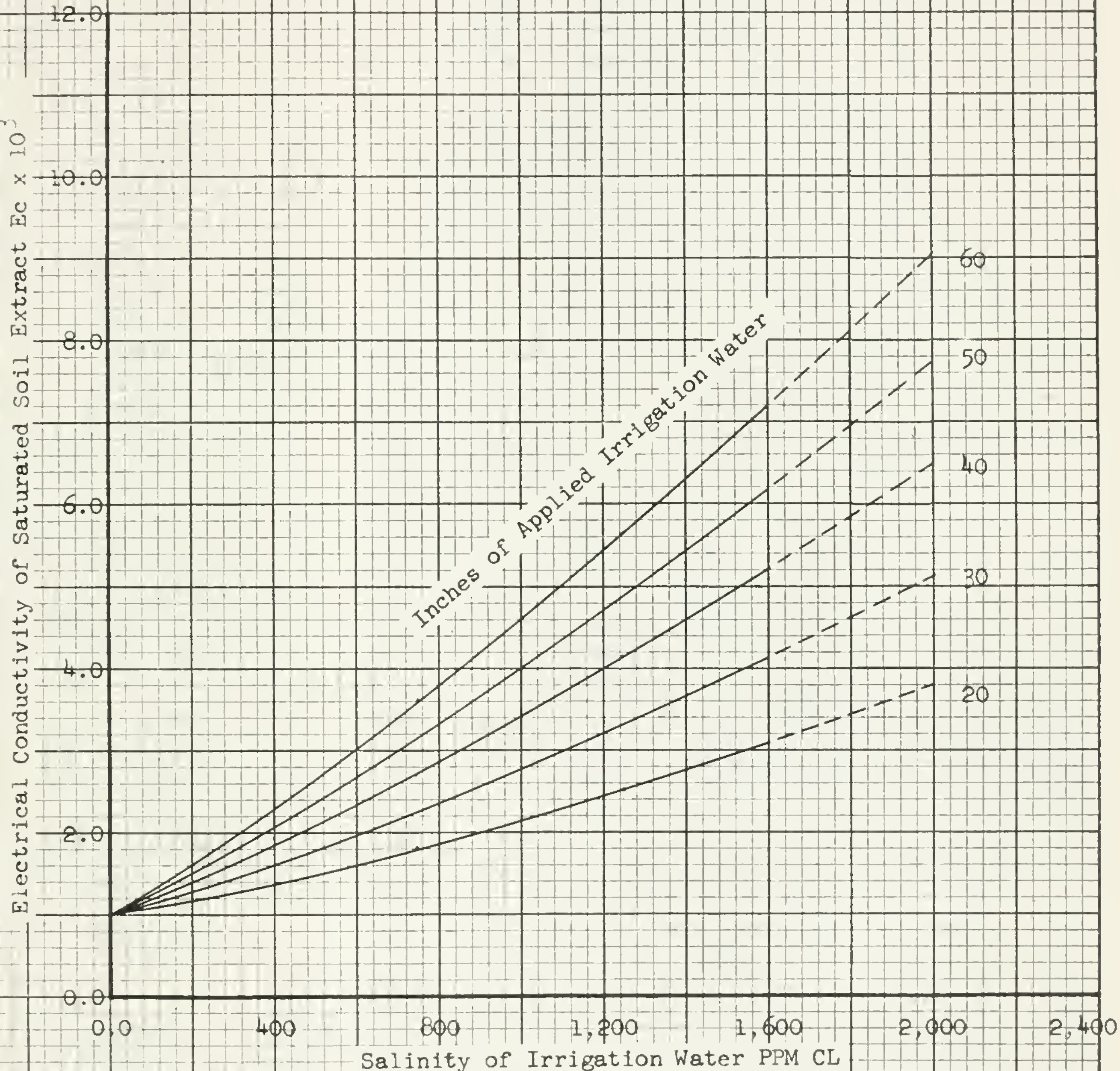
HISTORICAL SALINITY INCURSION SACRAMENTO-SAN JOAQUIN DELTA

FEBRUARY 1962

SCALE OF MILES

2 0 2 4 6



NOTE: Salinity refers to chlorides primarily, other constituents are present in minor quantities.

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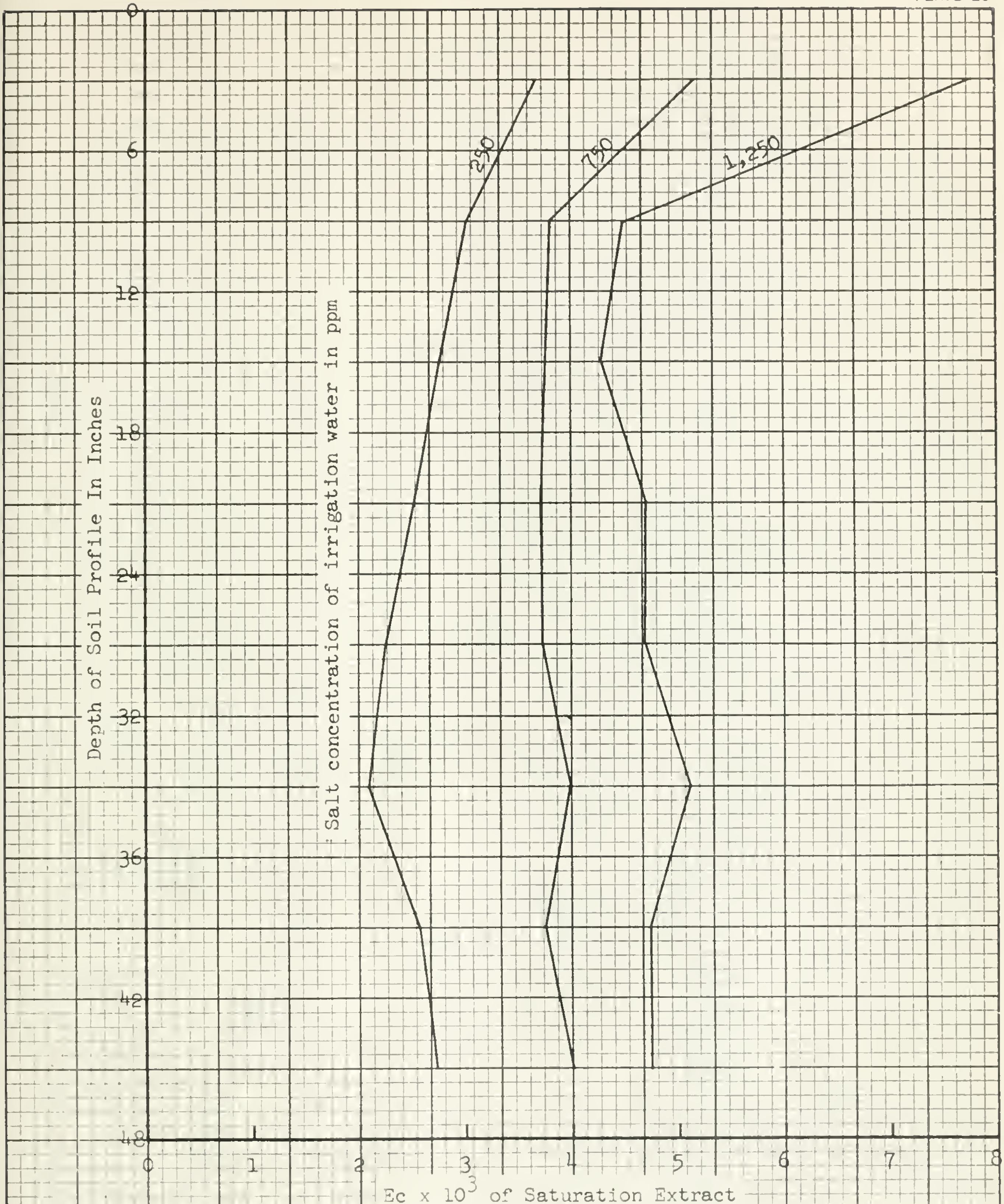
DELTA BRANCH

SALINATION OF DELTA SOILS
VERSUS
SALINITY OF THE IRRIGATION WATER
SACRAMENTO-SAN JOAQUIN DELTA
FEBRUARY 1962



NOTE: Typical Delta soil salinity accumulation after conventional irrigation practice applying approximately 50 inches of water.

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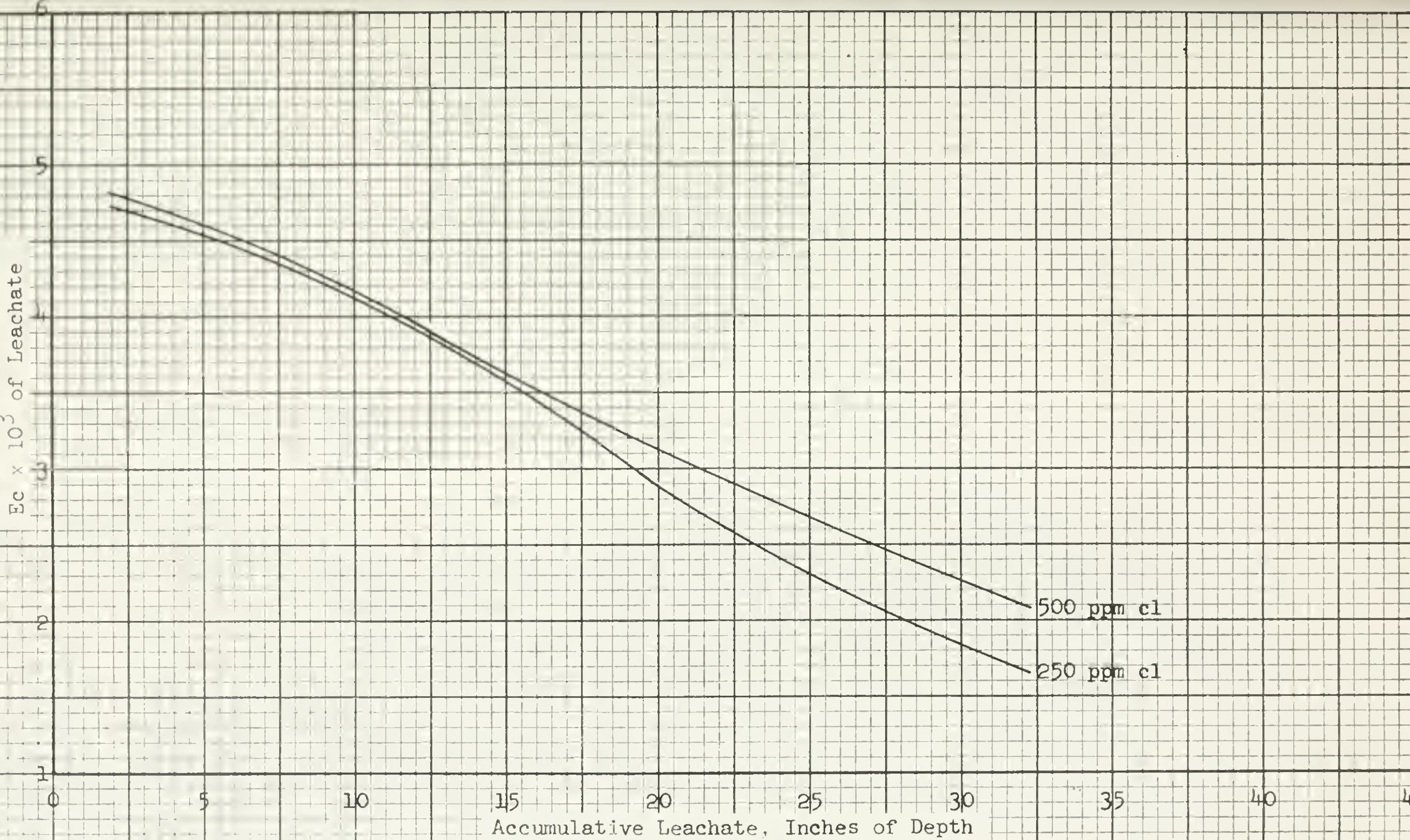
SALT ACCUMULATION
IN DELTA SOILS

FEBRUARY 1962



NOTE: Effluent concentration with progressive leaching of soil columns, with 250 and 500 ppm chloride leaching water.

