STATE OF CALIFORNIA
The Resources Agency
Department of Water Resources

BULLETIN No. 123

DELTA AND SUISUN BAY WATER QUALITY INVESTIGATION

AUGUST 1967

RONALD REAGAN
Governor
State of California

WILLIAM R. GIANELLI
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FOREWORD

Seven hundred miles of meandering waterways interlace the low-lying islands of California's agriculturally rich Delta. Into this area of waterway and farmland flow the waters of the great Central Valley; south through the Sacramento River, and north by way of the San Joaquin River.

This bulletin presents the results of a comprehensive study of the water of the channel system of the Sacramento-San Joaquin Delta, Suisun Bay, and the surrounding waterways as they relate to potential improvement in water quality which can be accomplished as a result of the construction of major works of the State Water Project.

The Delta and Suisun Bay Water Quality Investigation was conducted over a four-year period. Water quality information resulting from the investigation has aided in the planning of the Delta facilities and the San Joaquin drainage facilities. This is important because maintenance of satisfactory water quality within the Delta is related to the successful operation of these facilities.

Data regarding past, present, and future water quality of the waters in the Delta and Suisun Bay are summarized in this report. Water quality relationships are characterized under various conditions of hydraulic regimen and waste disposal. Hydrographic data are presented to aid in the design and future operation of facilities of the State Water Project. Results are presented that show the importance of project operation and pollution control in meeting water quality objectives within the Delta.

The studies reported on in this bulletin were essentially completed during 1965. Partially on the basis of the results of these studies, additional studies have been made and other studies are currently in progress to further refine and evaluate the information as reported in this bulletin. In addition, negotiations with local Delta water users since the completion of the studies have established certain criteria for water quality in the Delta. The State Water Project in coordination with the Federal Central Valley Project will be operated to meet these criteria. Therefore, the operation of the Peripheral Canal will be different than was assumed for these studies and will be flexible to meet the two basic objectives -- water transfer and protection of the various resources dependent on Delta waters.

W R Gianelli

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The Resources Agency
State of California

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ABSTRACT

Continued development of water supplies in the Central Valley of California, to meet export requirements and other beneficial needs, will result in decreased annual Delta outflows to the San Francisco Bay. Future expansion of municipal, industrial, and agricultural development will result in increased waste water in the Central Valley and at the same time, population increases and industrialization of the bay area will result in substantial increases in waste water discharged directly to the bay. /The Delta and Suisun Bay Water Quality Investigation was composed of several studies, each designed to yield information to meet one or more specific objectives. Field dye tracer studies were used to develop data on flow distribution, circulation patterns, diffusion characteristics, and residence times in the major channels and waterways of the Delta-Suisun Bay system. Present water quality was determined throughout the area of investigation primarily from data collected by other investigators and augmented by limited supplemental sampling at certain locations. Sources and amounts of natural and man-made water quality degradation were examined to evaluate their present and future effect on the quality of receiving waters. Estimates of changes in water quality constituent concentrations were made with respect to Peripheral Canal operation and San Joaquin Master Drain discharge at several alternative outfall locations. /The studies reported on in this bulletin were essentially completed during 1965. Partially on the basis of the results of these studies, additional studies have been made and other studies are currently in progress to further refine and evaluate the information as reported in this bulletin. In addition, negotiations with local Delta water users since the completion of the studies have established certain criteria for water quality in the Delta. The State Water Project in coordination with the Federal Central Valley Project will be operated to meet these criteria. Therefore, the operation of the Peripheral Canal will be different than was assumed for these studies and will be flexible to meet the two basic objectives -- water transfer and protection of the various resources dependent on Delta waters.

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ENGINEERING CERTIFICATION

This report has been prepared under my direction as the professional engineer in direct responsible charge of the work, in accordance with the provisions of the Civil and Professional Engineers' Act of the State of California.

Jerry D. Vayder
Registered Civil Engineer

Registration No. C9746

Date June 1, 1967

ATTEST:

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Registration No. C8123

Date June 1, 1967

Sacramento-San Joaquin Delta

Along the lower course of the two rivers a delta has been formed, extending up the Sacramento River from Suisun Bay nearly to the City of Sacramento and up the San Joaquin River to a point 20 miles south of Stockton. In the Delta approximately 700 miles of interconnected winding waterways divide the area into many separate islands varying in size from a few hundred to several thousand acres. Most of the land has been reclaimed gradually over a period of 75 years to comprise the more than 400,000 acres of highly productive farm land within the Delta. Generally, the reclaimed land lies near or below sea level and is protected from flooding by levees.

Before the levees were constructed the character of the area was that of a permanent tule marsh of boggy peat, impregnated with silt, over which the water surface regularly oscillated with the tide. In its original state of nature the Delta consisted of swamp and overflow lands built up gradually through the ages by accumulations of decayed vegetation and deposits of silt brought down by the Sacramento and San Joaquin rivers. These swamp lands were covered with various types of aquatic vegetation, trees, and grasses.

Sycamores, willows and cottonwoods lined the banks of the Sacramento River and its branch channels while the interior of the islands and lower-lying lands of the Delta supported a dense growth of tules and other aquatic plants.

The Channels

The network of channels which separate the islands in the Delta is of great importance to the area. The channels not only are the source of water supply used for irrigation of crops, but they also provide efficient and economical water transportation. The Stockton and Sacramento deep water channels make it possible for deep-draft ocean-going vessels to navigate inland as far as Stockton and Sacramento.

The numerous channels form the reservoir from which water is drawn for irrigation of the Delta islands. Under normal conditions the runoff, or continuous discharge, from the Central Valley not only replenishes the supply of fresh water but serves as a natural barrier against the encroachment of salt water from the bays. The same channels receive the agricultural drainage water removed from the fields.

Since 1940 the Delta channels have been used to transport water across the Delta, from north to south, and thereby enabled diversion of water from the southern Delta for transport into Contra Costa County and the San Joaquin Valley.

The Levees

The exceptional fertility of the Delta lands was a great attraction to the early settlers, and attempts to reclaim some of the islands were made as early as 1852. The initial levees were small, two to four feet high, and were constructed to keep out high tides. Though small and of little weight, difficulty was experienced in their maintenance, and it is reported that during the flood of 1861-62 they were overtopped with disastrous results.

As the development of agriculture progressed, more substantial levees were built. The levee system was extended to either fully or partially protect every island in the Delta against floods from the rivers, as well as from high tides.

The levees were not built without difficulty, particularly in the San Joaquin area where the top layer of peat is underlain by fine sand, blue clay, and a very fine muck, which under load, acts much like quicksand. Under the weight of the constructed bank, the ground, for a short distance on each side, settles. The theory is that the mucky material, not being stable enough to support the load, moves out laterally until stability is established. As a result of the settlement, the ground immediately back of the levee is lower than the general elevation of the island and the water collecting there tends to aggravate conditions by softening the spongy peat foundations.

The over 1,100 miles of levees that confine the rivers and navigable waterways above the level of the land have mostly been created by those who use the Delta for many activities of profit and pleasure.

The Islands

The lands along the banks of the natural channels were built up by deposits of sediment from the overflow of the streams during flood, so that the rims of the islands were considerably higher in elevation than the interior of the islands. In many cases these banks were high enough to keep out the tidal waters during the period of low streamflow in the summer and fall.

Reclamation development in the Delta was started in the 1850's. The first work was done on a very small scale by individuals who put up small levees, usually by hand labor, to partially reclaim small acreages. Following the adoption of several legislative acts, between 1850 and 1860, providing for the sale of swamp lands, reclamation development increased rather rapidly. The works required were of considerable magnitude and, it soon became the usual practice for groups of individuals to band together in a cooperative organization to carry out the required construction work.

The reclamation of lands in the Delta has made considerable alteration of the open channels. Some of the smaller natural channels have been closed, but many new artificial channels have been created by dredge cuts for levee construction. Most of the main natural channels have been widened by the excavation of levee material. The federal government has created new channels along the San Joaquin River for improvement of navigation. All of this work probably has increased the area and volume of open channels within the tidal prism. However, the simultaneous leveeing-off of lands which were originally submerged by tidal flow probably has more than counterbalanced the increase in open channels.

Suisun Bay

Suisun Bay, into which the Sacramento and San Joaquin rivers jointly discharge immediately west of the Delta, is a relatively shallow body of water. Its two main arms are separated by a peninsula and close-lying islands extending out from the north shore. Its southerly arm is practically a continuation of the river and includes the deeper waters of the main navigation channels. The other arm extends in a northeasterly direction from the lower end of Suisun Bay and spreads out into a broad, shallow basin, locally known as Grizzly Bay. Large quantities of silt and debris brought down by the rivers have been deposited in Suisun Bay, and through the passage of time the gradual accumulations have resulted in diminishing the area and depth of the bay. Dredging operations are required periodically to keep the navigation channels open.

Contra Costa County

Along the south shore of Suisun Bay, there is a large industrial development extending from Antioch to Martinez. Much of this development centers around the City of Pittsburg. Other large industrial plants are scattered at various locations on or near the bay shore from Pittsburg to Martinez. The low-lying marsh areas skirting the shore are for the most part unreclaimed and uncultivated. The upland area east of Antioch is devoted largely to orchards and vineyards with some grain and hay, most of which is dry farmed.

West of Antioch the upland area continues to develop with both urban and industrial complexes. The Contra Costa Canal, constructed 25 years ago, serves water to most of the area.

Solano County

Adjoining the north shore of Suisun Bay is an extensive area of marshlands aggregating about 60,000 acres and consisting of numerous islands separated by a network of channels. One of these main channels, Montezuma Slough, extends in a circular path from the upper end of Suisun Bay to join the Sacramento River just below Collinsville. Suisun Slough, another important channel, meanders northerly to a dead end near Suisun and Fairfield.

The marshlands north of Suisun Bay have been largely reclaimed by levees; the area within these levees aggregates about 45,000 acres. However, only a small portion of the leveed land is farmed. Agricultural development has been largely unsuccessful, due to the salt-marsh character of the soil and the fact that during most of each year, the water supply in the adjacent channels is of a brackish quality. The leveed lands are now used mainly as private hunting preserves.

Formation and Evolution

The geologic history of the Sacramento-San Joaquin Delta region dates back to the late Tertiary period, some 10,000,000 years ago. Prior to that time, the area, like much of California, was a part of the sea, and was the site of deposition of a great succession of marine strata. Beginning in the late Tertiary period the mountains to the west of the Delta area were uplifted. This uplift continued into the Quaternary period, about 1,000,000 years ago. By that time, most of the landforms seen today had been created.

During the early part of the Quaternary period sea level stood at an elevation several hundred feet lower than it does today. This lower level caused the Sacramento River to cut a deep gorge now known as Carquinez Strait. The Delta area had the form of a broad plain across which passed the rivers which drained the great Central Valley. This plain had an average elevation of about 200 feet above the ancient sea level.

With the melting of the glaciers after the ice age the level of the sea rose gradually. This was accompanied by a gradual shifting of the earth's crust which caused subsidence of certain parts of San Francisco Bay, the Delta and adjacent mountainous areas. The net result was a gradual invasion of the sea into the lowland areas. This transformed the broad upland plain into a land of tidal marshes and peat bogs. It has been estimated that the invasion has taken place during the last 20,000 years, and evidence indicates that the maximum amount has not yet been attained. This is attested to by a rise of sea level of about three inches during the 50-year period from 1880 to 1930.

CHAPTER II

WATER RELATED CONSIDERATIONS

The Delta and Suisun Bay has so far been described in glowing terms, and with a considerable amount of justification. Praise, however, is in itself not enough. It is necessary that we continue to reevaluate our natural resources and plan for their maintenance, environmental control, and when practicable, for enhancement of their more desirable elements in order to more fully develop their potential.

Water Quality

California's Central Valley, one of the 18 major river basins in the continental United States, will continue to provide a suitable environment for an energetic society. It will, that is, if the people of California continue to remind themselves that water, and particularly the quantity and quality of water, is a prominent factor in controlling future growth and development. The increasing importance of comprehensive planning for optimum development and conservation of the State's land and water resources, in order to ensure the everlasting maintenance of our irreplaceable resources and the enhancement rather than degradation of desirable elements, cannot be overemphasized.

Continued development of water supplies in the Central Valley of California, to meet export requirements and other beneficial needs, will result in decreased annual Delta outflows to the San Francisco Bay system. Future expansion of municipal, industrial, and agricultural development in the Central Valley will result in increased waste water in the Central Valley and hence into the bay. At the same time, population increases and industrialization of the bay area will result in substantial increases in waste water discharged directly to the bay system.

Pollution problems, more severe than ever experienced before in the bay area, will result from increased waste discharges, within and without the bay system, unless steps are taken to regulate and control their occurrence and plans are made for a feasible solution to the waste problems.

In order to properly and adequately plan for the maintenance, control and enhancement of our environment, knowledge of the assimilation capacity, hydraulic characteristics, and water quality conditions of the Delta and bay system is essential. This knowledge is also essential to the successful operation and regulation of the facilities of the State Water Project.

Beneficial Uses

Present beneficial uses of the Sacramento-San Joaquin Delta and Suisun Bay vary according to specific location and from season to season. Generally, the area can be divided into three zones; northern Delta, southern Delta, and the western Delta and Suisun Bay. Two distinct seasons, summer and winter, can be differentiated by low uniform flows and high erratic flows.

At the present time, beneficial uses in all three zones include domestic and agricultural water supply, fish and wildlife, recreation, waste water disposal, navigation, and scenic enjoyment. In the southern and western Delta there is also industrial water use. Exportation of water from the southern Delta is currently a beneficial use in that zone.

Future beneficial uses in the Delta and Suisun Bay, following construction of the Peripheral Canal, will be somewhat modified. The southern Delta will no longer be used for export there will be alternative water supplies to meet some of the needs in the western Delta and water will be exported from the northern Delta.

Accepted Standards

Water quality control authorities, public health officials, and water resources engineers have long been aware of the need for adequate water quality criteria. They recognize a responsibility to the public to maintain a healthy environment for recreation and fisheries, suitable water for irrigation, and safe water for municipal and industrial uses. Criteria are needed so that limits on specific concentrations of constituents in receiving waters can be established. However, because of the difficulty of establishing exact criteria, values for quality parameters have been selected by various public agencies as objectives for present and anticipated beneficial uses. Guides have been developed to assist in the determination of the suitability of water for municipal, industrial, and agricultural use, recreation, and the preservation of fish and wildlife.

Municipal Water Supply. Drinking water standards, established by the United States Public Health Service, have been adopted by the State of California. They set mandatory limits on the concentrations of eight constituents and recommend limits of fourteen more. Interim standards adopted by the California State

Board of Public Health provide for issuance of permits for drinking water supplies on the condition that certain selected mineral constituents do not exceed specified concentrations. The State Board also defines maximum safe amounts of fluoride ions in drinking water, in relation to mean annual temperature.

Industrial Water Supply. Industrial water quality requirements vary greatly between industries. Food processing, beverage production, pulp and paper manufacturing, and textile industries require better quality water than some cooling and metallurgical operations. As an example, the degree of hardness that can be tolerated in water supplied for industrial purposes may vary from as little as 2 mg/l (milligrams per liter) to over 500 mg/l of $CaCO_3$ (calcium carbonate), depending on the planned use for the water. Usually, if a water supply meets drinking water standards it will be satisfactory for industrial use.

Agricultural Water Supply. Only general limits of quality may be suggested for irrigation water because soil permeability, drainage, temperature, humidity, and rainfall alter the response of a crop to a particular quality of water. However, the United States Department of Agriculture places irrigation waters in three general classes for which allowable constituent concentrations have been determined.

Class I - Regarded as safe and suitable for most plants under most conditions of soil and climate.

Class II - Regarded as possibly harmful for certain crops under certain conditions of soil and climate, particularly in the higher ranges of this class.

Class III - Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

Recreation. Generally, water supporting a healthy aquatic population, with BOD (biochemical oxygen demand) of 2.5 mg/l or less, and a population of coliforms resulting in a most probable number (MPN) of 1,000 per 100 ml (milliliters) or less, is adequate for water contact sports. Water used for recreation purposes should be free from obnoxious floating or suspended substances, objectionable color, objectionable odor, and substances which are toxic upon ingestion or irritating to the skin.

Fish and Wildlife. Water quality requirements for fish and wildlife must be general because the requirements differ for different types of aquatic life. Fresh water fish for example, cannot tolerate high concentrations of chloride, and salt water fish usually cannot survive where chloride concentrations are low. Many mineral and organic substances in low concentrations are harmful to fish life; pesticides, ether-soluble materials, and salts of heavy metals are of primary concern. Fish are also affected by rapid changes in temperature. Dissolved oxygen concentration of 5 mg/l is considered to be the minimum desirable for sustaining fish and aquatic life.

Established Requirements

Water quality requirements, related directly to specific purposes or which are policies and recommendations of specific agencies, vary in relation to the objectives of the organization or project.

State Water Project. Quality limits for the water to be delivered by the State Water Project were established in 1955 with the assistance of a special board of consultants who recommended specific limiting values for the more important mineral constituents and characteristics. This board considered the recommendations of many interested parties, including federal, state, and local agencies, agricultural and industrial water users, and associations and societies concerned with water quality. The board recognized that allowances must be made for increases in population and in agricultural and industrial development, and that water flowing in all portions of the system should be of satisfactory quality to meet the intended uses without extensive treatment.

The board refrained from recommending specific limits for indices of contamination or for constituents bearing directly on fish and wildlife, as limits for such constituents are subject to regulation by the Regional Water Quality Control Boards, the State Board of Public Health, and the State Fish and Game Commission.

For purposes of the water quality objectives of the water supply contracts, the recommendations of the board of consultants were considered but most of the limits were increased by about 10 percent to allow for moderate deterioration of quality between the points of diversion in the Delta and the points of delivery.

Article 19(a) of the "Standard Provisions for Water Supply Contract" states that:

> "It shall be the objective of the State, and the State shall take all reasonable measures to make available at all delivery structures for delivery of project water to the Agency, project water of such quality that the following constituents do not exceed the concentrations stated as follows:

Constituent	Unit	Monthly Average	Average for any 10-year Period	Maximum
Total Dissolved Solids	ppm	440	220	---
Total Hardness	ppm	180	110	---
Chlorides	ppm	110	55	---
Sulfates	ppm	110	20	---
Boron	ppm	0.6	---	---
Sodium Percentage	%	50	40	---
Fluoride	ppm	---	---	1.5
Lead	ppm	---	---	0.1
Selenium	ppm	---	---	0.05
Hexavalent Chromium	ppm	---	---	0.05
Arsenic	ppm	---	---	0.05
Iron and Manganese together	ppm	---	---	0.3
Magnesium	ppm	---	---	125
Copper	ppm	---	---	3.0
Zinc	ppm	---	---	15
Phenol	ppm	---	---	0.001

The objectives contained in the contracts for delivery of State Water Project water are more exacting than criteria contained in Bureau of Reclamation contracts for delivery of water from the Contra Costa and Delta-Mendota canals, which also divert from the Delta.

Regional Water Quality Control Boards. The Regional Water Quality Control Boards set specific requirements for most individual dischargers. Limits established by the Regional Boards, are based on the type of discharge and the uses of the local receiving waters. Requirements which must be met by the discharger are designed to prevent nuisance conditions, protect beneficial water uses, control hazards to public health, and preserve fish and other aquatic life.

Regional boards not only set limits for individual dischargers but also establish quality limitations for specific reaches of receiving waters. The limits are necessary in order to maintain supplies of suitable quality water for the specific uses of water from the particular reach. For example, the major discharger into the Sacramento River is the City of Sacramento. The Board established water quality limitations on this discharger which would maintain the present high quality of the river water and make it of suitable quality for municipal, domestic, and industrial use, irrigation, fish propogation, navigation, and other associated beneficial uses.

Waste dischargers within the area of investigation are controlled by the San Francisco Bay Regional Water Quality Control Board and the Central Valley Regional Water Quality Control Board.

Resources Agency of California. The Administrator of the Resources Agency of California established interim water quality objectives for the Delta and San Francisco Bay to govern the activities of the Agency. These interim water quality objectives are applicable only for the period preceding the establishmen of permanent objectives by the State Water Quality Control Board, and are shown in Table 1.

The objectives were presented on the basis of beneficial uses. They were not intended to specify what beneficial uses should be protected in any particular area, but to protect all possible beneficial uses. All units of the Resources Agency were directed to operate the waste discharge facilities under their control so as to meet the objectives at the points in the Delta and in San Francisco Bay where the various beneficial uses exist.

Water Development Projects

The history of water resource development in California largely has been that of control and regulation of the supply at its source, to insure its timely availability when needed, and conveyance to the service area where required. Water development in the Sierra Nevada has proceeded without too much concern over water quality since, in general, water flowing into the Central Valley is of good quality.

As the Central Valley has become more intensely developed, water quality has become increasingly important. In the Delta, water quality is affected both from river discharges coming out of the Sacramento and San Joaquin valleys and from the tidal action which brings ocean salts into the Delta channels. Water development projects to maintain, control, and enhance water quality are receiving high priority from all levels of government.

The California Water Plan

During the 1950's the State published three important reports: Bulletin No. 1, "Water Resources of California", Bulletin No. 2, "Water Utilization and Requirements of California", and Bulletin No. 3, "The California Water Plan". These three reports represented almost ten years of planning, investigation, and study. When the studies leading to these reports were completed, the results showed that there were 70 million acre-feet of runoff annually from California streams, that approximately 19 million acres of land would one day be irrigated and consumptively use 30 million acre-feet of applied water, that an

TABLE I

INTERIM WATER QUALITY OBJECTIVES FOR DELTA AND SAN FRANCISCO BAY
APRIL 1 1965

Uses	Toxic Ions Mg/l	Gross Solids	Grease and Oil	TDS[a] Mg/l	Oxygen Index		pH	Bacteria MPN/100ml		Pesticide Chlor. Hydroc.	Nutrient[b] Mg/l		Turbidity		Hardness Mg/l
					DO Mg/l	BOD		Fresh	Salt		Nitrogen Phosphate	Algae	Mg/l	Secchi Disc	
Domestic	Cl 250[a] SO_4 250[a] Mg 125[a] NO_3 45 F 1.0 Pb 0.5		None visible	1000		*	6.5 to 8.5	Coliform 5000 > 20% Time		*		No Bloom[c]	150		
Industrial				2000			6.5 to 8.5						200		150
Agricultural	Cl 175[a] B 0.5[a]			750											
Recreational		None	None visible		5			Fecal-Coliform 200 Median	Coliform 1000 > 20% Time		Total Nitrogen 3.0 PO_4 0.5	No Bloom[c]	100	*	
Fish and Wildlife	Bio-Assay 1/10 T.L.M. 96 hr.	No Sludge Deposits	None visible		5		6.5 to 8.5			Plankton 1 ppm Filtrate 1 ppb					
Navigation							6.5 to 8.5								
Export	d	None	None visible	400	5		6.5 to 8.5	Coliform 5000 > 20% Time Fecal-Coliform 200 Median		Plankton 1 ppm Filtrate 1 ppb	Total Nitrogen 3.0 PO_4 0.5	No Bloom[c]	100	*	d
Scenic Enjoyment		None									Total Nitrogen 3.0 PO_4 0.5	No Bloom[c]			

*Means that numbers are to be added.

[a]The objectives indicated[a] above shall not apply to areas subject to salinity intrusion from the bay nor to waterways within the Delta where the inchannel quality is a subject of current negotiations.

[b]The standard for "Total Nitrogen" is intended to serve as a measure of the potential for algal growth and as a control on the development of an algal bloom (see note c). The dry weight of algae divided by 13.3 gives the approximate quantity of nitrogen which has been incorporated into the living cell material. The assumption (supported by studies) is made that 50-60 ppm of algae on a dry weight basis will produce a green color in water. The number used, 3 ppm, (N - in all its forms) appears to be considerably on the safe side since this concentration creates a maximum potential growth of about only 40 ppm assuming that all the other growth factors are present and assuming further that the conversion of nitrogen into cell material is 100% efficient which it decidedly is not. This objective is to be applied to water having a temperature of 60° F or more. Higher concentrations will be set for lower temperatures where information is available.

[c]An algal bloom is defined as that quantity of growth which produces an undesirable effect. The purpose of the nitrogen objective is to prevent an algal bloom. Further study may well show that the nitrogen objective specified above should be modified either up or down.

[d]As per applicable contract and/or agreement.

additional 6 million acre-feet of applied water would be used for other purposes, and that the total ultimate water requirement for the State of California would be about 52 million acre-feet per year. It was anticipated that 5,362,000 acre-feet of this water requirement would be met from California's anticipated rights in and to waters of the Colorado River.

On the basis of studies leading to the formulation of the California Water Plan, it was concluded that the projected water requirements could be met through conservation, regulation, and development of California's water resources.

The Central Valley covers some 40 percent of the State of California; however, the Central Valley's water requirement is a little over 60 percent of the total State requirement. The Central Valley of California is important to the remainder of the State, since it is in this valley that most of the water distribution facilities for exporting water from surplus areas to deficient areas will be constructed.

One facet of the California Water Plan, the coordinated plan to guide the development of the State's land and water resources by redistributing the State's water supply, is of concern to those studying the San Francisco Bay and the Delta area. This concern relates to any possible future impairment to the quality of water in the San Francisco Bay or the Delta drainage area.

Development and regulation of Central Valley water supplies for agricultural use on the valley floor has all but depleted the quantity of natural summer outflow from the Sacramento-San Joaquin Delta. Even in normal water years there are periods of time during the summer months when the natural outflow would be essentially zero. However, since 1944, releases from Shasta Reservoir have helped repel the summer salinity threat to the Delta. There has been no year since completion of the Shasta Dam that a severe intrusion problem has been experienced within the interior Delta. Had there been no releases for salinity control, salt water would have intruded well into the interior Delta.

For several years the U. S. Bureau of Reclamation has utilized the natural channels of the Delta to convey Sacramento River water to the Tracy Pumping Plant, a feature of the Central Valley Project. In recent years, North Coastal water has been added to this system through the Trinity River Division of the Central Valley Project. To accomplish this cross-Delta transport of water, it is desirable to maintain a positive Delta outflow at Chipps Island in order that brackish water not be sucked toward the Tracy Pumping Plant. At times, flow reversals have occurred in the lower San Joaquin River in the vicinity of Antioch, causing these brackish waters to be borne toward the pumps.

Because of the increased quantities of water to be exported southward with the authorized expansion of the Central Valley Project and through the State Water Project facilities and because of the higher quality standards set for this export water, more control over Delta water quality is necessary. This will be accomplished through use of the Peripheral Canal. With a Peripheral Canal it will be possible to transport required quantities of water across the Delta. The increased use of the Central Valley water supplies will result in an increase in the duration of saline water intrusion in the western Delta. The Peripheral Canal offers, however, an almost unlimited opportunity to control the hydraulic characteristics and the water environment of the Delta. Before the Peripheral Canal could become an efficient reality, however, it was necessary that we acquire the knowledge to understand the present hydraulic characteristics and water quality in the area.

Another facet of this increased development that will affect the Delta and San Francisco Bay is the increase in waste water drainage that will be created out of the expansion brought about by new water supplies in the Central Valley. The increase in irrigation will generate relatively large quantities of drainage water, while urban and industrial growth will result in degradation to the available water supply.

Local Water Projects

California's early irrigation supplies were diverted from nearby streams without storage, thus limiting irrigated lands to those that could be watered from available low summer flows. This procedure was practical until the natural summer streamflow was exhausted and it became necessary to conserve winter runoff for use during the following summer. Hydroelectric power development projects on the streams of the Sierra Nevada Range provided storage and regulation necessary to augment the natural low summer flow and were in many cases integrated with local irrigation developments.

The metropolitan areas of San Francisco and the East Bay, under the pressure of ever increasing water requirements and diminishing resources of undeveloped local water, exercised considerable initiative in solving their water supply problems. Remote sources of supply in the Sierra Nevadas were chosen for development and extensive conveyance systems were used to bring the water across mountains and valleys to the service area. While these water supply developments on the Mokelumne (East Bay Municipal Utility District) and Tuolumne (San Francisco's Hetch Hetchy system) rivers are outstanding examples of initiative and leadership in water supply development in California, the results must be analyzed as they affect the water supply situation today.

Regulating and conserving water originating in the Sierra Nevadas and transporting it by a closed conduit to areas of need around San Francisco Bay has a more profound effect on the Delta and Suisun Bay than do the activities of the local water developers in the Central Valley. Water regulated and developed by Central

Valley users is released primarily during the summer months for agricultural use. Depending upon location and economics, the drainage and return flow may be reused one or several times before it appears as Delta outflow to San Francisco Bay. Water thus developed for Central Valley use serves a variety of needs.

Local water projects in the Central Valley, particularly those constructed during the early portion of the century, were generally single-purpose water development projects; Central Valley water supplies were developed for either agricultural use on the valley floor or municipal and industrial use in the San Francisco Bay area. The more recent projects have been primarily dual-purpose in that they have been used to generate hydroelectric power and provide flood control as well as to conserve water for consumptive purposes. In addition, local water projects now often include recreation and fish and wildlife enhancement as project purposes. Water released for fisheries enhancement during the dry summer months could also serve to improve water quality conditions in the main river channels, the Delta, and San Francisco Bay. In general, however, improving water quality conditions in the Delta or San Francisco Bay has not been included as a project purpose of local water development.

Federal Water Projects

During the early 1900's water supply projects in the Central Valley were generally conceived and consumated through local efforts. However, starting in the 1930's, federal agencies entered the field of water resources development in California. The U. S. Army Corps of Engineers, through its responsibilities for flood control and navigation, and the U. S. Bureau of Reclamation have each constructed comprehensive projects. The most extensive of these is the Central Valley Project of the Bureau of Reclamation. The Central Valley Project, originally envisioned and formulated by the State of California and constructed and operated by the Bureau of Reclamation, is a multiple-purpose development. It is designed to supply water for irrigation, municipal, industrial, and other uses; improve navigation on the Sacramento River; provide adequate flows to maintain suitable water quality in the Sacramento-San Joaquin Delta; control floods in the Central Valley; and produce hydroelectric power. Water is stored in reservoirs such as Engle, Shasta, and Folsom, and is released during the dry summer months to meet these purposes. Release of storage water at specified times can give assurance that the net Delta outflow will be positive.

Facilities proposed provide for a conveyance system hydraulically isolated from Delta channels. The Peripheral Canal would begin with an intake and fish screen located on the Sacramento River, near Hood, followed by a low lift pumping plant. The canal would cross the eastern edge of the northern Delta, be siphoned underneath the Mokelumne River and continue toward Stockton where it would be siphoned underneath the San Joaquin River. It would then proceed southwesterly across the southern Delta and be siphoned underneath Old River. The canal would divide at this point into two branches: one terminating at the Bureau of Reclamation's Tracy Pumping Plant intake canal, and the other proceeding to the Clifton Court Forebay and terminating at the State's Delta Pumping Plant.

These facilities are key features of the State Water Project and are important in achieving the objective of the California Water Plan: to conserve water in areas of surplus and to transport water to areas of deficiency.

San Joaquin Master Drain. There are today agricultural lands in the San Joaquin Valley that can no longer produce crops or on which production has been curtailed because of drainage problems. The importation of additional quantities of water by the State Water Project and the San Luis Division of the Central Valley Project will further aggravate this condition unless provisions are made for adequate water quality control and removal of poor quality drainage waters from the area. Drainage problems and the need for disposal facilities are evidenced in three ways: (1) loss or curtailment of agricultural production, (2) water quality degradation in surface streams, and (3) water quality degradation in ground water supplies.

The California Water Plan recognized the need for drainage disposal facilities in the San Joaquin Valley and the importance of protecting its agricultural bounty. Drainage disposal facilities have been authorized by the California Legislature and the United States Congress, and recently a plan for a San Joaquin Master Drain was formulated and presented in Department of Water Resources Bulletin No. 127, "San Joaquin Valley Drainage Investigation, San Joaquin Master Drain". This report recommends construction of a San Joaquin Master Drain to maintain the agricultural economic structure of the San Joaquin Valley and also as the first step toward protection of the surface and ground water quality in the area.

CHAPTER III

DELTA-SUISUN BAY WATER QUALITY INVESTIGATION

The Delta region is a vital area since it is through here the surplus water conserved in the north will be transported to areas of deficiency in the south. Surplus water must be transferred either around or through the Delta channels without undue loss or deterioration in quality.

Continued development of Central Valley water supplies for agricultural, domestic, and industrial purposes will result in decreased annual fresh water outflow to the San Francisco Bay system and increased volume and concentration of waste water drainage. Construction and operation of the Delta water facilities will have a strong influence on future conditions, and water quality deterioration will occur if measures are not taken to control and prevent such degradation.

Intimate knowledge of the present and projected future waste assimilative capacities of the Delta channel system and the Suisun Bay area, and the factors affecting this assimilative capacity, is necessary before criteria for future control of Delta and Suisun Bay water quality can be determined. Of principal concern is the complex factor of tidal hydraulics peculiar to this area and its relationship to water quality. Sufficient knowledge necessary to cope with future conditions can be obtained only from intensive and thorough study of conditions now existing in the Delta and Suisun Bay area.

Many water quality factors have been studied in earlier investigations and some are included in current studies. However, certain additional information and collation and evaluation of data from a number of sources was necessary to establish planning, design, and operating criteria for proposed works in the Delta. Thus, the Delta and Suisun Bay Water Quality Investigation was initiated as the water quality portion of the overall planning of the Delta water facilities. The investigation also included estimation of water quality changes which could result from discharges from the San Joaquin Master Drain. During the investigation specialized subjects were studied, interpretations were made, and results were compared to findings of other investigations to assess their validity. The investigation was primarily concerned with water quality and related hydrology.

Goals and Objectives

The general objective of the Delta and Suisun Bay Water Quality Investigation was to characterize present natural and man-made sources of water quality degradation, to determine their effects on beneficial uses, to evaluate these and future sources with respect to operation of the Delta water facilities and the San Joaquin Master Drain, and to provide data on hydraulic characteristics required for the design and operation of these facilities.

To fulfill the general objective, the following specific objectives were established:

1. Determine flow distribution, circulation patterns, diffusion characteristics, and residence time throughout the major channels and waterways of the Delta-Suisun system, under various tidal and inflow-outflow circumstances, with particular emphasis on summertime conditions when Delta outflow is at a minimum and water use at a maximum.

2. Determine present water quality throughout the area of investigation including dissolved minerals, organic materials, nutrients (nitrogen and phosphorus), and oxygen relationships; and, evaluate natural and man-made sources of degradation in order to provide the basis for evaluating changes in Delta water quality under future conditions, irrespective of the physical works selected for the Delta facilities.

3. Estimate the probable effect of discharge from the San Joaquin Master Drain upon water quality conditions in the receiving waters.

4. Collate water quality aspects of present beneficial uses and present quantities and qualities of waste discharges.

5. Provide information which would serve as a guide for operation of the Delta water facilities and the San Joaquin Master Drain.

Scope of Investigation

The Delta and Suisun Bay Water Quality Investigation was programmed as a four-year multiple-phase study to define and delineate existing and potential problems in the Delta channel system and Suisun Bay area. The two main phases of the investigation were established as:

1. Evaluation of the tidal hydraulic regime of the Delta, its western channels and Suisun Bay, under various conditions of fresh water outflow and ocean tides.

2. Evaluation of water quality and waste assimilation characteristics of the channel system and Suisun Bay.

Tidal hydrographics were considered inseparable and basic to water quality in estuarial systems of the type found in the San Francisco-Suisun Bay complex. Water quality sampling and waste discharge inventory monitoring, simultaneously with the hydraulic studies, were necessary. Continuous assessment and evaluation of analytical results of both water quality and hydraulic data were made as the program progressed.

The investigation was coordinated with the various sampling programs being conducted by state, federal, and local agencies. Several existing programs were directly applicable to the Delta and Suisun Bay Water Quality Investigation and data obtained from these programs were used. Programs used to provide valuable information regarding mineral quality of surface and ground waters are included in a subsequent section of this report, titled "Related Studies".

Exact boundaries for geographical limits of the investigation were not established since they would be influenced to a considerable extent, by the hydraulic regimen of the San Francisco Bay estuary and the Delta channel system. However, it was generally established that the physical area of the investigation would encompass a triangular section of the State from Sacramento on the north, Vernalis on the south, and Vallejo on the west.