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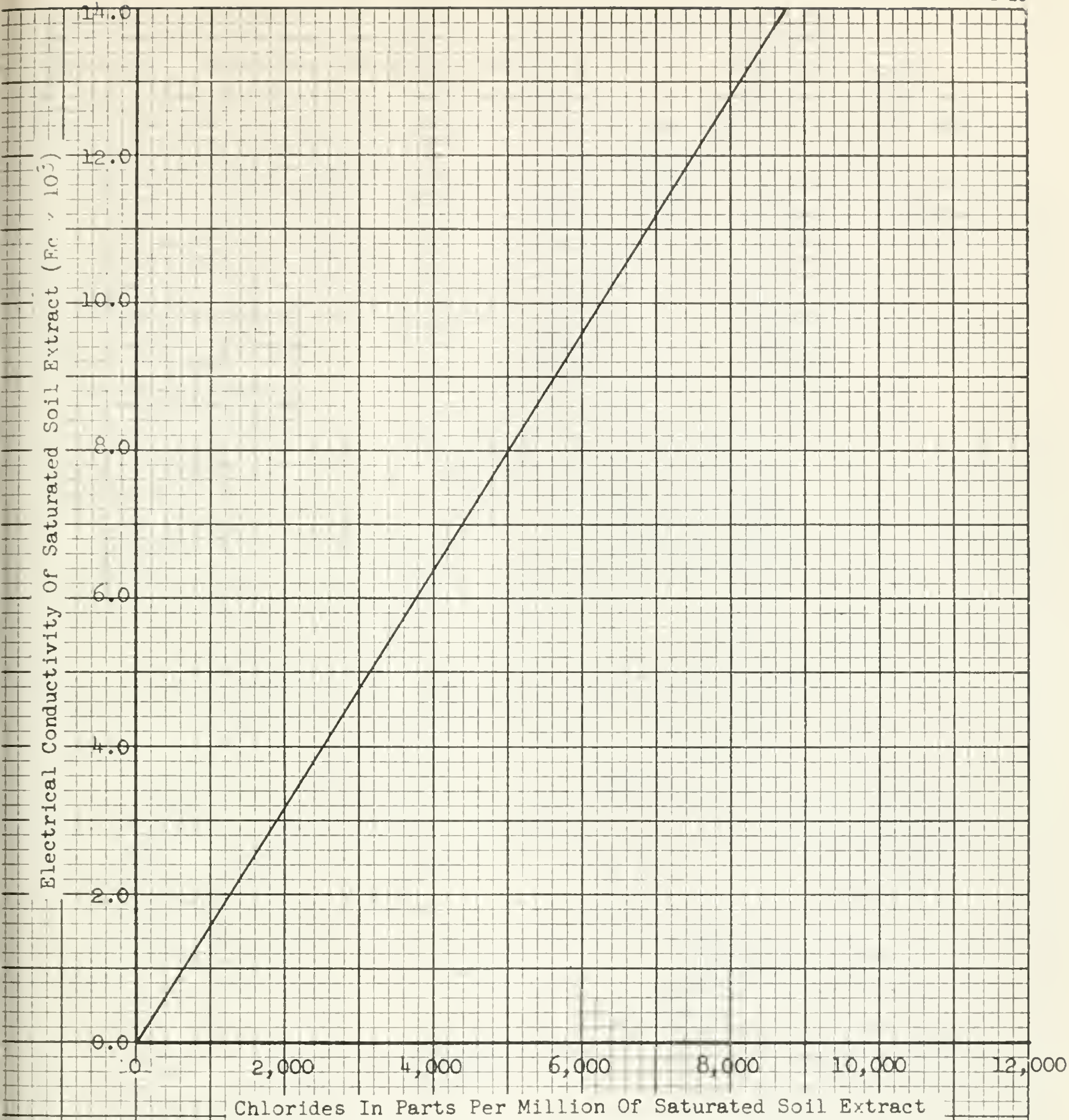
EFFECTIVENESS OF LEACHING
PEATY SOILS
IN THE SACRAMENTO-SAN JOAQUIN DELTA

FEBRUARY 1962



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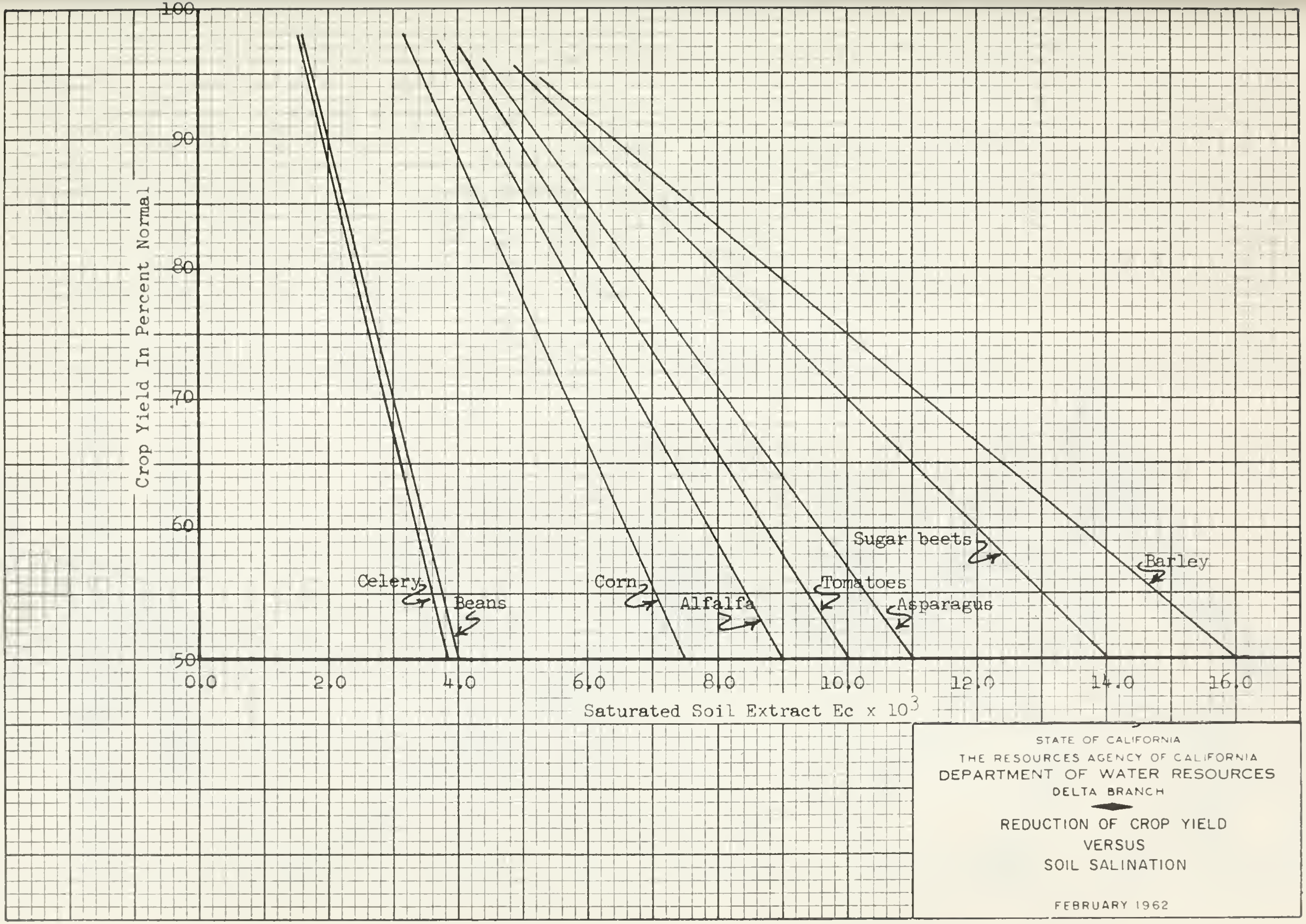
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

ELECTRICAL CONDUCTIVITY OF SATURATED SOIL EXTRACT VERSUS SALINITY OF WESTERN DELTA AREA SOILS

FEBRUARY 1962



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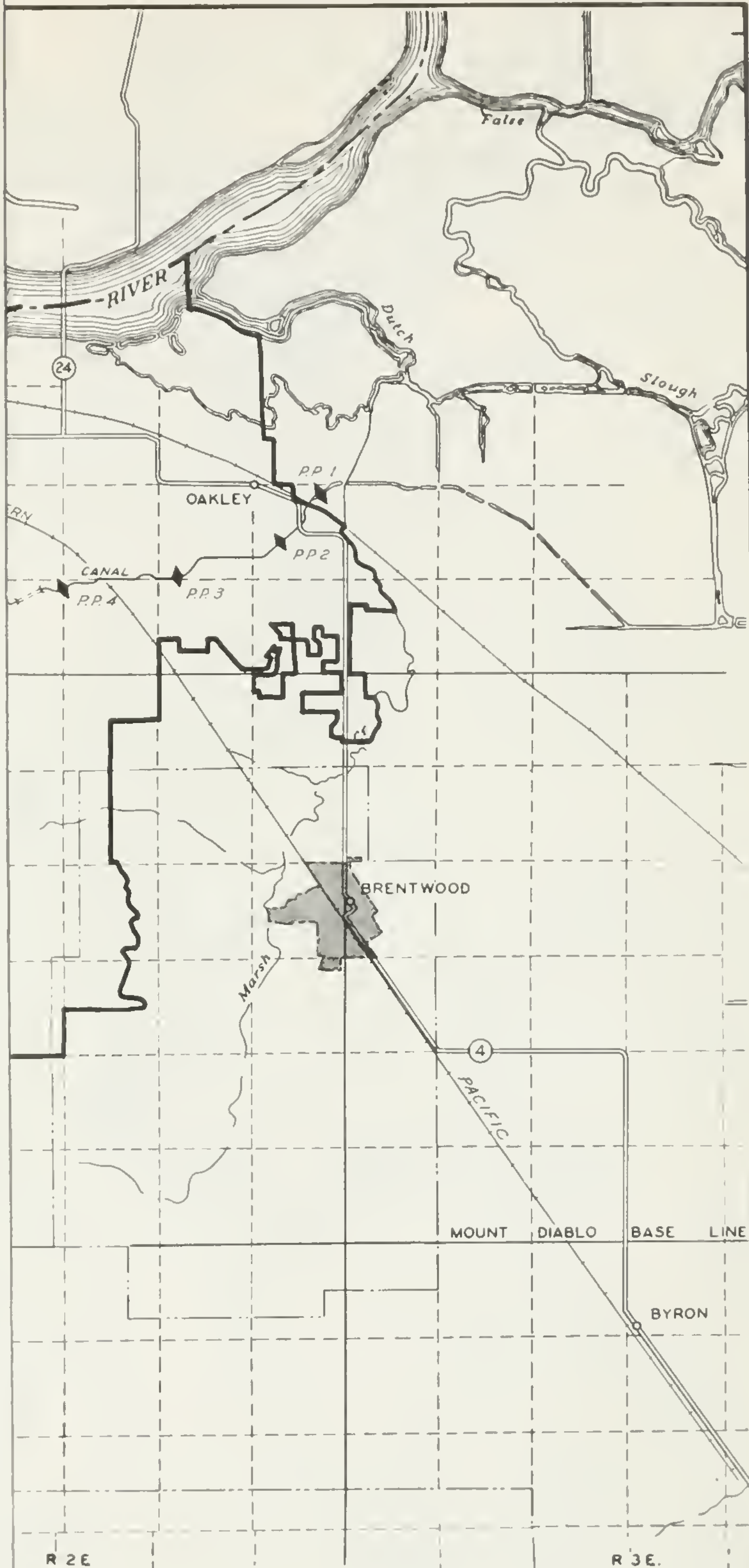
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

REDUCTION OF CROP YIELD
VERSUS
SOIL SALINATION

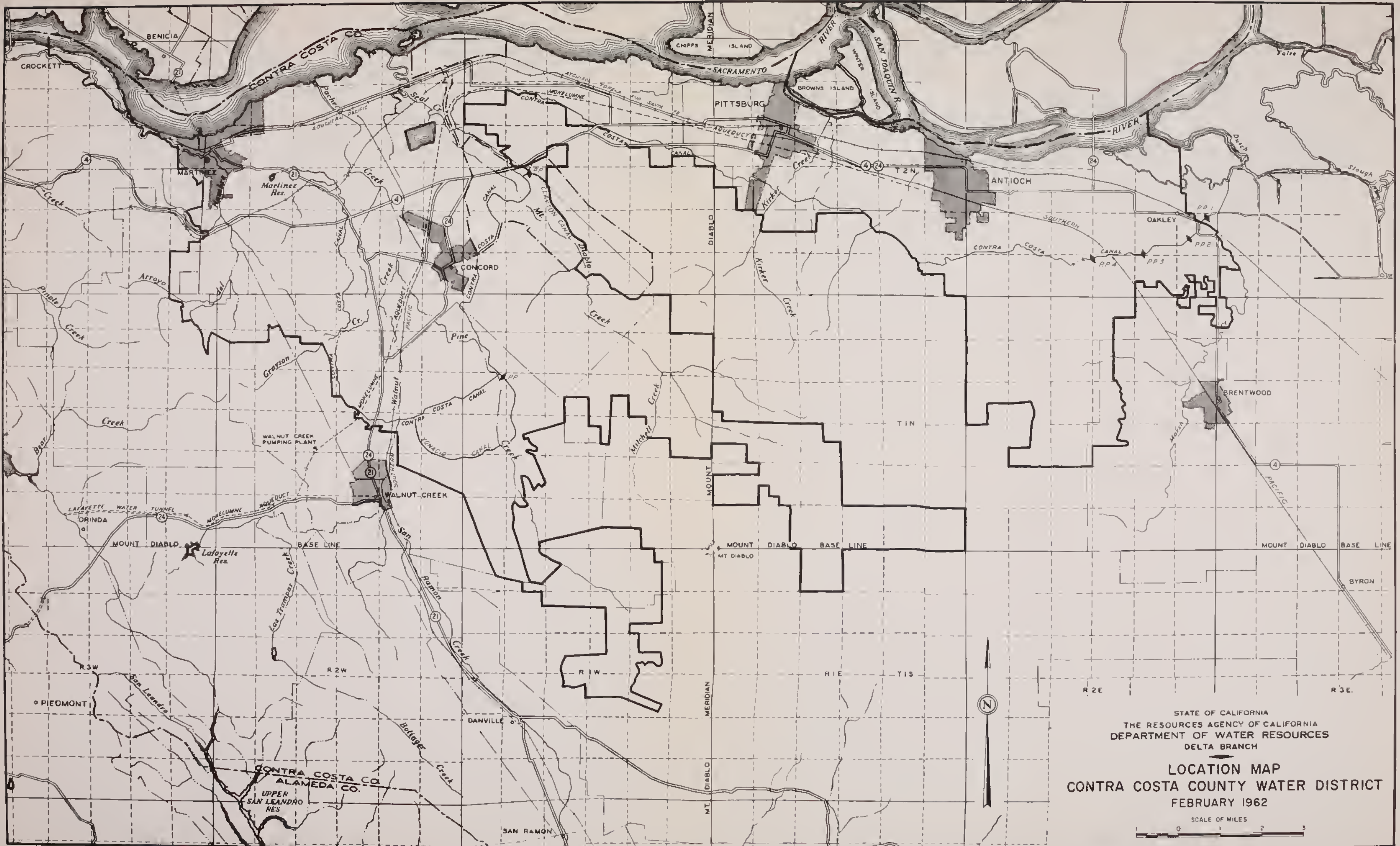
FEBRUARY 1962

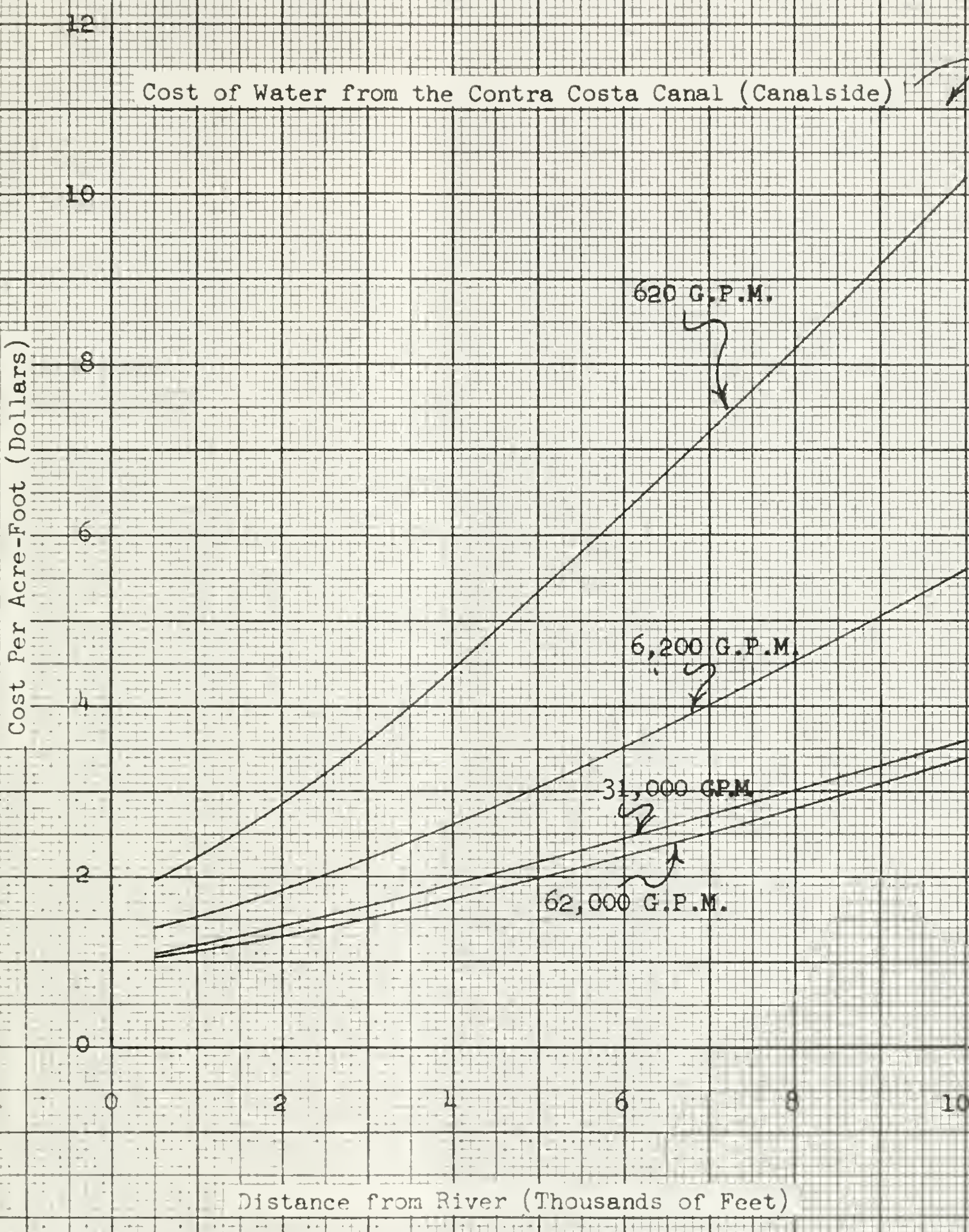


STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

LOCATION MAP
CONTRA COSTA COUNTY WATER DISTRICT
FEBRUARY 1962

SCALE OF MILES
1 0 1 2 3

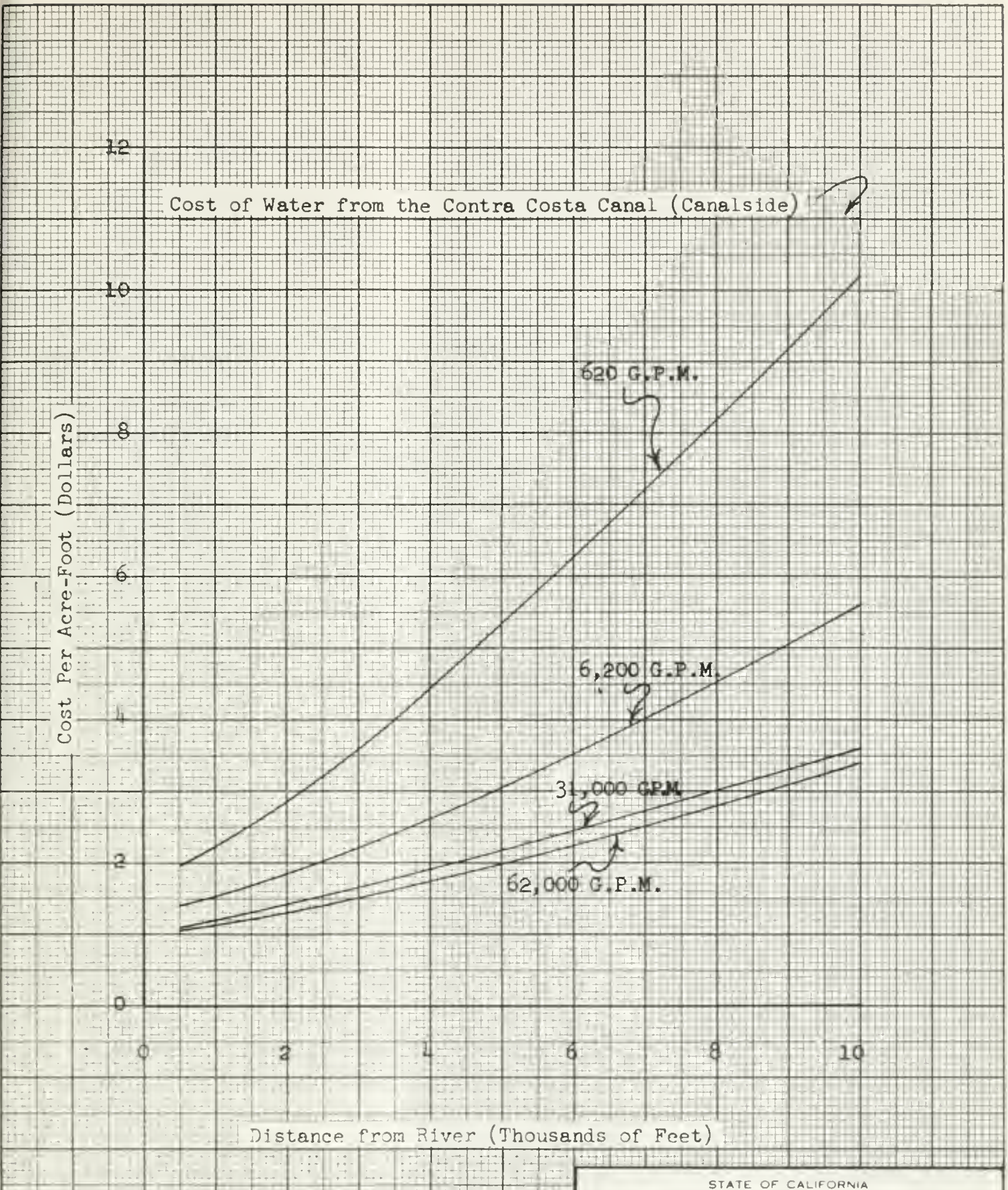

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
LOCATION MAP
CONTRA COSTA COUNTY WATER DISTRICT
FEBRUARY 1962
SCALE OF MILES
0
1
2
3
BENICIA
CROCKETT
CONTRA COSTA CO.
CHIPPS ISLAND
SACRAMENTO
RIVER
SAN JOAQUIN R.
BROWNS ISLAND
WINTER ISLAND
PITTSBURG
ANTIOCH
OAKLEY
MARTINEZ
Martinez Res.
CONCORD
WALNUT CREEK
WALNUT CREEK PUMPING PLANT
ORINDA
Lafayette Res.
BRENTWOOD
BYRON
DANVILLE
SAN RAMON
PIEDMONT
CONTRA COSTA CO.
ALAMEDA CO.
UPPER SAN LEANDRO RES.
LAFAYETTE WATER TUNNEL
MOKELUMNE AQUEDUCT
CONTRA COSTA CANAL
YGNACIO CANAL
CLAYTON CANAL
MOUNT DIABLO BASE LINE
MT. DIABLO MERIDIAN
MT DIABLO
T2N
T1N
T1S
R3W
R2W
R1W
R1E
R2E
R3E
PP 1
PP 2
PP 3
PP 4
Dutch Slough
Marsh
Kirker Creek
Mitchell Creek
Walnut Creek
Grayson Creek
Pine Creek
Pinole Creek
San Ramon Creek
Las Trampas Creek
Bollinger Creek
San Leandro Creek
Arroyo del Hambre
Bear Creek
Seal Cr.
Pacheco Creek
SOUTHERN PACIFIC
ATCHISON TOPEKA AND SANTA FE