Movement of Water

Flow distribution, circulation patterns, diffusion characteristics, and residence times were determined by two methods.

Several detailed hydraulic dye tracer studies were conducted in the major channels and waterways of the Delta using Rhodamine B and Pontacyl Brilliant Pink. The fluorescent properties of these dyes permit their detection at concentrations as low as 0.05 parts per billion. At these low concentrations the dye is not visible in the water. Its concentration is measured by an instrument called a fluorometer. Dye dispersion tests were also conducted in the U.S. Army Corps of Engineers' San Francisco Bay Model in Sausalito to provide data for estimating the probable effects of discharge from the San Joaquin Master Drain on the water of Suisun Bay.

Analysis was made of continuous records of specific conductance of water throughout the Delta where discharges of high salinity water from Reclamation District No. 108 into the Sacramento River above Knights Landing or from other sources could be traced. Data from the Sacramento River Water Pollution Survey indicated that the study of data available from the Department's Surface Water Quality Monitoring Program and from the Bureau of Reclamation's recorder stations would yield a better understanding of the manner in which water moves through and mixes within the Delta. During the investigation, three specific conductance (EC) recorders were installed in the Delta area and maintained in coordination with EC recorders of the Bureau of Reclamation. These supplied continuous information relative to dissolved solids in the waters of the Delta.

Oxygen Relationships

Oxygen relationships were studied by means of intensive surveys where samples were taken at about two-hour intervals from closely spaced stations. Samples were analyzed for dissolved oxygen, alkalinity, and temperature. Selected composites were analyzed for mineral and organic constituents, including trace elements. These data permitted determination of factors in, and recovery rates of, dissolved oxygen concentrations from the Delta Cross Channel (the approximate oxygen sag-point in the Sacramento River), across the Delta to Tracy.

Pesticide Concentrations

A sampling program was conducted to provide information on present concentrations of pesticides in surface waters, irrigation waters, and agricultural drainage wastes in the San Francisco Bay-Delta complex, the San Joaquin Valley, the Imperial Valley (Salton Sea area), and at other selected stations. Fish samples and bottom sediments were also collected for pesticide analysis.

Waste Water Discharges

Information on beneficial uses and waste water discharges were obtained from various state and federal agencies, then collated and evaluated. Agricultural drains in the Delta were sampled to determine present water quality characteristics of the drainage. This data was used to evaluate changes in water quality, to correlate present and 1954-55 drainage quality, and to predict future drainage qualities and resultant changes in water quality within the Delta channels.

The effects of discharges from the proposed San Joaquin Master Drain were predicted on the basis of hydrographic data from tracer studies, chemical and biological features of the receiving water, and the estimated characteristics of the drainage water. Present environmental conditions in the Imperial Valley were compared with those observed in the Delta and Suisun Bay to predict changes in future receiving water quality within the Delta and Bay systems.

Water Quality

Present water quality throughout the area of investigation was determined from the several programs which routinely collect water quality information in the Delta and Suisun Bay. In addition, a number of special studies have been conducted by various governmental agencies. A supplemental surface water sampling program was conducted as a part of this investigation to provide necessary information on Delta surface water quality not previously available from other programs.

The development of water quality guides for operation of the Delta water facilities and the San Joaquin Master Drain was dependent upon completion of the previously noted studies and predictions of the future water quality of Delta inflows. Investigations leading to such predictions were within the purview of the Department's Water Requirements and Project Staging Program and the work of this investigation was accordingly coordinated with that program.

Information collected before 1962 by various state and federal agencies has been summarized and is regarded in this report as historical data. Data from January 1962 through December 1964 were evaluated as representative of present conditions. Information collected during field studies was incorporated with other available data and is presented as the most recent knowledge.

Related Studies

To coordinate and integrate other state and federal programs with the Delta and Suisun Bay Water Quality Investigation, particular attention was given to several activities related to basic data collected in the Delta. Historic and present environmental characteristics of the Delta were determined primarily from information routinely collected by these associated studies.

California Department of Water Resources

Implementation of Delta Water Facilities. This advanced planning program is the Department's core study and is basic to the formulation of a final plan for State Water Project facilities required for transfer of water across the Delta. Planning objectives for the Delta water facilities include provision for supplying local water needs, diminishing flood and seepage damage, improving transportation, protecting and enhancing fisheries resources, and serving recreational demands in the Delta area. The program includes planning studies of certain problems to aid in the design of the Delta water facilities, to develop adequate data for operational plans, and to guide negotiations with local, state, and federal agencies for implementation of construction and operation of such facilities.

San Joaquin Valley Drainage Investigation. This investigation was initiated in June 1957 to determine the quantity and quality of waste water that should be removed from the San Joaquin Valley under future conditions and the most feasible method of doing this. A report on the investigation, Bulletin No. 127, along with several appendixes, has been published.

Surface Water Quality Monitoring Program. This is a basic data program to secure continuous water quality information throughout the State. Twenty-one stations in the study area are sampled monthly for physical, bacteriological, and partial mineral analyses; semiannually for trace elements, standard mineral, and radiological determinations. Prior to July 1963 three of these stations (Sacramento River at Freeport, San Joaquin River at Vernalis, and Delta-Mendota Canal at Tracy) were sampled daily by the U.S.G.S. and results were combined at ten-day intervals for a complete mineral analysis.

Waste Water Quality Survey. This is a continuing statewide program to obtain and evaluate data on waste water presently reclaimed for subsequent reuse or which has potential for future reclamation. At least once every five years samples are collected for mineral and detergent analysis. Discharges, which incorporate reclamation operations or are located in water-short areas, are investigated more frequently.

Sacramento River Water Pollution Survey. This investigation, conducted from September 1959 through June 1962, provides the best available data on the quality of the major inflow to the Delta. Information from this investigation was presented in Bulletin No. 111, "Sacramento River Pollution Survey", published in August 1962.

Four-Day Chloride Sampling Program. This program, initiated by the State in 1931 and sponsored since 1943 by the U.S. Bureau of Reclamation, provides frequent information regarding location and magnitude of salinity intrusion in the Delta. Data from this program define the extent of the intrusion of salinity of 1,000 parts of chloride per million parts of water, as affected by tidal and other hydraulic conditions.

Surface Water Measurement Program. This is a continuous basic data program to provide information on perimeter inflows to the Delta and tidal stage data concerning the western Delta and the San Francisco Bay complex.

Climatological Data Collection. The objectives of this program are to augment information received from United States Weather Bureau stations, provide a repository for current climatological data, and to supply dependable information on rainfall, temperature, evaporation, and wind velocities for use by agencies during the development and planning of water projects.

California Department of Fish and Game

Delta Fish and Wildlife Protection Study. This five-year study was initiated in 1961 under terms of an agreement between the Department of Fish and Game and the Department of Water Resources. Biological studies are made by the Department of Fish and Game and engineering studies by the Department of Water Resources.

The study was established to assure adequate protection of the fish and wildlife resources of the Delta during and after construction of the Delta water facilities.

The general objectives are: (1) to determine how the design, construction, and operation of Delta facilities will affect fish and wildlife resources of the area; (2) to recommend any changes in project plans, facilities, or operations required to protect fish and wildlife; (3) to recommend means for compensation of any unavoidable loss of fish and wildlife resulting from construction or operation of the Delta facilities; and, (4) to recommend practical measures which might be taken to enhance fish and wildlife resources in connection with development, construction, and operation of the Delta water facilities.

San Francisco Bay Study. This study of the fisheries resources of San Francisco Bay, south of Point San Pablo, is conducted by the Marine Resources Operations Branch and is coordinated with the Delta study.

Central Valley and San Francisco Bay Regional Water Quality Control Boards

Municipal and Industrial Waste Discharge Monitoring. Major municipal and industrial waste discharges to the Delta, its western channel system, and the San Francisco Bay system are monitored continuously. The physical, chemical, biological, and bacteriological characteristics of the waste discharges are evaluated.

Data from this program meet the needs of the Delta and Suisun Bay Water Quality Investigation for general knowledge of quantities and characteristics of municipal and industrial waste discharges.

California Department of Public Health

Environment Radiological Surveillance. Radiological analyses of surface water samples are made monthly under this program for the cities of Sacramento and Antioch.

Special Public Health Investigations. Studies are conducted in areas where there are suspected problems involving water supplies or recreation. A major study of the Stockton area was made in 1962. Other studies have been conducted in the Antioch and Tracy areas.

University of California

Comprehensive Study of San Francisco Bay. This program was initiated with a reduced area survey of south San Francisco Bay in 1959. The comprehensive study began in 1960 under terms of an agreement with the State Water Quality Control Board. A final report was scheduled for 1966. The physical, chemical, and biological quality of the water and sediments, and the pollution characteristics of the Bay were investigated. Emphasis was placed upon developing analytical techniques and methodology, particularly in the biological phases. The study area included San Francisco Bay, San Pablo Bay, and portions of the fairway of the western channel system to Antioch. Detailed data, on waste discharges made immediately before periods when bay water was sampled, were used to establish the general interrelationship of waste waters, receiving waters, and aquatic life.

Analytical data on water quality in San Pablo Bay and Suisun Bay provide background information on chemical and biologica characteristics of saline waters which enter the Delta. The detailed information on waste discharges is the major source of such data for the Delta and Suisun Bay Water Quality Investigation.

Silt Transport Studies. This program, supported by the U.S. Army Corps of Engineers, provides knowledge of sedimentation processes, including sources, routes and deposition.

U.S. Bureau of Reclamation

Conductance Recorder Stations. This continuing program began in late 1940 and provides for the monitoring of the electrical conductance of water throughout the Delta and of deliveries to the Delta-Mendota and Contra Costa canals. Fifteen stations are monitored continuously during the irrigation season. Certain stations are discontinued in winter.

Delta Water Quality Study. This study is concerned with drainage disposal in the Delta, future Delta outflows, fish and wildlife, future flow distribution in Delta channels, and probable water yield obtainable from the Delta. Water requirements of the counties surrounding the Delta and changes in operatio of the San Joaquin Valley stream system are also being considered.

Federal Water Pollution Control Administration

Water Pollution Surveillance System. Under this cooperative program, a continuing record of physical, chemical, radiological, and biological characteristics is obtained from stations on the Sacramento River at Courtland and on the San Joaquin River near Vernalis.

Public Health Aspects of Proposed Salt Water Barrier and Land Reclamation Projects in San Francisco Bay. This study was conducted for the Corps of Engineers from September 1957 to April 1961. The effect of various barrier plans upon public water supply, waste treatment and disposal, solid waste disposal, barrier pool temperatures, biological nuisance problems, and insect control were predicted. The San Francisco Bay Model was used for special studies of waste dispersion.

Delta Projects Study. Short term studies of Delta water quality problems are conducted for the Bureau of Reclamation. Their purpose is to provide advice and assistance on water quality matters under the authority of Public Law 660, the Federal Water Pollution Control Act, as amended by PL 87-88. This act provides for consideration of reservoir storage capacity for water quality control.

Pollution Problems in the San Joaquin River near Stockton. The State Water Quality Control Board requested federal assistance to study pollution problems which occur in the San Joaquin River, near Stockton, during late summer and early fall. Efforts were concentrated on the environmental aspects of algae and the associated oxygen relationships.

United States Geological Survey

Daily Sediment Sampling Stations. Data from three stations (Sacramento, Vernalis, and Tracy) indicate the amount and general nature of suspended sediment added to cross-Delta flows.

Quality of Surface Water Program. Under this program records are maintained of chemical analysis, suspended sediment, and temperature of surface waters throughout the United States. Annual records have been published since 1941. Beginning in 1950, records have been published in four volumes; each volume representing a major section of the country. This program supplements the California Department of Water Resources' Surface Water Quality Monitoring Program by furnishing additional data.

United States Army Corps of Engineers

Comprehensive Bay Area Studies. Over the years numerous plans have been proposed for the operation of barrier concepts to control intrusion of sea water into the Bay and Delta channel system. The Corps of Engineers, San Francisco District, conducted a study to determine the engineering and economic feasibility of the various alternative barrier plans.

Delta Flood Control and Navigation Studies. These studies are designed to determine the nature and extent of federal interest in flood control and navigation aspects of the State's proposed Delta facilities. Interagency cooperation and exchange of information relative to these studies is accomplished through the Interagency Delta Committee.

Sacramento Deep Water Channel Program. This program started when Delta landowners showed increased interest in the operation of the Sacramento Deep Water Channel. The program purpose was establishment of the actual water quality in the affected areas of the Delta before and after operation of the channel.

Program of Investigation

Development of a detailed program of study for the Delta and Suisun Bay Water Quality Investigation was initiated in the fall of 1961, and considerable effort was devoted to establishing a solid foundation from which to launch the investigation of the Delta-Bay complex.

Advisory Committee

An interagency advisory committee was formed whose membership included representatives from each state agency conducting programs or having regulatory responsibilities in the area of the investigation. Included were the Department of Public Health, Department of Fish and Game, State Water Quality Control Board, Central Valley Regional Water Quality Control Board, San Francisco Bay Regional Water Quality Control Board, and the University of California. The purpose of the committee was to ensure proper evaluation of currently available data, good use of the knowledge and experience of other state agencies, and maximum benefit from the findings and reports to all organizations concerned.

Training of Personnel

As part of the development of professional competence and experience in estuarine surveys during the initial year of the program, a basic course covering field and laboratory methods and evaluation of data in pollution investigations was given to all personnel involved in the investigation. It was conducted, at Department request, by the U.S. Public Health Service's Robert A. Taft Sanitary Engineering Center, at Sacramento State College from July 25, to August 1, 1962.

Consulting Services

Consultations with Dr. D. W. Pritchard, Chesapeake Bay Institute, John Hopkins University, were held in Baltimore, Maryland, in February 1962 and in June 1963. In June 1962, Dr. Pritchard consulted with Department personnel in Sacramento on methods for determining the hydrographic characteristics of the Delta and Suisun Bay. Dr. Pritchard has pioneered in the use of Rhodamine B dye, visible in distilled water in concentrations of about 50 parts per billion, which, with suitable instruments, can be detected at concentrations down to 0.05 ppb. Tracer studies using Rhodamine B have been successfully used in pollution investigations in East Coast estuaries and bays. Dr. Pritchard's experience was utilized in the investigation where the Department extended the use of this tracer technique to the highly complex Delta area.

Consultations with Mr. Sheppard T. Powell, Consulting Engineer, were held at Baltimore in February 1962 in connection with industrial water requirements in the western Delta.

Equipment

Two 26-foot steel-hulled boats were leased and equipped with navigation and testing equipment. Major equipment items included water and bottom sampling gear, precision temperature recorders, and fluorometers for use in tracer studies.

Hydrographic Studies

One of the inherent fundamental objectives of any water pollution investigation is the development of correlations between quantity and quality of waste discharges, and pollutional parameters of the receiving waters. Such analyses require careful and detailed consideration of the physical and hydrological characteristics of the receiving waters and are inseparably related to the resultant water quality found to exist in the tidal estuary.

The solution to problems of water quality and pollution in an estuarine environment depend to a considerable extent on the type and character of the estuarial basins comprising the investigative area. The amount of fresh water discharged into an estuary, the degree to which it mixes therein with the salt water of the ocean, and the mixing and dispersal characteristics of waste discharges, are major factors in establishing the hydraulic regimen of the tidal basin. The presence in tidal estuaries of waters of variable density causes marked differences in the magnitude, distribution, and duration of the currents as compared to those of a single density system. It was anticipated that the regions of Carquinez Strait, Suisun Bay, the Delta, Sacramento and San Joaquin rivers, would provide widely different hydrologic characteristics, and that different portions of this same estuarial basin were well mixed, partly mixed, and highly stratified for identical conditions of tide and upland discharge. It was, therefore, a matter of first importance to establish the type or types of estuaries involved, so as to develop the most practical and precise methods of examination into the correlation phenomena of tidal hydraulics and water quality.

Methodology for study of the area of investigation to determine flushing rates and rates of renewal (dilution), current velocities, flow distribution patterns, and residence times in the major channels and waterways of the Delta and Suisun Bay was required. All these data are necessary to define the circulation and mixing processes in the Delta.

To fulfill the objectives of the investigation, the following hydraulic studies were selected:

1. Residence time and mixing within isolated sloughs as they affect the physical and chemical characteristics of the water.

2. Time of travel and flow distribution in the northern Delta and major routes of water transfer from the Sacramento and Mokelumne rivers to the San Joaquin River.

3. Residence time, time of travel, and distribution throughout the major waterways and channels of the central Delta.

4. Velocity and distribution in the southern Delta in the vicinity of the cities of Tracy and Stockton.

5. Mixing and dispersion in the lower San Joaquin River near Antioch to define processes of advection and diffusion of wastes from the proposed discharge location of the San Joaquin Master Drain.

6. Tidal mixing, dispersion, and movement in Suisun Bay and resultant constituent concentrations from wastes discharged at alternative locations.

Initial field efforts were directed toward determination of hydrographic characteristics of the Delta and Suisun Bay by means of fluorescent tracer techniques. These dye tracer studies were conducted in the areas shown in Figure 3 and are listed in Table 2.

Studies were conducted employing both continuous discharge of dye and instantaneous releases, under various conditions of tide and fresh water discharge from the Sacramento and San Joaquin rivers. Dye releases, from instrumented boats, were followed for different increments of time depending on the nature of the particular study being conducted. In order to study broad areas with precision, two boats were equipped with continuous recording fluorometers, and sometimes releases were made simultaneousl

Water Quality Studies

Studies of the interrelationship of surface water quality and waste discharge quality were based primarily upon evaluation of a large amount of existing data from other programs.

Slugs of high salinity water introduced into the Delta by periodic discharges of irrigation return waters or by tidal action provided natural tracers in Delta channels. Although records are inevitably complex, historical data from 15 recorders operated by the Bureau of Reclamation and new data from two Department recorders were studied to determine: (1) hydrographic characteristics of Delta waterways, and (2) the nature and effect of agricultural drainage which originates in the Delta.

Preliminary examination of data showing areal distribution of water types and concentrations of salts indicated when quality degradation at a particular point was due to sea water intrusion, local drainage, or both. In order to extend this analysis throughout the Delta, a limited amount of additional sampling was required in the area between Middle River and the San Joaquin River.

A study of parameters and computational procedures for predicting future mineral composition of agricultural supply and drainage waters in the Delta was undertaken.

A coordinated program of sampling for pesticides was pursued, based upon use of model analytical techniques to identify and measure all of the chlorinated hydrocarbons and many of the organic phosphates at levels less than one part per billion.

Reports

Office reports on specific technical aspects of the investigation were scheduled and released as each phase of study was completed. Preliminary copies were distributed within the Department and to members of the Interagency Advisory Committee for review and comment prior to being finalized. This had the further advantage of disseminating information and knowledge to those elements of the Department engaged in related studies.

TABLE 2

HYDRAULIC STUDIES

Code[a] Number	Location	Flow Distribution	Travel Time	Dispersion	Residence Time	Evaluation	Model Verification
1	Lower San Joaquin River	X	X	X			
2	Elk Slough				X	X	
3	Hog Slough				X	X	
4	Sycamore Slough				X	X	
5	Middle Mokelumne River	X	X	X			
6	Sacramento Deep Water Channel					X	
7	Suisun Bay						X
8	Georgiana Slough		X				
9	Delta Cross Channel	X	X				
10	Lower Mokelumne River	X	X				
11	Old River		X				
12	Middle River	X	X				
13	Little Potato Slough	X	X				
14	Lindsey-Cache Slough		X		X		
15	Upper Old River		X				
16	San Joaquin River		X				
17	San Joaquin River		X				
18	Upper Mokelumne River	X	X		X		
19	Sacramento River			X			
20	San Joaquin River		X				

[a] As shown in Figure 3.

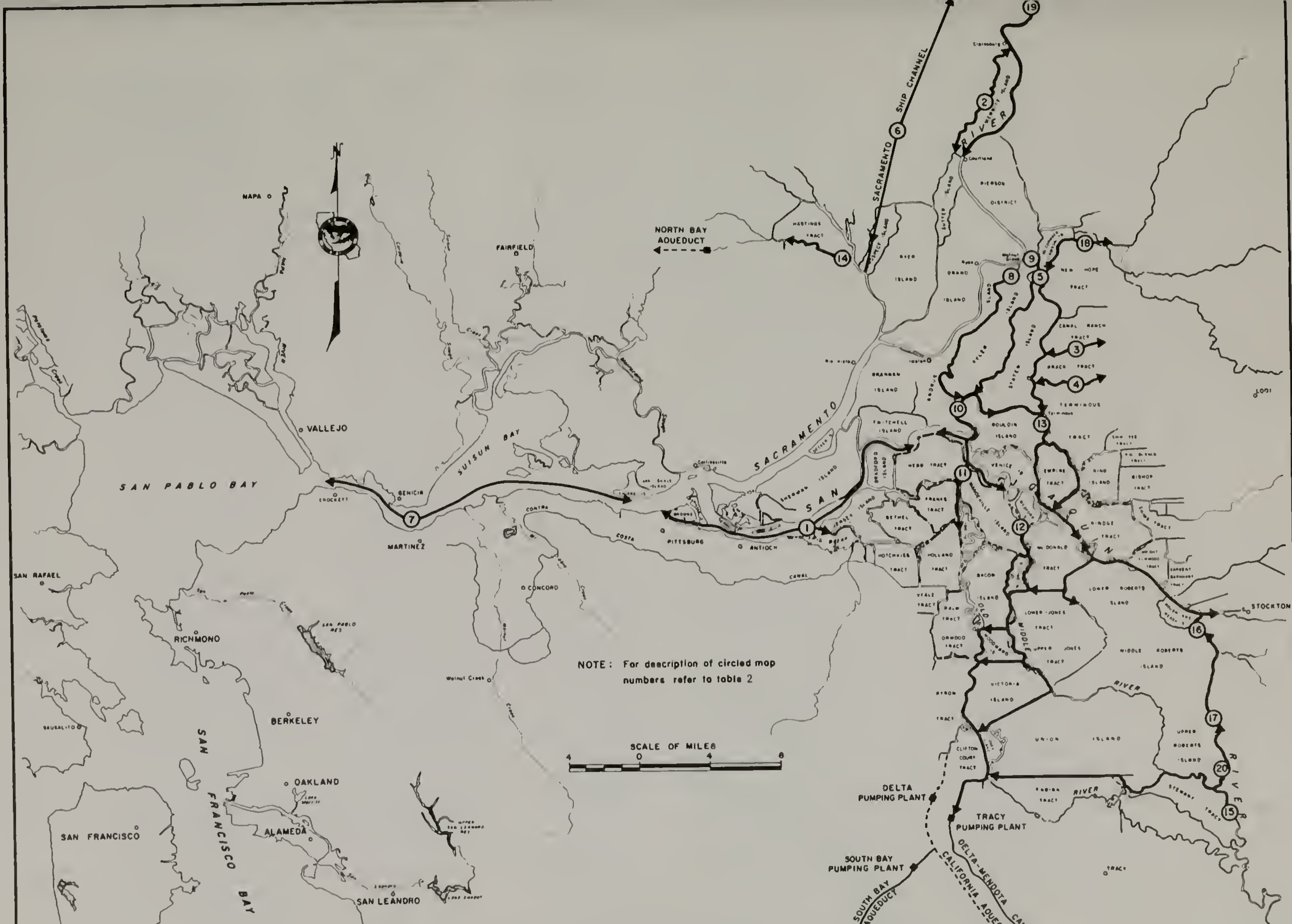


Figure 3. LOCATION OF HYDRAULIC STUDIES

CHAPTER IV.

INVESTIGATION METHODS

Previous studies have shown the Delta to be a complex hydraulic system influenced by fresh water runoff and reservoir releases, tidal action, and variations in density due to saline concentrations. Various methods and techniques, some relatively new to this environment, were employed to assist in the investigation and evaluation of the Delta and Suisun Bay.

Fluorescent Tracers

Use of fluorescent tracers was selected as the principal method to determine flushing and dilution rates, current velocities, flow distribution patterns, and residence times in the major channels; and to define the circulation and mixing processes in the Delta and Suisun Bay. This involved the use of two selected tracers, Rhodamine B and its acid derivative Pontacyl Brilliant Pink, which had been used successfully in Chesapeake Bay and other eastern estuaries.

To facilitate efficient dye tracing of broad areas, to determine tracer distribution, and to obtain detailed profiles, two boats were fitted with dye injection equipment, sampling apparatus, and continuous recording fluorometers. A submersible pump, mounted on a stabilized diving plane (Figure 4) was used for continuous sampling.

Dye solution was pumped through a diffuser pipe, generally over one tidal cycle, for the continuous releases. Instantaneous slug releases were made by dumping dye from a boat or by pumping it through a submerged discharge pipe during one channel traverse. The tracer solution was mixed with methanol to adjust it to the density of the receiving waters. This allowed complete mixing within a minimum time and avoided density stratification.

The fluorescence of known concentrations of dye in distilled water was used to calibrate the instruments. To compensate for reduced interference from suspended materials, the background fluorescence of the receiving water was measured before dye injection and just beyond the limits of the dye cloud after dye injection. The equivalent dye concentrations of the background fluorescence were then subtracted from indicated dye concentrations measured during each test.

Figure 4. CONTINUOUS TRACER SAMPLING EQUIPMENT

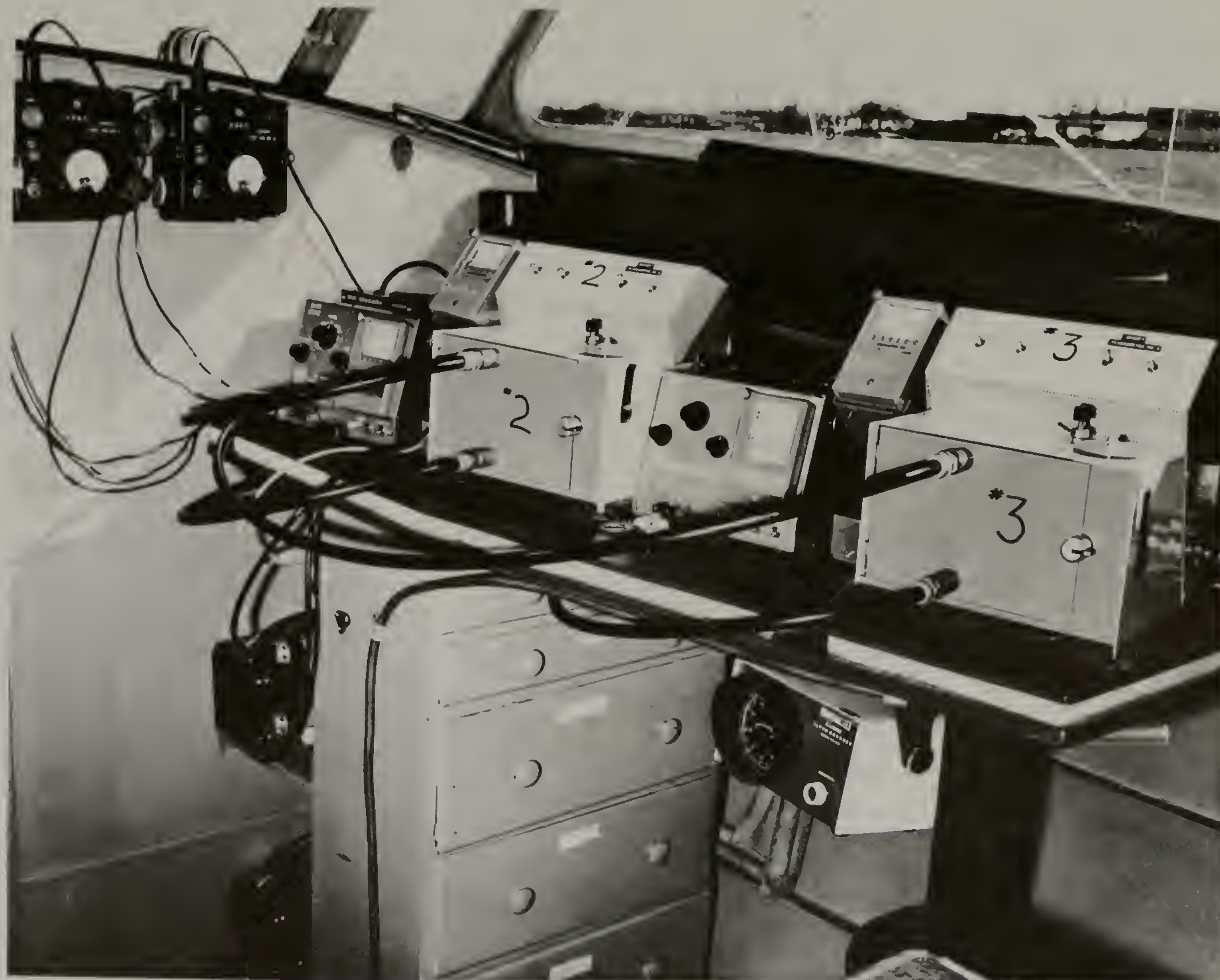


Figure 5. INSTRUMENT CONSOLE FOR FIELD TRACER OBSERVATION AND DETECTION

The water being sampled flowed through black polyethylene tubing to a lucite flow cell (containing a thermistor), and to an instrument console similar to that shown in Figure 5. Since fluorescence decreases with increasing temperature, a correction factor of 2.3 percent per degree Centigrade was applied to each tracer observation.

Fluorometric detection of dyes is one of the best methods presently available for tracer studies, due to the sensitivity of the method, the low cost, ease of handling, and low toxicity of the dyes.

However, there are specific limitations to dye tracer applications in the Delta and Bay system. The instruments used during the study had to be calibrated separately for each dye (Rhodamine B or Pontacyl Pink), each form of dye (powder or liquid), and each scale range (30X, 10X, 3X, 1X) on each fluorometer. When discrete samples were collected, rather than continuous ones, a separate set of calibrations was required. Background fluorescence in the water of the Delta and Suisun Bay varied from 0.02 to 0.18 equivalent parts per billion (ppb) of Rhodamine B and Pontacyl Pink, when measured on more than 60 separate occasions over relatively short intervals of time and space. Background variations limited the minimum sensitivity of detection of absolute dye concentration to the maximum background fluorescence observed within any specific investigative area. As with the dye calibrations, natural background fluorescence varied for each fluorometer. The causes of background fluorescence were not quantitatively defined during the study.

Early in the investigation, simple field experiments were conducted to determine whether rigorous studies of adsorption and decay of Rhodamine B under field conditions were necessary. Resulting data indicated much greater dye loss when suspended materials were present in the water. In one test, the dye concentration increased after the fourth day, presumably because of some unknown biological activity. This suggests that, under special conditions, apparent dye concentrations in Delta waters may exceed true values.

The most reliable data on dye losses were obtained from tests in the Sacramento Deep Water Channel where the water contained about 175 ppm chloride and 25 ppm suspended solids. The total quantities of dye remaining were determined by integrating the concentration-distance curves, and multiplying these values by the unit cross sectional weight of water.

For a Rhodamine B release into western Suisun Bay waters with 2,000 to 10,000 ppm chlorides and 50 to 400 ppm suspended solids, a decay rate coefficient was found to be only about three-fourths that found in the Sacramento Deep Water Channel. The inverse relationship between decay rate coefficients and chloride concentrations is shown in Figure 6.

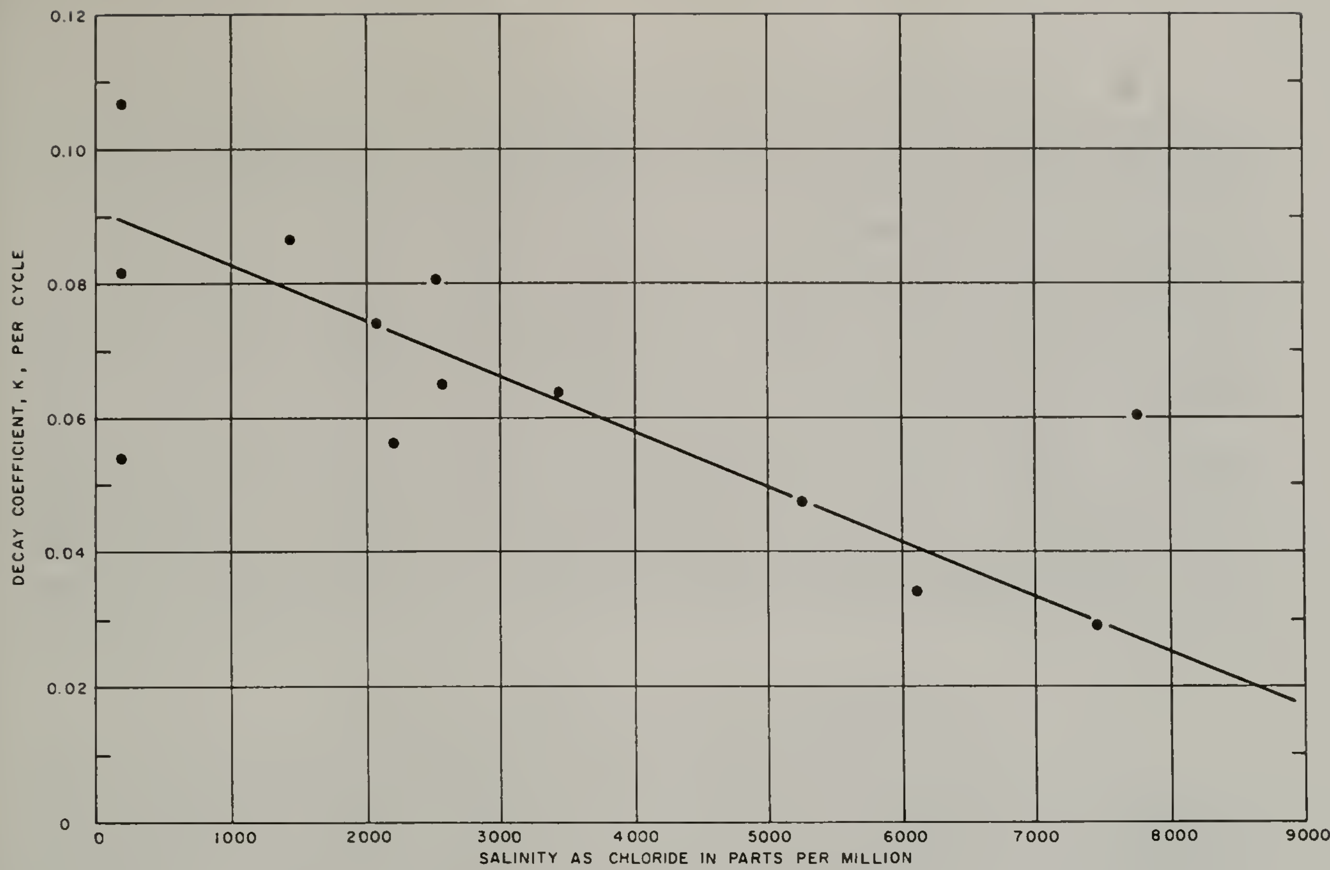


Figure 6. RHODAMINE B DYE DECAY RATE COEFFICIENTS OBSERVED AT VARIOUS PROTOTYPE SALINITIES

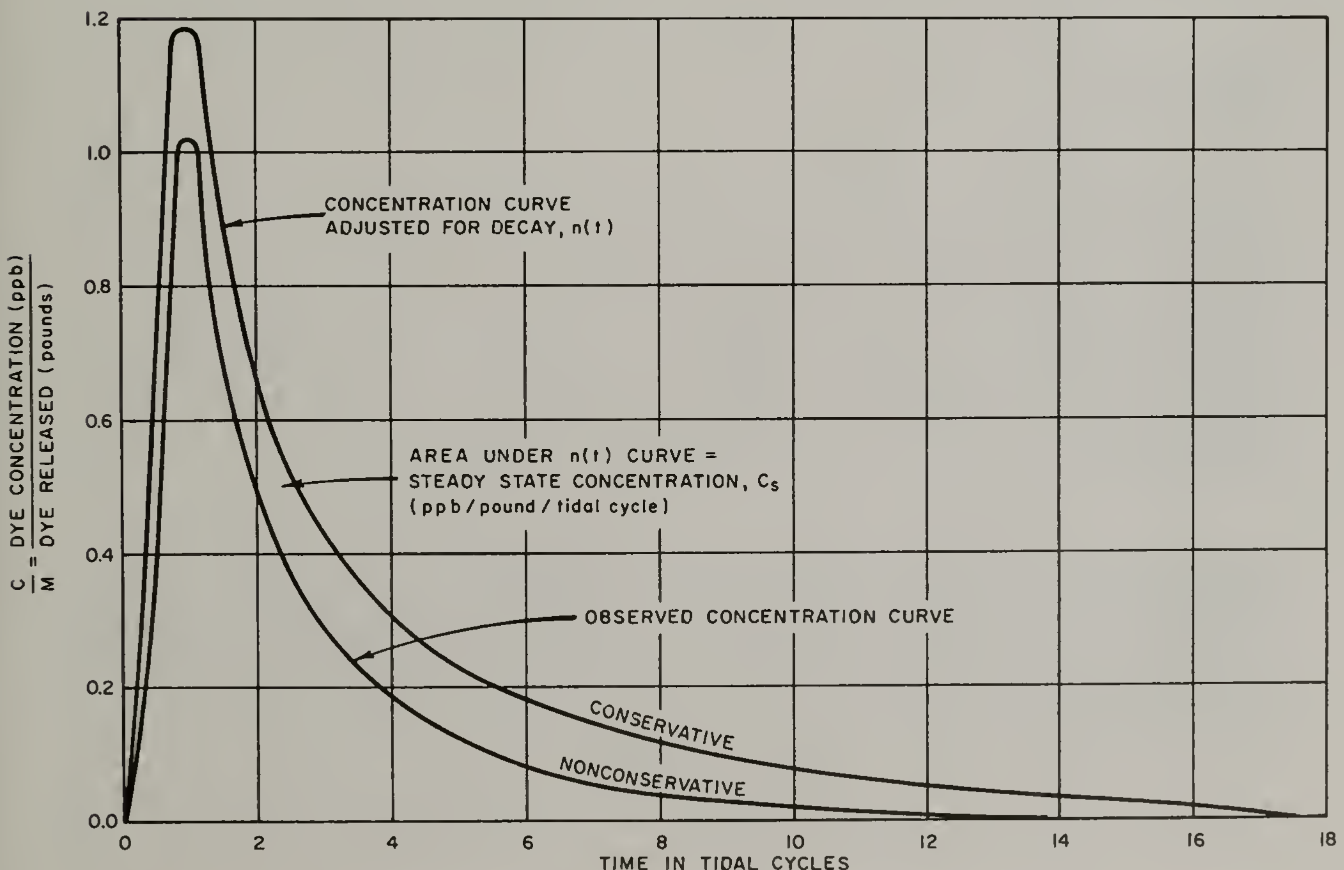


Figure 7. TYPICAL STATION DYE CONCENTRATION CURVES

The dye discharged during the studies is a nonconservative material, that is, it decays with time. Therefore, the concentrations measured in the field represent those that would result from a discharge of an organic pollutant, with a first order exponential decay rate, and are represented in Figure 7 by the observed concentration curve. These values, after being adjusted for dye decay by using known decay rates, represent a conservative material defined by curve n(t). The curve, n(t) represents a mass-concentration relationship that can be adjusted to any total quantity of discharge.