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

COST OF SELF-SUPPLIED
INDUSTRIAL WATER FROM THE
SACRAMENTO-SAN JOAQUIN RIVER
IN PITTSBURG-ANTIOCH AREA
(ONE HUNDRED PERCENT AVAILABILITY)

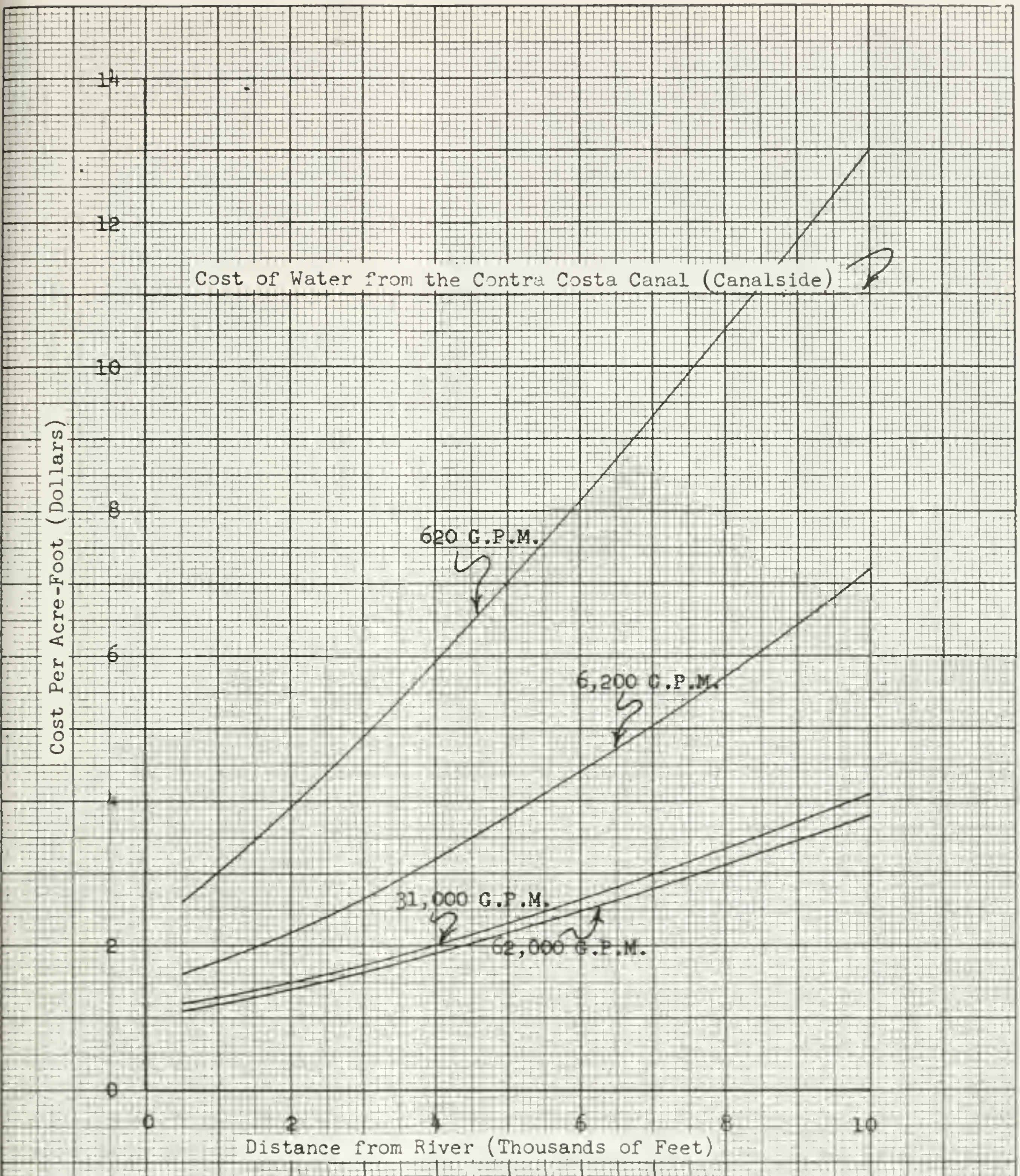
FEBRUARY 1962



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

COST OF SELF-SUPPLIED INDUSTRIAL WATER FROM THE SACRAMENTO-SAN JOAQUIN RIVER IN PITTSBURG-ANTIOCH AREA (ONE HUNDRED PERCENT AVAILABILITY)

FEBRUARY 1962



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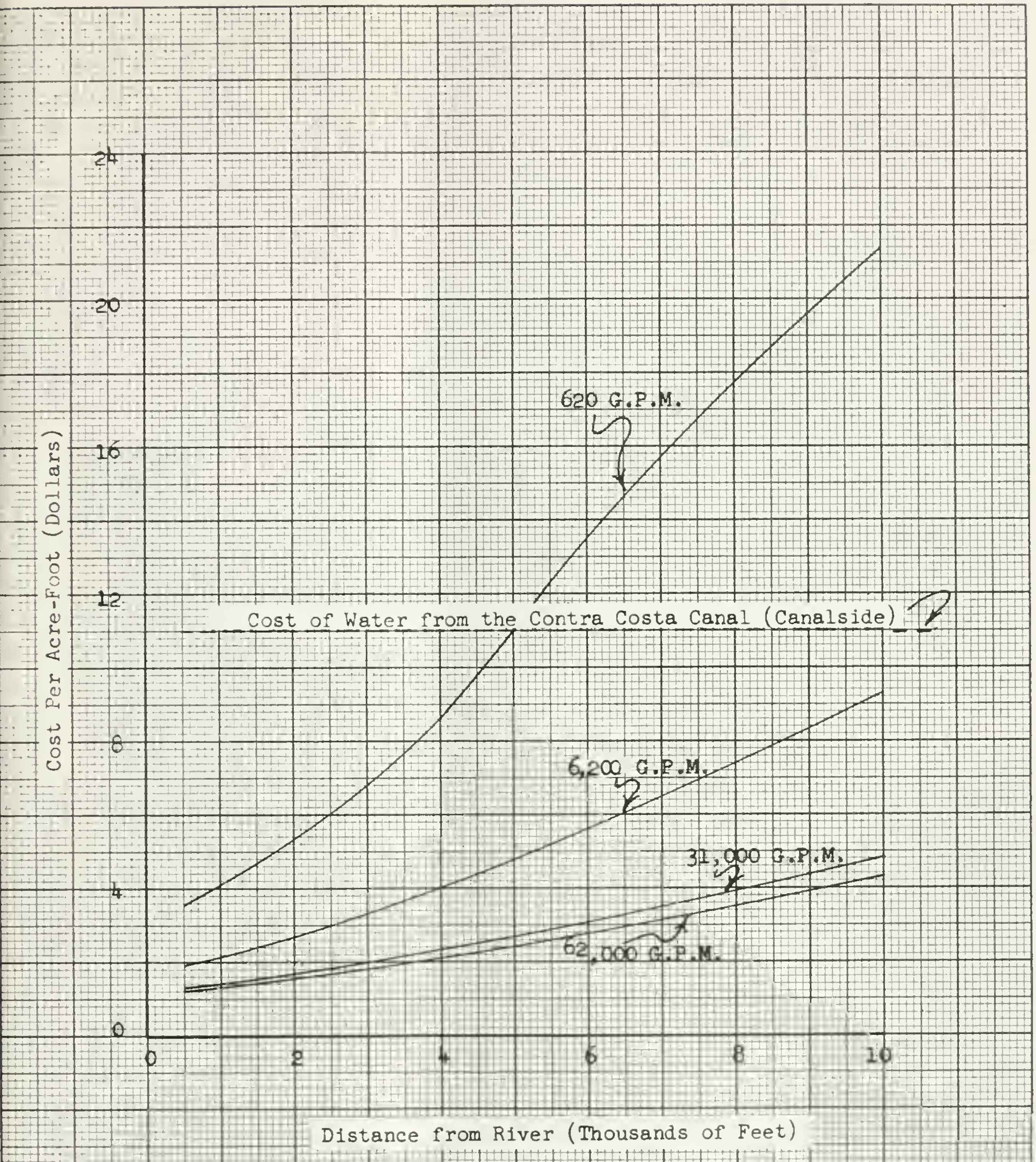
COST OF SELF-SUPPLIED INDUSTRIAL WATER FROM THE SACRAMENTO-SAN JOAQUIN RIVER IN PITTSBURG-ANTIOCH AREA (SIXTY PERCENT AVAILABILITY)

FEBRUARY 1962



STATE OF CALIFORNIA
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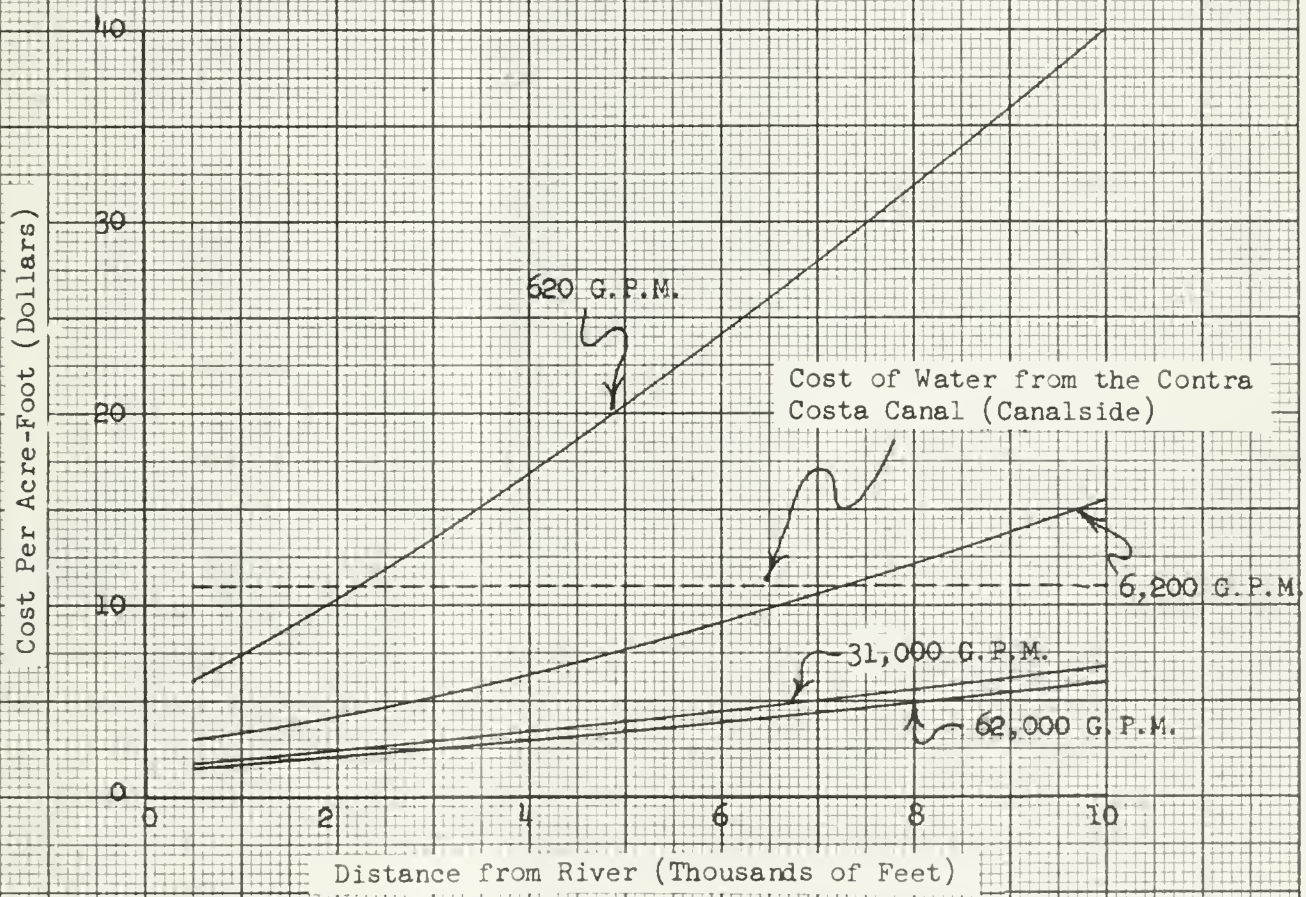
DELTA BRANCH