The steady state concentration, C_s, is the sum of the incremental concentrations resulting from a continuous discharge of an infinite number of successive slug releases, and therefore, the integral of the n(t) curve represents steady state concentration for the particular hydraulic conditions existing during the period of observation.

San Francisco Bay Hydraulic Model

As part of the comprehensive engineering investigation authorized by Congress in 1950, construction of a hydraulic model of San Francisco Bay was begun in 1956. The U.S. Army Corps of Engineers considers the model to be a scientific tool for engineers to use for analysis of hydraulic problems that cannot be resolved from textbooks, experience, or mathematical treatment alone.

The model reproduces to scale the rise and fall of the tide, flow and currents of the water, mixing of fresh and salt water, and trends in the disposition of sediments in San Francisco Bay.

In 1960, the U.S. Public Health Service made a series of dye dispersion tests in the U.S. Corps of Engineers' hydraulic model of San Francisco Bay. Examination of the data indicated that the model could be used to predict probable receiving water concentrations of both conservative and nonconservative constituents resulting from the discharge of agricultural drainage from the San Joaquin Valley. Additional tests were scheduled with releases at the head of Carquinez Strait in both prototype and model to determine the reliability of model data and to extend these data.

Although a number of dye dispersion tests already had been made in the model, there was some uncertainty as to the ability of the model to duplicate dispersion patterns in the real estuary. Neither the sign nor the magnitude of error was known, although the general agreement of model and prototype salinities, representing dispersion from a point at the Golden Gate, was encouraging.

As part of the Delta-Suisun Bay Water Quality Investigation additional tests were scheduled in the model and in Suisun Bay, to determine the reliability of model data, and to extend these data to include the effect of changing net model inflow and drainage discharge at several alternative locations.

The model includes the area of San Francisco Bay from Napa to Alviso and from the Pacific Ocean to Pittsburg. The model is equipped with facilities necessary to reproduce and measure hydraulic phenomena relative to a specific test, such as tides, current velocities and directions, and salinity. The rise and fall of the ocean tide and the resulting tidal currents are reproduced by means of a primary tide generator at the ocean end of the model and a secondary tide generator at the present upstream limit of the model, the confluence of the Sacramento and San Joaquin rivers. Since the conclusion of this investigation, construction has begun on extension of the model to include the area of the Delta.

Pesticide Detection and Measurement

California uses approximately 20 percent of the total pesticides nationally consumed, but very little information on concentrations of pesticides in water throughout the State was available before 1963. Because of the widespread use of pesticides in agricultural development, it was considered desirable to obtain information on the space and time distribution of pesticides in the present environment.

Periodic sampling was initiated at several stations in the Central Valley and throughout the area of investigation. Because of the minute concentrations of chemical compounds that can be detected by the analytical procedures currently used, extreme care was exercised in all steps of sample collection.

Pesticide sampling began late in 1963 and by the end of 1964 over 500 pesticide samples from about 93 sampling locations in California had been analyzed. Water, soil, and fish samples were collected from both fresh and saline waters. Two stations, Sacramento River at Walnut Grove and San Joaquin River near Vernalis, were sampled at weekly intervals. Five stations were sampled at monthly intervals and the remaining stations were sampled intermittently.

Analytical methods of determining the types and concentrations of pesticides in foods and in water have rapidly been improved. The gas chromatograph enables the identification of many members of the chlorinated hydrocarbon family of pesticides and a number of the organic phosphorus group. A sample of solvent containing pesticides is injected into the instrument. An attached recorder releases a sheet of graph paper from which the amount and identity of the pesticide in the solvent can be determined. The gas chromatograph is reported to be able to measure pesticides to fractions of a part per billion.

A private laboratory, working under contract to the Department of Water Resources, made pesticide analyses using a Dohrmann microcoulometric gas chromatograph for chlorinated hydrocarbons. A gold cell was used with the Dohrmann equipment to determine thiophosphate concentrations. Thiophosphates (phosphate compounds containing sulfur) were the only organophosphate pesticides identified by use of the gas chromatograph.

Nearly all of the chlorinated hydrocarbon and thiophosphate pesticides can be identified with the microcoulemetric gas chromatograph (including gold cell), although only 25 were specifically identified in the Department of Water Resources' sampling program through November 1964.

Lindane, DDT, DDE, DDD, toxaphene, BHC, chlordane, dieldrin, and heptachlor epoxide were the most common of the chlorinated hydrocarbons. Parathion and malathion were the most commonly found thiophosphate pesticides.

The laboratory contract specified that the pesticides be identified with an accuracy of plus or minus one ppb for chlorinated hydrocarbons, and plus or minus 10 ppb for thiophosphates. Almost all the water samples contained concentrations less than one ppb, in terms of maximum total chlorinated hydrocarbons, so the laboratory was asked to estimate the concentration of pesticides in parts per trillion (ppt). One ppt would be 0.000008 pounds of pesticide in a million gallons of water. Pesticides can be identified at these extremely low concentrations but the amounts are approximate. The sensitivity of the method is believed to be between 20 and 50 ppt for chlorinated hydrocarbons and about 20 to 80 ppt for thiophosphates. The accuracy and precision of the concentrations, reported at concentration levels less than 500 ppt, are uncertain because of the extreme care necessary in the laboratory analysis and the danger of contamination from a variety of outside sources.

Pesticides are reported to be only semisoluble in water. Common solubilities of pesticides are in the ppb range, and maximum solubility cannot always be expected throughout their chemical transition from one form to another. Investigators have reported the range of solubilities for chlorinated hydrocarbons to vary from insoluble, or practically insoluble, for aldrin and dieldrin, to 10 mg/l for lindane. Organic phosphorus solubilities were reported to range from slight for EPN to 130 gr/l for Dipterex.

The type and frequency of observation of various pesticides distributed throughout California is presented in Table 3.

TABLE 3

PESTICIDES DETECTED IN WATERS OF CALIFORNIA

Chlorinated hydrocarbons		Thiophosphates	
Compound	Number of times detected[a]	Compound	Number of times detected[a]
DDD-DDT	349	Malathion	22
DDE	171	Parathion	21
Toxaphene	163	Ethion	10
Heptachlor epoxide	85	Disyston	9
Lindane	66	Systox	5
BHC	60	Methyl Parathion	4
Dieldrin	45	Thimet	2
Chlordane	36	Baytex	3
Heptachlor	25		
Aldrin	11		
Endrin	11		
Pentachlorophenol	6		
Kelthane	5		
Perthane	2		
Methoxychlor	2		
Tedion	1		

[a] Approximately 520 samples collected from 93 stations 9/23/63 through 11/19/64.

In this report, the term "maximum total chlorinated hydrocarbons" has been used as a quantitative indication of the amount of chlorinated hydrocarbon pesticides. The maximum total chlorinated hydrocarbons (MCH_t) figure is a computed amount, based on the assumption that the average chlorinated hydrocarbon is 50 percent chlorine.

The MCH_t value is a good indication of the presence of pesticide residuals because about half of the pesticides are insecticides. Over 75 percent of the insecticides are chlorinated hydrocarbons or thiophosphates, and specific insecticides were identified at all stations where chlorinated hydrocarbons were measured (except for four samples, or less than one percent of the total samples analyzed). However, the qualitative and quantitative characteristics of specific pesticide compounds cannot be determined from the MCH_t measurement.

Thiophosphate concentrations were reported as the sum of the total specific compounds identified. The reasons for the lower number of thiophosphate identifications were probably the precision of the laboratory techniques used and the decomposition of the compounds through biological action.

Digital Computer Simulation of Delta Hydraulics and Quality

Exact solutions for direct determination of the flow distribution and mineral quality in the various branches of the Delta system do not exist. Practical solutions, however, can be obtained with the aid of physical, analog, or mathematical models. Physical models and electronic analogs have proven useful for such problems, particularly where unsteady varied flows are involved, but both are expensive and require considerable time for construction and verification. Mathematical models, however, are generally inexpensive to prepare and problems can be solved rapidly with the aid of electronic digital computers. The mathematical models have limitations, but solutions obtained from them can be valuable.

A mathematical model was used to estimate the probable effect of several operational conditions. The problems to be solved involved determination of flows in each branch of the Delta system under selected conditions of supply and demand. Subsequently with the knowledge of flow distribution and water use, it was possible to estimate the quality of water at various points in the system.

Rigorous mathematical formulation of the problem of flow distribution in the Delta must account for the unsteadiness resulting from both variations in inflow and outflow on a diurnal basis and variations in potential related to tide and river stage. Although it is possible to write the differential equations which describe the mechanics of flow under these conditions, there is no direct solution. Numerical methods of computation must be used.

Water Resources Engineers, Incorporated has created a digital computer program to solve this problem. For this program each channel of the Delta was considered to be composed of a series of interconnected reservoirs, capable of accumulating flows caused by the potential differences between reservoirs.

Differences in flow or potential at any point in the system, such as the tidal fluctuations at the Delta outlet, were thus propagated from reservoir to reservoir at rates determined by the system's ability to store and move water. Beginning with certain assumed conditions at the boundary of the Delta, the propagation of these differences ultimately approached a representation of the time histories of flow or potential in the system, but did not adequately represent the western Delta quality under low flow conditions.

Program Development

To develop the program the complicated elements of the physical system first had to be simplified. The Delta was assumed to be comprised of a number of channels, each characterized by length, cross section, roughness, and frictional resistance. The location and spacing of channel junctions used in the computer solution represented real junctions. After the real junctions were located, the channels between them were divided into segments, the length of which was selected to minimize numerical instability.

Velocity and discharge were assumed to be constant along each channel segment. Energy and hydraulic gradients were assumed to have uniform slopes through the channel connecting any two junctions.

The solution of the equations governing the flow in open channels, under the dynamic conditions of tidal wave propagation, is obtained by a modified Runge-Kutta method using half-step increments. Beginning with given initial conditions, a forward numerical integration in time was performed. Subsequent values of head, flow, and other variables, for the entire system at the end of each succeeding time interval, were obtained from the numerical integration. A complete dynamic description of the hydraulics of the system was therefore available for a given input waveform and stipulated inflow-outflow conditions.

Tidal Input Wave

An analysis was made to determine the most reasonable form of tidal input wave to use at Pittsburg. The input wave selected for use was determined by analysis of prototype tides observed from August 6, to September 4, 1959. The pronounced skew, observed in actual tide records, was not reflected. However, the inclusion of this feature would not result in a significant difference in the prediction of net flows over extended time periods.

Program Verification

A computer program, no matter how sophisticated, cannot be considered as a valid solution until it produces results within acceptable limits, which match the behavior of the physical system. Care was taken during the program development to test the program under all possible conditions, to test ability to produce reflections, and to propagate solitary waves. Application of the testing process to the real physical system provided a basis for comparing model and prototype tidal elevations.

Results of these final tests indicate that agreement in stage was developed at most stations. A maximum discrepancy occurred at the station representing the Sacramento River at Sacramento. This fluctuation, a result of model boundary conditions in channels which actually extend beyond the periphery of the model system, is caused by the poorly reflected storage conditions above the final program junction.

The effect of inaccurate starting conditions on the ability of the model to reproduce prototype tides was determined. Because correct initial conditions, such as tidal elevations and velocities are never precisely known, it becomes necessary to operate the program long enough to damp out all discrepancies caused by the initial error. At Mossdale Bridge, this period was approximately 10 hours.

Water Quality Program

Following the hydraulic solution in which net flows in each of the Delta channels were computed for given conditions of Delta inflow, export pumping, internal use, and proposed Delta project operation, a water quality solution was developed. For a general system of interconnected channels in which the flow was known, the water quality program determined the steady-state response to any conservative constituent, assuming complete mixing at all channel junctions. After forming a mixing equation for each junction the program solved the resulting set of simultaneous equations for the unknown concentrations.

The program was developed for use on the IBM 7094 computer, but can be adapted for other machines. The data input required: the listing of the total number of junctions and channels in the system, the number of each channel entering a particular junction, the inflows and outflows at each junction, the constituent concentration for each inflow, the junction numbers at the ends of each channel, and the flow in each channel.

The water quality program used the same inflow, outflow, export and consumptive use data as the transient flow hydraulic program, plus the total dissolved solids concentration for all inflows. The network used for the water quality program consisted of 191 channels and 140 junctions, in contrast with the 625 channel and 578 junctions of the transient-flow hydraulic solution program.

The assumption of complete mixing at all junctions was an approximation, which may depart significantly from a more rigorous solution, including the effect of tidally induced advective flow and eddy diffusion. At the time of these studies no such solution was available.

Water Quality Influence Coefficients

During development of the water quality program for the Delta, the value of a subroutine to determine the effect of a change of quality at one junction on the quality at all other junctions became apparent. The number of times the water quality program would have to be repeated would be reduced, as would the total cost of analyzing the Delta by digital computer simulation. The process of solving the 140 equations of the water quality program forms a readily manipulated matrix to yield the desired influence coefficients.

Because the hydraulic program did not have an input at every junction, two different conditions of salt input were required. One condition was used for those junctions at which an inflow was applied from the input data for the hydraulic program. The influence coefficients were calculated as concentration factors resulting from a unit salt concentration; 1 ppm, in the applied inflow. The other condition of salt input was used for those junctions at which no inflow was applied in the hydraulic solution. At these junctions, influence coefficients were determined for an input of unit concentration, 1 ppm, of a conservative salt in a unit quantity of flow, 1 cfs. Influence coefficients were reported as concentration factors in ppm at all junctions. The individual coefficients are valid only for the Delta flow conditions from which they are generated.

The original objective in determining influence coefficients was to characterize the effect of a unit change in inflow quality so that corrections could be made by hand computation when inflow quality changes. The coefficients were for conservative constituents. However, a conservative constituent can be considered nonconservative with a decay factor of zero, i.e., any values developed for conservative materials may be used as maximums for nonconservative materials.

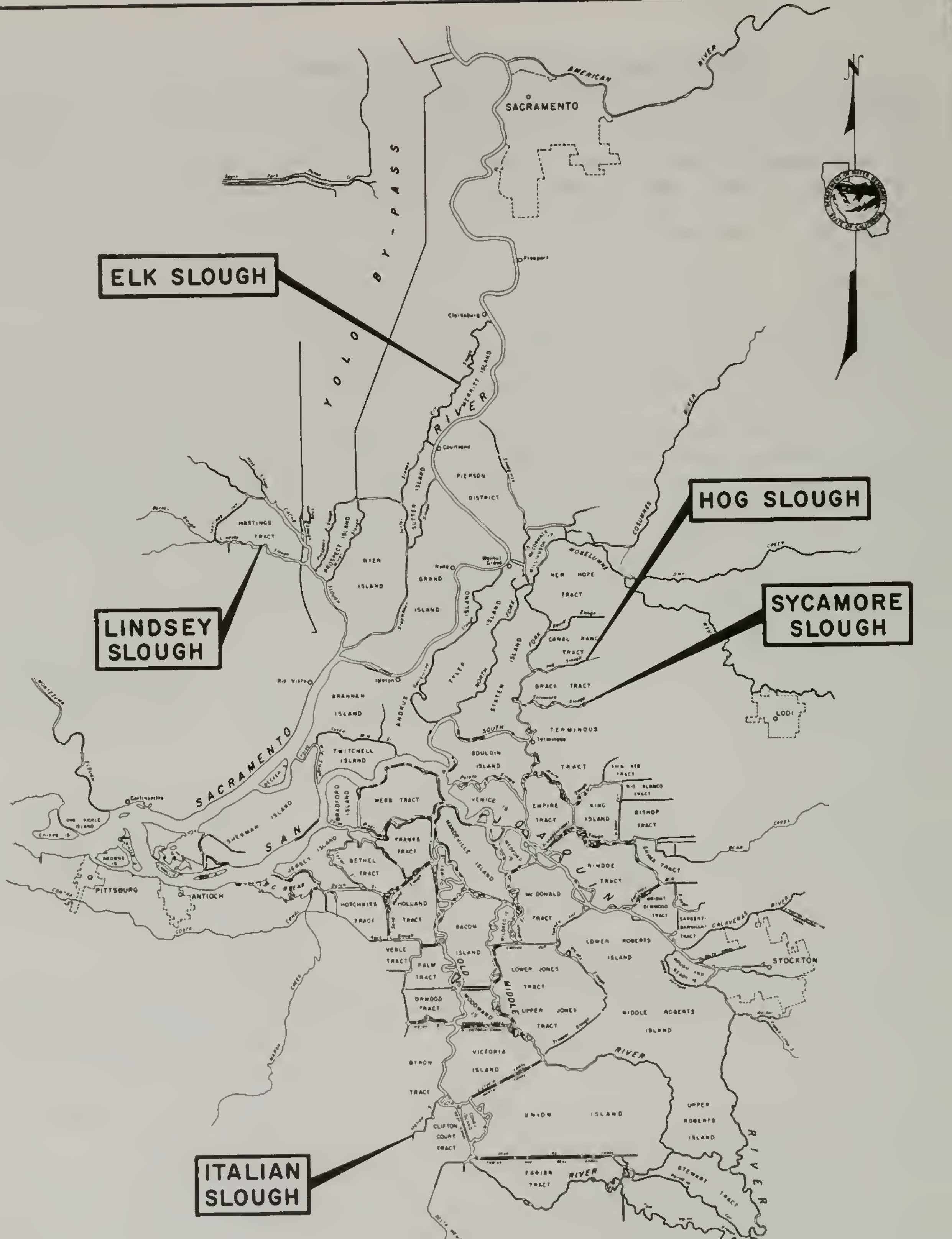


Figure 8. LOCATION OF DEAD-END SLOUGH STUDIES

CHAPTER V.

RESULTS AND FINDINGS

Previous chapters in this report have covered the description of the Delta and Suisun Bay, the water related considerations of the area, and the program of investigation. The goals and objectives of an investigative program for the Delta and Suisun Bay were established, a work program was developed, and investigation methods used were outlined. In this chapter, the results and findings of the investigation are described.

Characteristics of Dead-End Sloughs

Major sloughs in the Delta are feeding areas for striped bass and are habitat for resident fishes, fur-bearing animals, and other Delta wildlife. Operation of the Delta water facilities will have a direct influence and effect on the physical quality and hydraulic conditions of water in sloughs throughout the Delta.

As the initial step in determining the magnitude of influence or degree of any significant alteration in the aquatic environment caused by construction or operation of Delta water facilities, information was obtained on the present physical and chemical conditions in several dead-end sloughs. It was envisioned that establishment of relationships among present parameters would serve as a basis for projecting future changes.

The following descriptions of the physical and hydraulic factors of five Delta sloughs are based on data collected during field studies. The sloughs studied are closed at their upper ends and are open to tidal action at their mouths. Figure 8 shows location of the dead-end sloughs studied.

In general, it was found that the quality of water in dead-end sloughs located throughout the Delta is closely related to irrigation pumping, agricultural drainage discharge, tides, and precipitation. During periods of irrigation, the quality of slough water is generally good. As drainage water is discharged into the sloughs, quality deteriorates until precipitation begins to flush the slough and displace the low quality water into the large channels. Tidal flushing and dilution tend to improve water quality, except at the upper end of the sloughs where it is not effective.

Elk Slough

Elk Slough is located a short distance to the west of the Sacramento River between Clarksburg and Courtland. Its course roughly parallels that of the river. The slough varies in depth from eight to twelve feet, in width from 100 to 200 feet, and is about nine miles long. Its banks are covered by a lush growth of trees and brush.

The greatest water movement was observed in the lower half of the slough, and is attributed to tidal action and irrigation drainage pumped into the slough by a few small dischargers and one large reclamation district drain near the middle of the slough. Information on the hydraulics of Elk Slough was obtained from two separate dye releases conducted in October 1962. These dye studies, one about two miles above the mouth of the slough, and the other about six miles above the mouth of the slough, were in the form of slug injections 45 minutes before higher lower water slack.

Complete cross sectional mixing was accomplished within 24 hours at the mouth end of the slough while it took 96 hours near the closed end. The locations and concentrations of the dye clouds during various periods of observation are shown in Figures 9 and 10.

The most significant environmental influence in the slough was tidal activity. The mean tidal velocity was ±1.75 feet per second (fps); the maximum tidal velocity was approximately ±2.34 fps. Ten thousand feet above the mouth of the slough tidal flushing produced a 90 percent turnover of the water in 10 to 20 days. At 30,000 feet from the mouth the turnover rate, due to tidal flushing, was indeterminate. Calculated limits for 90 percent turnover varied from 26 days to infinity.

Field analyses were made for dissolved oxygen (DO), specific conductance (EC), chloride (Cl), and water transparency using a Secchi disc. Samples were collected for laboratory determination of plankton, suspended solids, and turbidity.

The data indicate that good quality water enters Elk Slough and is present as far as 3,500 feet upstream. At stations more than 10,000 feet from the mouth of the slough, irrigation return flows affect Cl, DO and EC values. The chlorides increase approximately threefold from the mouth of the slough to a point approximately four miles upstream. Dissolved oxygen values generally decrease about 50 percent in the same reach.

Laboratory analyses of samples collected indicate that suspended solids increase from 20 to 25 mg/l between the mouth and four miles upstream, to over 170 mg/l near the upper end of the slough. Corresponding increases in turbidity were from about 20 to 30 mg/l.

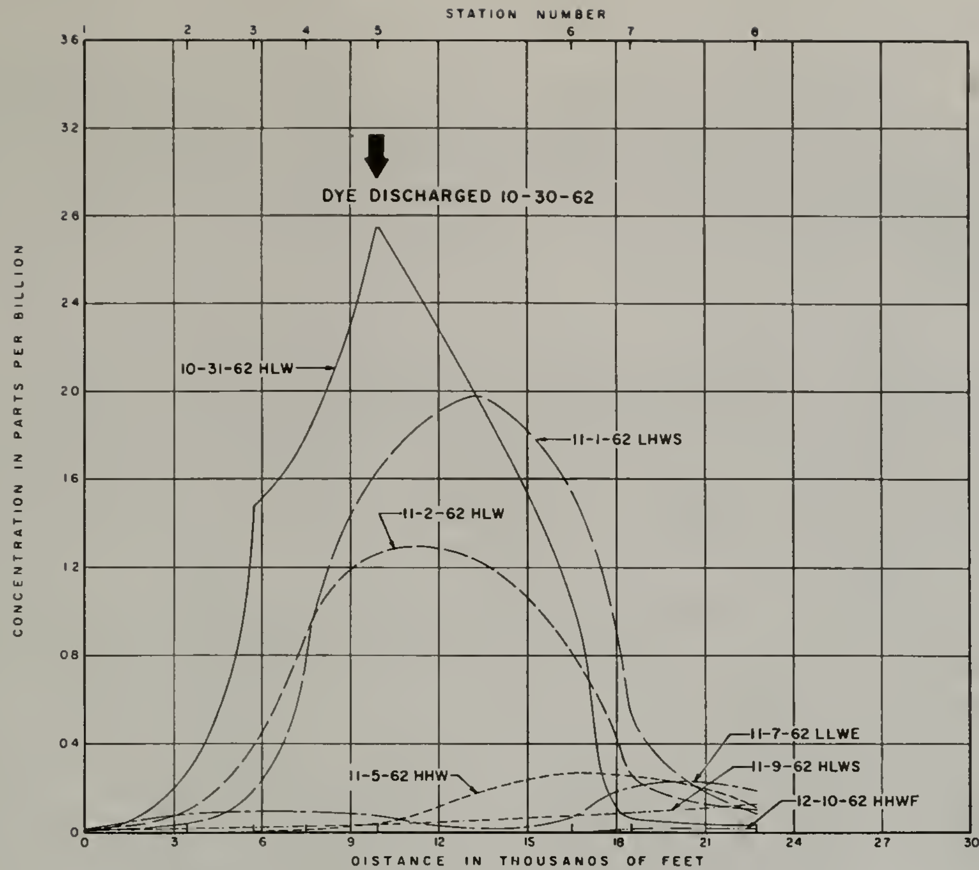


Figure 9. ELK SLOUGH DYE STUDY - RHODAMINE B

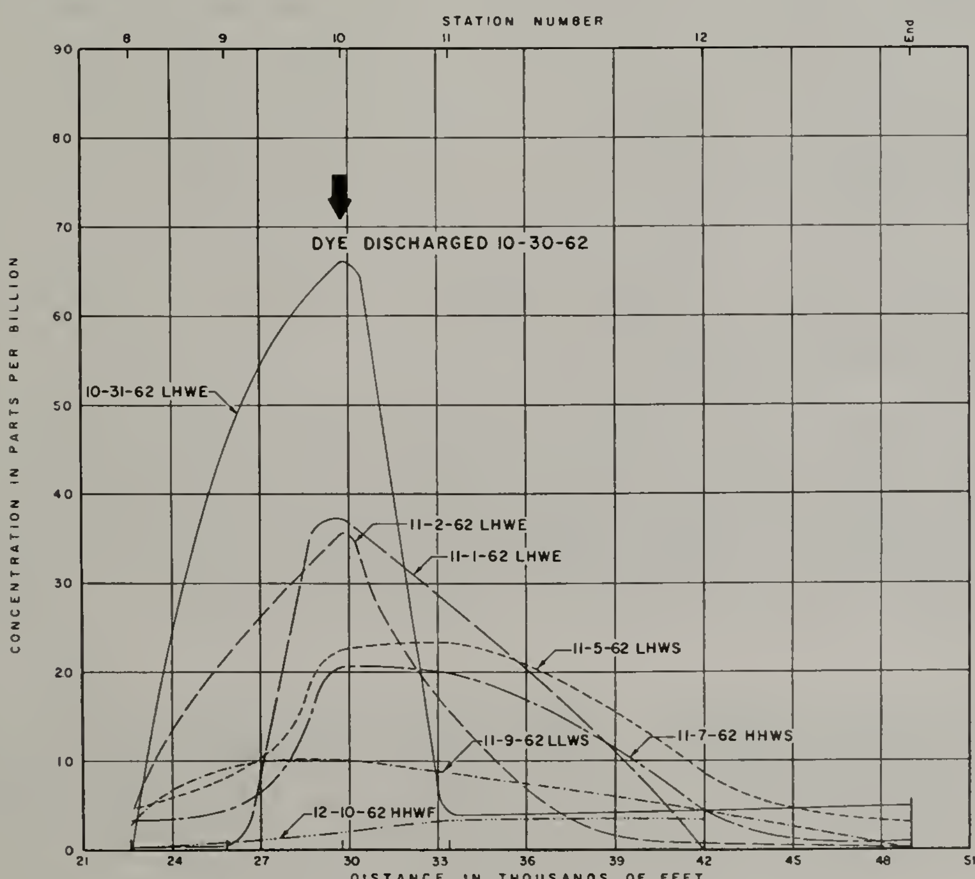


Figure 10. ELK SLOUGH DYE STUDY - PONTACYL PINK

A plankton analysis of two samples collected indicate a total of 2,100 organisms per milliliter at the 10,000 foot station and 320 organisms per milliliter 30,000 feet into the slough. In both samples the predominant phytoplankton organisms were pennate diatoms.

Hog Slough

Hog Slough is tributary to the South Fork of the Mokelumne River midway between Lodi and Rio Vista. It is only 3.5 miles long, and has little to distinguish it from other dead-end sloughs in the eastern Delta. Depths below mean low water are generally greatest, 14 feet, near the mouth of the slough, and become progressively shallower, 2 to 4 feet, toward the upper end.

A small number of irrigation diversions, varying from two to four cfs, were made from the slough during the period of observation. Agricultural drainage was flowing into the slough continuously throughout the test at a rate of about four cfs.

The mixing and tidal flushing characteristics of Hog Slough were determined by means of a fluorescent dye tracer study in November 1962. A slug injection was made 15,000 feet above the mouth of the slough. Only partial mixing had occurred one day after injection and mixing was virtually complete after two days. After 30 days, water that had been at the release point at the time of injection had moved about two miles downstream.

Tidal velocities, resulting from conditions observed during the study, ranged from a minimum of 0.48 fps to a maximum of 0.94 fps. Tidal flushing and net positive flow, caused by irrigation discharges into the slough, resulted in a 90 percent turnover of material in periods of 54 to 120 days.

Both field and laboratory tests were used to determine water quality in Hog Slough. During November and December 1962, field sampling and testing was used to determine DO, Cl, temperature and light penetration.

The water quality data clearly show the effect of agricultural drainage in the upper end of Hog Slough. Return drainage causes higher chloride concentrations, greater EC values, and greater temperature fluctuations in the upper end of the slough. The temperature variations also reflect changing air temperatures in the upper slough, where depths are less and more surface area is exposed per unit volume, than near the mouth.

Water samples taken at three locations for plankton determination contained: 274 organisms per milliliter at the mouth of the slough, 1,320 at 13,400 feet, and 667 approximately 15,200 feet upstream. The increasing plankton count in the upper slough probably was caused by agricultural drainage water.

Sycamore Slough

During November and December of 1962 studies were conducted in Sycamore Slough, which is about two miles south of Hog Slough. Sycamore Slough is slightly longer than Hog Slough, but has a similar east-west orientation. Sycamore Slough extends eastward about 27,000 feet from its intersection with the South Fork of the Mokelumne River.

The lower 23,000 feet of the slough is an island-laden channel where depths below mean low water vary from 14 feet near the mouth to about 2 feet at the upper end. Widths vary from 100 to 600 feet, including the channel islands. There is no irrigation drainage discharge into this slough but during the investigation several siphon intakes were observed in operation at various locations. Estimated demands for irrigation supplies from Sycamore Slough range from a late summer maximum of 160 cfs to a minimum of 40 cfs during the winter.

A slug release of fluorescent dye injected into the slough about 17,000 feet above its mouth at higher low water slack resulted in fairly thorough mixing after only 22 hours. Observation of water movement in the slough for a one-month period following the dye injection showed a definite upstream movement of water. Results of the study indicate that relatively large irrigation withdrawals from the slough during the first week of observation caused the steady upstream movement of water. Dissolved oxygen content was quite high and uniform during the first week. During the fourth week the dissolved oxygen content dropped significantly. This was probably due to a downstream movement of water containing very low amounts of dissolved oxygen. No measurements of the amounts of water diverted for irrigation were made. During the end of the third week almost two inches of rain fell on the area and undoubtedly irrigation withdrawals were terminated which would account for the downstream movement of water.

Field measurement of water quality in Sycamore Slough included determination of chloride and dissolved oxygen content and temperature. Dissolved oxygen content throughout Sycamore Slough was relatively high during the first three weeks of sampling. After that a significant reduction in DO was noted in the upper end of the slough. At the uppermost end there was practically a complete oxygen depletion. The reduction in DO substantiated the conclusion that when irrigation diversions ceased, there was no longer an upstream movement of water.

Lindsey Slough

Lindsey Slough lies north of Rio Vista and west of the Sacramento Deep Water Channel. It can currently be classified as a dead-end slough, but in the early 1980's it will become a connecting link between the North Bay Aqueduct of the State Water Project and the Sacramento River. The slough is about 30,000 feet in length, with a width of 100 to 200 feet, and a depth below mean low water of 10 to 15 feet.

In September of 1963 a dye study was conducted to evaluate the movement of water in the slough during the late summer. Results of the study showed a steady upstream movement of water. These results can be attributed to the local agricultural and domestic use of the waters in the slough. There are periodic diversions from the upper end of Lindsey Slough near Calhoun Cut, which amount to 1 to 10 cfs. Irrigation drainage into the slough varies from 1 to 6 cfs.

Mineral concentrations in the waters of Lindsey Slough were found to be higher than those in the Sacramento River at Rio Vista. This is attributed to seepage of poor quality ground water and irrigation return flows. The sluggish circulation of water in Lindsey Slough, compared to faster movement of the Sacramento River also tends to lower the quality.

Italian Slough

A cursory investigation of the hydraulic characteristics of Italian Slough indicated that there was cross contamination between agricultural waste discharged into the slough and irrigation waters diverted from the slough.

The channel is a little over three miles long and varies in width from 175 feet near the mouth of the slough on Old River, to about 75 feet at Clifton Court Road Bridge. The average depth increases from 18 feet near the lower end to about 4 feet at the upper end. The slough is located immediately north of the Delta Pumping Plant of the State Water Project, and along the northwestern edge of Clifton Court Tract.

Very small discharges of agricultural waste water were observed during the test period in April 1964. Drainage flows were generally less than 2 or 3 cfs, but contained high concentrations of dissolved minerals, specifically boron and nitrate. The largest irrigation diversion from the slough is at the dead-end near Byron Road. Here, between 80 and 130 cfs are diverted during the summer and 40 to 60 cfs during the winter. Mineral quality of the water in this slough is strongly influenced by springs that discharge highly mineralized ground water containing up to 700 mg/l of boron. The large irrigation diversion at the head of the slough provides impetus to the water and affords some protection by allowing dilution water to flow from the mouth of the slough. Without this flow, highly mineralized spring waters trapped at the head of the slough would become concentrated and eventually toxic.

Water Transport Across the Delta

Historically, runoff from the Central Valley has flowed through the meandering maze of Delta channels toward San Francisco Bay. Except for channel depletions of evaporation, channel growth evapo-transportation, and diversions for agriculture, the flow finally found its way to the confluence of the Sacramento and San Joaquin rivers in the western Delta. Water quality conditions permitting, water was diverted from the channel for municipal and industrial uses along the Contra Costa County shore. Except for the pulsating influence of the tide, the general flow pattern was similar to that of a funnel where water entering the Delta from the north, east and south was channeled to the only natural exit on the western edge of the Delta near Collinsville.

Beginning in 1940, water for the Contra Costa Canal, a unit of the Central Valley Project, was diverted from Rock Slough. In 1951, water for the Delta-Mendota Canal, another unit of the Central Valley Project, was diverted from the southern Delta. There was not sufficient water in the southern Delta for these two diversions and continued depletion would have allowed saline water from the Bay to flow into the pump intakes.

To facilitate the transfer of Sacramento River water across the Delta, the Delta Cross Channel was constructed near Walnut Grove to connect the Sacramento River and Snodgrass Slough, a tributary of the Mokelumne River. During periods of low inflow to the southern Delta it is possible to open the gates of the cross channel and transport Sacramento River water across the Delta to feed the export pumps.

A series of fluorescent dye tracer studies were conducted in 1963 to determine the route of water transport through the cross Delta channels from the Sacramento River at Walnut Grove to the Tracy Pumping Plant in the southern Delta. Estimates were made of time of travel, residence time, and flow distribution through the major transfer routes. The periods chosen for observation generally coincided with a specific flow regime that could provide the most complete systems analyses for each area. The pattern of flow distribution and travel time is depicted in Figure 11.

Information provided by these studies aided in the comparison of various concepts of transferring Sacramento River water through the Delta to export points within the southern periphery of the Delta.

There are two channels leading from the Sacramento River into the central Delta. Georgiana Slough branches off immediately downstream from Walnut Grove and the Delta Cross Channel is located immediately upstream from Walnut Grove.

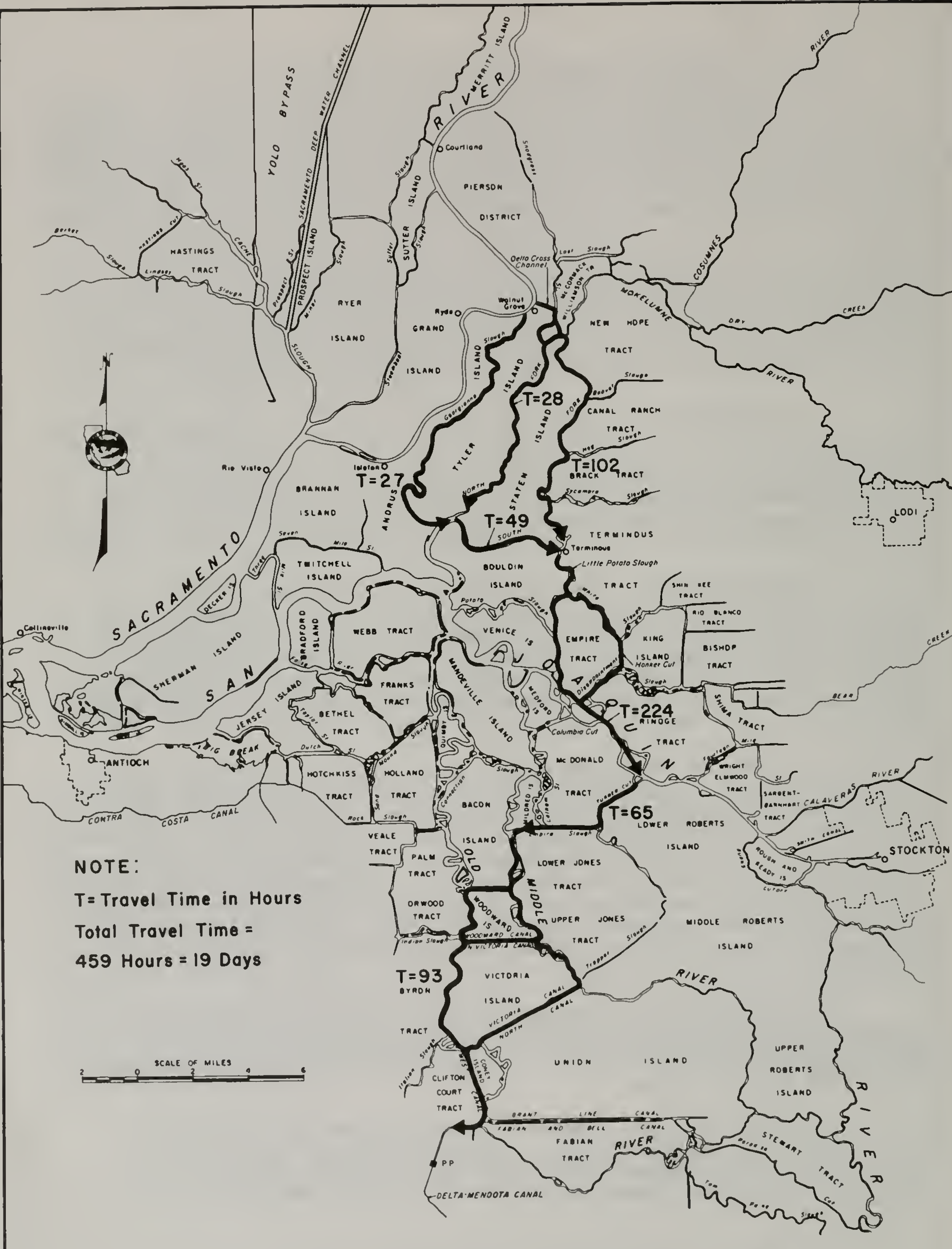


Figure II. FLOW DISTRIBUTION AND TRAVEL TIME

Georgiana Slough is about 12 miles long and joins the North Fork of the Mokelumne River near its southern end. Therefore, all water entering Georgiana Slough from the Sacramento River finally flows into the North Fork of the Mokelumne River. Georgiana Slough flows continue on down the North Fork of the Mokelumne River into the San Joaquin River during ebb tide and thence into Suisun Bay. During flood tide, the flow from Georgiana Slough is carried up the South Fork of the Mokelumne River to Terminous and thence into Little Potato Slough.

Water diverted from the Sacramento River through the Delta Cross Channel enters Snodgrass Slough and flows south to enter the Mokelumne River at a point where the Mokelumne River bifurcates into the north and south forks. The major portion of this water, usually 80 to 95 percent, flows down the North Fork of the Mokelumne River. The remaining portion flows down the South Fork of the Mokelumne River toward Terminous.

A study of the hydraulic characteristics in the lower Mokelumne River, downstream from Georgiana Slough, determined that small amounts of Mokelumne River water enter Potato Slough and Old River; however, there was no definite indication that water moving down the Mokelumne River crossed the San Joaquin River and moved toward the Delta-Mendota Canal.

Travel times for water traveling from the Sacramento River toward Terminous were found to be 27 hours in Georgiana Slough, 28 hours in the North Fork of the Mokelumne River to its junction with the south fork, 49 hours in the South Fork of the Mokelumne River from the junction of Georgiana Slough and the North Fork of the Mokelumne River, and 102 hours in the South Fork of the Mokelumne River.

Further studies traced the cross Delta flow from Terminous. From Terminous water continued south through Little Potato, White and Disappointment sloughs. Travel time from Terminous and up the San Joaquin River to Turner Cut during the 1963 study was 224 hours.

Dye tracer studies conducted south of the San Joaquin River revealed Turner Cut and the Middle River system as the primary route of water flowing to the Tracy Pumping Plant. Water traveled primarily through Turner Cut, Empire Slough, and Middle River, then crossed to Old River via the canals on both sides of Woodward Island and Victoria Island. Travel time from the San Joaquin River was about 65 hours from Turner Cut to Middle River and an additional 93 hours to the Tracy Pumping Plant. Results of studies in Old River near Franks Tract indicated that there was no appreciable net flow south to the Tracy Pumping Plant.

The studies conducted in the northern and central Delta channels provided valuable information on flow characteristics, but they represent the conditions existing at the time of each test. Any changes in quantity of perimeter inflows, fluctuations in export demands, or variations in the hydrologic balance of the Delta would result in an infinite number of different hydraulic conditions. Mokelumne River hydraulics depend, in a large measure, on upstream inflow, operation of the Delta Cross Channel gates, flow in Georgiana Slough, and the tidal phase.

In summary, it was found that water from the Sacramento River enters the Delta Cross Channel and Georgiana Slough near Walnut Grove in its cross Delta journey toward the Tracy Pumping Plant. Water entering the Delta Cross Channel moves south through Snodgrass Slough into the Mokelumne River system, most of its traveling down the north fork. The flows in Georgiana Slough and the water in the North Fork of the Mokelumne River merge and the water then travels eastward in the South Fork of the Mokelumne River toward Terminous. At Terminous, this flow is joined by the smaller amount coming down the South Fork of the Mokelumne River and all the water then moves southward in Little Potato Slough. The Sacramento River water continues toward the San Joaquin River via the channels of Little Potato and White sloughs, using Little Connection Slough, Honker Cut, and Disappointment Slough. Water arriving at the San Joaquin River via these channels begins a slow net eastward movement toward and into Turner Cut.

Water flowing down the San Joaquin River from the vicinity of Stockton joins the Sacramento River water and also flows into Turner Cut. The southwesterly flow in Turner Cut travels down through Empire Cut and into Middle River, thence southward to Old River via the three canals on the north and south sides of Woodward and Victoria Islands. About one third of the total flow moves through each canal.

Total travel time for the cross Delta flows between Walnut Grove and the Tracy Pumping Plant was about 459 hours or 19 days. This was calculated on the observed movement of apparent centers of mass of the dye. Some quantities were probably flowing into the Delta-Mendota Canal as much as two to four days ahead of the peak concentration. These amounts could not be detected, however, because of the extent of dilution and dispersion of the dye mass.

Mixing and Dispersion

Studies of mixing and dispersion were conducted in the Sacramento River, in the San Joaquin River near Antioch, in Suisun Bay between Pittsburg and Crockett, and in the various channel systems of the Delta. Results of these studies were used to help define the processes of advection and diffusion of waste disposal. In addition, the results were invaluable in understanding flow distribution and the probable effect of future operational plans.

Sacramento River near Freeport

The experience gained by using dye as a tracer led to the conclusion that a conservative tracer would be required to obtain quantitative results. Heavy water containing tritium (radioactive hydrogen with half-life of about 12.5 years) was suggested as an ideal tracer for possible use in future work. To determine the possibility of using tritium as a surface water tracer, two dye dispersion studies were conducted in the Sacramento River near Freeport.

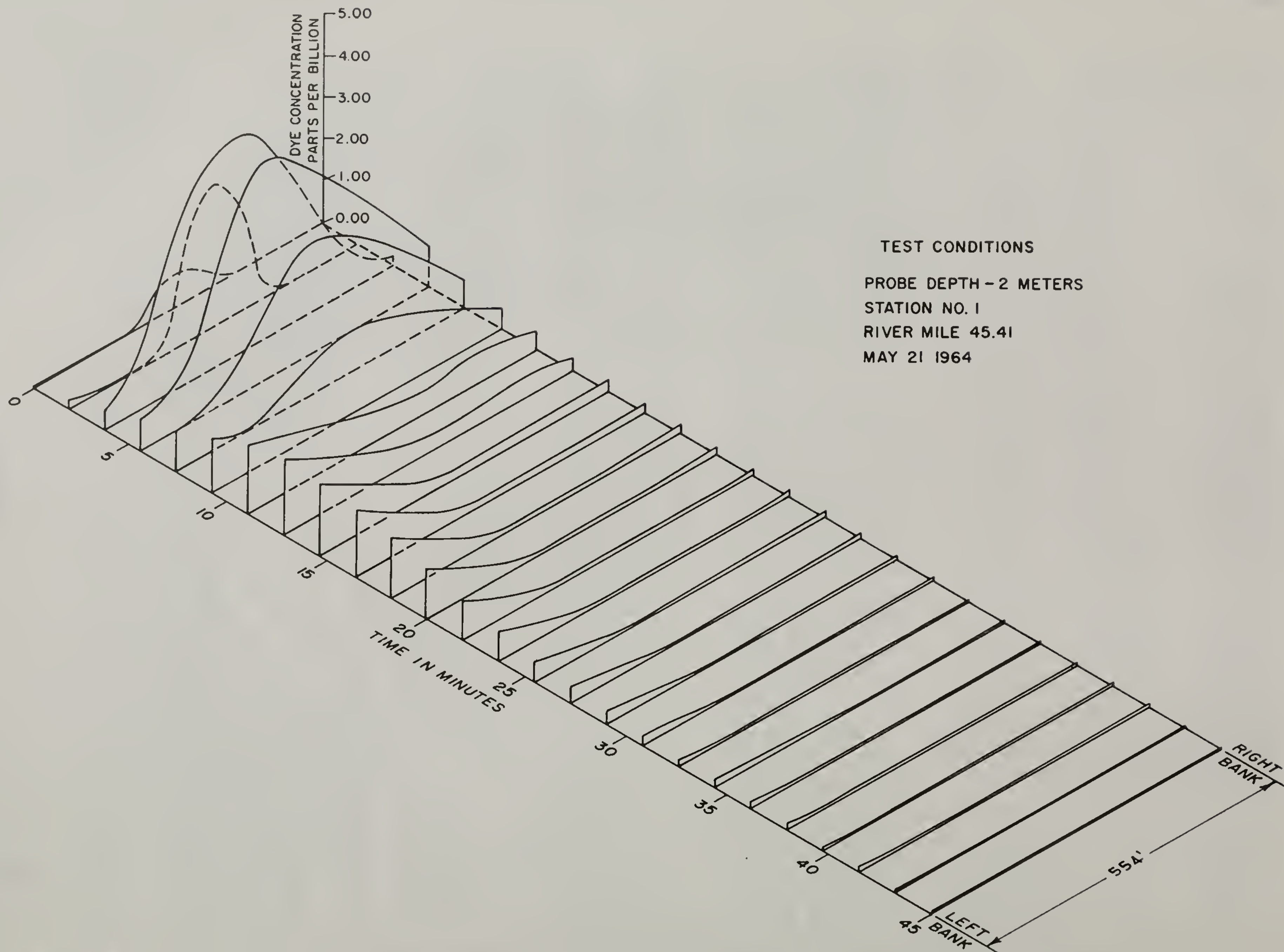
The first study was conducted to determine the distance, downstream from the release point, where the maximum permissible concentration of the radiosotope (0.003 microcuries per milliliter) would be reached. Indications from study results were that the maximum tritium concentration, for an injection of 25 curies, would fall within permissible limits at a distance of 600 feet from the injection point. The study also indicated that mixing was fairly complete 15,000 feet downstream from the injection point.

A second, more extensive, dispersion study was conducted to verify the first one, and to better evaluate the mixing characteristics of the reach under investigation. The second study showed that at a distance of 5,000 feet from the release point mixing was not complete. Downstream, 20,000 feet, it was fairly complete, while 41,000 feet from the release point essentially complete mixing had taken place.

Continuous observation of dye at a station (Figure 12) showed the effect of bank friction on streamflow and current velocities. After the maximum concentration of dye passed the station, dye concentrations were higher at the sides of the channel than in the middle.

San Joaquin River near Antioch

In 1964, three dye tracer studies were conducted to simulate waste discharges into the San Joaquin River in the vicinity of Antioch. Two of these studies simulated a continuous release of waste water; the third simulated an intermittent release during high tide. The primary goal of each study was to obtain data on increases in constituent concentrations and determine net movement for net flow calculations.


DYE CONCENTRATION
PARTS PER BILLION
5.00
4.00
3.00
2.00
1.00
0.00
0
5
10
15
20
25
30
35
40
45
TIME IN MINUTES
TEST CONDITIONS
PROBE DEPTH - 2 METERS
STATION NO. 1
RIVER MILE 45.41
MAY 21 1964
RIGHT
BANK
LEFT
BANK
554'

Hydraulic conditions affecting the Delta, such as perimeter inflows, Delta exports, and agricultural water demands, fluctuate significantly throughout the year and can have a notable effect on the results of hydraulic studies. However, fluctuations during study periods were minimal and generally amounted to less than ten percent of the average flows. Table 4 lists the hydraulic conditions occurring during the 1964 assimilative studies.

TABLE 4

AVERAGE HYDRAULIC CONDITIONS DURING 1964 ASSIMILATIVE STUDIES

Location	Flow in cubic feet per second		
	May Study	August Study	September Study
Sacramento River at Sacramento[a]	11,780	11,400	13,630
San Joaquin River at Vernalis[a]	670	370	660
Delta Mendota Canal near Tracy[a]	2,990	4,270	1,970
Channel Depletion[b]	1,600	3,430	2,140
Outflow at Chipps Island[b]	7,860	4,070	10,180
San Joaquin River at Antioch[b]	3,300	-200	4,200
Tidal Prism Flow at Antioch[b]	151,300	123,600	126,000

[a] DWR surface water records.

[b] Estimates based on refinements of data in "Salinity Incursion and Water Resources", appendix to Bulletin No. 76, Delta Water Facilities, April 1962.

Dye was injected into the San Joaquin River near Antioch Bridge. Dye concentrations were measured during each higher high water (HHW) and lower low water (LLW) slack following the dye release. Measurements indicated that material released into the San Joaquin River was mixed and dispersed upstream throughout the San Joaquin River to a point near the Mokelumne River confluence and throughout the greater portion of the western Delta channels, including Threemile Slough and the Sacramento River. Figure 13 depicts the area of major influence.

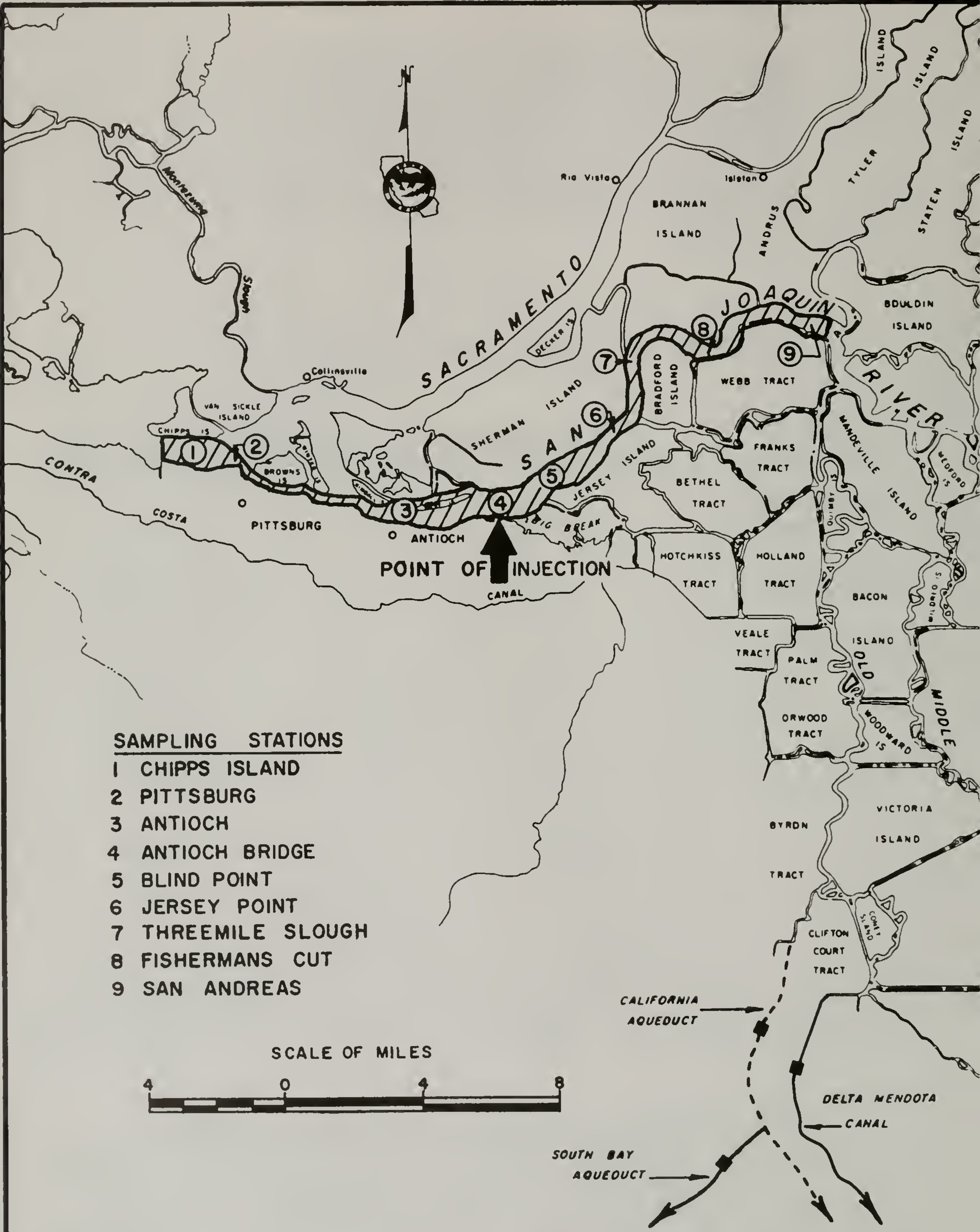


Figure 13. AREA OF INVESTIGATION FOR ASSIMILATION STUDIES OF SAN JOAQUIN RIVER NEAR ANTIOCH

The extent of intrusion of material into the Delta was found to be related directly to hydraulic conditions and primarily to the direction of net flow in the San Joaquin River past Antioch.

In a study designed to evaluate the conditions necessary to provide maximum flushing of waste water out of the lower San Joaquin River, an injection, to simulate a controlled release, was made beginning two hours before and terminating two hours after HHW slack. This was planned to take full advantage of maximum ebb flow to enhance the river's assimilative capacity. Nearly 50 percent of the dye was lost by the end of the first tidal cycle, due to tidal flushing on the initial ebb flow following the injection.

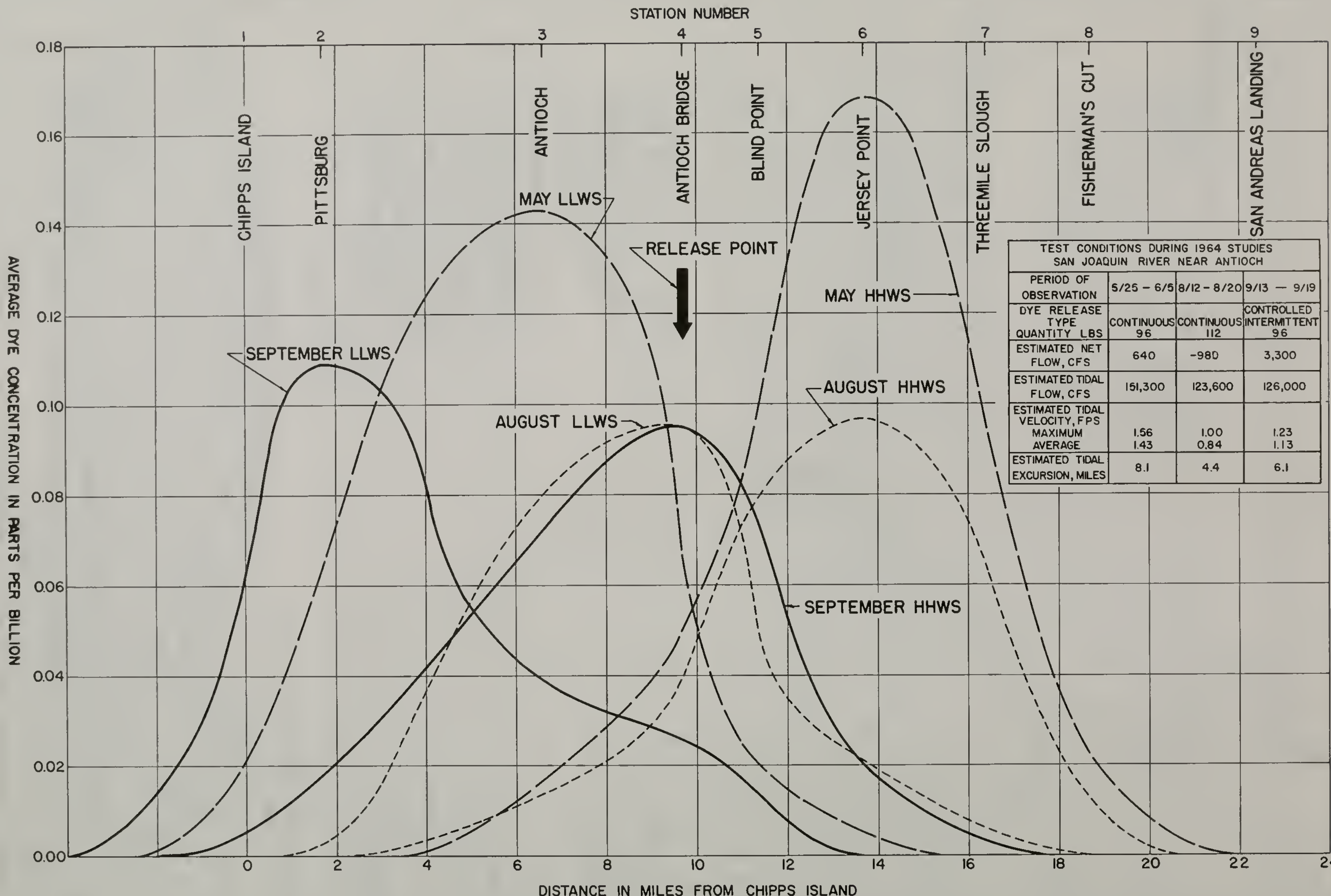
Because of the confined nature of the dye cloud, concentrations observed during the study were about 30 percent higher than expected. In spite of the advantage gained from the initial flushing action, only a portion of the tidal prism passed the injection point during the four hour release period; therefore, the tidal prism volume available for dilution during the controlled intermittent release was only 20 to 30 percent of that available during the first continuous release. The effect of the tidal flushing of the initial ebb flow, and the higher net flows, was partially offset by the reduction in the available tidal prism dilution volume. Subsequent to the first tidal cycle, mixing and tidal dispersion proceeded as a naturally uniform function, dependent on net inflows, tidal prism volume and tidal excursion.

The average extreme tidal excursions in the river (distance from average location of HHW and LLW centers of mass) varied from 8.1 miles, at a net flow of 640 cfs when the tidal flow was 151,300 cfs, to 4.4 miles, at a net flow of -980 cfs when the tidal flow was 123,600 cfs.

These tidal excursions, and the resulting distribution of dye in the San Joaquin River on each of the three assimilation studies are shown in Figure 14. The distribution and location of the dye, averaged over each period of observation, reveals a number of factors relevant to an interpretation of local hydraulics. In addition to the influence of tidal and net flows on the extent of tidal excursions, Figure 14 also indicates the longitudinal distribution and concentration of dye under specific hydraulic conditions. The inclusive areas of maximum influence extend from Station 2 (river mile 2) upstream to Station 6 (river mile 14).

<u>San Francisco Bay System</u>

A number of dye dispersion tests had been made in the Corps of Engineers hydraulic model, but there was some uncertainty as to the ability of the model to duplicate dispersion patterns in the estuary. Therefore, a series of fluorescent dye tracer studies were conducted in the prototype to obtain data to define the ability of the model to reproduce mixing patterns at various net outflows. Simultaneous current velocity and salinity measurements were made at Roe Island and Chipps Island. Velocity measurements were taken over one tidal cycle. Chloride determinations were made hourly with samples collected at top, bottom, and mid-depth. Tidal elevations were recorded.



TEST CONDITIONS DURING 1964 STUDIES SAN JOAQUIN RIVER NEAR ANTIOCH			
PERIOD OF OBSERVATION	5/25 – 6/5	8/12 – 8/20	9/13 — 9/19
DYE RELEASE TYPE QUANTITY LBS	CONTINUOUS 96	CONTINUOUS 112	CONTROLLED INTERMITTENT 96
ESTIMATED NET FLOW, CFS	640	-980	3,300
ESTIMATED TIDAL FLOW, CFS	151,300	123,600	126,000
ESTIMATED TIDAL VELOCITY, FPS MAXIMUM AVERAGE	 1.56 1.43	 1.00 0.84	 1.23 1.13
ESTIMATED TIDAL EXCURSION, MILES	8.1	4.4	6.1

Figure 14. COMPARISON OF TIDAL AND NET FLOW EFFECTS ON LONGITUDINAL DISTRIBUTION OF DYE IN THE SAN JOAQUIN RIVER

Sixteen separate tests, as shown in Table 5, were conducted in the model at inflows ranging from 1,000 to 16,000 cfs. Five alternative discharge locations were chosen, and dye was released over six different time increments. Dye was released in instantaneous or slug injections, intermittent releases on ebb tide only, and continuous release of one or 40 tidal cycles.

TABLE 5

HYDRAULIC MODEL TESTING PROGRAM

Test No.[a]	Inflow: cfs	Discharge: Location[b]	Type	Duration[d]	Length of Test, T.C.[e]
31	16,000	B	Slug	1/50	20
32	16,000	B	Continuous	40	40
33	16,000	B	Intermittent	1/2	26
34	16,000	B	Continuous	1	40
35	1,000	B	Continuous	1	20
12	16,000	A	Continuous	1	40
11	16,000	C	Continuous	1	40
10	16,000	D	Continuous	1	20
36	2,000	B	Slug	1/50	28
37	6,000	B	Slug	1/50	28
38	2,000	B	Continuous	1	28
39	16,000	B	Continuous	1	28
40	9,000	B	Continuous	1	28
41	2,000	B	Intermittent	1/6	28
42	2,000	Sump[c]	Slug	1/8	28
43	9,000	Sump[c]	Slug	1/8	28

[a] Tests 31-43 conducted by DWR; 10-12 by Corps of Engineers.

[b] Locations shown on Figure 15.

[c] Inflow sump was seeded with dye for 3 hours on first tidal cycle.

[d] Period of release in tidal cycles (T.C.) per injection.

[e] Tests 1-8 conducted with tide of September 1956; 9-16 with July 1964 tide.

Results of these studies, both in the prototype and the model, were compared to determine the following:

1. Model reproduction of prototype tides, current velocities and chloride concentrations;

2. Comparison of model and prototype mixing and dispersion characteristics;

3. Effect of varying net inflow on receiving water quality concentrations due to a waste discharge;

4. Comparison of the mixing and dispersion patterns resulting from various types of discharges;

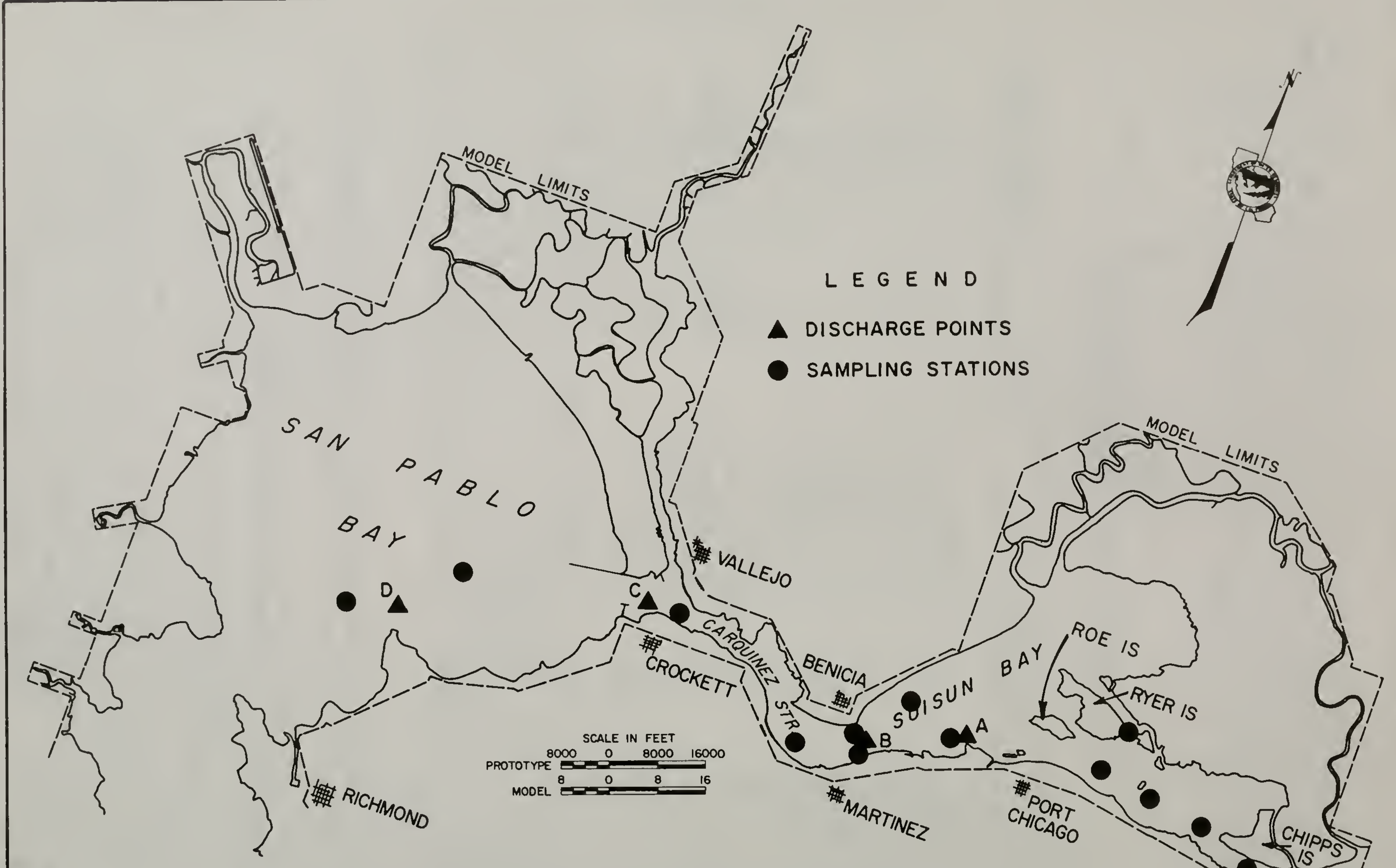


Figure 15. LOCATION OF SAMPLING STATIONS AND DISCHARGE POINTS FOR DYE DISPERSION TESTS IN THE SAN FRANCISCO BAY SYSTEM

5. Differences in concentration patterns resulting from discharging at selected alternative locations;

6. Differences in distribution and concentration of conservative and nonconservative constituents.

Comparison of Prototype and Model. Model verification test results indicate that the hydraulic model does adequately reproduce tides, salinities, and current velocities found in the prototype at 2,000 cfs inflows, as well as at the Corps of Engineers original verification inflow of 16,000 cfs. Subsequent tests, of both model and prototype dye dispersion patterns, confirmed the ability of the model to duplicate prototype mixing at 16,000 cfs inflow. Model dye dispersion tests, at lower inflows, showed equally satisfactory and consistent results.

Effects of Variations in Inflow. Results indicate that at higher inflows, greater concentrations of wastes can be expected at stations below the point of discharge. This is due to displacement of the effluent field downstream by the greater currents.

The distribution patterns shown in Figure 16, represent conditions at four different inflows with the tidal activity of July 1964. A reduction in concentrations because of increased flows is apparent upstream from the discharge point.

Figure 17 shows the longitudinal distribution of conservative and nonconservative steady-state concentration (C_s) values at 1,000 and 16,000 cfs. Peak conservative concentrations decrease about one third as flows increase from 1,000 to 16,000 cfs. Downstream from the discharge point, nonconservative concentrations are higher at 16,000 cfs. Essentially identical patterns of dispersion were observed at most stations in Suisun Bay, at both extreme test inflows.

Comparison of Concentration Patterns Resulting from Different Types of Release. Results from three individual tests conducted at 16,000 cfs inflow, indicate only minimal differences in steady-state concentrations resulting from release of equal quantities of dye from various types of simulated waste discharges. The three tests included: discharging continuously over 40 tidal cycles, discharging intermittently on each high water ebb flow for 26 cycles, and discharging continuously for 1 cycle. Diffusional processes seem to be within the same order of magnitude for practically any pattern of discharge.

Absolute concentrations at any specific point and time for the various releases were generally not equal. This inequality was expected, and was caused primarily by the differences in actual quantities of dye remaining in the system after each tidal cycle.