COST OF SELF-SUPPLIED
INDUSTRIAL WATER FROM THE
SACRAMENTO-SAN JOAQUIN RIVER
IN PITTSBURG-ANTIOCH AREA
(FORTY PERCENT AVAILABILITY)

FEBRUARY 1962



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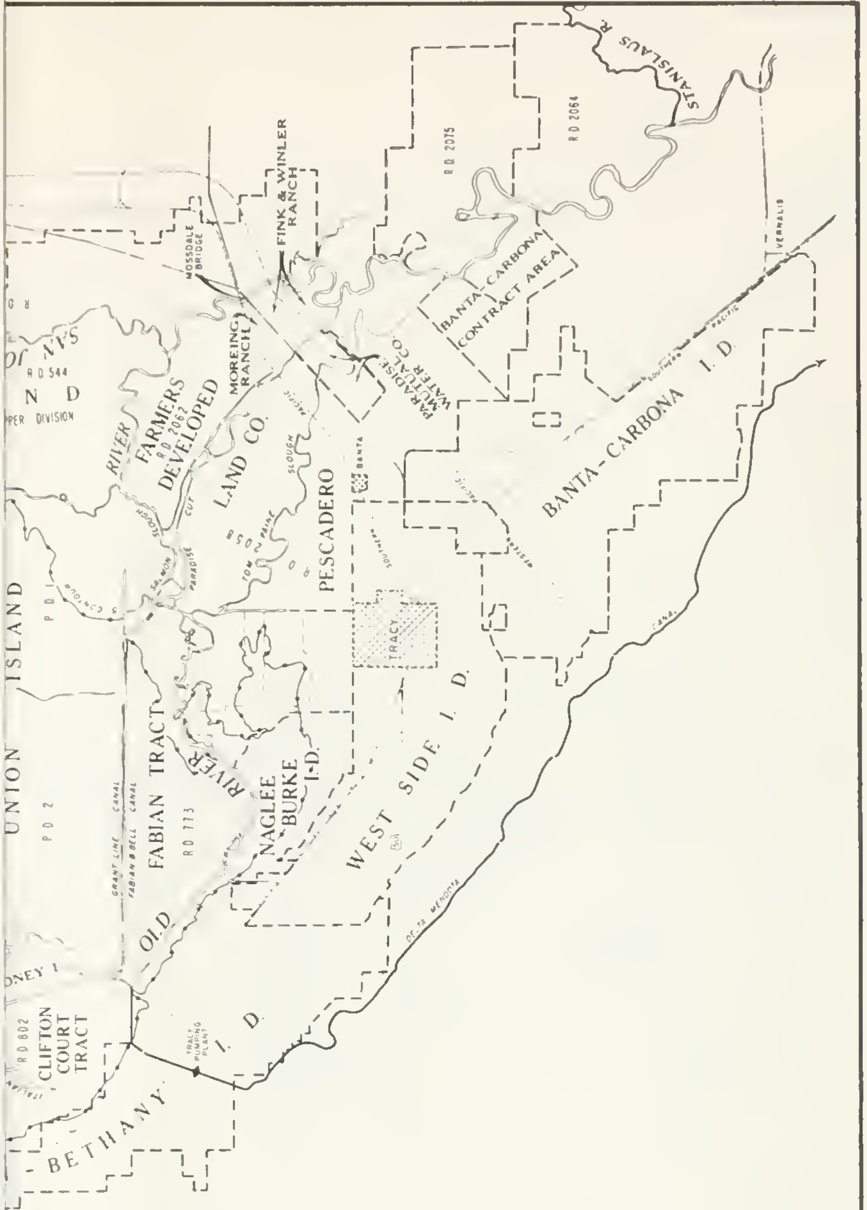
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

COST OF SELF-SUPPLIED INDUSTRIAL WATER FROM THE SACRAMENTO-SAN JOAQUIN RIVER IN PITTSBURG-ANTIOCH AREA (TWENTY PERCENT AVAILABILITY)

FEBRUARY 1962



STATE OF CALIFORNIA
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DELTA BRANCH

IRRIGATION AND RECLAMATION DISTRICTS
WITHIN THE
SACRAMENTO - SAN JOAQUIN DELTA
FEBRUARY 1962

SCALE OF MILES
1 0 1 2 3 4 5 6

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DEPARTMENT OF WATER RESOURCES
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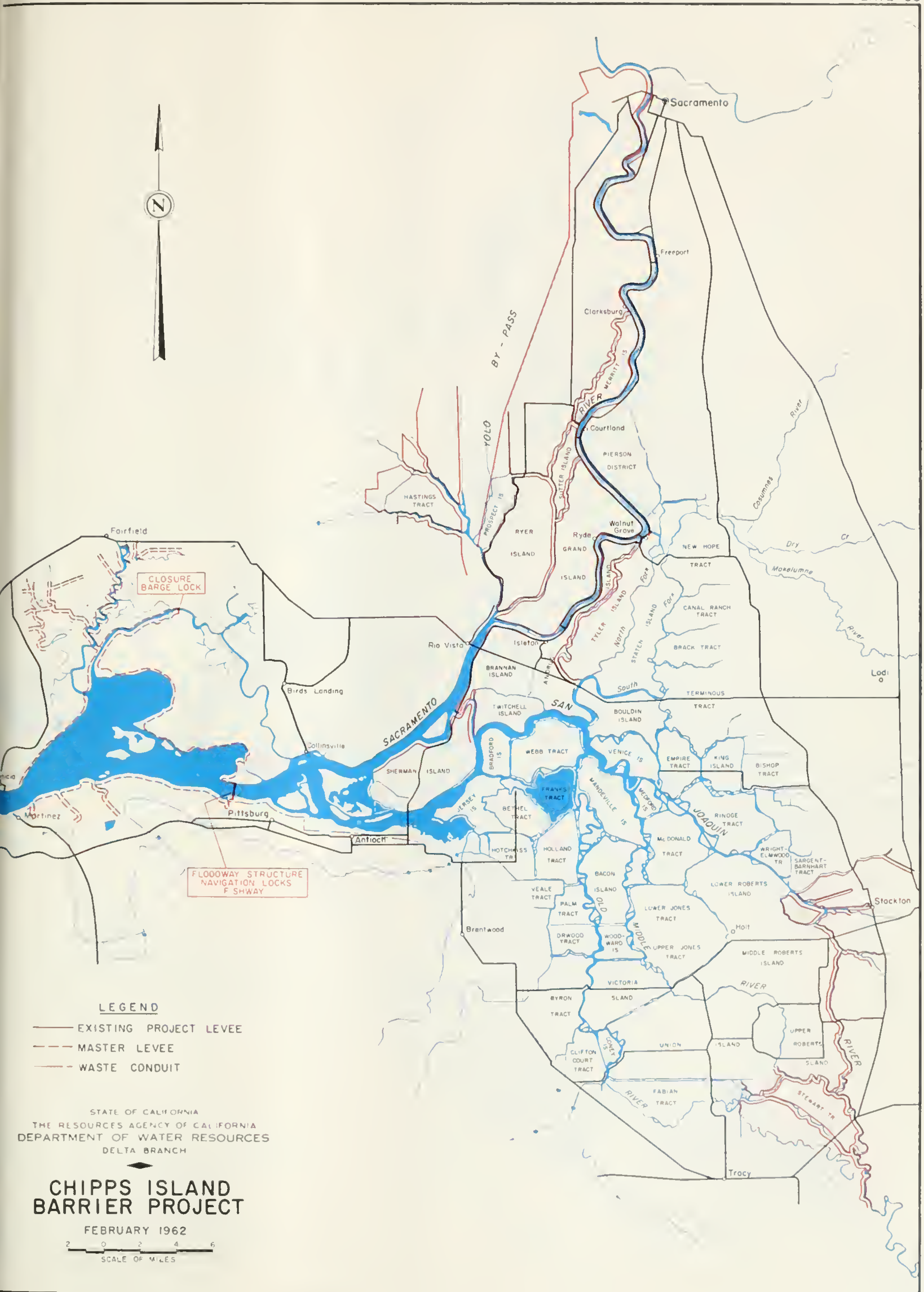
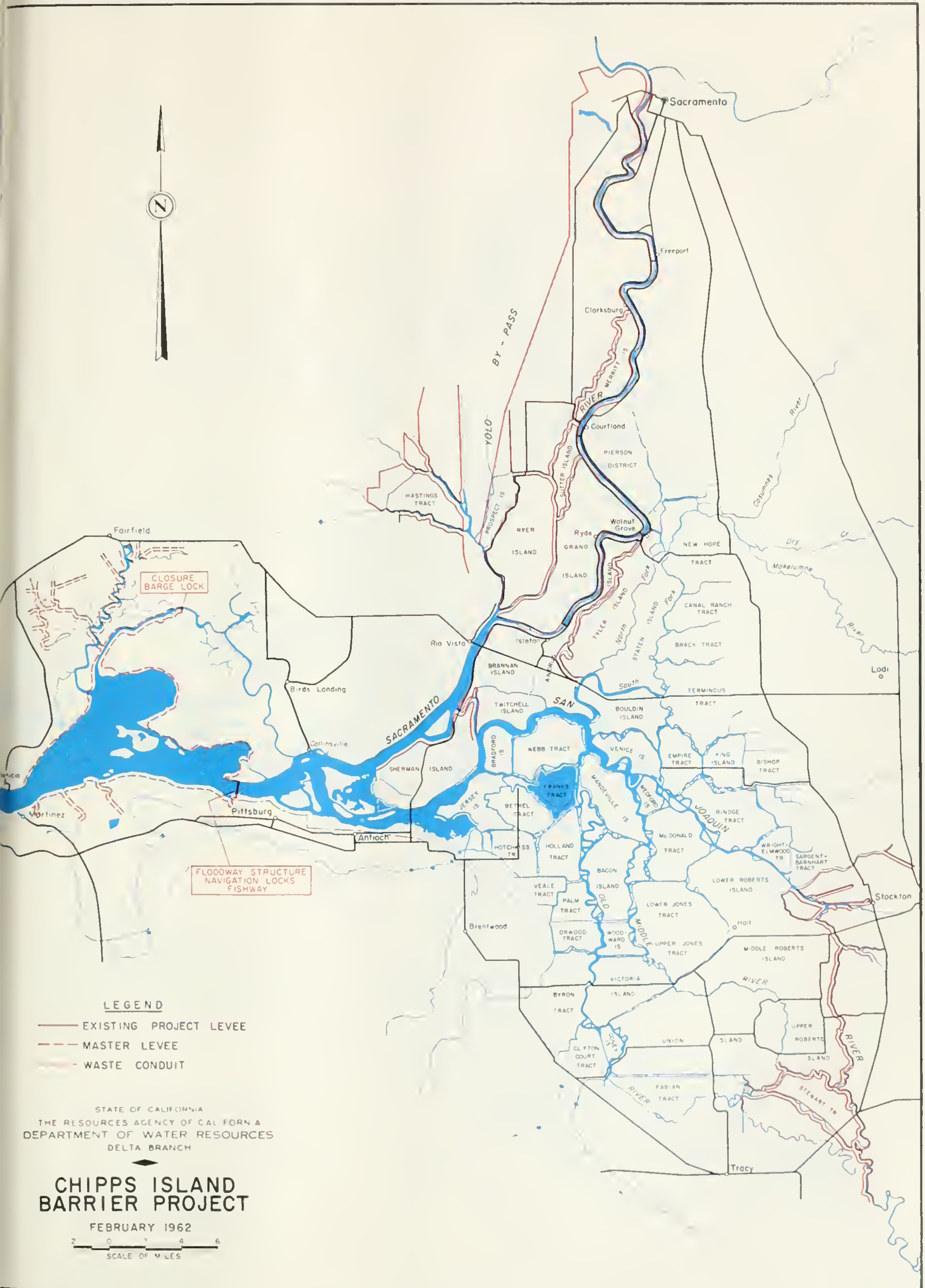
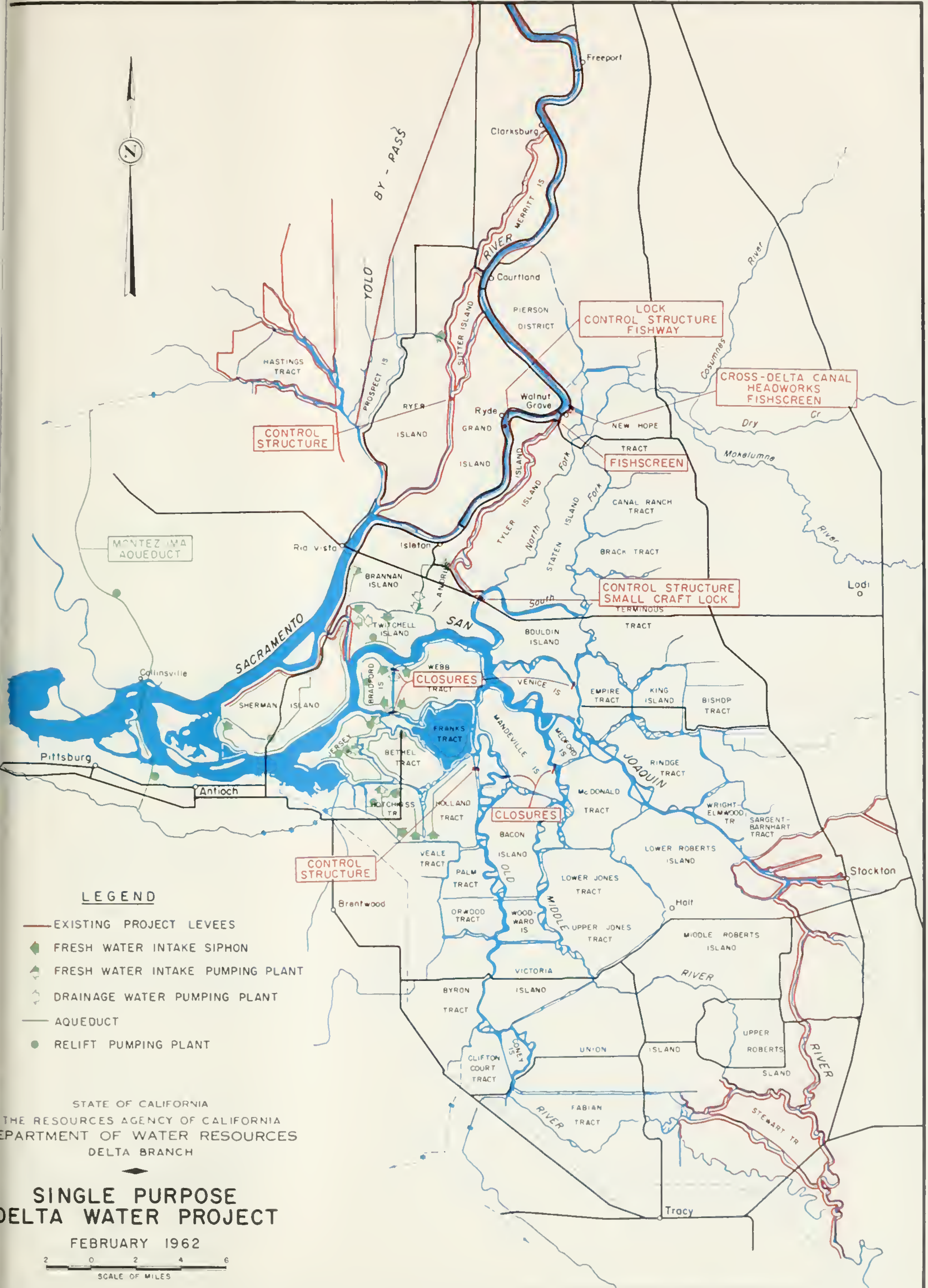
IRRIGATION AND RECLAMATION DISTRICTS
WITHIN THE
SACRAMENTO-SAN JOAQUIN DELTA
FEBRUARY 1962