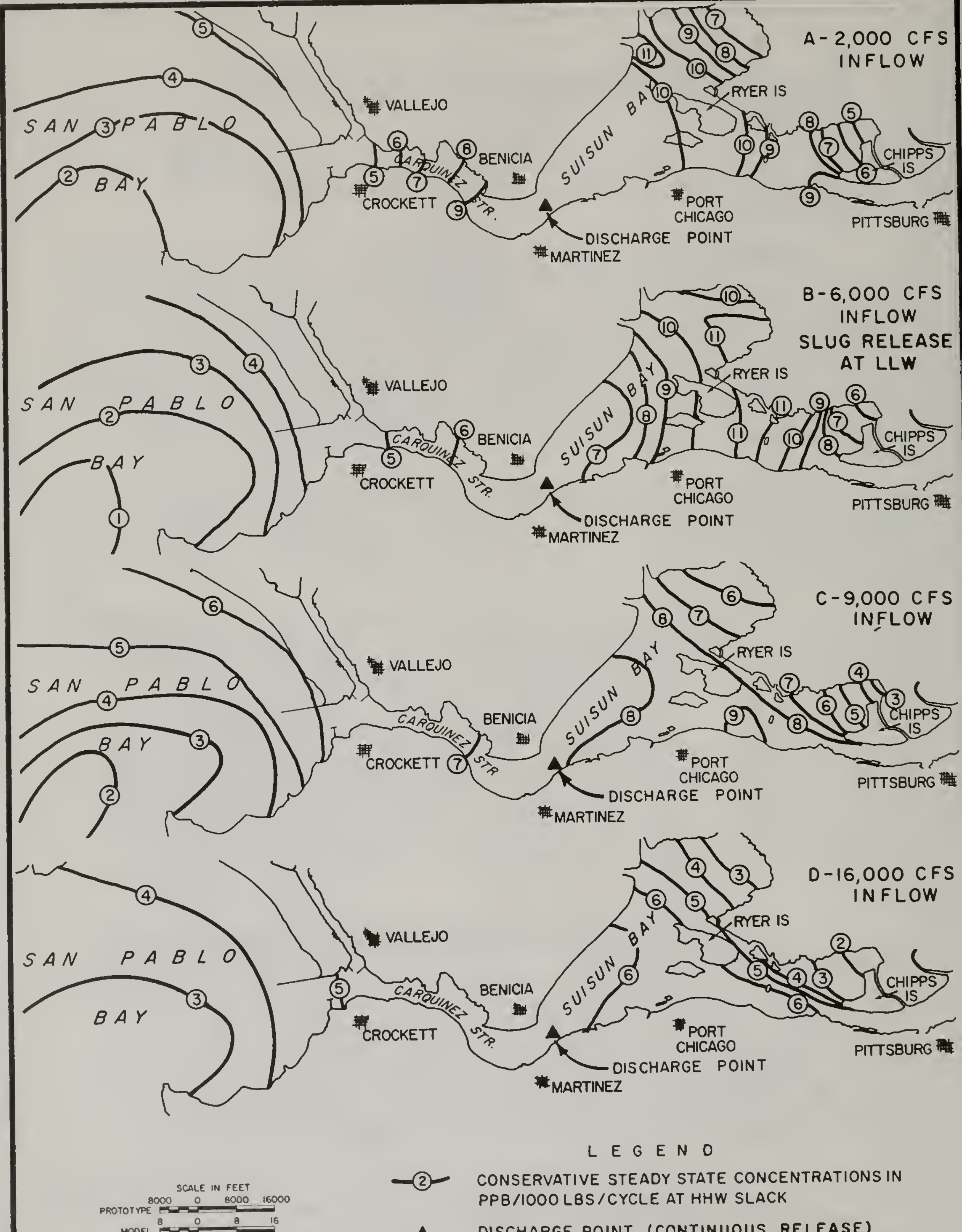
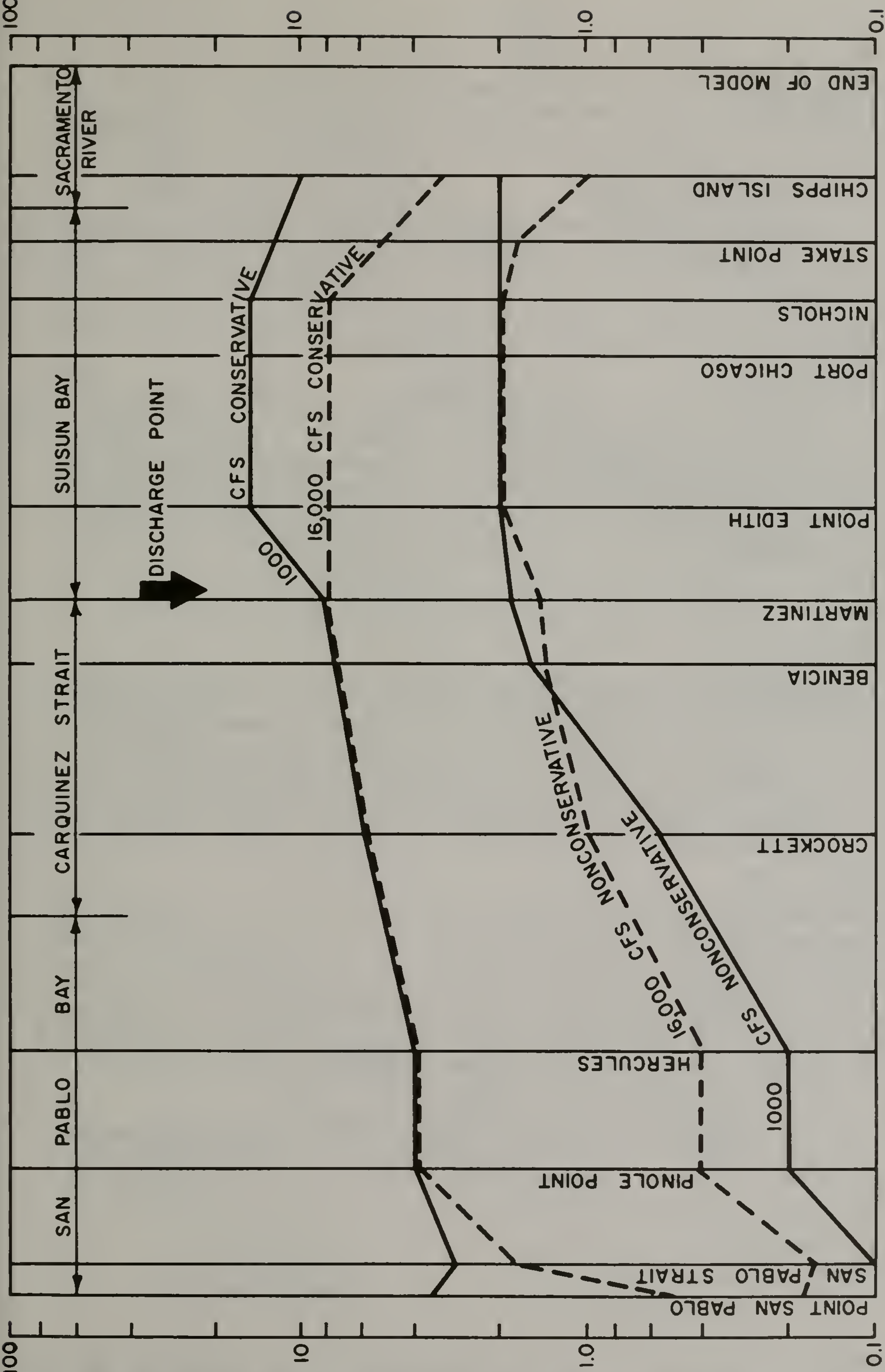


Figure 16. DISTRIBUTION PATTERNS OF STEADY STATE CONCENTRATIONS RESULTING FROM A DISCHARGE AT MARTINEZ AT FOUR DIFFERENT INFLOWS



CONCENTRATION RATIOS, PARTS PER BILLION/1000 POUNDS/CYCLE

Figure 17. COMPARISON OF CONCENTRATION RATIOS OF CONSTITUENTS DISCHARGED AT MARTINEZ INTO 1000 AND 16,000 CFS INFLOWS

Observations generally indicated that the concentration differentials between the continuous and intermittent discharges were negligible or nonexistent after 20 tidal cycles. Numerical integration of the model station history data, of a release over one tidal cycle, proved the ability of this method to simulate steady-state concentrations.

Effects of Discharging at Four Alternative Locations. Figure 18 shows the steady-state concentrations measured at HHW slack, resulting from the discharge of conservative constituents at four locations when the inflow was 16,000 cfs. Concentration discharge ratios, which result from each 1,000 pounds discharged per cycle, are shown in ppb in the receiving waters.

Differences in areal distribution of concentration ratios, resulting from moving the discharge point downstream, are quite apparent, particularly in Suisun Bay. There is little difference in concentrations caused by discharges from Point Edith (Figure 18-A) or from Martinez (Figure 18-B). Marked improvement, 25 percent reduction, resulted in Suisun Bay when the discharge point was moved downstream near Crockett (Figure 18-C). Additional dilution benefits were derived when the discharge point was moved downstream into San Pablo Bay, near Pinole Point (Figure 18-D). Concentrations in San Pablo Bay changed very little regardless of the discharge location.

Differences in Distribution Patterns of Conservative and Nonconservative Constituents. Model results after being corrected for losses and converted to prototype units, were modified to represent nonconservative constituents. Concentrations of nonconservative constituents were calculated by using a decay factor of K = 0.1 per day. This value is a typical reduction rate for biochemical oxygen demand in surface waters. The resulting time concentration curves were integrated to steady-state.

Station history curves of nonconservative constituents discharged at Martinez, with an inflow of 16,000 cfs, indicated than an equilibrium condition could be reached in about 25 percent of the time required for conservative materials. For an inflow of 16,000 cfs, nonconservative concentrations within Suisun Bay were about 20 to 25 percent of the conservative concentrations measured there. Values in San Pablo Bay were about 10 percent of the conservative concentrations.

At 1,000 cfs inflow, nonconservative constituents were generally about 15 percent of the conservative value in Suisun Bay, and were 5 percent of the conservative values in San Pablo Bay.

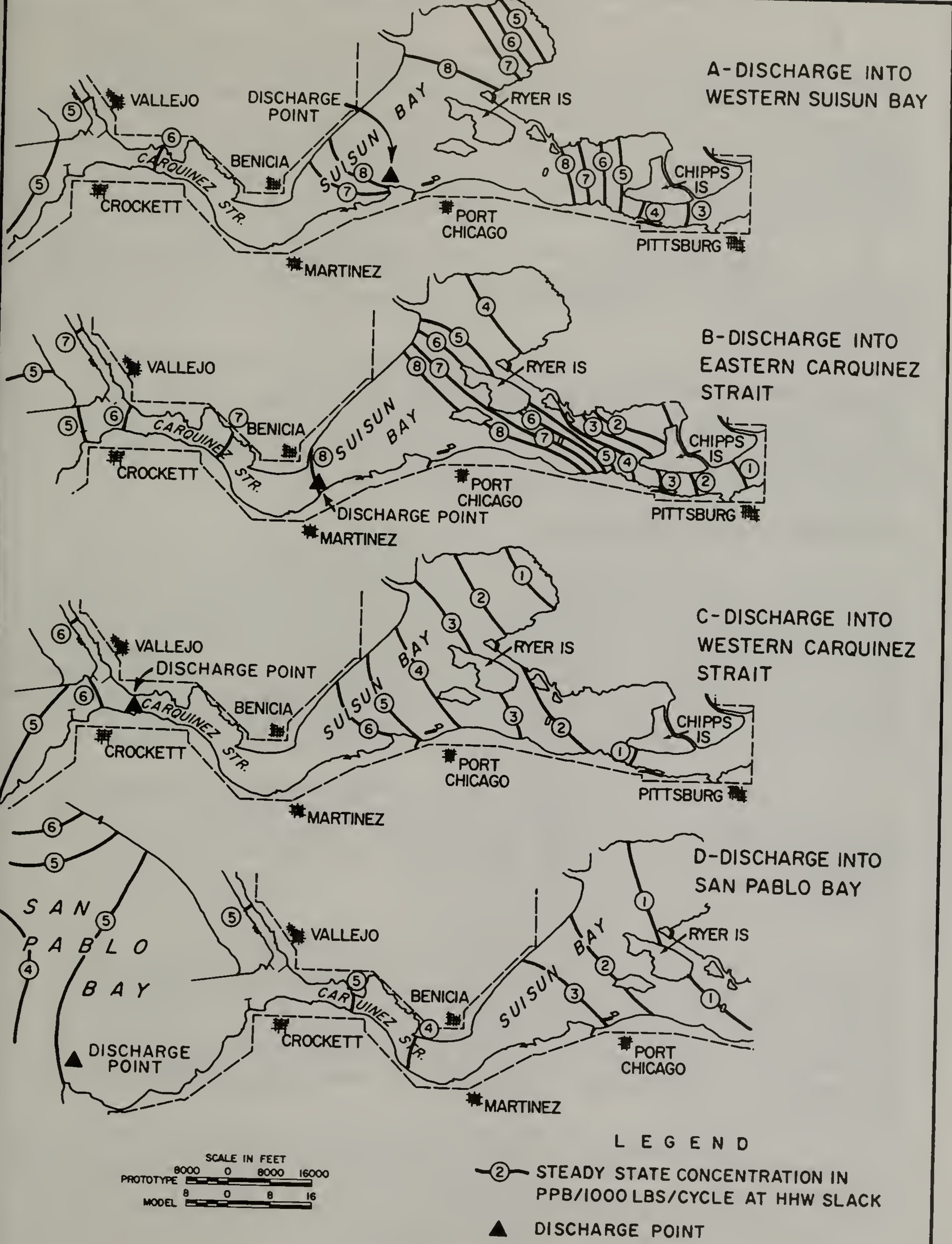


Figure 18. DISTRIBUTION PATTERNS OF CONSERVATIVE STEADY STATE CONCENTRATIONS RESULTING FROM FOUR SEPARATE DISCHARGES AT 16,000 CFS INFLOW

Figure 17 shows differences in distribution of conservative and nonconservative concentrations. While conservative values in Suisun Bay were quite different at the two inflows, differences in nonconservative concentrations were slight. Downstream from Benicia, significantly lower nonconservative concentrat ratios were observed at 1,000 cfs than at 16,000 cfs. This condition resulted from the inability of the low flow to displace large quantities of the nonconservative material into San Pablo Bay

Results from tests at the intermediate inflows of 2,000, 6,000, and 9,000 cfs, show similar distribution patterns and are generally numerically consistent with results from the two extreme inflow tests.

While discharging at alternative locations apparently changes the conservative constituents very little in San Pablo Bay (Figure 18), nonconservative constituent concentrations change by a factor of between three and five. Moving the discharge location closer to San Pablo Bay causes nonconservative concentrations to be reduced upstream and increased downstream.

Sacramento-San Joaquin Delta

In the chapter on "Investigation Methods" there is a discussion on the development of a mathematical model programmed for solution by the electronic digital computer. One of the first Delta hydraulic conditions to be simulated by the digital computer program was an inverse estuary or a hypothetical situation of zero tributary inflows and outflows. Evaporation from the Delta water surface was taken into account and results in a net upstream movement of water from Suisun Bay. The purpose was to show the effect of tidal pumping flow on the interior channel hydraulics.

While a real hydraulic environment, consisting exclusively of tidal flows, does not exist within the Delta, the results of the solution provide insight into the estuarine processes. Understanding the influence of tidal flows can be useful to indicate areas where channel flow might either be increased or retarded by tidal action.

The direction of net tidal flows throughout the Delta is shown on Figure 19. These directions depend on the waveform and reflect a condition similar to that found in an inverse estuary. Calculations of quantities of tidal flow, derived from known tidal prism volues, combined with estimated quantities of inflow and information on direction of flows from Figure 19, can be used to determine the direction and magnitude of net flows in specific channels.

Determination of guides for the operation of the Delta water facilities under all conceivable conditions could be a study of almost infinite size and time. Therefore, specific criteria were chosen and the Peripheral Canal concept was selected as the basis for investigating probable changes in receiving water quality under project conditions.

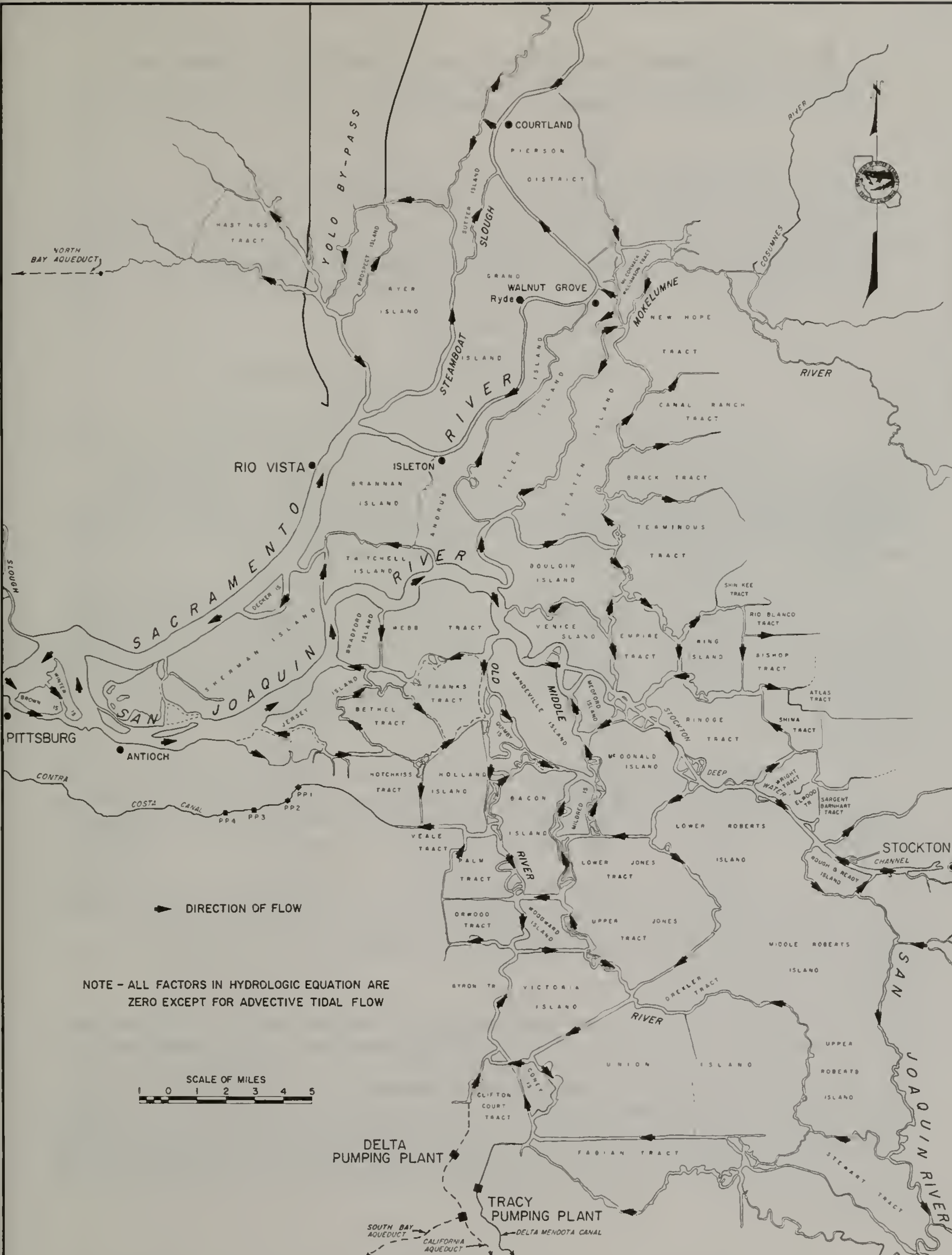


Figure 19. DELTA TIDAL FLOW DISTRIBUTION BY DIGITAL COMPUTER SIMULATION OF AN INVERSE ESTUARY

The periods and conditions selected for study were:

1955 - January-February
July
August

1995 - January-February
May-June
July-August
July-August with the San Joaquin Master Drain discharging at Antioch Bridge
September-October
November-December
November-December at low inflow (dry year condition)

Data for the 1955 periods were obtained from Department records, and calculations were based on available information concerning agricultural development in the Delta. Quantities relative to perimeter inflows into the Delta were taken directly from published reports, and the internal diversions and drainages were computed, using the hydrologic equation.

By use of the hydrologic equation, mean precipitation and estimated future consumptive use data were projected to represent 1995 agricultural practices. A separate drainage calculatio was made to represent the 1995 dry period. Perimeter Delta inflows for 1995 conditions were estimated from a 33-year (1922-1954) median inflow and from the seven-year (1928-1934) mean dry period inflow.

Program Evaluation. In addition to checking the ability of the model to reproduce prototype tides, the program's simulation of 1955 conditions was evaluated to determine areas of model correlation with observed conditions.

The areas in the prototype which had been characterized most fully were chosen for comparison. Available data from tidal cycle measurements and information obtained from dye tracer studies, were the primary sources of material for computer program evaluation.

Eight areas were evaluated by comparing flow distribution equations and determining prototype-model relationships. The data compare favorably when the method of determining flows in both model and prototype is considered. Model flows represent mean monthly values dependent on theoretical criteria; prototype flows represent instantaneous values derived from flow measurements over a tidal cycle. While the ratios of model to prototype flow ranged from 0.81 to 1.36, an average of 1.11 indicates general agreement.

Mean velocities, based on the net quantity of flow and cross-sectional area, were determined from the computer program and field dye studies. Comparison of results at five stations showed excellent agreement.

Present Conditions. Average monthly quantities of flow into and out of the Delta, which are representative of the predominant inflows and major diversions of water in the Delta, are presented in Table 6. The largest single outside demand for water from the Delta is the exportation by the Delta-Mendota Canal which begins at the Tracy Pumping Plant in the southern Delta.

TABLE 6

AVERAGE MONTHLY DELTA INFLOWS AND EXPORTS
1955-64

Month	Inflow in cfs		Export in cfs		
	Sacramento River	San Joaquin River	Delta Mendota Canal	City of Vallejo	Contra Costa Canal
January	25,140	4,510	215	10	50
February	38,600	4,730	590	10	50
March	33,740	3,710	1,500	10	55
April	28,830	4,930	2,000	15	75
May	26,690	5,500	2,210	20	95
June	16,040	4,490	2,960	25	125
July	10,970	1,020	3,820	25	145
August	11,230	650	3,440	25	145
September	12,140	990	1,940	20	120
October	12,820	1,340	1,500	15	90
November	13,610	1,580	470	10	65
December	23,390	2,870	90	10	55
Average	21,100	3,025	1,730	15	90

Seasonal use of water within the Delta varies from about 2,000 cfs in February to a maximum of almost 8,000 cfs during July and averages approximately 3,900 cfs.

Antioch diverts 2,200 acre-feet of water during the winter for municipal uses. This is equivalent to an average diversion of about six cfs for a period of six months. Another diversion near Chipps Island (Mallard Slough) averages 20 cfs for an equal period of time during the winter.

Figure 20. DIGITAL COMPUTER SIMULATION OF PRESENT DELTA WINTER FLOW DISTRIBUTION

Figure 21. DIGITAL COMPUTER SIMULATION OF PRESENT DELTA SUMMER FLOW DISTRIBUTION

The computer program to simulate 1955 prototype hydraulics was considered successful since it produced results comparable to natural conditions, within the accuracy of field measurements. Therefore, computer results for the 1955 hydraulic solution were used in defining present Delta hydraulic characteristics.

Nineteen stations were selected as being most significant in terms of Delta flow patterns and were used for analysis. Absolute tidal velocities and average net velocities for each station were obtained from the program output.

The average individual channel hydraulics within the Delta vary seasonally, and depend primarily upon demands created by the Tracy Pumping Plant and Sacramento River inflows.

Generally, the Delta maintains rather uniform tidal velocities between the summer and winter flow conditions. However, in the northern areas, flows in the Sacramento and Mokelumne river channels are significantly different between January and July. Both channels have larger tidal velocities during the winter. This appears to be a direct result of operation of the Delta Cross Channel gates.

Average net velocities in individual channels were determined to be a function of pumping for the Delta-Mendota Canal. Some velocities varied directly while other varied inversely. Specific velocities for the two flow conditions could be used to determine intermediate flow.

Hydraulic conditions within the Delta channels are in a constant state of flux between the high flow winter period and the low flow summer period.

Figures 20 and 21 show the average annual limits of flow distribution patterns as they presently exist in the Delta. Until a major change alters the hydraulics, the conditions shown on these two figures will be generally representative of the Delta. A major change would consist of the operation of an agricultural waste water drain discharging significant quantities of water at Antioch, operation of the Delta Pumping Plant and California Aqueduct, and operation of Delta water facilities to transport water around the Delta.

Directions and relative distribution ratios can be obtained from the figures to show seasonal changes which occur in and around specific areas of the Delta.

Future Conditions. Export requirements of the State Water Project and the federal Central Valley Project are expected to cause significant changes in the Sacramento-San Joaquin Delta. For the purpose of evaluating future conditions, these changes are combined and simulated in the digital computer model in the form of a Peripheral Canal concept for Delta water transfer.

The important features of the Peripheral Canal concept are: a canal hydraulically isolated from Delta channels to convey water around the eastern edge of the Delta directly to the export pumping plants of the southern Delta, release points along the canal route to meet local water requirements for water quality control and to control the environment for fish, fish protection works at the canal intake, a controlled outflow for salinity control, a local distribution system to meet the agricultural needs of the western Delta lowlands; and recreation facilities along the canal.

The major changes in Delta hydraulics, as envisioned in the Peripheral Canal concept, will be within the lower Sacramento and San Joaquin rivers, the Delta Cross Channel, Georgiana Slough, Mokelumne River, and the Old River-Middle River system.

The digital computer model, with probable project operating criteria included, was able to simulate hydraulic conditions of 1995. Tidal velocities and average net velocities were determined for January-February and for July-August by the same methods used to determine present conditions. These data provide average limits of seasonal changes expected for conditions in 1995. The two periods selected represent extreme hydraulic limits at a few stations where comparisons may be made between present and future conditions.

Changes likely to occur within the Delta can be better evaluated by studying Figures 20,21, 22, and 23. Specific areas of interest may be investigated with regard to alterations of Delta flows caused by the proposed Delta facilities.

Water Quality Conditions

Water quality conditions in the Delta and Suisun Bay can be expected to change with time and with changing environment. To determine trends in water quality and the manner in which such quality has been or may be influenced by various seasonal and climatic conditions, past and present data were collected and evaluated.

Physical and Chemical Characteristics

Important to this investigation are the historical seasonal, and geographical variations in water quality within the Delta and Suisun Bay area. Present and historical values of water quality constituents were compared by summarizing data from the Department of Water Resources Bulletin No. 65, "Quality of Surface Waters in California", for the years 1952 through 1964; the

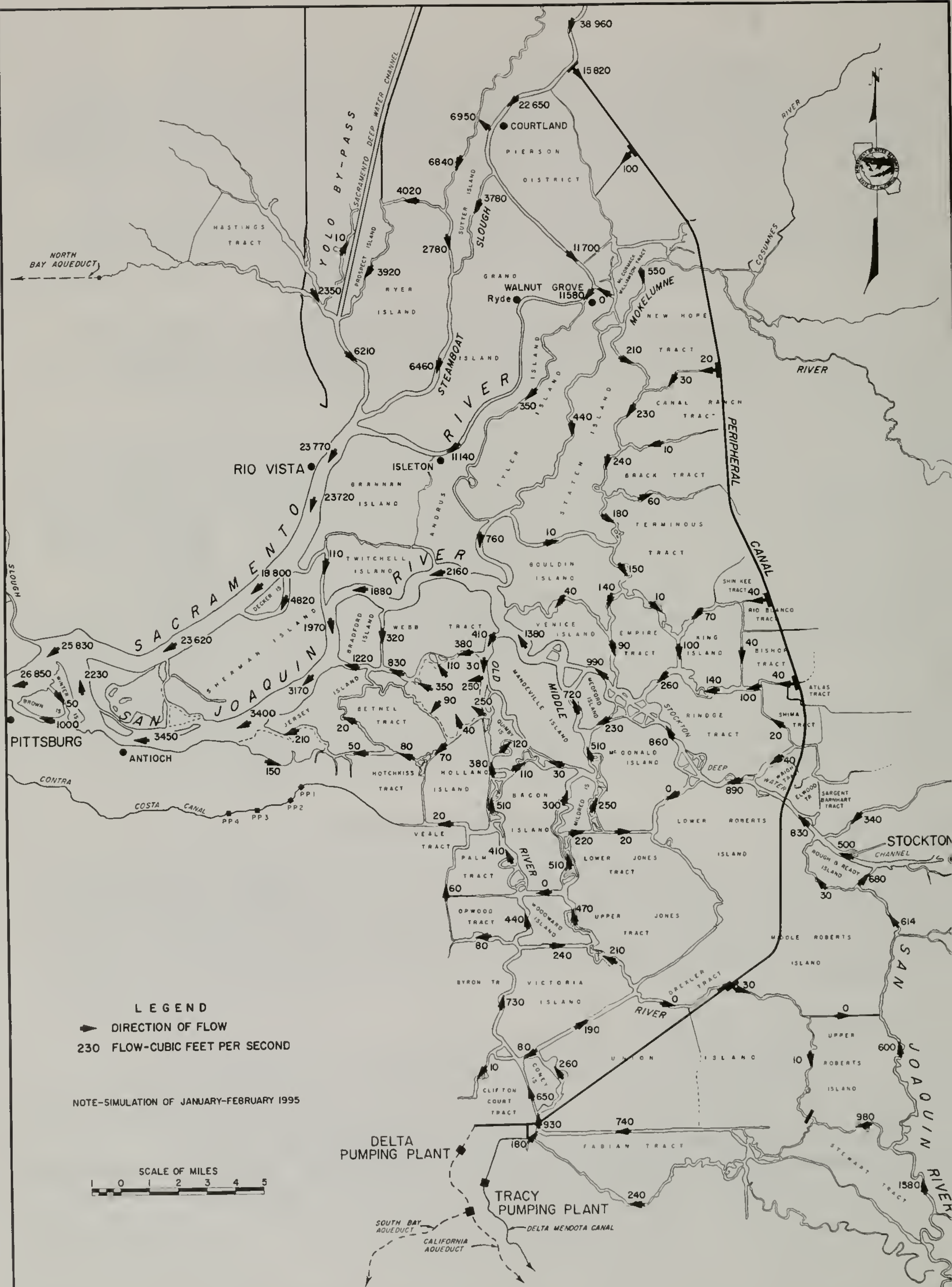


Figure 22. DIGITAL COMPUTER SIMULATION OF 1995 DELTA WINTER FLOW DISTRIBUTION

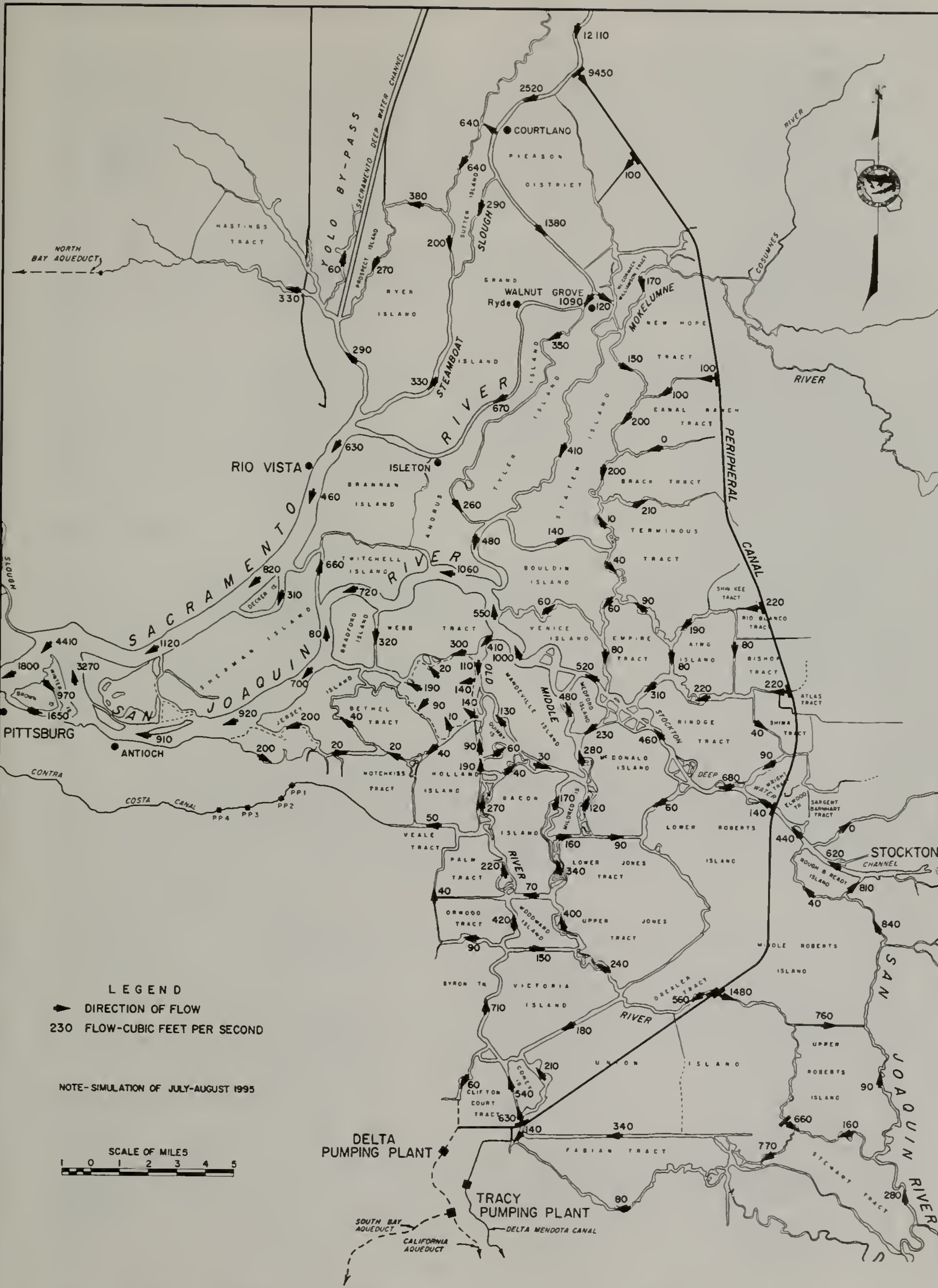


Figure 23. DIGITAL COMPUTER SIMULATION OF 1995 DELTA SUMMER FLOW DISTRIBUTION

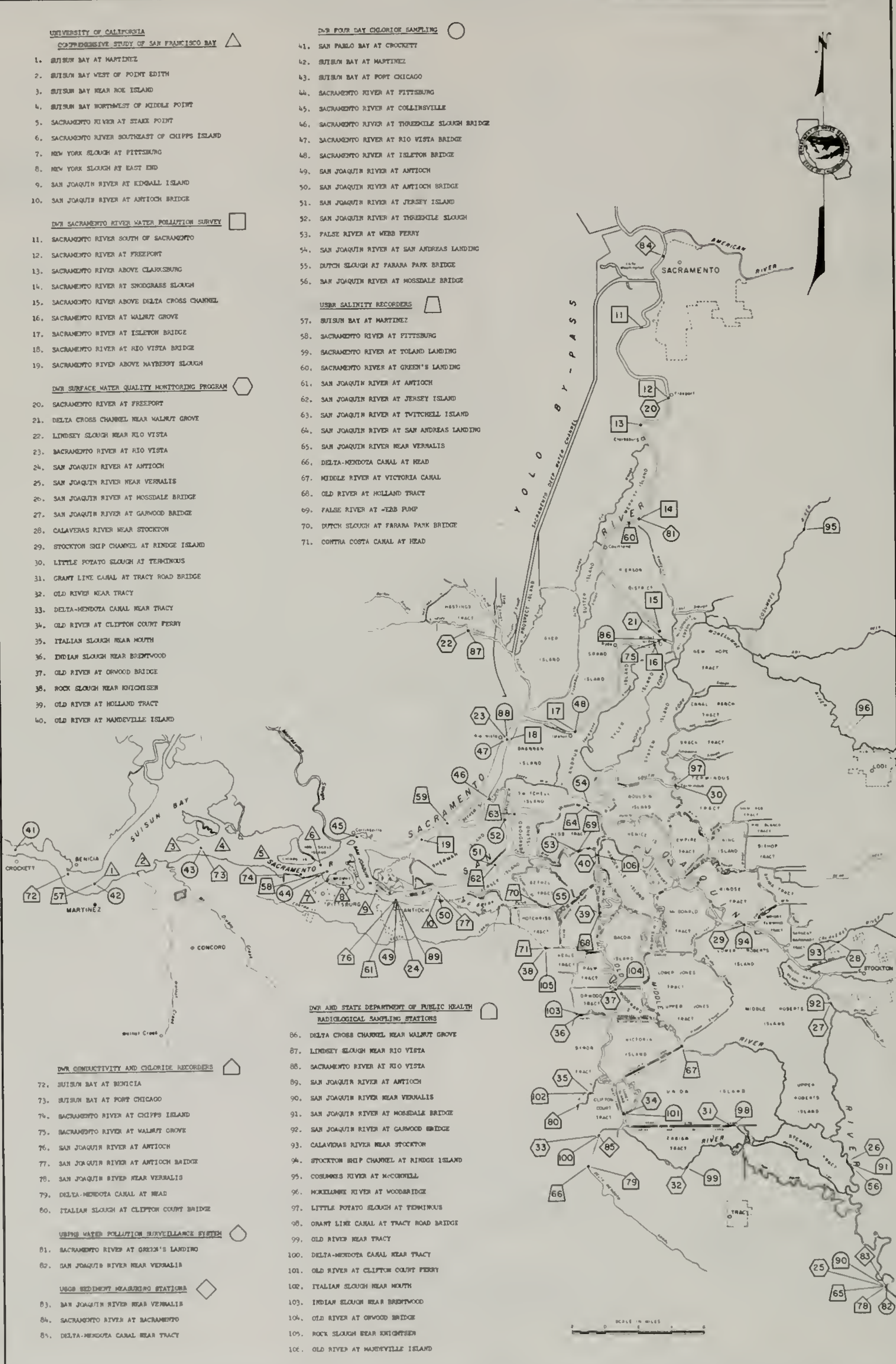


Figure 24. WATER QUALITY SAMPLING STATIONS OF PROGRAMS AND ACTIVITIES RELATED TO SACRAMENTO-SAN JOAQUIN DELTA

Department of Water Resources four-day chloride sampling program for 1958 through 1964; and the U.S. Bureau of Reclamation data from salinity recorders for 1954 through 1964. Other sources of data were the Suisun Bay-lower San Joaquin River portion of the University of California's Comprehensive Study of San Francisco Bay, and the lower Sacramento River stations which were part of the Sacramento River Water Pollution Survey.

A limited sampling of 14 surface water stations was conducted at selected locations from June through November 1964. Names and locations of all water quality sampling stations related to the investigation are shown on Figure 24.

Data were collated on both seasonal and geographical bases for historic (1952-61) and present (1962-64) conditions. All data from various sources were compared so results would be consistent. Constituents, when reported as alternative equivalents were adjusted to equal forms and summarized as weighted mean monthly or annual concentrations.

Temperature

Water temperature is important in fish migration and spawning, irrigation, industrial cooling, recreation and waste assimilation. Review of the available data on water temperature indicated that average temperatures for both historic and present periods changed little, generally only 1 or 2 degrees Fahrenheit (°F). Maximums have dropped about 4 degrees while minimums have remained constant.

Water temperatures in the Delta vary throughout the year with lows occurring in December and January (44°F), and highs in July, August, and September (78°F). These variations in water temperature are caused by seasonal changes in atmospheric temperature and other influences such as agricultural drainage, sunlight intensity, and turbidity.

The present average monthly water temperature during September, October, and November for stations within the Delta is slightly greater than the temperatures recorded for those monthly in the historic period. Stations on the Sacramento and San Joaquin rivers showed no change. The higher present temperatures within the Delta may be caused by increased agricultural drainage during the post-irrigation season.

Acidity and Alkalinity

Waters of the Delta were found to be typically alkaline; most of the pH values are over 7.0. Variation in pH is a function of both temperature and salinity, and biological activity caused pH values to be highest during daylight hours.

The lowest average pH, over both the ten-year historic period and the present period was 7.2 in Little Potato Slough. The highest average was 7.8, observed at three stations in the southern Delta.

No pattern of seasonal variation in pH was noted in the Delta. However, the waters of the Sacramento River influenced the pH of Delta waters as far south as a line extending from Indian Slough to Garwood Bridge on the San Joaquin River. The average pH in Suisun Bay for the period of record varied seasonally from a high of 8.0 in June and July to a low of 7.4 in December, with little or no variation between stations. In Suisun Bay seasonal fluctuations of pH appeared to be consistent with seasonal changes of phytoplankton productivity.

Suspended Solids

The Bay and Delta system serves as a retention basin for sediments from tributary streams which drain the Central Valley. In the past, much of this sediment resulted from natural erosion and hydraulic mining. Mud, silt, sand, and gravel, in large quantities, were washed into the Sacramento River and its tributaries and carried into the Bay during the period of uncontrolled hydraulic mining between 1850 and 1884. Presently, sediments are carried into the Delta and Bay during flooding in the Sacramento and San Joaquin rivers, and are gradually transported through Suisun and San Pablo bays.

The pattern, volume, and rate of sedimentation in the bays have been studied since 1850. To supplement and evaluate data from earlier works, limited sediment sampling was conducted in the Sacramento River, near Sacramento. Data obtained was included in Appendix G, "Sedimentation", to the report entitled "Feasibility of Construction by the State of Barriers in the San Francisco Bay System", published in 1955.

Dredging to maintain navigation channels and flood protection projects has altered the natural shape of the channel bottom. In the Delta and Suisun Bay area, from 1930 to 1955, an average of 1,640,000 cubic yards was dredged annually.

Suspended solids in the waters of the Delta are important since they interfere with the agricultural practice of leaching and also cause excessive wear on Delta pumps. Data concerning suspended solids for stations on the Sacramento River at Sacramento, on the San Joaquin River at Vernalis, and on the Delta Mendota Canal near Tracy were obtained from the U.S. Geological Survey.

Sediment inflow to the Delta from 1950 though 1959, was estimated by the U.S. Army Corps of Engineers to be about 8,000,000 cubic yards annually, varying from one percent of the annual loading in August to 19 percent in February. The estimated average annual sediment inflow to Suisun Bay from the Delta was 5,100,000 cubic yards. The remaining 2,900,000 cubic yards were deposited in the Delta or removed by exports and diversions.

TABLE 7

SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS
IN SACRAMENTO-SAN JOAQUIN DELTA

Station	1952 - 1961									1962 - 1964								
	Temperature in °F			pH			Specific Conductance Micromhos at 25°C			Temperature in °F			pH			Specific Conductance Micromhos at 25°C		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Sacramento River at Freeport	73	45	60	8.0	7.1	7.3	260	120	180	73	42	58	8.2	7.1	7.5	220	60	160
Delta Cross Channel near Walnut Grove	77	44	60	8.2	6.8	7.3	280	60	160	75	42	59	8.3	6.9	7.4	220	60	160
Lindsey Slough near Rio Vista	80	44	61	8.2	7.0	7.5	380	70	220	73	41	60	8.1	7.3	7.6	490	170	270
Sacramento River at Rio Vista	78	43	60	8.1	6.8	7.4	326	109	180	74	46	59	8.1	7.1	7.5	253	77	180
San Joaquin River at Antioch	78	44	62	8.0	6.8	7.4	6530	101	1070	76	47	62	8.2	7.1	7.5	3450	164	750
San Joaquin River near Vernalis	83	45	63	8.5	6.5	7.6	1830	92	670	76	45	62	8.3	6.8	7.5	1400	162	740
San Joaquin River at Mossdale Bridge	82	44	63	8.5	6.8	7.7	1460	102	660	78	47	63	8.5	7.1	7.7	1300	114	710
San Joaquin River at Garwood Bridge	82	44	63	8.4	6.8	7.6	1260	109	600	79	46	64	8.5	6.9	7.5	1270	159	590
Calaveras River near Stockton	78	40	68	8.1	7.1	7.4	234	135	200	75	42	60	8.2	7.1	7.7	304	83	180
Stockton Ship Channel at Rindge Island	84	43	63	8.4	6.9	7.4	856	130	480	79	46	64	8.4	7.1	7.6	944	143	500
Little Potato Slough at Terminous	77	43	61	8.1	6.8	7.2	372	70	210	73	45	60	7.7	6.4	7.2	266	90	190
Grant Line Canal at Tracy Road Bridge	80	44	64	8.9	7.2	7.8	1570	332	850	76	46	62	8.7	7.0	7.7	1270	125	740
Old River near Tracy	81	44	62	8.5	7.0	7.6	1470	135	740	77	46	62	8.7	6.9	7.8	1300	160	810
Delta Mendota Canal near Tracy	80	44	63	8.4	6.8	7.6	1820	173	570	76	44	63	8.6	7.1	7.4	1440	150	560
Old River at Clifton Court Ferry	82	43	63	8.5	6.8	7.5	1070	140	510	77	45	63	8.5	7.1	7.5	1330	140	480
Italian Slough near Mouth	84	45	64	8.1	6.8	7.4	1130	149	520	78	40	63	8.4	7.1	7.5	1610	153	530
Indian Slough near Brentwood	83	46	64	8.4	6.8	7.6	2220	203	820	78	48	64	8.4	7.1	7.8	1590	189	810
Old River at Orwood Bridge	79	43	62	8.1	7.0	7.4	1080	148	490	78	46	62	8.6	7.1	7.5	1390	150	450
Rock Slough near Knightsen	81	44	63	8.0	6.8	7.3	1190	148	520	81	44	63	7.7	6.9	7.4	1090	184	470
Old River at Holland Tract	78	43	62	--	--	--	1830	117	460	--	--	--	--	--	--	--	--	--
Old River at Mandeville Island	81	43	61	8.1	7.0	7.4	810	77	350	77	45	62	8.2	7.1	7.4	590	143	340

Station	Concentrations in milligrams per liter																	
	1952 - 1961									1962 - 1964								
	Total Dissolved Solids			Boron			Total Hardness ($CaCO_3$)			Total Dissolved Solids			Boron			Total Hardness ($CaCO_3$)		
	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]
Sacramento River at Freeport	130	80	110	0.10	0	0.07	87	24	58	130	80	110	0.30	0	0.03	79	24	53
Delta Cross Channel near Walnut Grove	180	60	110	0.59	0	0.06	90	28	60	140	70	110	0.30	0	0.07	77	23	57
Lindsey Slough near Rio Vista	210	100	140	0.70	0	0.14	139	42	78	230	120	160	0.50	0	0.16	151	56	88
Sacramento River at Rio Vista	181	73	120	0.39	0	0.09	122	40	65	134	87	110	0.20	0	0.07	86	30	62
San Joaquin River at Antioch	3580	66	710	1.10	0	0.14	1260	66	153	1050	111	370	0.40	0	0.11	390	50	122
San Joaquin River near Vernalis	1080	66	450	0.70	0	0.21	294	26	147	791	141	590	0.70	0	0.21	306	41	150
San Joaquin River at Mossdale Bridge	826	58	510	0.60	0	0.18	320	39	152	600	81	430	0.50	0	0.23	290	36	162
San Joaquin River at Garwood Bridge	640	71	400	2.10	0	0.18	286	31	133	469	87	330	0.50	0	0.23	286	38	131
Calaveras River near Stockton	149	94	130	0.30	0	0.07	149	94	125	137	115	130	0.20	0	0.08	130	27	75
Stockton Ship Channel at Rindge Island	476	86	280	1.60	0	0.16	236	36	119	375	155	240	0.50	0	0.16	236	40	118
Little Potato Slough at Terminous	223	62	130	1.10	0	0.07	143	26	69	136	89	120	0.30	0	0.07	86	30	66
Grant Line Canal at Tracy Road Bridge	914	198	490	0.50	0	0.22	308	76	183	611	97	440	0.60	0	0.24	292	37	170
Old River near Tracy	825	81	500	0.70	0	0.25	356	36	172	711	125	530	0.70	0	0.29	326	43	197
Delta Mendota Canal near Tracy	591	100	340	1.00	0	0.23	263	42	119	527	164	260	1.00	0	0.23	344	25	123
Old River at Clifton Court Ferry	580	89	300	0.50	0	0.15	248	38	118	435	150	280	0.90	0	0.13	308	38	108
Italian Slough near Mouth	645	88	310	1.70	0	0.22	233	38	117	313	153	220	1.90	0	0.38	348	41	122
Indian Slough near Brentwood	1010	122	430	2.70	0	0.90	408	43	188	760	155	370	3.00	0	1.18	404	50	196
Old River at Orwood Bridge	607	86	290	0.60	0	0.16	270	36	110	221	117	180	0.80	0	0.18	334	40	110
Rock Slough near Knightsen	685	107	300	0.80	0	0.20	269	11	123	300	53	220	0.60	0	0.24	302	53	123
Old River at Holland Tract	804	96	280	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Old River at Mandeville Island	578	81	220	0.50	0	0.12	217	40	95	232	106	170	0.90	0	0.09	165	46	92

[a] Average of all available data from Bulletin No. 65, "Quality of Surface Waters".

Measurements at Pittsburg and Martinez show that suspended material was deposited in Suisun Bay at an annual average rate of 10 percent of the average influent concentration, with the greatest deposition occurring in the summer.

Turbidity

The amount of sunlight that can penetrate to a certain depth in surface waters is of concern since water transparency, light penetration, or turbidity, each a measure of the clarity of water, indicate at what depth photosynthetic organisms will survive, how well organic material might be oxidized, or at what depth a submerged object can be seen.

Turbidity was measured in the Delta Cross Channel near Walnut Grove, the San Joaquin River near Vernalis, and in the Delta-Mendota Canal near Tracy.

The maximum turbidity was 95 units in the Delta Cross Channel and 69 units in the San Joaquin River near Vernalis. These values occurred during February. In May, at the Delta-Mendota Canal station, the value was 78. Minimum turbidities occurred at all stations in the late fall or winter, between November and January.

To determine light penetration, measurements were made with a Secchi disc and recorded as depth in inches. Values throughout the Delta were generally 10 to 12 inches. Only the Sacramento River had relatively clear water, with Secchi disc readings ranging from 24 to 33 inches, and averaging about 28 inches.

Water clarity at Martinez was about 30 percent greater than at Pittsburg. The average Secchi disc readings ranged from 8 to 10 inches at Pittsburg, and from 11 to 14 inches at Martinez. Minimums were as low as 6 inches, and maximums were about 20 inches.

Specific Conductance

Specific conductance (EC) in the Delta varied annually, seasonally, and geographically. Annual variations were generally due to changes in Delta inflow. Seasonal changes were caused by variation in streamflow throughout the year and agricultural drainage practices within the Delta. Geographical variations in EC principally resulted from the influence of the Sacramento River, which had a low EC, and the San Joaquin River with a higher EC. The EC downstream from Vernalis generally decreased as the water became mixed with Sacramento River water drawn into the central and western Delta. During winter, when there was practically no demand at the Delta-Mendota Canal, the EC of the area increased because of the absence of better quality Sacramento River water. An area of high EC, in the southern Delta between Vernalis and the Delta-Mendota Canal, was caused principally by the large quantities of agricultural drainage.

Data indicate that the Delta Cross Channel near Walnut Grove had an average of 160 micromhos and the lowest EC for all periods of record. Antioch, on the lower San Joaquin River, which was affected by salinity intrusion, recorded 1,070 micromhos, the highest average reading for the ten-year historic period.

Average monthly specific conductance in the Sacramento River reached a maximum in September because of low river flows and high agricultural drainage waters which occur at that time. A secondary peak during January and February resulted from releases of highly mineralized drainage flows immediately following maximum streamflows in the river. The San Joaquin River near Vernalis recorded maximum conductivity in August and a lesser peak in April. The high in April was due to lower flow in the San Joaquin River, caused by operation of storage reservoirs on major east side streams and agricultural diversions. The high point in August was caused by low summer flows and upstream agricultural drainage. Monthly variations in the summer, at Antioch and Vernalis, were greater during the 1964 supplemental study than during the historic period, partly due to lower than normal flows in the San Joaquin River for this period.

Specific conductance in Suisun Bay was monitored in the 1964 study at Pittsburg and Martinez. An average EC of 5,950 micromhos was recorded at Pittsburg and 19,200 at Martinez. Conductivity generally increases in Suisun Bay from east to west because of salinity intrusion from the ocean.

Total Dissolved Solids

The highest average total dissolved solids (TDS) in the Delta, from 1952 through 1961, was at Antioch. The ten-year average of monthly grab samples was 710 mg/l. An eight-year average, 1954 through 1961, from the USBR recorder at Antioch was 770 mg/l. The lowest average TDS during the 1952-61 and 1962-64 periods occurred in the Sacramento River above Walnut Grove with readings of 110 mg/l.

Monthly TDS, in the spring and early summer, were usually reduced in the southwestern part of the Delta due to the flow of Sacramento River water through the Delta to the Delta-Mendota Canal, when the agricultural drainage was at minimum. The increase of TDS in that area in late summer, when the pumping demand was high, was due to the sharp increase in agricultural drainage within the Delta, and on occasion, a small amount of salinity intrusion. The San Joaquin River near Vernalis had the highest TDS in July, August, and September, when river flows were at minimum. Antioch had the highest TDS in the summer, when flows were low and unable to prevent salinity intrusion. Seasonal trends in TDS were generally the same for historic and present data; differences in magnitude were principally caused by flow changes.

Major Cations

Calcium. Calcium concentrations were found to be lowest at stations influenced by Sacramento River water. Average historical concentrations in the Delta varied from a minimum of 13 mg/l, to a maximum of 40 mg/l. The minimum concentration was found in the Delta Cross Channel near Walnut Grove, and the maximum concentration was found in Old River near Tracy. The present three-year average varied from 12 to 47 mg/l. The minimum and maximum concentrations were found again near Walnut Grove in the Delta Cross Channel and in Old River near Tracy.

Magnesium. The concentration of magnesium in the Delta varied from an average ten-year low of 7.2 mg/l, to an average ten-year high of 24 mg/l. The station at Antioch on the lower San Joaquin River showed the highest average concentration, and the minimum was found in the Delta Cross Channel near Walnut Grove. The three-year present period had a variation in magnesium concentrations from 22 to 6.7 mg/l. The high was found at Old River near Tracy, and the low was found at Rio Vista on the Sacramento River. The San Joaquin River at Antioch averaged 54.7 mg/l for July, August, and September. Because sea water salts are about four percent magnesium, these high readings indicate the effect of salinity intrusion.

Sodium. The sodium concentration in the Delta varied from an average ten-year minimum of 6.9 mg/l measured in the Calaveras River near Stockton to an average ten-year maximum of 164 mg/l at Antioch. The high three-year present average of 106 mg/l was also observed at Antioch, and the low three-year average of 6.6 mg/l was found in the Calaveras River.

In the northern Delta, stations affected by Sacramento River water generally measured less than 20 mg/l of sodium. The stations along the San Joaquin River decreased from an average of about 80 mg/l near Vernalis, to about 50 mg/l at Rindge Island. The two stations along Old River averaged from 47 to 93 mg/l for all periods of record. These high values were probably caused by agricultural return drainage. The San Joaquin River near Antioch had a high in sodium concentration during July, August, and September. The average for these months was 455 mg/l. The high concentrations indicate salinity intrusion during the summer.

Major Anions

Bicarbonate. The variation in bicarbonate concentrations within the Delta, for the historic period, average 174 mg/l in Indian Slough near Brentwood, to 72 mg/l in Little Potato Slough at Terminous. The three-year present average varied from a high of 191 mg/l in Indian Slough to a low of 66 mg/l in Little Potato Slough. Agricultural return flow was the predominant influence in the southern Delta area. The concentration in Little Potato Slough was lower than in the Delta Cross Channel, thereby indicating that waters of the Mokelumne River were lower in bicarbonate than the waters of the Sacramento River.

TABLE 8

SUMMARY OF MAJOR CATIONS AND ANIONS
IN SACRAMENTO-SAN JOAQUIN DELTA

Station	Cation Concentrations in milligrams per liter																	
	1952 - 1961									1962 - 1964								
	Calcium			Magnesium			Sodium			Calcium			Magnesium			Sodium		
	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]
Sacramento River at Freeport	18	14	16	10	6.7	8.4	21	3.8	11.7	15	9.6	13	8.4	4.3	6.9	17	2.7	10.4
Delta Cross Channel near Walnut Grove	20	6	13	11	3.1	7.2	24	1.6	11.4	14	10	12	9.6	3.8	7.1	17	2.7	9.8
Lindsey Slough near Rio Vista	24	11	15	19	6.5	9.8	32	8	17	23	14	16	18	6.8	10.4	44	14	20.3
Sacramento River at Rio Vista	88	8.8	14	12	4.3	7.6	26	5.4	12	16	9.6	13	8	4.7	6.7	18	4.6	11.6
San Joaquin River at Antioch	61	8	20	138	3.2	23.8	1050	7.1	164	55	11	19	38	5.8	20	532	13	106
San Joaquin River near Vernalis	75	7.5	33	43	2.3	15	204	8.7	77	50	16	36	25	5.8	15	180	13	76
San Joaquin River at Mossdale Bridge	67	7.2	38	44	2.4	17.5	190	6.9	73	67	7.2	38	25	4.1	16	151	8.4	80
San Joaquin River at Garwood Bridge	54	8.4	30	23	2.5	13.3	152	9.2	67	47	10	32	17	4.0	14	151	9.3	66
Calaveras River near Stockton	26	13	21	9.2	4.7	8.0	8.6	5.0	6.9	26	20	23	8.3	7.8	8	11	3.6	6.6
Stockton Ship Channel at Rindge Island	50	9.2	26	22	1.5	12.6	107	12	51	35	16	25	15	6.8	11.6	99	12	53
Little Potato Slough at Terminous	24	5.2	15	12	3.4	8.0	32	3.3	14.5	16	9.6	14	9.2	4.6	7.3	18	5.5	13
Grant Line Canal Tracy Road Bridge	64	18	39	30	7.9	18.9	174	35	89	62	9.6	43	30	3.6	19	149	10	83
Old River near Tracy	67	9.2	40	37	3.2	18.5	171	12	82	66	12	47	32	5.4	22	160	14	93
Delta Mendota Canal near Tracy	54	10	25	23	2.9	12.9	136	15	63	45	16	22	23	7.9	11.4	175	13	58
Old River at Clifton Court Ferry	52	9	24	23	3.3	12.1	121	12	56	41	15	20	20	6.9	11.1	154	12	47
Italian Slough near Mouth	51	9.3	23	22	3.5	11.8	148	13	56	39	10	19	13	4.0	9.3	198	13	59
Indian Slough near Brentwood	75	6.4	30	44	4.7	18.8	250	17	90	65	16	26	41	7.3	16.6	206	18	89
Old River at Orwood Bridge	55	10	22	27	3.3	11.9	109	11	52	20	12	15	16	6.3	8.9	164	13	44
Rock Slough near Knightsen	53	9.2	22	29	1.2	13.0	171	13	54	20	15	18	15	4.5	9.7	110	14	49
Old River at Holland Tract	--	--	--	--	--	--	240	8.5	45	--	--	--	--	--	--	--	--	--
Old River at Mandeville Island	38	11	19	18	3.9	10.6	135	11	39	16	11	15	12	4.5	8.2	76	9.9	32

Station	Anion Concentrations in milligrams per liter																	
	1952 - 1961									1962 - 1964								
	Bicarbonate			Sulfate			Chloride			Bicarbonate			Sulfate			Chloride		
	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]
Sacramento River at Freeport	121	53	78	13	12	13	15	3.8	8.5	106	26	72	13	5	9.7	12	2.5	7.4
Delta Cross Channel near Walnut Grove	123	33	73	19	4	11	20	1.3	8.9	102	31	70	19	6	10.3	15	1.4	7.1
Lindsey Slough near Rio Vista	160	56	97	25	11	16	29	0.1	13.6	170	68	104	34	10	18.3	37	8.3	16
Sacramento River at Rio Vista	164	43	78	18	3.1	11.5	21	3.1	9.5	107	33	75	33	8.8	17	15	4.2	9.2
San Joaquin River at Antioch	130	35	78	294	7	51	1950	8	262	190	52	78	79	14	40	968	16	173
San Joaquin River near Vernalis	222	32	124	77	4.2	41	435	8	123	200	40	122	82	21	47	259	19	109
San Joaquin River at Mossdale Bridge	224	32	125	115	4.9	49	289	9	113	191	38	126	76	6	48.8	289	9.0	113
San Joaquin River at Garwood Bridge	208	37	127	61	5.8	21	233	11	96	204	40	119	49	7.4	27	237	12	90
Calaveras River near Stockton	119	60	102	20	6	11.5	11	4	7.5	136	32	86	12	11	12	12	1.5	6.6
Stockton Ship Channel at Rindge Island	198	42	104	98	7.6	29.1	158	14	76	204	40	104	33	13	30	154	16	75
Little Potato Slough at Terminous	127	28	72	21	2.4	10.9	52	5.5	22.2	101	27	66	12	7	8.3	38	7.6	17
Grant Line Canal Tracy Road Bridge	208	67	146	77	27	57	292	52	153	216	39	131	75	7	52	235	12	160
Old River near Tracy	232	38	135	107	9.1	53	315	17	126	216	43	150	91	16	67	288	19	146
Delta Mendota Canal near Tracy	186	39	106	71	13	33	208	22	92	205	36	99	68	25	34	252	15	75
Old River at Clifton Court Ferry	182	40	100	79	10	33	192	14	82	187	39	90	54	22	28	236	16	68
Italian Slough near Mouth	151	39	95	41	11	25.9	232	16	85	176	40	95	64	12	29	326	19	85
Indian Slough near Brentwood	370	50	174	78	17	39	312	19	125	386	47	191	106	22	41	212	21	110
Old River at Orwood Bridge	166	42	92	132	7.7	37	220	14	76	160	34	86	29	15	21	234	17	63
Rock Slough near Knightsen	146	36	97	46	14	26	295	15	80	140	53	94	43	17	24.8	184	18	67
Old River at Holland Tract	--	--	--	--	--	--	349	15	70	--	--	--	--	--	--	--	--	--
Old River at Mandeville Island	194	42	85	68	1	28	237	11	55	106	30	80	41	11	20.2	122	12	44

[a] Average of all available data from Bulletin No. 65, "Quality of Surface Water".

Sulfate. Sulfate concentration in the Delta varied from an average of 10.9 mg/l at Terminous in Little Potato Slough, to 57 mg/l in Grant Line Canal near the Tracy Road Bridge. The maximum present average of 67 mg/l was found in Old River near Tracy, and the minimum of 8.3 mg/l was in Little Potato Slough. The average concentration in the San Joaquin River near Vernalis was between 40 and 50 mg/l, which was 10 mg/l lower than concentrations in Old River near Tracy, indicating the influence of local irrigation.

Chloride. Calaveras River near Stockton had the lowest average chloride concentration, 7.5 mg/l, for the historic period of record. The high average concentration of 262 mg/l was found at Antioch. During the present period the low average, 6.6 mg/l was also in the Calaveras River. The high average for the present conditions, 173 mg/l, was at Antioch. Results of the June-November 1964 study showed the same general trends of high and low concentrations, over 1,000 mg/l at Antioch and 20 mg/l in the Sacramento River near Walnut Grove. The concentrations which were observed in the 1964 study were higher than average because the sampling was done primarily during the period of low flows and maximum agricultural returns.

Monthly values of Cl and EC in the Sacramento River generally were maximum during February and September. February maximums were caused by operation of upstream agricultural drains; September maximums by minimum river flows and general agricultural practices. The seasonal variation in the San Joaquin River near Vernalis was much the same for EC and Cl. Like EC, Cl was the highest during August at Antioch, due to salinity intrusion. Present and historic seasonal trends in average Cl concentrations were generally the same. Lower values for the present period were caused by higher than normal river flows in 1963, which somewhat impeded salinity intrusion. Concentrations found during the 1964 sampling were higher than average because the net flow past Antioch was upstream in the summer of 1964.

The chloride concentrations in Suisun Bay, determined during the investigation by the University of California, varied from an average of 1,200 mg/l at Pittsburg, to 6,650 mg/l at Martinez. The average concentrations found in 1964 at Martinez and Pittsburg were 7,780 and 2,570 mg/l.

Boron

The highest average boron concentration for the historic period was measured in Indian Slough near Brentwood at 0.90 mg/l. Indian Slough was also highest for the present period, with an average concentration of 1.18 mg/l. The high surface water boron concentration in this area was caused by irrigation drainage from ground water with high boron concentration. The lowest average concentration, 0.06 mg/l, for the historic period was at the Delta Cross Channel. The minimum for the present period, 0.03 mg/l was in the Sacramento River at Freeport. The average concentration throughout the Delta was less than 0.30 mg/l, except in the Indian-Italian Slough area.

Total Hardness

Total hardness in the Delta, reported as $CaCO_3$, varied from an average minimum of 58 mg/l in the Sacramento River near Freeport, to an average maximum of 188 mg/l in Indian Slough near Brentwood. The lowest average concentration of 57 mg/l during the present period was measured in the Delta Cross Channel. The highest present average was 197 mg/l observed in Old River near Tracy.

The water at the three stations in the Sacramento River and Little Potato Slough, can be considered soft because the highest average concentration was only 69 mg/l. San Joaquin River water is considered moderately hard to hard. It has an average concentration of 150 mg/l at Vernalis, and 118 mg/l in the Stockton Ship Channel at Rindge Island. The Grant Line Canal and Old River near Tracy had concentrations of 170 and 197 mg/l. The central Delta, influenced by the Sacramento River water as it travels to the Delta-Mendota Canal, is considered moderately hard because concentrations were near 100 mg/l.

Water in the San Joaquin River at Antioch was high in hardness during July, August, and September. Total hardness concentrations in Indian Slough, Rock Slough, and Italian Slough were high during the winter. These three sloughs also had high concentrations of calcium, magnesium, and bicarbonate during the winter.

Mineral Characteristics

Studies of the interrelationships of surface water mineral quality in the Delta were based primarily upon an evaluation of a large amount of existing data on inflows, agricultural drainage, salinity intrusion, and base-exchange capacities of suspended solids. An analysis of the mineral characteristics often indicates the source of the water found in a particular channel. Historical data were studied to determine areal distribution of water types, seasonal variations of mineral concentrations, the effect of fresh water-sea water interchange, and base-exchange reactions and related phenomena.

Physical and chemical data already presented were used to develop correlations among seven separate constituents and specific conductance at 34 stations in the Delta. These correlations indicate water types, seasonal and geographic variations of perimeter inflow qualities, influence of quality degrading forces, and general distribution of individual chemical characteristics related to the total dissolved mineral content.

Numerical values of the correlations can be applied to present and future conditions when flow distributions are known. For example, when correlation ratios are known, measurements of EC can be used to estimate concentrations of Ca, Mg, Na, Cl, SO_4, hardness, and TDS. These data make it possible to establish a reasonably complete monitoring program for mineral constituents based only on EC measurements.

Sacramento River water was determined to be of a typically calcium-magnesium-bicarbonate type, while San Joaquin River and western Delta waters were of a sodium-sulfate-chloride type. The effect of each river system on Delta hydraulics can be evaluated by noting the influence of each type of water on the different areas in the Delta and having a knowledge of the chemical components of the various waters.

The general composition of the waters of the Delta indicates that Sacramento River water influences southern and southwestern channels from April through July. During that period, Sacramento River waters also influence the central Delta at Mandeville and Orwood when salts from the San Joaquin River and the bay are not predominant.

To define the tidal diffusion processes, tidal cycle measurements have been made and analyses conducted to determine the extent of salinity intrusion in the Delta channels.

Data from the coordinated USBR-DWR four-day chloride sampling program show that before Shasta Dam was in operation, chlorides usually intruded to Antioch in concentrations of 1,000 mg/l or higher for approximately 28 percent of each year. Subsequent to operation of Shasta Lake the period of intrusion was reduced to 15 percent of each year.

Ratios of constituents to various counterpart cations, or anions, can be used to characterize water types and movements. The ratio of calcium to magnesium equivalents per million (epm) for natural inland surface waters range from about five to as low as one. The calcium-magnesium ratio of sea water is approximately 0.20. Therefore, a low value for this ratio theoretically indicates salinity intrusion.

The Ca/Mg ratios in the Delta ranged from 1.5 to 1.0 and were generally lowest during the period of maximum intrusion, August through October. Maximum intrusion usually occurs during August. As would be expected, data indicate that ratios were lowest at Antioch, 0.36 to 0.80.

Pesticides

The use of pesticides during the last 20 years has made possible increased production of food, higher quality foodstuffs, reduction in livestock losses, improved control of disease-carrying insects, broader protection of forests and desirable plant growth, and a more comfortable way of life. At the same time, data resulting from studies of specific pesticide eradication and control programs show evidence of increasing environmental contamination from pesticide residue.

In 1960, a special committee reported to the Governor on the public policy regarding agricultural chemicals. The committee stressed the beneficial role of pesticides in California's agricultural development, but also pointed out some of the hazards associated with the use of these materials.

Pesticides are found in practically every segment of man's natural surroundings. They have been detected in surface and ground waters, soils, air, many food items, clothing, fish and animals. Undesirable side effects have resulted at times from pesticide applications to farm lands, forests, lakes and urban areas, including: fish kills, reduction in game bird population, contamination of edible foodstuffs, and poisoning of game animals.

The characteristics that make pesticides useful and effective also make them potentially dangerous. Most of the pesticides are highly toxic in concentrated amounts. They are designed to kill or upset the metabolism of living organisms. Chlorinated hydrocarbons are resistant to biodegradation and tend to become concentrated in food chain organisms.

During this investigation, practically every type of surface water was analyzed for pesticide materials. Rivers, lakes, bays, estuaries, irrigation diversions, and agricultural drains were sampled at various locations throughout the State. Average MCH_t (maximum total chlorinated hydrocarbons) were generally below 0.30 ppb (parts per billion) in the streams and bays, and varied between 0.30 and 1.00 ppb in canals and drains.

Concentrations of thiophosphates were not sufficient for qualitative detection at most of the surface water stations. Some thiophosphate insecticides were found in agricultural drains.

Within the immediate area of investigation for this study, the Sacramento-San Joaquin Delta, 145 pesticide samples were collected and analysis showed pesticide concentrations ranging from 2.70 ppb to 0.02 ppb, with an average MCH_t of 0.18 ppb. Table 9 shows pesticide concentrations in various portions of California.

Weekly samples collected at Vernalis and Walnut Grove indicated that MCH_t concentrations were about 70 percent higher in the San Joaquin River. Definite seasonal trends were observed at both stations with summer values approximately 2.5 and 4 times as high as winter values in the Sacramento and San Joaquin rivers.

Thiophosphate concentrations averaged 0.01 ppb at Walnut Grove and 0.04 ppb at Vernalis. These residues were first detected in March 1964 and persisted until September 1964. Thiophosphates were not detected during the winter at either station.

TABLE 9

PESTICIDE CONCENTRATIONS IN CALIFORNIA
OCTOBER 1963 - DECEMBER 1964

Source of Samples	Number of Samples	Maximum total chlorinated hydrocarbons, in ppb		
		Maximum	Minimum	Average
Central Valley Streams	35	1.09	0.02	0.18
Central Coastal Streams	13	0.60	0.06	0.19
Sacramento-San Joaquin Delta	145	2.70	0.02	0.18
San Francisco Bay System	30	0.70	0.03	0.15
Lakes in California	22	0.70	0.04	0.21
Central Valley Canals	37	0.30	0.02	0.11
Imperial Valley Canals	19	0.90	0.03	0.36
Agricultural Surface Drains	64	7.20	0	0.86
Tile Drainage (San Joaquin)	14	3.00	0.05	0.60
Tile Drainage (Imperial)	11	0.35	0.08	0.14
Bottom Sediments	59	1460	trace	220

Persistence and Occurrence in Sediments. Sediment samples were collected at a number of stations in the San Francisco Bay system, the San Joaquin Valley, and the Imperial Valley.

Because different percentages of dry material were encountered, special attention was placed on the method of reporting concentrations. At the laboratory, the samples were extracted and chromatographed, and concentrations were reported as parts of pesticide per billion parts wet sediments. A representative fraction of the sample was dried and the moisture content determined. The concentrations were then calculated as parts per billion parts dry sediment. The sediment samples contain many times the concentration of the surrounding waters, with results ranging from 1460 ppb to a trace, with an average of 220 ppb.

Preliminary investigation of the samples and results indicated that the chlorinated hydrocarbon pesticide concentrations were somewhat related to the sediment particle size. The highest concentrations were generally found in the mucks and highly organic materials, while the lowest values were associated with larger grain sizes, such as fine to coarse sands, and other inorganic materials.