Sacramento
Freeport
Clarksburg
YOLO
BY - PASS
MERRITT IS
RIVER
Courtland
PIERSON
DISTRICT
SUTTER ISLAND
HASTINGS
TRACT
PROSPECT IS
RYER
ISLAND
Walnut
Grove
Ryde
GRAND
ISLAND
NEW HOPE
TRACT
Cosumnes
River
Dry
Cr
Mokelumne
River
Fairfield
CLOSURE
BARGE LOCK
TYLER ISLAND
North
Fork
STATEN
ISLAND
CANAL RANCH
TRACT
BRACK TRACT
Rio Vista
Isleton
BRANNAN
ISLAND
ANDRUS
South
TERMINOUS
TRACT
Lodi
Birds Landing
SACRAMENTO
TWITCHELL
ISLAND
SAN
BOULDIN
ISLAND
Collinsville
BRADFORD
IS
WEBB TRACT
VENICE IS
EMPIRE
TRACT
KING
ISLAND
BISHOP
TRACT
SHERMAN
ISLAND
FRANKS
TRACT
MANDEVILLE IS
MEDFORD IS
JOAQUIN
RINDGE
TRACT
Martinez
Pittsburg
JERSEY IS
BETHEL
TRACT
Antioch
McDONALD
TRACT
WRIGHT-
ELMWOOD
TR
SARGENT-
BARNHART
TRACT
HOTCHKISS
TR
HOLLAND
TRACT
BACON
ISLAND
LOWER ROBERTS
ISLAND
Stockton
FLOODWAY STRUCTURE
NAVIGATION LOCKS
FISHWAY
VEALE
TRACT
PALM
TRACT
OLD
LOWER JONES
TRACT
Holt
Brentwood
ORWOOD
TRACT
WOOD-
WARD
IS
MIDDLE
UPPER JONES
TRACT
MIDDLE ROBERTS
ISLAND
VICTORIA
ISLAND
RIVER
BYRON
TRACT
UPPER
ROBERTS
ISLAND
CLIFTON
COURT
TRACT
CONEY IS
UNION
ISLAND
RIVER
FABIAN
TRACT
RIVER
STEWART TR
Tracy
LEGEND
EXISTING PROJECT LEVEE
MASTER LEVEE
WASTE CONDUIT
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
CHIPPS ISLAND
BARRIER PROJECT
FEBRUARY 1962
2 0 2 4 6
SCALE OF MILES


Sacramento
Freeport
Clarksburg
YOLO BY - PASS
RIVER
MERRITT IS
Courtland
PIERSON DISTRICT
SUTTER ISLAND
PROSPECT IS
HASTINGS TRACT
RYER ISLAND
Walnut Grove
Ryde
GRAND ISLAND
NEW HOPE TRACT
Cosumnes River
Dry Cr
Mokelumne River
TYLER ISLAND
North Fork
STATEN ISLAND
CANAL RANCH TRACT
BRACK TRACT
Lodi
Fairfield
CLOSURE BARGE LOCK
Rio Vista
Isleton
BRANNAN ISLAND
ANDRUS
South Fork
TERMINOUS TRACT
Birds Landing
SACRAMENTO
TWITCHELL ISLAND
SAN
BOULDIN ISLAND
Collinsville
SHERMAN ISLAND
BRADFORD IS
WEBB TRACT
VENICE IS
EMPIRE TRACT
KING ISLAND
BISHOP TRACT
FRANKS TRACT
MANDEVILLE IS
MEDFORD IS
JOAQUIN
RINDGE TRACT
Martinez
Pittsburg
JERSEY IS
BETHEL TRACT
Antioch
HOTCHKISS TR
HOLLAND TRACT
McDONALD TRACT
WRIGHT-ELMWOOD TR
SARGENT-BARNHART TRACT
FLOODWAY STRUCTURE NAVIGATION LOCKS FISHWAY
BACON ISLAND
LOWER ROBERTS ISLAND
Stockton
VEALE TRACT
PALM TRACT
OLD
LOWER JONES TRACT
Holt
Brentwood
ORWOOD TRACT
WOODWARD IS
MIDDLE
UPPER JONES TRACT
MIDDLE ROBERTS ISLAND
VICTORIA ISLAND
RIVER
BYRON TRACT
UNION ISLAND
UPPER ROBERTS ISLAND
CLIFTON COURT TRACT
RIVER
FABIAN TRACT
STEWART TR
Tracy
LEGEND
EXISTING PROJECT LEVEE
MASTER LEVEE
WASTE CONDUIT
STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH
CHIPPS ISLAND BARRIER PROJECT
FEBRUARY 1962
2 0 2 4 6
SCALE OF MILES



LEGEND

- EXISTING PROJECT LEVEES
- FRESH WATER INTAKE SIPHON
- FRESH WATER INTAKE PUMPING PLANT
- DRAINAGE WATER PUMPING PLANT
- AQUEDUCT
- RELIFT PUMPING PLANT

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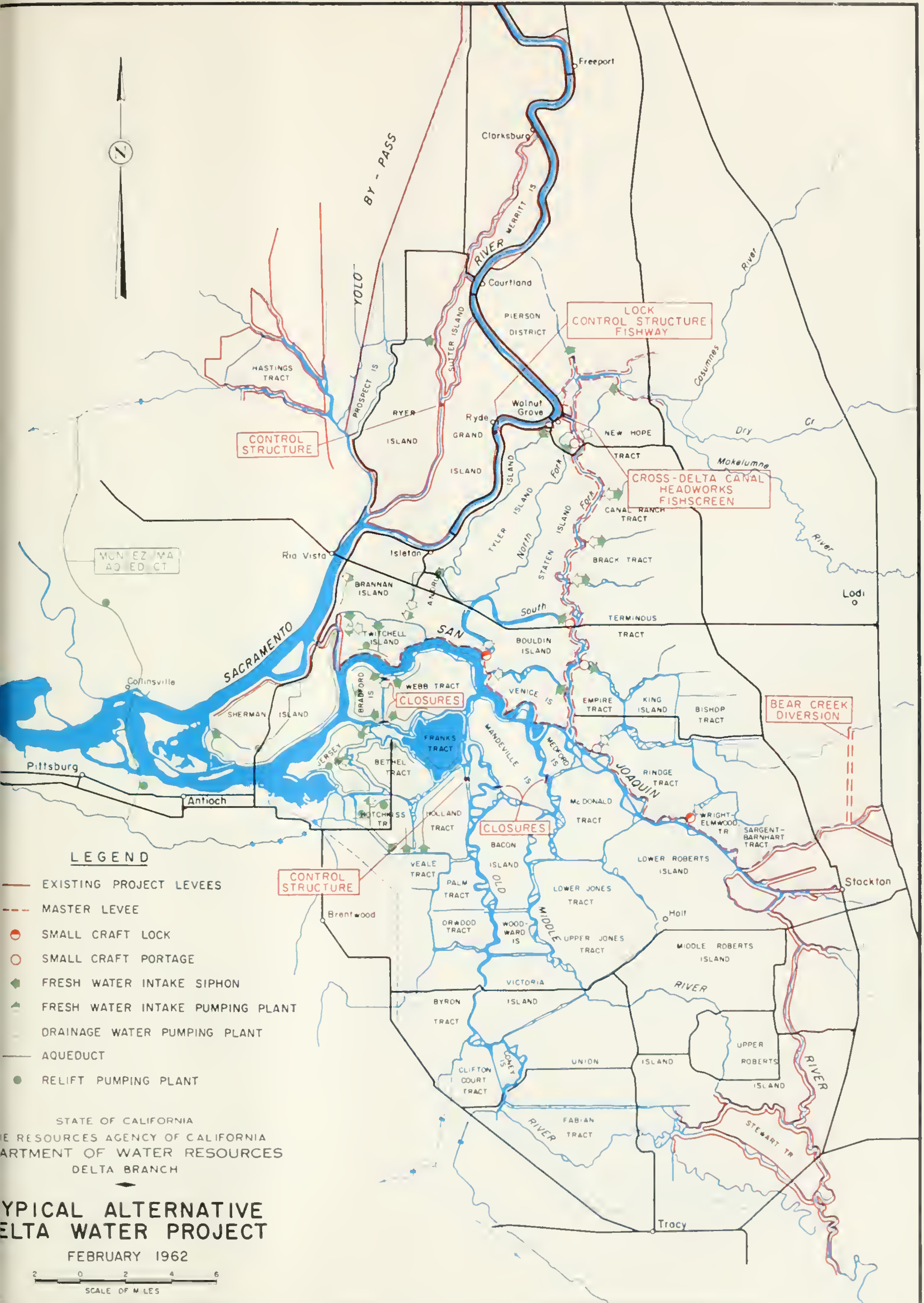
DELTA BRANCH

SINGLE PURPOSE DELTA WATER PROJECT

FEBRUARY 1962

2 0 2 4 6
SCALE OF MILES



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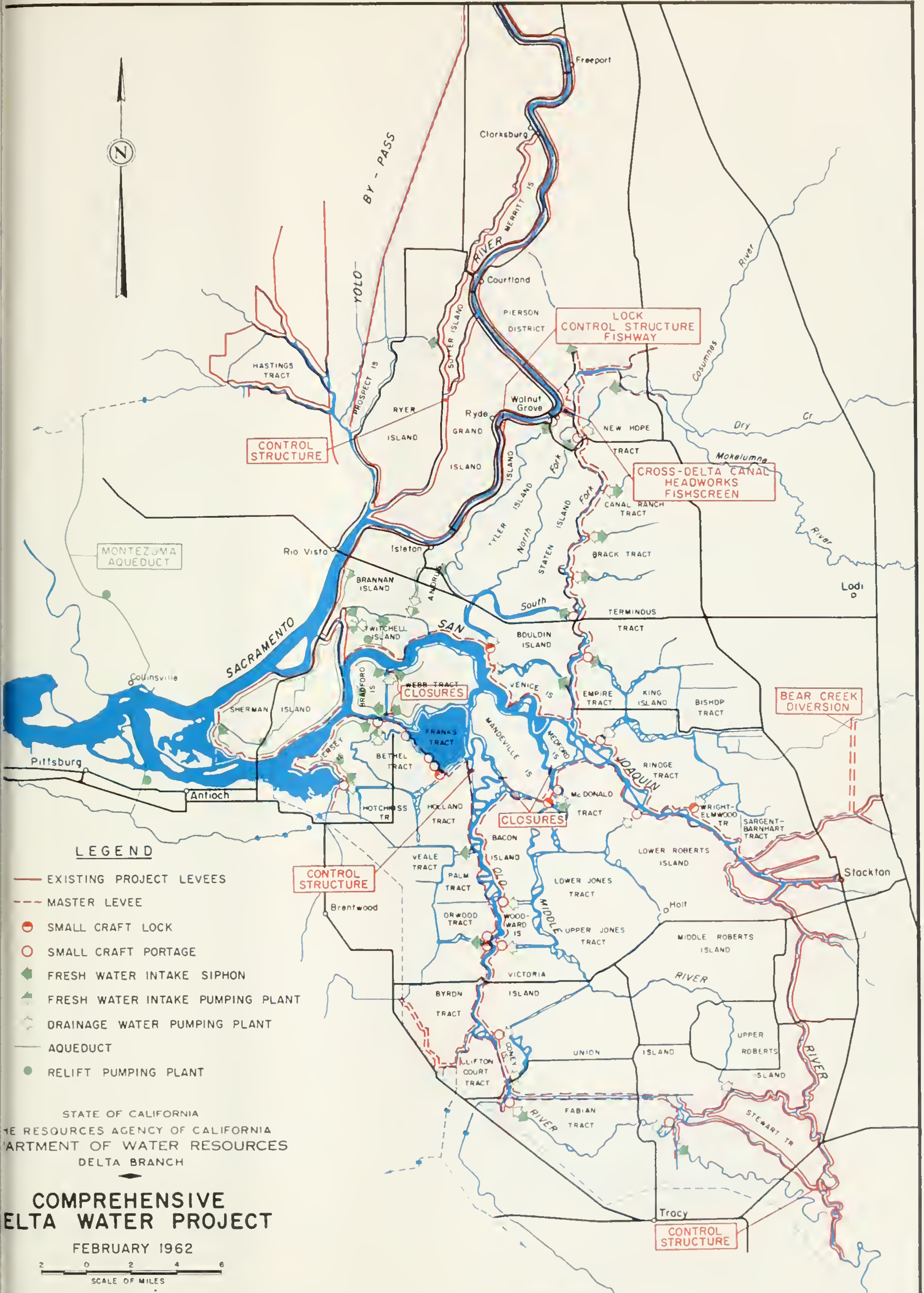
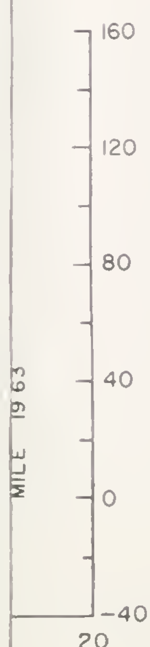
...E RESOURCES AGENCY OF CALIFORNIA
...ARTMENT OF WATER RESOURCES
DELTA BRANCH

...YPICAL ALTERNATIVE ...ELTA WATER PROJECT

FEBRUARY 1962


COMPREHENSIVE
ELTA WATER PROJECT
FEBRUARY 1962
STATE OF CALIFORNIA
HE RESOURCES AGENCY OF CALIFORNIA
ARTMENT OF WATER RESOURCES
DELTA BRANCH
SCALE OF MILES
2 0 2 4 6
LEGEND
EXISTING PROJECT LEVEES
MASTER LEVEE
SMALL CRAFT LOCK
SMALL CRAFT PORTAGE
FRESH WATER INTAKE SIPHON
FRESH WATER INTAKE PUMPING PLANT
DRAINAGE WATER PUMPING PLANT
AQUEDUCT
RELIFT PUMPING PLANT
N
LOCK
CONTROL STRUCTURE
FISHWAY
CONTROL STRUCTURE
CROSS-DELTA CANAL
HEADWORKS
FISHSCREEN
MONTEZUMA
AQUEDUCT
CLOSURES
CLOSURES
BEAR CREEK
DIVERSION
CONTROL STRUCTURE
CONTROL STRUCTURE
YOLO
BY - PASS
SACRAMENTO
RIVER
SAN
JOAQUIN
Freeport
Clarksburg
Courtland
Walnut Grove
Ryde
Rio Vista
Isleton
Collinsville
Pittsburg
Antioch
Brentwood
Holt
Stockton
Lodi
Tracy
HASTINGS TRACT
PROSPECT IS
RYER ISLAND
GRAND ISLAND
SUTTER ISLAND
MERRITT IS
PIERSON DISTRICT
NEW HOPE TRACT
CANAL RANCH TRACT
BRACK TRACT
TERMINOUS TRACT
TYLER ISLAND
STATEN ISLAND
North Fork
South Fork
BRANNAN ISLAND
ANDRUS IS
TWITCHELL ISLAND
BOULDIN ISLAND
SHERMAN ISLAND
BRADFORD IS
WEBB TRACT
FRANKS TRACT
BETHEL TRACT
JERSEY IS
VENICE IS
MANDEVILLE IS
MEDFORD IS
EMPIRE TRACT
KING ISLAND
BISHOP TRACT
RINDGE TRACT
Mc DONALD TRACT
WRIGHT-ELMWOOD TR
SARGENT-BARNHART TRACT
HOTCHKISS TR
HOLLAND TRACT
BACON ISLAND
VEALE TRACT
PALM TRACT
ORWOOD TRACT
WOODWARD IS
LOWER JONES TRACT
UPPER JONES TRACT
LOWER ROBERTS ISLAND
MIDDLE ROBERTS ISLAND
UPPER ROBERTS ISLAND
OLD
MIDDLE
VICTORIA ISLAND
BYRON TRACT
CLIFTON COURT TRACT
CONEY IS
UNION ISLAND
FABIAN TRACT
STEWART TR
RIVER
Cosumnes River
Dry Cr
Mokelumne River



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

MONTEZUMA AQUEDUCT

FEBRUARY 1962

SCALE OF MILES

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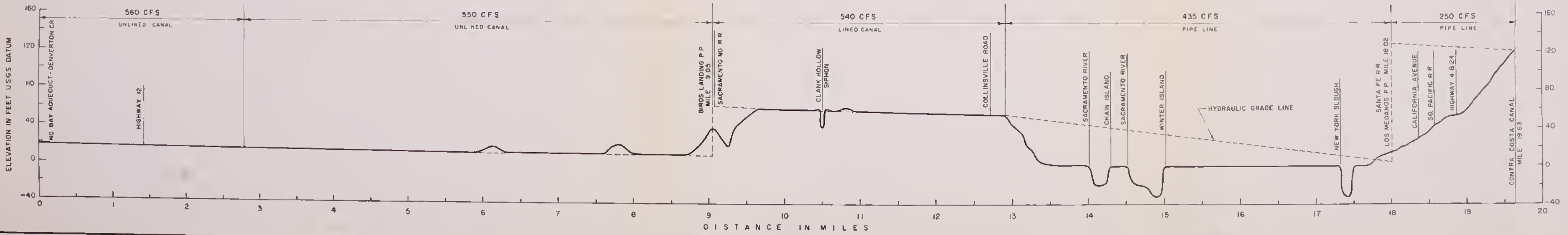


STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

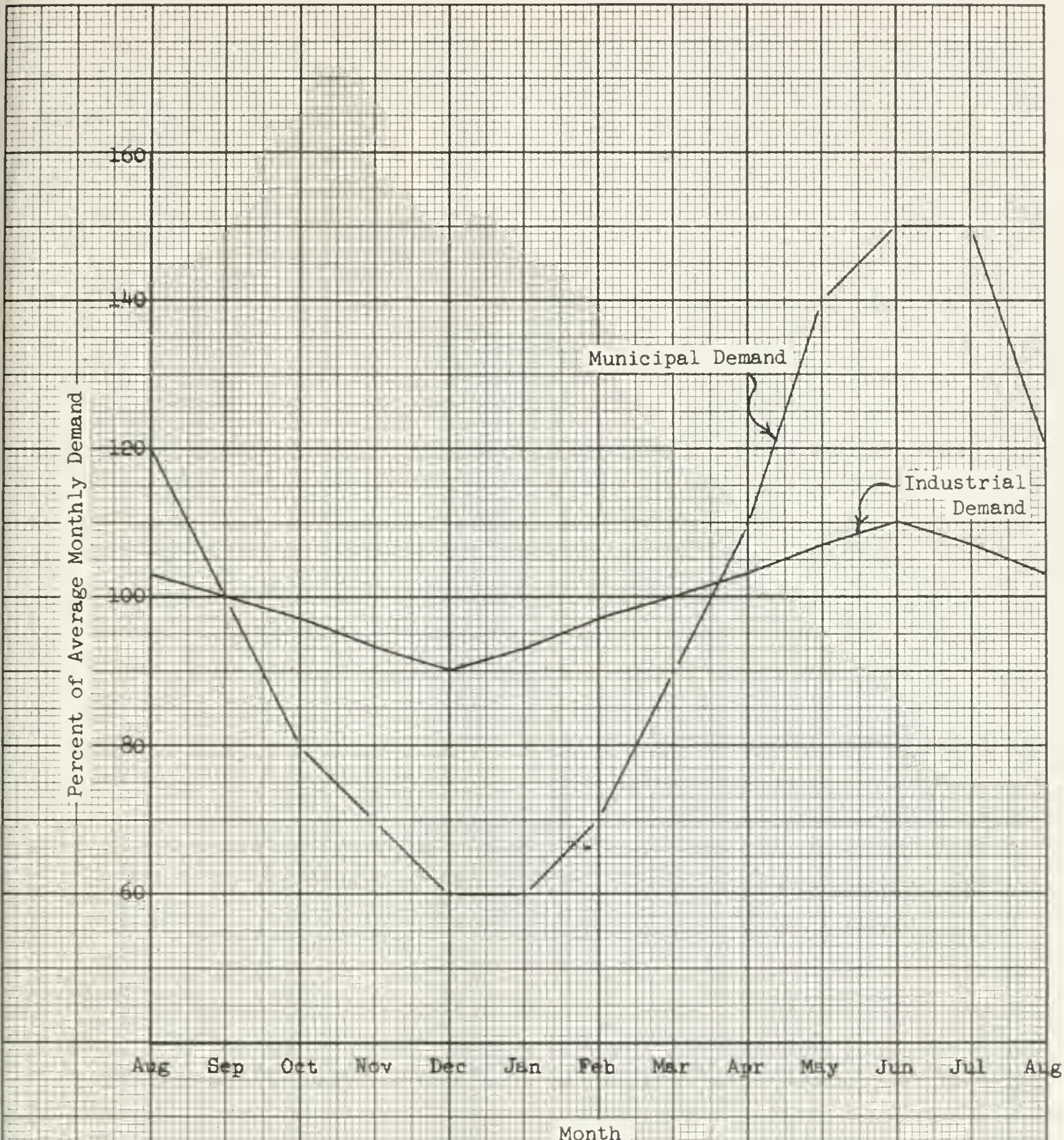
MONTEZUMA AQUEDUCT
FEBRUARY 1962

SCALE OF MILES

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

CONTRA COSTA CANAL
OPERATION DEMAND SCHEDULE

FEBRUARY 1962



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

CONTRA COSTA CANAL
OPERATION DEMAND SCHEDULE

FEBRUARY 1962

AGRICULTURAL SUBSTITUTE

WATER FACILITIES

NUMBER	LOCATION		SIPHON CAPACITY C.F.S.	PUMP CAPACITY C.F.S.
1	Bronnon Islond			15
2	Georgiana Slough		310	
3	Jockson Slough at Sevenmile Sl.			270
4	Sevenmile Slough		165	
5	Threemile Slough	1/	165	165
6	Twitchell Islond		30	
7	Twitchell Islond			10
8	Brodford Islond		10	
9	Webb Troct		20	
10	Fishermon's Cut (Droin Pump)			30
11	Brodford Islond			5
12	Bradford Islond		15	
13	Webb Troct		25	
14	Folse River	2/		120
15	Bethel Islond			20
16	Jersey Islond	3/	60	200
17	Jersey Islond			10
18	Dutch Slough	4/	225	225
19	Hotchkiss Troct			20
20	Hotchkiss Troct			20
21	Rock Slough		235	
22	Hotchkiss Troct		20	
23	Holland Troct		20	
24	Hollond Troct			20
25	Moyberry Slough			30
26	Moyberry Slough		10	
27	Miner Slough		400	

1/ The focility includes o fresh woter supply pump, ond on inverted siphon under Threemile Slough, for Sherman Islond. The pump olso serves to dischorge seasonol drainage from Sevenmile Slough.