TABLE 10

PESTICIDE CONCENTRATIONS IN FISH SAMPLES (SPECIES CORVINA) FROM SALTON SEA[a] AUGUST - SEPTEMBER 1964

Age group years	Size: Length in inches	Size: Weight in lbs	Crude fat in percent	Total chlorinated hydrocarbon pesticides in ppb
I	12.0	0.7	3.03	36
II	17.5	1.8	1.35	147
III	18.0	2.0	1.10	840
III	20.0	2.5	2.30	568

[a] Total derived by summation of concentrations of individual compounds.

TABLE 11

PESTICIDE CONCENTRATIONS IN ORGANISMS FROM SUISUN BAY[a] OCTOBER 1964

Sample organism	Approximate age in years	Crude fat in percent	Total chlorinated hydrocarbon pesticides in ppb
Plankton (net)[b]	-	0.58	30
Shrimp[c]	1	2.0	60
Anchovy fry[c]	<1	2.1	330
Anchovy[c]	2-3	4.8	1,340
Pond smelt[c]'	1-2	8.7	1,040
Starry flounder[c]	2	3.4	710
American shad[c]	<1	4.5	920
Striped bass			
Flesh 1	2	0.9	490
Flesh 2	3-4	4.7	1,030
Entrail fat 2	3-4	69	22,580
Carp			
Flesh	4-6	7.5	2,950
Eggs		3.9	360

[a] Total derived by summation of concentrations of individual compounds.

[b] Net used was 20 mesh.

[c] Composite samples.

Residual Concentrations in Aquatic Organisms. A sampling program was conducted in Suisun Bay and in the Salton Sea to determine pesticide concentrations.

Fish samples were collected from the Salton Sea and from Suisun Bay. Small fish, shrimp, and net plankton were composited by age group and species to form a sample large enough for analysis. Fish tissue and eggs were obtained from larger individuals and analyzed separately.

Because thiophosphate compounds are readily metabolized to compounds that cannot be detected by the analytical techniques used, only two fish samples were examined to determine if non-metabolized thiophosphates were present. None were detected.

Results of analyses of aquatic organisms sampled from the Salton Sea and Suisun Bay are shown in Tables 10 and 11.

From the limited number of samples analyzed there was some association of concentrations with the age and size of the fish, and as previously documented, analysis showed that there is a tendency for successive concentration of chlorinated hydrocarbons in higher food chain organisms. The listing order from plankton to striped bass, as shown in Table 11, shows the successive positions within the food chain. There is an apparent relationship between concentration and position, and between concentration and the age of the organism.

Nitrogen and Phosphorus

While concentrations of nitrate in domestic water supplies are of public health significance, the primary interest in concentration levels of nitrogen and phosphorus in surface waters concerns their role in providing food for aquatic life. Both are essential for the growth of lower forms of organisms and hence are fundamental to the nutrition of fish.

Nitrogen and phosphorus constituents were determined from the Department's surface water quality program and these data were supplemented by a special sampling program conducted during this investigation so that the total series could be evaluated. Nitrogen compounds occur in water in four forms, each of which should be measured to get a true picture of the total nitrogen content. In the supplemental work, the individual constituents of organic, ammonia, nitrite, and nitrate nitrogen were determined. In the case of phosphorus, water samples were analyzed for ortho, poly, organic, and total phosphate and were reported as phosphate.

Nitrogen. The progression of normal events causes concentrations of nitrogen, present in the organic form, to be converted first to ammonia, then to nitrite and finally to nitrate. In waters containing relatively recent pollution, nitrogen will be present in the organic and ammonia forms.

For comparison, data have been grouped into three categories: historic, 1952 through 1961; present, 1962 through 1964; and supplemental, which includes data from a sampling program conducted as part of this investigation during the summer and fall of 1964. All values are reported as nitrogen.

The highest average concentration of nitrate during the historic period, 2.5 mg/l, occurred in the Stockton Ship Channel at Rindge Island. The lowest average value of nitrate, 0.4 mg/l, occurred in the Sacramento River at Freeport. The inflow at Vernalis had an average concentration of 1.8 mg/l. Downstream in the San Joaquin River, concentrations increased to 2.1 mg/l at Garwood Bridge and to 2.5 mg/l in the ship channel. The Sacramento River water mixed with the San Joaquin River water before it reached Antioch and reduced the average concentration to 1.0 mg/l at Antioch.

The export water at the Delta-Mendota Canal contained an average nitrate concentration of 1.3 mg/l during the historic period. The influence of Sacramento River water being transported across the Delta to the Tracy pumps was noticeable as the nitrate concentration at the Delta-Mendota Canal was lower than in Old River at Orwood Bridge.

Phosphorus. Average concentrations of orthophosphate for May and September, from 1952 through 1961, and 1961 through 1964, were analyzed. From these data, it was determined that the general level of orthophosphate throughout the Delta from 1952 through 1961 was between 0.20 and 0.40 mg/l.

The maximum average concentration of orthophosphate, 0.99 mg/l, occurred during the historic period at Garwood Bridge. The minimum average value of 0.17 mg/l occurred at Antioch. The maximum concentration was probably caused by the Stockton treatment plant discharge which contained an average of 12.0 mg/l of phosphate. The minimum value was a result of the aquatic organisms' metabolization of the phosphate as it moved through the Delta. This is indicated by the decrease in concentration in the San Joaquin River water as it continues past Stockton.

During the 1962-1964 period, the maximum average orthophosphate was 1.10 mg/l at Garwood Bridge. The high value was again the result of wastes discharged in the Stockton area. Minimum average for the present period in the Delta was 0.10 mg/l at the Mandeville Island station.

TABLE 12

NITRATE AND ORTHOPHOSPHATE IN SACRAMENTO-SAN JOAQUIN DELTA
HISTORIC AND PRESENT

Station	Milligrams per liter as NO_3 1952 - 1961 Maximum			Milligrams per liter as NO_3 1962 - 1964 Maximum			Milligrams per liter as PO_4 1952 - 1961 Maximum			Milligrams per liter as PO_4 1962 - 1964 Maximum		
	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]	Maximum	Minimum	Average[a]
Sacramento River at Freeport	0.7	0.2	0.4	1.9	0.2	1.0	0.45	0.35	0.40	1.10	0.15	0.42
Delta Cross Channel near Walnut Grove	2.1	0	0.6	2.6	0.3	1.2	0.45	0.20	0.25	0.35	0	0.22
Lindsey Slough near Rio Vista	1.6	0.4	0.8	2.7	0.9	2.1	0.35	0.15	0.24	0.30	0.15	0.25
Sacramento River at Rio Vista	1.7	0	0.6	1.8	0.4	1.0	0.30	0.10	0.18	0.25	0.15	0.22
San Joaquin River at Antioch	6.3	0.1	1.0	5.8	0.2	1.3	0.30	0.10	0.17	0.20	0	0.13
San Joaquin River near Vernalis	6.8	0	1.8	6.6	1.2	3.7	0.55	0.15	0.37	0.60	0.25	0.44
San Joaquin River at Mossdale Bridge	3.7	0	1.2	8.1	0.1	2.7	0.70	0.20	0.43	0.60	0.15	0.31
San Joaquin River at Garwood Bridge	4.7	0.3	2.1	12.0	0.3	5.0	1.90	0.20	0.99	2.40	0.20	1.10
Calaveras River near Stockton	2.5	0	0.8	1.9	1.6	1.8	1.40	0	0.70	0.10	0.05	0.08
Stockton Ship Channel at Rindge Island	14.0	0.3	2.5	3.9	0.3	2.0	1.50	0.20	0.41	1.10	0.25	0.46
Little Potato Slough at Terminous	7.8	0.3	1.0	1.4	0.4	0.9	0.25	0	0.18	0.25	0	0.16
Grant Line Canal at Tracy Road Bridge	3.7	0	1.1	6.6	0.1	2.7	0.55	0.30	0.42	0.60	0	0.31
Old River near Tracy	5.1	0	1.5	8.4	1.9	3.1	0.50	0.25	0.40	0.60	0	0.32
Delta-Mendota Canal Near Tracy	3.0	0.3	1.3	4.3	0.8	1.5	0.30	0.15	0.22	0.50	0	0.24
Old River at Clifton Court Ferry	4.7	0.1	1.3	2.2	0.3	1.1	0.35	0.10	0.21	0.81	0.15	0.34
Italian Slough near Mouth	1.8	0	0.9	7.1	0.5	1.9	0.30	0.10	0.19	0.20	0.03	0.13
Indian Slough near Brentwood	3.7	0.6	1.3	12.0	0.7	3.4	0.25	0.15	0.18	0.20	0	0.13
Old River at Orwood Bridge	13.0	0	1.8	2.5	0.7	1.6	0.25	0.10	0.18	0.69	0.15	0.27
Rock Slough near Knightsen	2.2	0	0.7	2.6	0.8	1.5	0.35	0.10	0.18	0.20	0.15	0.16
Old River at Mandeville Island	8.1	0.3	1.9	3.2	0.7	1.5	1.50	0.10	0.29	0.20	0	0.10

[a] Average of all available data from Bulletin No. 65, "Quality of Surface Waters".

TABLE 13

NITROGEN AND PHOSPHATE IN SACRAMENTO-SAN JOAQUIN DELTA
JUNE 1964 - NOVEMBER 1964

Station	Concentrations in milligrams per liter as nitrogen															Concentrations in milligrams per liter as phosphate								
	Organic - N			(NO_2 - N)			(NO_3 - N)			(NH_4 - N)			Total N in Series			Ortho - PO_4			Organic - PO_4			Total - PO_4		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Stockton Ship Channel near Stockton	1.8	0.1	0.9	.10	.04	.07	1.8	0.3	1.1	.81	.09	.41	2.88	1.81	2.46	.88	.42	.62	.58	.02	.18	1.20	.46	.85
San Joaquin River near Vernalia	1.4	0	0.8	.07	.01	.03	1.4	0	0.7	.36	0	.09	2.16	1.13	1.62	.53	.16	.36	.34	0	.18	.81	.35	.58
Delta-Mendota Canal at Head	0.7	0	0.5	.01	0	0	1.4	0	0.7	.22	0	.06	1.41	.60	1.22	.26	.18	.21	.32	.06	.18	.59	.29	.44
San Joaquin River at Antioch	0.9	0	0.5	0	0	0	5.9	0	1.2	.07	0	.03	5.90	.40	1.72	.24	.05	.16	.23	.03	.12	.54	.18	.34
Suisun Bay at Martinez	1.0	0.4	0.6	.03	.02	.02	1.8	0.1	0.6	.16	.07	.11	2.40	.77	1.38	.39	.17	.25	.33	.06	.16	.57	.24	.42
Sacramento River at Pittsburg	1.0	0.2	0.5	.01	0	.01	1.2	0	0.5	.31	.04	.12	1.46	.68	1.07	.28	.09	.18	.47	.07	.24	.64	.24	.47
Sacramento River at Rio Vista	0.7	0.3	0.5	.01	0	0	0.5	0	0.2	.06	0	.02	1.11	.43	.68	.28	.20	.23	.18	.03	.09	.50	.25	.35
Sacramento River at Walnut Grove	0.6	0	0.3	0	0	0	0.9	0	0.3	.25	0	.10	1.55	.10	.74	.36	.15	.27	.09	.02	.06	.56	.24	.39
San Joaquin River at Jersey Towers	0.8	0.3	0.5	.01	0	0	0.4	0.1	0.3	.42	0	.08	1.62	.51	.87	.26	.08	.16	.12	.01	.07	.37	.12	.27
San Joaquin River at San Andreas Landing	0.7	0.3	0.5	.01	0	.01	0.3	0	0.2	.05	0	.02	1.06	.41	.65	.31	.20	.23	.22	0	.08	.46	.21	.36
Little Connection Slough at Venice Island Ferry	0.7	0.3	0.5	.01	0	0	0.4	0.1	0.2	.03	0	.02	1.13	.51	.76	.26	.19	.22	.10	.01	.06	.38	.25	.33
Turner Cut near Mouth	1.0	0.2	0.6	.04	0	.01	1.7	0	0.7	.33	0	.08	2.73	.28	1.37	.48	.18	.29	.23	.01	.09	.74	.23	.42
Middle River at Victoria Canal	0.7	0.2	0.5	.01	0	0	1.8	0	0.7	.07	0	.02	2.51	.20	1.19	.28	.18	.22	.15	0	.06	.45	.24	.32
Old River at Holland Tract	0.9	0	0.5	0	0	0	0.4	0	0.2	.10	0	.04	1.30	0	.66	.22	.14	.17	.16	0	.10	.41	.21	.32

Data collected on phosphate concentrations during this study included organic and total phosphate as well as orthophosphate. Total phosphate concentrations consist of organic and inorganic constituents. The inorganic form can be further reduced to compounds of polyphosphates and orthophosphates. Polyphosphates hydrolyze in solution and change to the ortho form.

Oxygen Concentrations

Maintenance of desirable fish and aquatic life depends to a significant degree on dissolved oxygen (DO) concentrations. Furthermore, dissolved oxygen contributes to the potability of a domestic water supply, assists in stabilization of organic materials, and enhances recreational activities.

The DO concentrations throughout the Delta are generally good, but there have been localized problem areas. In many sections of the Delta, with the possible exception of the western areas near Antioch, DO levels at various times have approached the 5.0 mg/l minimum concentration recommended for sustaining desirable fish populations. The worst problems have occurred near Stockton in the San Joaquin River and near Tracy in Old River.

Historic data (1952-1961), present data (1962-1964), and supplemental data collected during this investigation display similar trends and temporal fluctuations for most stations in the study area. The greatest deviation between data was found by examining the percent saturation values for the station near Vernalis on the San Joaquin River.

The stations most affected by influent river waters usually have the lowest DO concentrations between August and October. Internal Delta stations display relatively high DO levels during the summer and low DO levels in winter.

The lower DO values observed throughout the internal Delta during the winter could be the result of decreased flows toward the Delta-Mendota Canal, increased agricultural drainage, and reduced photosynthetic oxygen production resulting from the lower water temperatures. The low DO values found at perimeter stations during the fall probably result from lower flows and increased waste loadings from agricultural drains and from cannery wastes discharged from municipal areas.

The most extensive sampling program for biochemical oxygen demand (BOD) concentrations conducted within the Delta was made by personnel of this investigation during 1964.

As with DO values, the 5-day 20°C BOD at Walnut Grove varied with stream flow and waste loadings from the Sacramento treatment plant. Sacramento River inflow to the Delta carried average BOD concentrations of 2.2 mg/l, while San Joaquin River flows had higher concentrations of BOD (almost 5 mg/l). Wastes

TABLE 14

TEMPERATURE AND DISSOLVED OXYGEN
IN SACRAMENTO-SAN JOAQUIN DELTA
HISTORIC AND PRESENT

Station	1952 - 1961									1962 - 1964								
	Temperature °F			Dissolved oxygen						Temperature °F			Dissolved oxygen					
				mg/l			% Saturation						mg/l			% Saturation		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Sacramento River at Freeport	73	45	60	11.5	7.1	9.0	101	79	89	73	42	58	12.2	7.7	9.6	103	73	93
Delta Cross Channel near Walnut Grove	77	44	60	12.2	5.7	9.0	123	63	87	75	42	59	12.3	6.6	9.4	106	73	91
Lindsay Slough near Rio Vista	80	44	61	11.4	6.5	8.8	105	88	71	73	41	60	11.5	5.7	8.9	103	57	89
Sacramento River at Rio Vista	78	43	60	18.8	5.9	9.1	180	63	90	74	46	59	11.0	7.6	9.3	111	78	91
San Joaquin River at Antioch	78	44	62	18.0	7.0	8.7	177	73	89	76	47	62	10.2	7.0	8.5	99	71	87
San Joaquin River near Vernalis	83	45	63	16.2	5.4	10.0	200	62	105	76	45	61	11.0	6.7	9.0	116	71	90
San Joaquin River at Mossdale Bridge	82	44	63	16.8	4.4	9.9	177	51	104	78	47	63	17.5	5.5	10.4	171	60	108
San Joaquin River at Garwood Bridge	82	44	63	13.3	0.5	8.1	143	5	84	79	46	64	12.0	4.0	8.3	137	45	85
Calaveras River near Stockton	78	40	68	10.5	4.0	7.7	114	44	81	75	42	60	14.6	8.0	10.3	120	91	101
Stockton Ship Channel at Rindge Is.	84	43	63	12.5	5.0	8.0	138	48	84	79	46	64	12.0	4.0	8.1	131	60	84
Little Potato Slough at Terminous	77	43	61	10.9	5.1	8.5	102	52	85	73	45	60	10.5	6.3	8.8	104	60	87
Grant Line Canal at Tracy Road Br.	80	44	64	13.3	4.9	9.3	151	60	96	76	46	62	15.7	7.2	9.6	160	69	98
Old River near Tracy	81	44	62	16.0	5.1	8.2	172	44	83	77	46	62	13.9	5.1	9.0	140	46	93
Delta-Mendota Canal near Tracy	80	44	63	13.1	6.2	8.7	123	65	90	76	44	63	10.5	4.3	8.4	114	35	86
Old River at Clifton Court Ferry	82	43	63	12.2	5.7	8.4	117	61	85	77	45	63	10.2	6.4	8.2	107	59	85
Italian Slough near Mouth	84	45	64	13.3	6.1	8.2	139	63	85	78	40	63	10.3	6.6	8.0	113	60	82
Indian Slough near Brentwood	83	46	64	16.1	5.3	8.2	129	66	83	78	48	64	13.5	5.6	8.4	148	58	87
Old River at Orwood Bridge	79	43	62	10.6	6.2	8.2	99	65	83	78	46	62	10.2	6.7	8.0	94	68	82
Rock Slough near Knightsen	81	44	63	11.9	4.5	7.6	108	52	78	81	44	63	10.0	6.1	7.7	95	64	78
Old River at Mandeville Island	81	43	61	11.0	6.1	8.7	100	67	88	77	45	62	10.8	7.4	8.8	105	70	90

[a]Average of all available data from Bulletin No. 65, "Quality of Surface Waters".

from the vicinity of Stockton added oxygen demand to the river flows, and resultant concentrations of BOD were 4.4 and 1.4 mg/l in the ship channel near Stockton and Turner Cut. Throughout the remaining areas of the Delta, BOD concentrations were generally between 1.0 and 1.3 mg/l.

Values near Pittsburg and Martinez indicated that significantly large organic loadings were being discharged into the receiving waters. On the average, concentrations increased from 1.0 mg/l at Antioch to 1.9 at Pittsburg and 2.3 at Martinez.

Digital Computer Simulation of Delta Mineral Quality

A mathematical model of the Delta channel system and an electronic digital computer were used to determine mineral quality relationships.

The water quality solution was based on the hydraulic solution in which net flows in each Delta channel were computed for given conditions of Delta inflows, export pumping, internal water use, and projected Peripheral Canal operation.

Mineral data collected since 1952 show that generally significant changes have not occurred within the Delta and present (1962-64) quality characteristics are not much different from historic (1952-61) conditions. Because no major physical changes have occurred to alter the natural hydraulic conditions throughout the Delta, the results of the 1955 digital computer solution for water quality basically represent present conditions.

Data Application and Program Evaluation. Mineral qualities of perimeter inflows of the Sacramento, San Joaquin, Mokelumne and Calaveras rivers were determined from historic data and relationships were developed for flow vs total dissolved solids (TDS). Relationships were subsequently checked with 1955 data to verify the accuracy of the general concept and were essentially found to be consistent for all ranges of conditions with maximum deviation at the lower flows.

Concentrations of minerals in Delta agricultural return drainage for 1955, were determined by a study of drainage from the Delta lowlands. Quality data on municipal and industrial waste discharges throughout the Delta were taken from Department records and information provided by the Regional Water Quality Control Boards.

Since present surface water qualities were known, the purpose of the program was to determine present hydraulics and provide data with which to define the ability of the model to reproduce Delta quality conditions.

Three distinct hydraulic and water quality conditions were simulated through the model and are shown on Figures 25, 26, and 27. The periods, January-February, July, and August of 1955 were chosen to provide a range of conditions that could be checked against prototype data. Twenty-four stations, selected for evaluation without regard for location, were used to make a comparison of model and prototype TDS concentrations. The only criteria used for station selection were availability and adequacy of prototype data.

The most consistent comparisons were obtained at stations where continuous, or at least long-term, records had been maintained. The input flow calculations, based on mean monthly conditions were more consistent with mean monthly qualities than with short-term or grab sample results.

The January-February data show that 50 percent of the results of the model simulation compare favorably with prototype values. The remaining stations are less consistent because of the inability of the model to reproduce prototype mixing patterns and inadequacy of prototype sampling results. In simulating July conditions, the model reproduced about two-thirds of the prototype qualities.

For prolonged salinity intrusion, mineral concentrations in the western Delta approach steady-state levels. These levels generally reach a maximum in August or September when ocean salts continue to move upstream as Delta outflows are reduced. This situation becomes quite apparent when comparing the results for August. Approximately 60 percent of the stations sampled in the prototype in August 1955 were influenced by salinity intrusion. Except for results from one station affected by poor flow distribution, data indicated consistent comparisons at the remaining sampling stations.

The data show that while the model did not simulate the salinity intrusion that occurs during periods of low or reverse flows near Antioch, excellent agreement was obtained in areas of positive net flow downstream where tidal diffusion of ocean salts was either nonexistent or slight.

Water Quality Degradation

Degradation of water quality occurs through both natural and man-made processes. The life cycle of aquatic organisms, surface water runoff from cities and forested areas, sediment transport by flood water flows, biochemical cycles, and contamination by highly mineralized surface or ground waters, all contribute to the transformation of good quality water into water unsuitable for one or more beneficial uses. Sources of degradation throughout the area of the investigation primarily include municipal, industrial, and agricultural wastes, salinity intrusion, and connate waters.

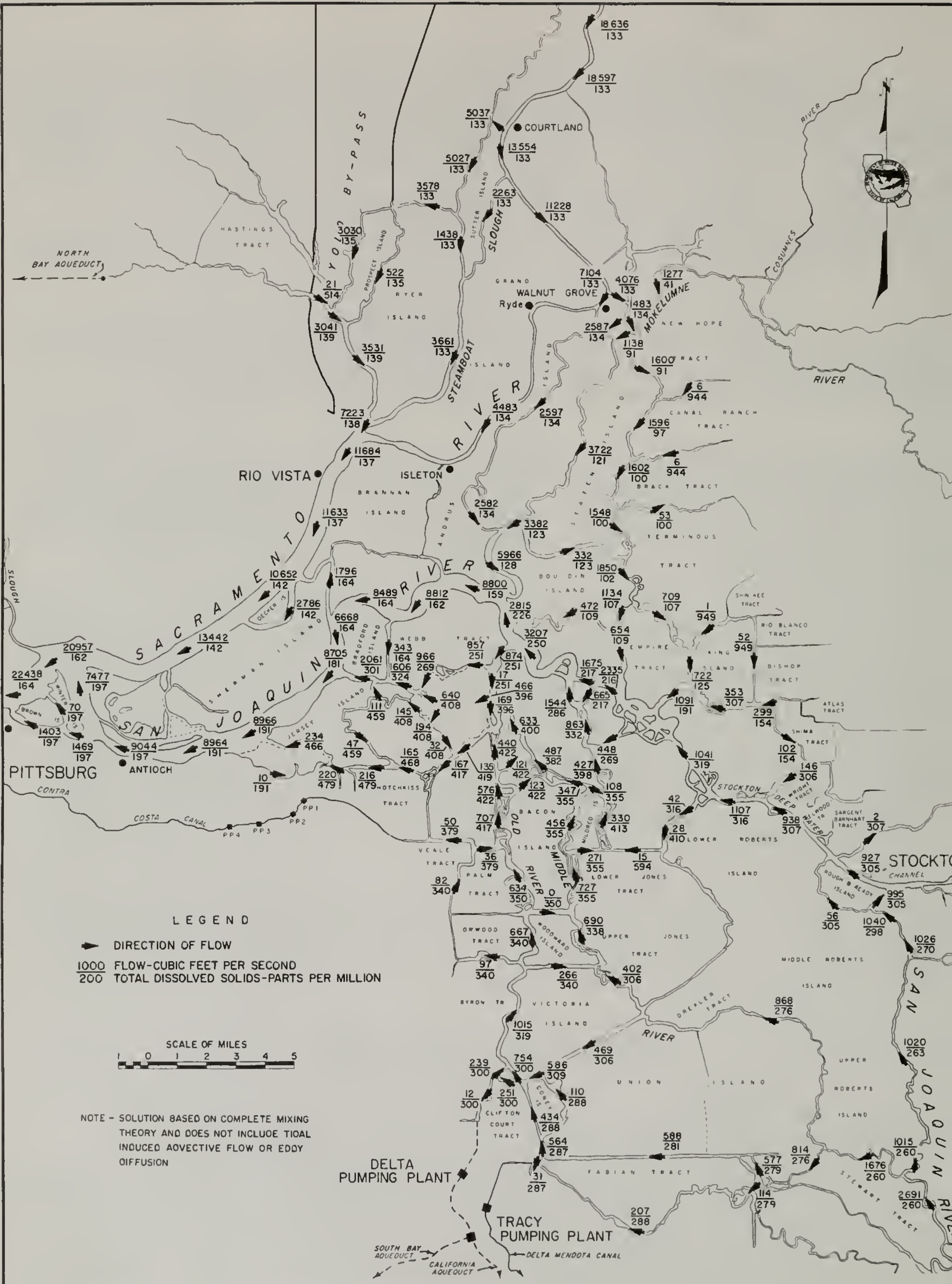


Figure 25. DIGITAL COMPUTER SIMULATION OF JAN-FEB 1955 DELTA WATER QUALITY

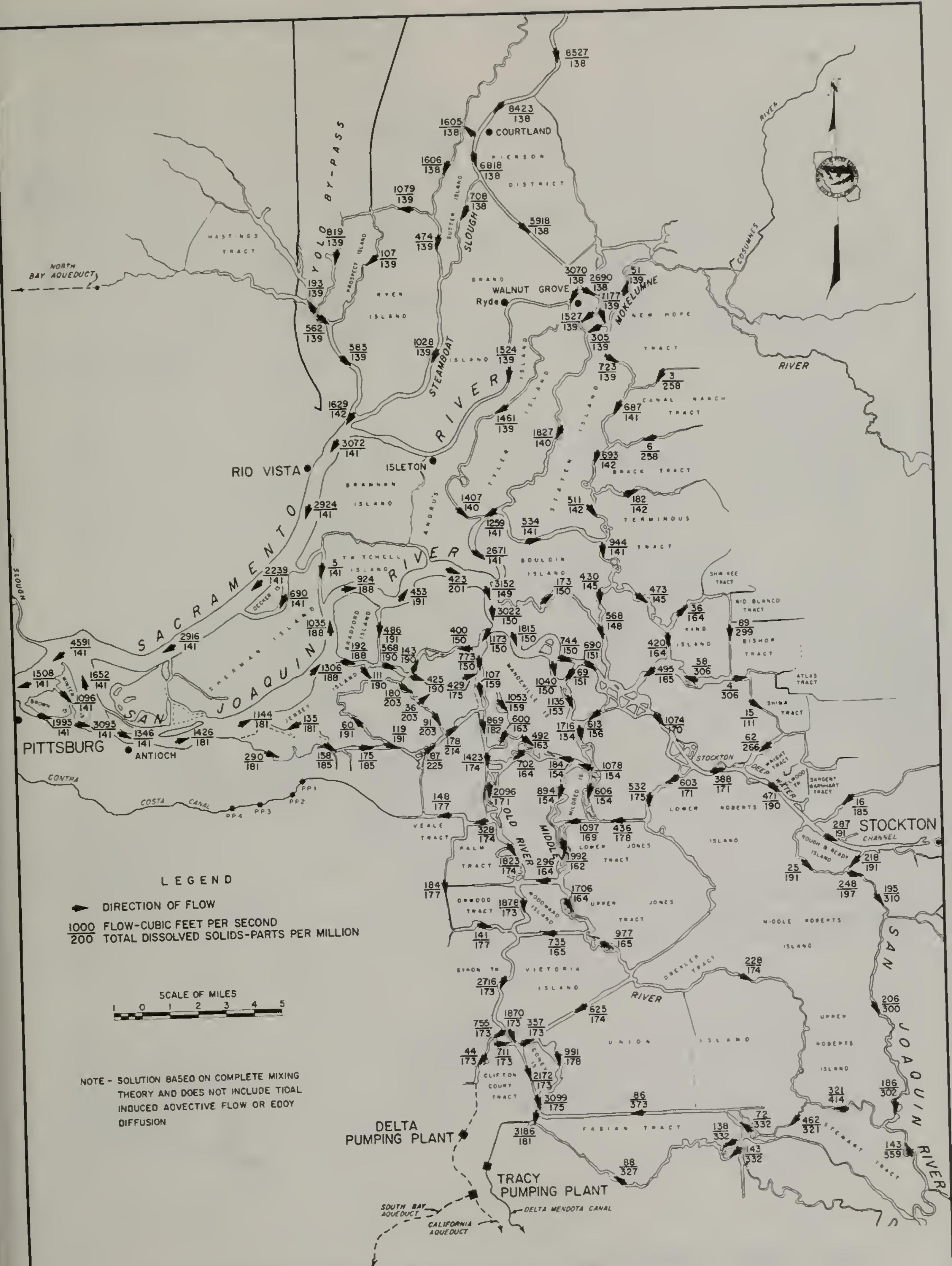


Figure 26. DIGITAL COMPUTER SIMULATION OF JULY 1955 DELTA WATER QUALITY

Figure 27. DIGITAL COMPUTER SIMULATION OF AUGUST 1955 DELTA WATER QUALITY

Municipal and Industrial Wastes

Waste waters resulting from a population of approximately 1,500,000 and their places of employment and associated supporting industries, are discharged into the surface waters of the Delta and Suisun Bay. These discharges are presently a primary source of water quality degradation. Their analysis and evaluation provide the basis on which predictions can be made to determine the quantities and qualities of future wastes.

The area of investigation was divided into four smaller areas, the boundaries of which were established on the basis of local geography, hydraulics, and location of waste discharges. These areas are illustrated in Figure 28.

Available data for present conditions were collated and a best value of several different constituents was determined for each discharge. Wastes vary because treatment methods, loadings, and controls are all subject to change based on new techniques, seasonal variations, and local pollution problems. The best value selected represents average conditions and should be used accordingly.

Wherever data for major discharges were not available, estimates were made using acceptable average discharge characteristics. Projections of future conditions were based on growth factors for both population and industries. In view of the variation in possibilities, future treatment methods and efficiencies were not estimated. Projections are based on present treatment practices.

Recreation Activities. There are about 100 small resorts and boat harbors scattered throughout the Delta. The resorts range in size from a boat dock to a 175 unit hotel with swimming pool and restaurant. A slightly larger than typical resort may have a bar and restaurant for 25 people. Many Delta resorts use septic tanks which discharge directly into the water. Because of the wide distribution of resorts, the discharge normally has little detrimental effect on the Delta, although water in the immediate vicinity of a resort may have a high coliform count, indicating a degree of pollution.

It is estimated that by 1995, use of the Delta for recreation will increase from the present 2,800,000 visitor days, to almost 8,000,000. It is expected that waste loadings associated with these visitors will continue to be distributed over a large area and only very localized problems are likely to occur.

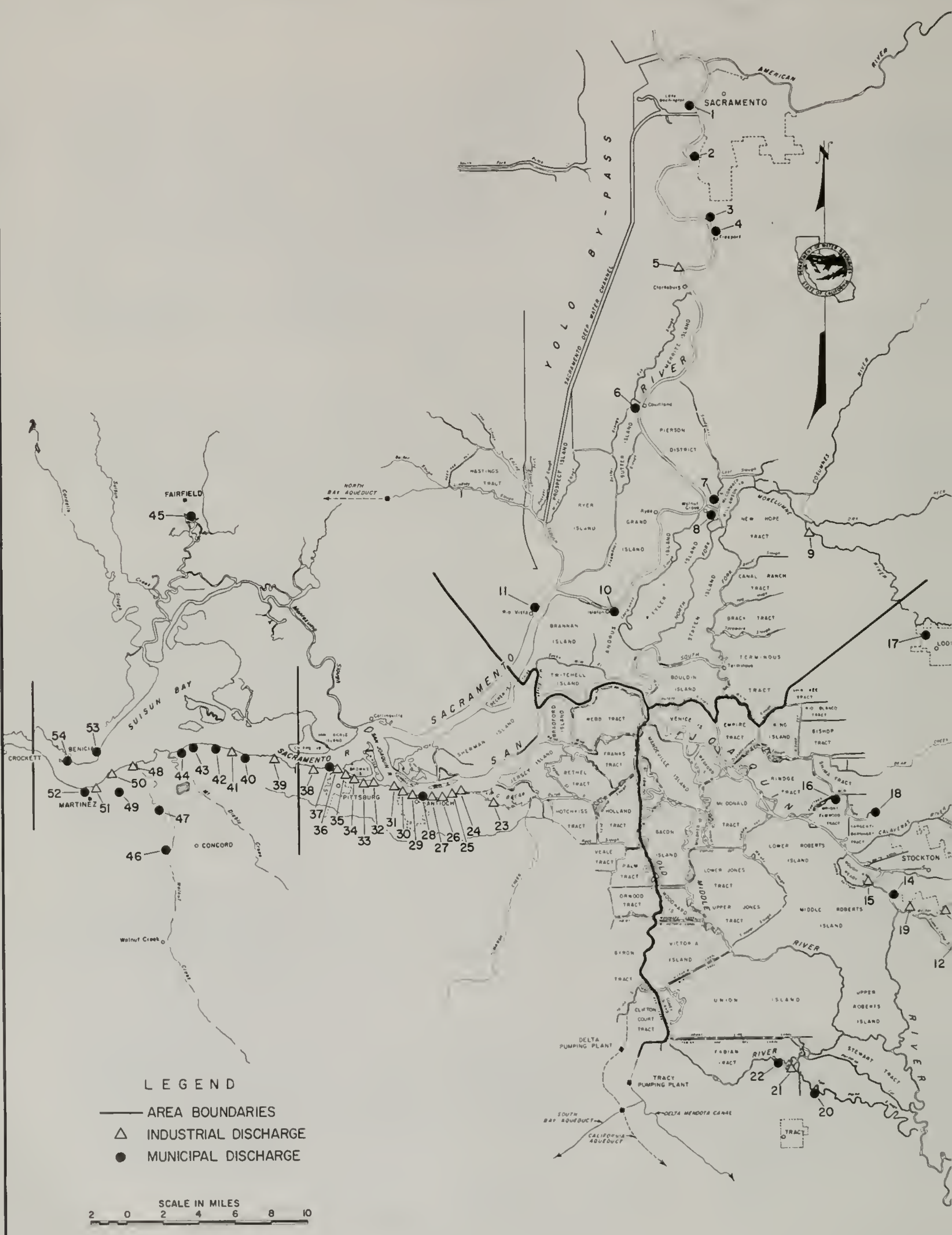


Figure 28. LOCATION OF MUNICIPAL AND INDUSTRIAL WASTE DISCHARGES TO THE DELTA AND SUISUN BAY

Processing of Asparagus. There were approximately 140 asparagus packing sheds in the Delta in 1960, with about 130 of them located in the southeastern area. Butts and culls, trimmed from asparagus, are ground and discharged directly into Delta water channels, agricultural drains for later pumping into these channels, or are spread on the land. Because of seasonal fluctuations and a lack of reliable information regarding the waste quantity and quality, these packing sheds were not included in the waste projections.

Asparagus wastes discharged to land created no water quality problem. Wastes discharged into agricultural drains were difficult to evaluate because the material often remained in the drains for periods as long as one month. During this time the drains act as stabilization ponds and wastes are partially oxidized before being pumped into the Delta channel. At least seven packing sheds ground the waste and discharged directly into Delta channels for a few weeks in April and May during the 1963 packing season. Calculations indicate that a tremendous BOD loading was placed on the surface waters; however, no detrimental effects were noted.

Quantities and Qualities of Present Waste. The results of the inventory of total wastes discharged in various areas by the different municipal and industrial entities are summarized in Table 15. Of the 54 discharges throughout the area of investigation, 32 are located in the western Delta or Suisun Bay. The City of Sacramento is the largest single discharger.