2/ The focility includes a fresh woter supply pump, ond on inverted siphon under Folse River, for Webb Troct ond Brodford Island, and o relift pump for the North Jersey Conol.

3/ The focility includes a fresh woter supply pump, ond on inverted siphon under Toylor Slough, for Bethel Islond, ond o relift pump to convey water northword to relift focilities on Jersey Islond ot Folse River.

4/ The focility includes o fresh woter supply pump, and on inverted siphon under Dutch Slough, for Jersey Islond.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

PRINCIPAL
IRRIGATION AND DRAINAGE FEATURES
OF THE
SINGLE PURPOSE DELTA WATER PROJECT

FEBRUARY 1962

SCALE AS SHOWN

AGRICULTURAL SUBSTITUTE

WATER FACILITIES

NUMBER	LOCATION		SIPNON CAPACITY C.F.S.	PUMP CAPACITY C.F.S.
1	Brannan Island			15
2	Georgiana Slough		310	
3	Jackson Slough at Sevenmile Sl.			270
4	Sevenmile Slough		165	
5	Threemile Slough	1/	165	165
6	Twitchell Island		30	
7	Twitchell Island			10
8	Bradford Island		10	
9	Webb Tract		20	
10	Fisherman's Cut (Drain Pump)			30
11	Bradford Island			5
12	Bradford Island		15	
13	Webb Tract		25	
14	False River	2/		120
15	Bethel Island			20
16	Jersey Island	3/	60	200
17	Jersey Island			10
18	Dutch Slough	4/	225	225
19	Hotchkiss Tract			20
20	Hotchkiss Tract			20
21	Rock Slough		235	
22	Hotchkiss Tract		20	
23	Holland Tract		20	
24	Holland Tract			20
25	Mayberry Slough			30
26	Mayberry Slough		10	
27	Miner Slough		400	

1/ The facility includes a fresh water supply pump, and an inverted siphon under Threemile Slough, for Sherman Island. The pump also serves to discharge seasonal drainage from Sevenmile Slough.

2/ The facility includes a fresh water supply pump, and an inverted siphon under False River, for Webb Tract and Bradford Island, and a relift pump for the North Jersey Canal.

3/ The facility includes a fresh water supply pump, and an inverted siphon under Taylor Slough, for Bethel Island, and a relift pump to convey water northward to relift facilities on Jersey Island at False River.

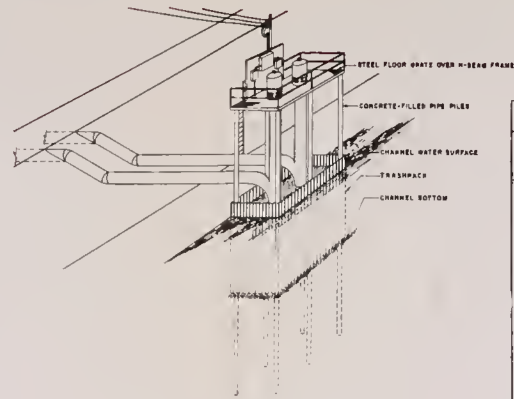
4/ The facility includes a fresh water supply pump, and an inverted siphon under Dutch Slough, for Jersey Island.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

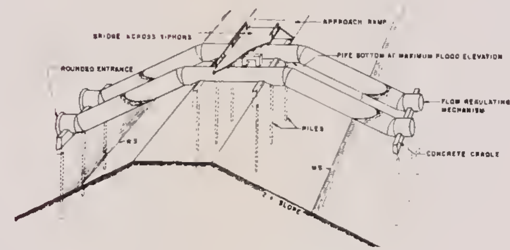
PRINCIPAL IRRIGATION AND DRAINAGE FEATURES OF THE SINGLE PURPOSE DELTA WATER PROJECT

FEBRUARY 1962

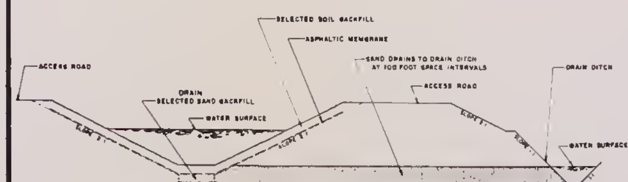
SCALE AS SHOWN



TYPICAL DRAINAGE PUMP UNIT
NOT TO SCALE



TYPICAL INTAKE SIPHON
NOT TO SCALE



TYPICAL WATER DISTRIBUTION CANAL
NOT TO SCALE

IRRIGATION, DRAINAGE AND AGRICULTURAL SUBSTITUTE WATER FACILITIES

AGRICULTURAL SUBSTITUTE WATER				IRRIGATION AND DRAINAGE			
NO.	LOCATION	SIPHON CAP. C.F.S.	PUMP CAP. C.F.S.	NO.	LOCATION	SIPHON CAP. C.F.S.	PUMP CAP. C.F.S.
1	Brannan Island		15	20	Miner Slough	400	
2	Georgiana Slough	310		21	Snodgrass Slough 3/	150	
3	Jackson Sl. at Sevenmile Sl.		270	22	Mokelumne River	40	
4	Sevenmile Slough	165		23	Georgiana Slough	380	
5	Threemile Slough 1/	165	165	24	Mokelumne River		15
6	Twitchell Island	30		25	North Fork Mokelumne R.	210	
7	Twitchell Island		10	26	Beaver Slough	140	10
8	Bradford Island	10		27	Hog Slough	80	130
9	Webb Tract	20		28	Sycamore Slough	210	155
10	Fisherman's Cut (Drain Pump)		30	29	South Fork Mokelumne R.	110	
11	Bradford Island		5	30	Mokelumne River at San Joaquin R.		350
12	Bradford Island	15		31	Potato Slough		130
13	Webb Tract	25		32	White Slough	700	
14	Jersey Island	20		33	Potato Slough	80	
15	False River 2/	100	100	34	Disappointment Slough		395
16	Jersey Island	20		35	Latham Slough	1400	485
17	Jersey Island		10	36	Turner Cut		160
18	Mayberry Slough		30	37	Fourteenmile Slough		335
19	Mayberry Slough	10		38	Dutch Slough		130
				39	Rock Slough	850	
				40	Santa Fe Cut		80
				41	Indian Slough	420	
				42	N. Victoria – Woodward Canal		160
				43	N. Canal – Victoria Canal		50
				44	Old River		30
				45	Old River	400	130
				46	Old River at Sugar Cut		40
				47	Middle R. at Stewart Tr.		60

1/ The facility includes a fresh water supply pump, and an inverted siphon under Threemile Slough, for Sherman Island. The pump also serves to discharge seasonal drainage from Sevenmile Slough.

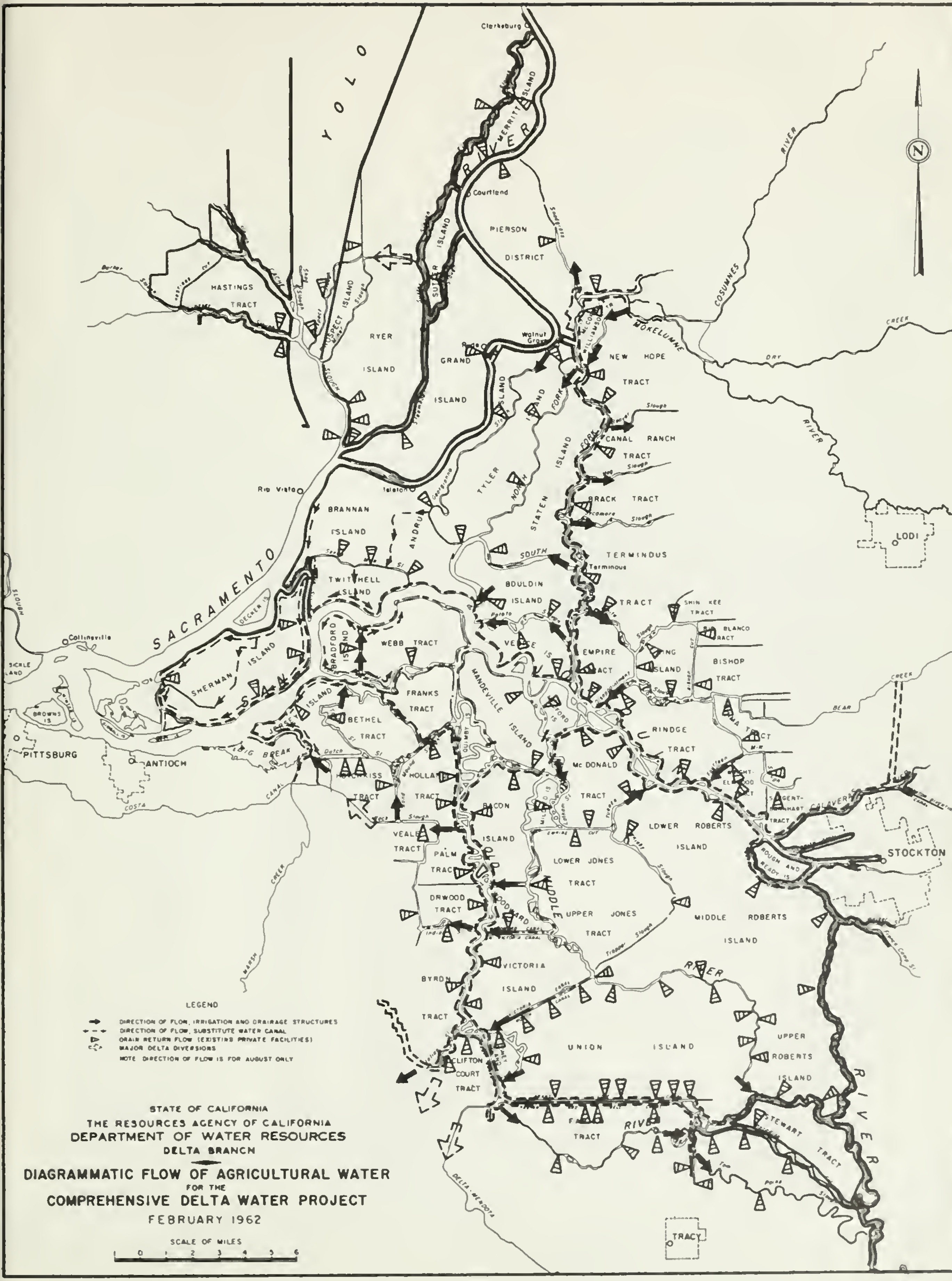
2/ The facility includes an inverted siphon under False River for fresh water to Webb Tract and Bradford Island. The pump also serves to discharge drainage from Piper Slough.

3/ The facility includes provision to pass flood flows.

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

PRINCIPAL IRRIGATION AND DRAINAGE FEATURES OF THE COMPREHENSIVE DELTA WATER PROJECT

FEBRUARY 1962
SCALE AS SHOWN



STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

DIAGRAMMATIC FLOW OF AGRICULTURAL WATER
FOR THE
COMPREHENSIVE DELTA WATER PROJECT
FEBRUARY 1962