The Sacramento Southeast Sewer Assessment District has not been included in this inventory. Their treatment plant began discharging approximately two cfs late in 1963 and no quality data were available. Tertiary treatment is provided by the plant and an estimate of 1,000 pounds per day of BOD, or less than two percent of the present loading in the northern Delta, seems reasonable.

The Thornton Canning Company, with a flow of up to 4.6 cfs during the canning season (July to October) is a major discharger in the northern Delta. Cannery wastes flow through 27 acres of ponds, then through drainage ditches to the Mokelumne River at New Hope Landing. Percolation and evaporation affect the effluent quantity and quality.

Channel hydraulics greatly limit the waste assimilative capacity of the southeastern Delta making this area of special concern. It has the highest degree of sewage treatment. The City of Stockton discharged an average of 20 mgd, or over 68 percent of the total waste volume discharged within the area. The Stockton treatment plant afforded secondary treatment, plus oxidation ponds, and reported more than a 95 percent removal of BOD. In the southeastern Delta, an estimated average overall BOD removal rate of 89 percent was maintained. Present treatment methods are ineffective, however, in reducing the nitrogen content of sewage and this is of major concern.

TABLE 15

MAJOR MUNICIPAL AND INDUSTRIAL WASTE DISCHARGES IN DELTA AND SUISUN BAY

Map No.[a]	Name	Type of Waste	Flow (mgd)	Flow (cfs)	BOD (mg/l)	BOD (lb/day)	Treatment
Northern Delta							
1	West Sacramento Sanitary District	Municipal	1.8	2.8	150	2,300	Primary, plain aeration, chlorination
2	City of Sacramento	Municipal	55.0	85.1	140	64,000	Primary, chlorination
3	Meadowview Sewer Treatment Plant	Municipal	0.2	0.3	140	230	Primary, chlorination
4	Sacramento SE Sewer Assessment District	Municipal	--	--	--	--	Secondary, ponds
5	American Crystal Sugar Company	Industrial	3.5	5.4	400	12,000	
6	City of Courtland[b]	Municipal	0.1	0.2	260	200	Assumed 50% septic tanks, 50% none
7	City of Locke[b]	Municipal	0.02	0.1	260	40	Septic tanks
8	Walnut Grove[b]	Municipal	0.04	0.1	260	90	Septic tanks
9	Thornton Canning Company	Industrial	--	--	--	--	Ponds
10	City of Isleton	Municipal	0.13	0.2	70	80	Primary
11	City of Rio Vista	Municipal	0.24	0.4	80	160	Primary
		Total	61.0	94.6		79,100	
Southeastern Delta							
12	Sharpe General Depot[b]		0.2	0.3	50	85	Secondary, chlorination
13	Stockton Airfield[b]		0.04	0.1	--	30	
14	City of Stockton	Municipal	20.0	30.9	29	4,840	Trickling filters, ponds
15	Naval Supply Depot[b]		0.3	0.5	10	25	Imhoff tanks
16	Lincoln Village, Pacific Garden	Municipal	1.1	1.7	110	1,010	Ponds
17	City of Lodi	Municipal	3.0	4.6	--	--	Activated sludge, ponds, land discharge
18	Stockton Northwest Plant	Municipal	1.0	1.6	--	--	Primary, ponds
19	Libby Owens Ford	Industrial	0.1	0.2	--	--	Secondary
20	Tracy Devel Vocational Institute[b]		0.5	0.8	50	210	Trickling filters, ponds
21	Tracy, Industrial Waste Disposal	Industrial	1.5	2.3	150	1,880	Primary ponds
22	City of Tracy	Municipal	1.5	2.3	30	380	Trickling filters, ponds
		Total	29.2	45.3		8,460	
Western Delta							
23	E. I. duPont	Industrial	0.6	0.9	38	190	Primary, ponds
24	PG&E Contra Costa Steam Plant	Industrial	cooling water only				
25	Fibreboard Pulp Mill, S.J. Div.	Industrial	18.8	29.1	200	31,400	Primary
26	Crown-Zellerbach Co., Inc.	Industrial	16.3	25.2	80	10,900	Chemical precipitation
27	Kaiser Gypsum Co., Inc.	Industrial	0.4	0.6	--	--	
28	City of Antioch	Municipal	1.1	1.7	185	1,700	Primary, chlorination
29	Hickmott Canning Company	Industrial	1.4	2.2	25	300	Screening
30	Fibreboard Board Mill, Antioch Div.	Industrial	5.5	8.5	140	6,400	None
31	Western California Canners, Inc.	Industrial	2.6	4.0	160	3,500	Screening
32	Ethyl Corporation[c]	Industrial	0.5	0.8	16	70	Clarification
33	Dow Chemical Company	Industrial	26.0	40.2	4	870	Clarification, ponds
34	Pioneer Rubber Company, H. K. Porter	Industrial	0.9	1.4	8	60	None
35	U.S. Steel, Columbia Geneva Div.	Industrial	18.8	29.1	20	3,100	Clarification, ponds
36	Johns Mansville Corporation		1.8	2.8	256	3,850	Partial screening
37	City of Pittsburg	Municipal	1.4	2.2	110	1,300	Activated sludge
38	PG&E Pittsburg Steam Plant	Industrial	cooling water only				
		Total	96.1	148.7		63,640	
Suisun Bay							
39	Shell Chemical Corporation	Industrial	12.8	19.8	20	2,150	Clarification, ponds
40	Contra Costa County Sanitation Dist. 7a	Municipal	1.0	1.6	190	1,600	Primary, chlorination
41	Allied Chemical Corp., General Chem. Div.	Industrial	3.8	5.9	6	190	Sedimentation, pH control
42	Port Chicago, Bay Point, Sewer Maintenance District[b]	Municipal	0.5	0.8	260	1,100	None or septic tanks
43	Rivercrest Sewer Maintenance District[b]	Municipal	0.2	0.3	260	450	Combined with C.C.C.S.D. No. 7a
44	Clyde Corporation[b]		0.1	0.2	260	220	Imhoff tank
45	Fairfield-Suisun Sewer District	Municipal	1.5	2.3	100	1,250	Primary, chlorinator
46	City of Concord	Municipal	3.7	5.7	35	1,100	High rate trickling filters, ponds, chlori
47	Central Contra Costa	Municipal	8.3	12.8	90	6,200	Activated sludge, chlorination
48	Tidewater Oil Company	Industrial	40.0	61.9	65	21,700	Primary (skim-sed.)
49	Mountain View Sanitary District	Municipal	1.0	1.6	116	970	Trickling filter, chlorination
50	Mountain Copper Company	Industrial	0.03	0.1	2	1	Sedimentation, pH control
51	Shell Oil Company	Industrial	2.0	3.1	260	4,340	Septic tank, sedimentation, pH control
52	City of Martinez	Municipal	1.0	1.6	150	1,250	Chemical precipitation, primary, chlorinat
53	Benicia Arsenal[d]	Industrial	0.4	0.6	100	330	None
54	City of Benicia	Municipal	0.4	0.6	120	400	Primary, chlorination
		Total	76.7	118.9		43,251	

a See Figure 28.
b Estimated values.
c Closed in November 1963, not in projections of future discharges.
d Operation, reduced, not used in projections.

Dischargers in the western Delta represent a variety of industries, thus a variety of wastes. The major contributor of BOD was Fibreboard Products, with a daily discharge of approximately 31,400 pounds or nearly 50 percent of the total loading in the area.

Two thermoelectric plants in the western Delta discharged only cooling water. Although the thermal pollution caused by discharging cooling water has not been considered in this report, the steam-electric power industry is often cited to illustrate the prospective danger of thermal loading, since the installed capacity of that industry tends to double approximately every decade. Besides the problem of thermal loadings created by thermoelectric plants, the possibility of discharge of large quantities of phosphate compounds, widely used in steam power plants to control scaling in boilers, should be considered.

Ten municipal and six domestic waste treatment plants discharge an average of about 120 cfs into Suisun Bay. Tidewater Oil Company, with a flow of 62 cfs and a BOD loading of 21,700 pounds per day, discharges 50 percent of the total loading in the area. The company removed about 35 percent of the BOD in its waste by skimming and sedimentation. Overall BOD removal in the area was approximately 43 percent.

The total municipal and industrial waste discharged in the study area is summarized in Table 16. Local water supplies in the western Delta and Suisun Bay are of lesser quality and have a direct influence on the resulting quality of the discharge.

Delta Agricultural Drainage

Drainage problems currently exist on many islands in the Delta lowlands because of seepage from adjacent channels. Seepage, together with tailwater from field application, is collected and conveyed from the fields by extensive systems of drainage ditches. Since the land elevation of many of the Delta islands is below the channel water level, pumps are required to lift the drainage water into the Delta channels.

Generally, each island or tract in the Delta has one or more drainage systems. Small drain laterals lead to larger main drains which terminate at the pumping plants. The plants are usually float-actuated between predetermined water levels in the main drains, and water is pumped intermittently into the adjacent channels.

Fertilizers and Pesticides. Although Delta soils are considered very fertile, they are gradually becoming less so with time. Fertilizers are used to maintain a high rate of agricultural production, and calcium and zinc are occasionally added to the soil.

TABLE 16

ESTIMATED 1960 MUNICIPAL AND INDUSTRIAL CONSTITUENTS DISCHARGED WITHIN THE DELTA AND SUISUN BAY

Constituent	Constituents in 1,000 pounds per day				
	Northern Delta	Southeastern Delta	Western Delta	Suisun Bay	Totals
Flow (cfs)	94.6	45.3	148.7	118.9	407.5
Solids					
TDS	218	188	1,240	2,260	3,906
Settleable	---	---	---	11	---
Total suspended	49	12	134	41	236
Volatile suspended	---	---	64	21	---
BOD					
Present treatment	79	8	64	43	194
Raw, prior to treatment	123	77	101	76	377
COD (Chemical Oxygen Demand)	190	---	230	195	---
Grease and oil	19.0	2.7	3.0	13.0	37.7
Total hardness	78	46	230	430	784
Alkalinity					
HCO_3	130	73	92	90	385
CO_3	---	---	---	---	---
Nitrogen					
Organic	5.1	1.5	0.8	2.4	9.8
NH_3	7.4	3.1	2.2	17.6	30.3
NO_3	0.5	1.0	0.8	0.5	2.8
Total	13.0	5.6	3.8	20.5	42.9
ABS	2.0	0.5	---	0.6	---
Chloride	38	53	340	600	1,031
Phosphate	8.0	2.6	0.9	4.6	16.1

Pesticides, perhaps more important than fertilizers in the Delta, are used extensively to prevent, control, or eliminate nuisance organisms. Soil fumigants are used to rid the soil of worms and root-infesting pests. Insecticides are used on foliage to prevent and eliminate leaf-eating insects and fungi. Herbicides and crude oil are used extensively to control weeds.

Seasonal applications of both fertilizers and pesticides reach a maximum during the spring and summer. In 1964, a total of 5,600 tons of fertilizer compounds were applied to 340,000 acres in the Delta. About 50 percent were distributed in April. More than 200 tons of pesticides were applied the year round, with maximum applications from April through August when 87 percent of the total annual quantity was distributed.

Present Drainage Study. In 1964, a special study was made of agricultural drainage in the Delta to determine present quantities and qualities of return flow. The field study was selective, rather than exhaustive, and was conducted from July through November. Figure 29 shows the location of each study unit and sampling station.

Pump installations sampled represented only seven percent of the 200 pump installations in the Delta. However, they accounted for the drainage from 20 percent of the irrigated land (73,400 acres).

After selecting the study units, a crop survey was made. Samples of drainage were collected biweekly for field determination of temperature, pH, EC, transparency (Secchi disc), DO, and chloride. Power meter readings for each pump installation were obtained to estimate drainage quantities and monthly samples were collected at 13 pump installations for laboratory analyses for nitrogen and phosphate series, TDS, and BOD. Results of field measurements are expressed on Tables 17, 18, and 19.

Drain flows, computed from power meter readings, indicate that more water per acre is drained from organic soils than from mineral soils. Conditions of pumping from the drains varied from intermittent pumping on Grand Island, composed mostly of mineral soils, to constant and high rate pumping on Staten Island, composed almost entirely of organic peaty soils.

Quality of Drainage. Although the maximum organic and nitrate nitrogen (NO_3-N) concentrations were uniformly distributed among the drains, the average organic concentration was higher than the average nitrate concentration in most drains. During the study period the predominant nitrogen form that was pumped into the Delta channels was organic. This may indicate that most of the surplus organic nitrogen moved through the soil

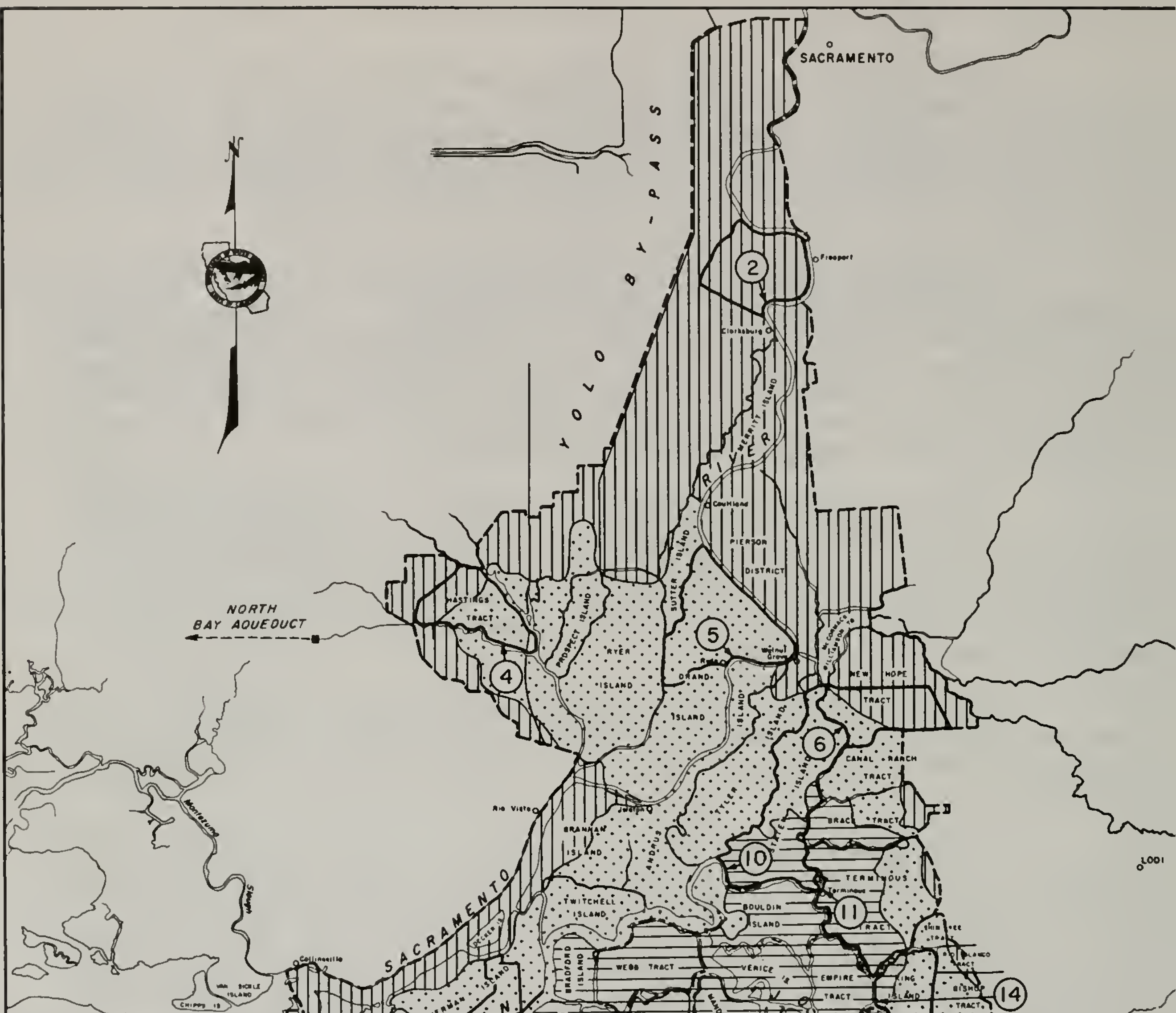


Figure 29. COMPOSITION AND DISTRIBUTION OF SOILS IN THE SACRAMENTO SAN JOAQUIN DELTA LOWLANDS

and was drained before it had mineralized to other forms. Drainage from Roberts Island and Terminous Tract, had higher nitrate concentrations. They are also the largest of the 13 study units. A large drainage canal on Sherman Island, where the pumping was intermittent also had higher nitrate concentrations. The intermittent pumping may have allowed the organic nitrogen to change to a mineral form, due to high retention time in the drainage canal.

Total nitrogen concentrations in the drains depended on crops grown, amount of fertilizer used, leaching practices, soils, type of drainage, and size of individual farms.

TABLE 17

AGRICULTURAL ACREAGE AND QUANTITY OF AGRICULTURAL DRAINAGE FOR JULY-NOVEMBER 1964 STUDY

Map No[a]	Station	Agricultural Acreage	Quantity of flow-AF/month Maximum	Minimum	Average
2	Clarksburg	5,560	330	70	160
5	Grand Island at Ryde	7,850	1,790	0	770
6	New Hope Tract	3,970	1,760	370	1,080
10	Staten Island	8,440	3,910	2,650	3,380
11	Terminous Tract	9,650	4,520	1,340	3,020
4	Hastings Tract	4,320	310	70	250
16	Sherman Island	3,510	700	280	530
14	King Island	2,860	1,430	460	1,000
22	Roberts Island at Whiskey Slough	9,860	2,290	930	1,560
24	Roberts Island at Burns Cut	8,810	---	---	---
27	Union Island	1,420	---	---	---
28	R. D. 2058 at Paradise Cut	4,460	420	20	240
30	R. D. 1007 near Old River	2,710	680	70	430

a Map No. refers to Figure 29.

TABLE 18

NITROGEN AND PHOSPHATE CONCENTRATIONS IN DELTA AGRICULTURAL DRAINAGE

JULY 1964 - NOVEMBER 1964

Station	Concentrations in milligrams per liter as nitrogen														
	Organic - N			(NO_2-N)			(NO_3-N)			(NH_4-N)			Total N in series		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Clarksburg	0.8	0.3	0.6	0	0	0	0.4	0	0.2	0.10	0	0.02	1.20	0.40	0.77
Grand Island at Ryde	2.1	0.4	0.7	0.01	0	0	1.8	0	0.5	0.45	0	0.07	3.35	0.71	1.57
New Hope Tract	0.9	0.1	0.6	0.01	0	0	2.1	0.1	0.5	0.40	0	0.09	2.80	0.51	1.21
Staten Island	4.9	0.1	2.1	0.03	0.01	0.02	4.4	0.3	1.3	1.50	0	0.54	9.84	0.45	3.89
Terminous Tract	2.6	0.3	1.2	0.03	0.01	0.02	7.7	0.1	1.5	0.36	0	0.13	10.64	0.66	2.80
Hastings Tract	2.2	0.6	1.2	0.02	0	0	3.7	0.1	0.9	0.22	0	0.06	5.20	1.00	2.14
Sherman Island	2.2	0.6	1.4	0.22	0.03	0.07	3.9	0.4	1.6	1.40	0.27	0.71	7.32	1.81	3.76
King Island	5.6	0.5	1.8	0.22	0	0.05	5.1	0.1	1.0	0.73	0	0.21	11.65	0.96	3.06
Roberts Island at Whiskey Slough	1.8	0.3	1.2	0.04	0.02	0.02	6.5	0.8	2.5	0.47	0	0.21	8.77	2.12	3.87
Roberts Island at Burns Cut	6.9	0.6	2.1	0.10	0	0.03	2.5	0.2	1.1	1.00	0.04	0.31	7.33	1.92	3.52
Union Island	1.6	0.2	1.2	0.03	0	0.01	3.0	0.1	1.0	0.17	0	0.04	4.60	0.81	2.15
R.D. 2058 at Paradise Cut	3.5	0.3	1.9	0.05	0	0.02	2.2	0.3	0.9	1.40	0	0.20	6.35	0.92	3.02
R. D. 1007 at Old River	2.4	0	1.7	0.10	0.02	0.04	1.6	0.1	0.7	4.10	0.11	1.12	6.10	1.98	3.58

Station	Concentrations in milligrams per liter as phosphate											
	Ortho-PO_4			Poly-PO_4			Organic-PO_4			Total PO_4 in series		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Clarksburg	2.80	0.20	1.05	0.63	0.01	0.16	1.70	0	0.37	5.13	0.21	1.58
Grand Island at Ryde	2.40	0.29	0.95	0.40	0	0.07	1.20	0	0.30	4.00	0.29	1.32
New Hope Tract	0.66	0.20	0.38	0.17	0	0.07	0.21	0.02	0.12	1.04	0.22	0.57
Staten Island	0.44	0.12	0.23	0.10	0	0.04	0.35	0.04	0.18	0.89	0.16	0.45
Terminous Tract	0.36	0.19	0.26	0.11	0	0.05	0.30	0.06	0.22	0.77	0.25	0.53
Hastings Tract	0.72	0.34	0.50	0.28	0.01	0.14	0.60	0.06	0.29	1.60	0.41	0.93
Sherman Island	2.10	0.20	0.59	1.10	0	0.24	0.70	0.03	0.33	3.90	0.23	1.16
King Island	0.85	0.31	0.44	0.20	0.02	0.08	0.48	0.03	0.24	1.53	0.36	0.76
Roberts Island at Whiskey Slough	0.62	0.12	0.27	0.98	0	0.18	3.40	0.04	0.58	5.00	0.16	1.03
Roberts Island at Burns Cut	1.80	0.38	0.67	2.70	0	0.44	0.50	0.01	0.25	5.00	0.39	1.36
Union Island	1.20	0.18	0.42	2.20	0	0.45	0.90	0	0.38	4.30	0.18	1.25
R.D. 2058 at Paradise Cut	0.56	0.13	0.35	1.04	0.01	0.23	1.00	0.11	0.34	2.60	0.25	0.92
R. D. 1007 at Old River	2.10	0.83	1.48	0.77	0.10	0.30	1.10	0.20	0.51	3.97	1.13	2.29

TABLE 19

QUALITY OF DELTA AGRICULTURAL DRAINAGE
JULY-NOVEMBER 1964

Station	pH			Specific conductance micromhos at 25° C			Total dissolved solids mg/l			Chloride mg/l		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Clarksburg	8.10	7.10	7.62	2,010	140	845	1,150	110	542	500	20	195
Grand Island at Ryde	7.30	6.80	7.03	716	225	381	402	160	272	72	32	46
New Hope Tract	7.40	6.98	7.14	660	270	428	430	165	285	160	48	91
Staten Island	6.90	6.48	6.69	1,360	320	720	1,050	158	563	256	72	133
Terminous Tract	7.50	6.70	7.10	941	360	556	545	238	369	220	68	117
Hastings Tract	7.78	7.18	7.47	622	255	384	355	189	250	52	36	43
Sherman Island	7.50	6.72	7.05	2,150	819	1,495	1,290	512	865	680	168	421
King Island	7.75	6.84	7.27	1,460	380	879	929	228	576	340	88	181
Roberts Island at Whiskey Slough	7.60	6.32	6.91	1,280	420	837	757	400	600	232	96	170
Roberts Island at Burns Cut	7.67	7.10	7.34	1,770	700	1,062	1,060	478	719	368	132	227
Union Island	7.38	6.90	7.18	1,360	640	1,175	827	714	776	328	160	279
R.D. 2058 at Paradise Cut	7.76	7.30	7.50	1,960	1,250	1,597	1,250	910	1,083	444	292	377
R.D. 1007 at Old River	8.00	7.40	7.67	6,170	1,800	3,359	4,490	1,750	2,794	1,192	468	697

Station	5-day BOD mg/l			Dissolved oxygen mg/l			Dissolved oxygen % Saturation			Temperature °F		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Clarksburg	7.7	2.2	3.8	9.5	5.4	7.1	90	60	75	78	47	67
Grand Island at Ryde	6.5	1.5	3.3	5.6	0.7	3.5	63	06	38	70	46	63
New Hope Tract	3.3	1.8	2.4	6.5	0.4	4.3	69	05	45	71	50	63
Staten Island	3.9	1.5	2.3	5.7	0.6	3.5	63	06	37	70	50	64
Terminous Tract	5.0	1.0	2.4	8.4	4.0	5.7	79	42	59	72	48	63
Hastings Tract	4.4	2.2	3.4	8.5	4.3	6.6	85	47	69	71	50	63
Sherman Island	15.0	2.5	6.3	8.4	2.7	4.9	93	33	53	78	52	66
King Island	9.1	0.4	4.3	6.8	0.9	5.1	65	09	52	70	50	63
Roberts Island at Whiskey Slough	8.2	1.6	3.2	6.2	3.4	5.0	65	40	52	74	46	63
Roberts Island at Burns Cut	5.7	3.5	4.2	8.6	3.3	5.3	79	35	54	78	52	64
Union Island	14.0	1.9	5.6	7.3	1.2	3.5	61	14	35	72	45	63
R.D. 2058 at Paradise Cut	8.3	1.6	6.0	9.0	3.8	6.4	92	42	65	74	45	63
R.D. 1007 at Old River	9.1	5.2	7.2	11.4	1.1	5.5	122	12	56	74	47	63

Except for two discharges, the drainage waters of the units studied were alkaline and pH values were usually above 7.10. Mineral concentrations of drainage water, as represented by EC, TDS, and Cl were lowest in the northern Delta and highest in the southern and western Delta. These trends undoubtedly result from the influence of the quality of supply waters.

The BOD concentrations imposed on the receiving waters by the agricultural drainage were approximately two to four times the BOD of the surface waters. The BOD of the drainage was generally 0.5 to 1.5 times the DO concentration. When BOD values are much less than the DO in the same drainage water, an appreciable oxygen demand can be imposed on the surface waters; therefore, when the BOD is equal to, or higher than, the available DO, the oxygen demand on the receiving waters will be increased further.

Oxygen demand is especially important considering the aquatic metabolism resulting from the nutrients in the drainage. The range of DO values found reflects the influence of algae on the oxygen concentrations. Large ranges indicate that the resultant respiration probably requires up to five times the amount of available oxygen.

The metabolic imbalance of the aquatic communities, as shown by large diurnal variations in DO concentration, was greatest in the drainage from RD 1007, indicating that when the relatively sterile but highly mineralized tile drainage was discharged into an open ditch, the biomass production increased sharply.

Records from a continuous recorder at the discharge installation on Staten Island show a trend similar to that observed in drains of the central Sacramento Valley. When consumptive use is high, during July and August, the drainage is primarily tailwater. In the winter salts are leached out of the soils and the dissolved minerals reach a maximum.

Seasonal and Areal Variations in Drainage Quality. Data obtained during the five-month study in 1964, were compared with the results of a study conducted in 1954 and 1955. From the comparison, and from the continuous electrical conductivity measurement of drainage from Staten Island, extrapolations were made to represent waste water for an entire year.

Seasonal concentrations of TDS, Cl, and N during 1964 appear reasonably consistent and indicate that the poorest quality water was discharged during the winter months. Nitrogen estimates were based on comparisons with annual data from Sacramento Valley drains of similar size and character.

TABLE 20

AVERAGE SEASONAL QUANTITIES OF DELTA AGRICULTURAL DRAINAGE, 1964

Delta Area[a]	Quantities in 1,000 pounds per day											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Northern												
Flow (cfs)	330	190	160	180	230	340	460	380	190	140	220	340
TDS	1530	930	680	600	520	330	490	500	340	460	710	1520
Cl	490	300	220	200	150	70	170	140	70	130	200	500
BOD	9.0	5.9	4.5	4.1	4.7	5.7	6.2	4.6	2.7	3.0	4.9	8.8
N	7.8	4.9	3.5	3.0	2.5	1.5	3.0	2.3	2.2	2.1	4.5	7.9
Western												
Flow (cfs)	260	120	120	160	120	160	180	160	110	100	130	240
TDS	1250	680	680	830	420	390	540	580	320	310	340	1030
Cl	480	240	230	280	150	150	260	250	130	120	100	370
BOD	7.2	3.7	3.6	3.6	2.5	3.6	2.4	1.9	1.6	2.1	3.3	6.2
N	6.8	3.5	3.6	3.8	2.2	2.0	2.3	2.5	1.5	1.7	2.7	4.9
Southeastern												
Flow (cfs)	1000	380	260	280	470	660	700	660	410	270	420	840
TDS	4640	1960	1410	1540	2180	2420	2540	3050	2220	1760	3200	3780
Cl	1560	660	480	520	740	810	950	990	690	560	980	1270
BOD	41.8	16.8	10.8	10.7	15.3	18.1	15.6	13.2	10.6	11.4	9.9	26.3
N	23.8	10.2	7.3	7.9	11.4	11.7	13.3	7.8	7.6	5.8	7.4	19.6
Totals												
Flow (cfs)	1590	690	540	620	820	1160	1340	1200	710	510	770	1420
TDS	7420	3570	2770	2970	3120	3140	3570	4130	2880	2530	4250	6330
Cl	2530	1200	930	1000	1040	1030	1380	1380	890	810	1280	2140
BOD	58.0	26.4	18.9	18.4	22.5	27.4	24.2	19.7	14.9	16.5	18.1	41.3
N	38.4	18.6	14.4	14.7	16.1	15.2	18.6	12.6	11.3	9.6	14.6	32.4

[a] Refer to Figure 28 for boundaries.

Table 20 presents the average flow, TDS, Cl, BOD, and N presently being discharged in the Delta. Examination of the data shows that the drainage waters discharged in the south-eastern Delta were of poorest quality.

Salinity Intrusion

Whenever bodies of fresh water intersect tidally influenced bodies of saline water, salinity intrusion occurs. By definition, salinity intrusion is the invasion of sea water into tidal estuaries or channels by tidal action. The three basic factors governing the extent to which sea water will intrude into an estuary and the rate of advance and retreat of the slinity are the quantity of outflow from the estuary, the shape of the estuary, and the tidal action.

The annual intrusion of saline water from the Pacific Ocean into the Delta channels usually occurs in the late summer, earlier during dry years, and causes significant water quality degradation. The extent of intrusion varies with the total inflow from tributary surface streams. The combined discharge of the Sacramento and San Joaquin rivers when in flood can flush out Suisun Bay and freshen San Pable Bay.

A chloride concentration of 1,000 mg/l is generally used as an indicator of salinity intrusion. In recent years the effect of the operation of Shasta and Folsom reservoirs has been significant. In the dry summer of 1955 it was estimated that if Central Valley Project reservoirs had not existed, chloride concentrations of 1,000 mg/l or greater would have affected nearly as much of the Delta as was affected in 1931, when the water suppl for 74 percent of the Delta was made unusable by salinity intrusio Figure 30 shows the extent of salinity intrusion in the Delta for several years.

Ground Water and Connates

Ground water samples were not collected during this investigation. A literature search provided the information necessa for evaluation of the extent to which subsurface waters might infl the quality characteristics of the Delta surface waters.

During April and May 1956, a subsurface exploration of Bouldin Island was conducted. Results showed that Cl concentratio ranged from 520 mg/l at a depth of 28 feet, to 1350 mg/l at 173 fe Artesian aquifers were found at depths of 80 feet and contained 300 mg/l chlorides.

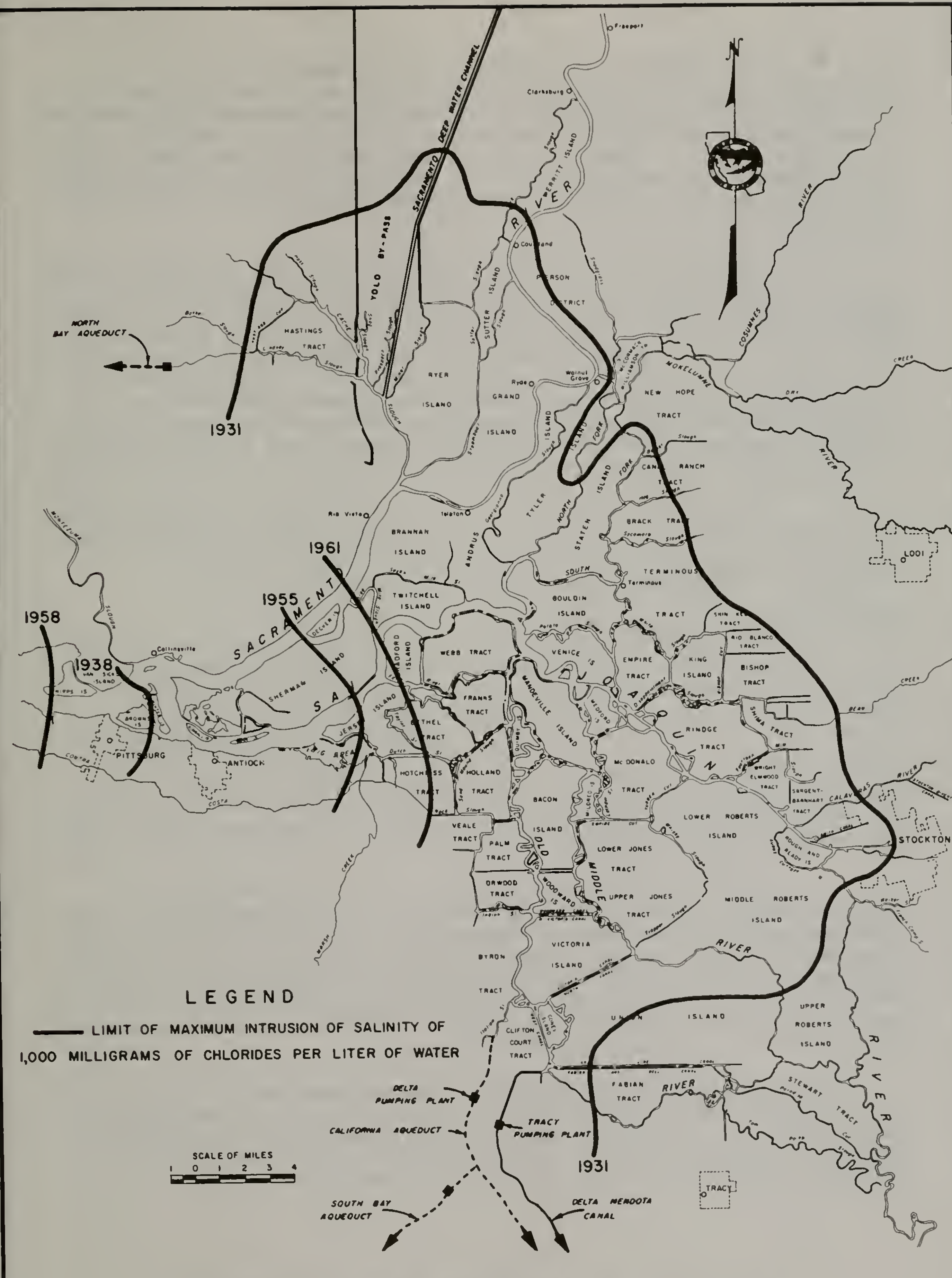


Figure 30. SALINITY INTRUSION IN THE DELTA

The ground water geology of the Delta was previously studied to provide information applicable to an evaluation of the State's water development program. Data indicated an apparent general movement of ground water toward the Delta from the north, east, and south. Ground waters in unconsolidated sediments in the periphery of the Delta were of excellent quality; but the rising mineralized waters in the central Delta were found to be unsuitable for most beneficial uses.

Ground waters in the Delta area were predominantly of the sodium-chloride type. These waters were of the saline connate variety with a corresponding high percentage of sodium and chloride ions and relatively low concentrations of calcium and sulfate ions. Ground waters at the perimeter of the Delta were generally of excellent quality and low in mineral content. The water varied from a calcium-magnesium-bicarbonate type, to a sodium-bicarbonate type. These ground waters entered the Delta as returns from irrigated lands and caused no appreciable surface water quality degradation.

Available data indicated that ground water presently has little effect on surface water quality within the Delta and may be disregarded in the future because conditions are not expected to change significantly.

San Joaquin River near Stockton

Pollution resulting from domestic, industrial, and agricultural waste discharged to the San Joaquin River near Stockton has created a recurring problem almost every year since 1939. A survey conducted in August 1941, revealed DO values below 5 mg/l in a six-mile reach of the river between Stockton and Rindge Tract. Additional studies in 1946, 1949, 1950, and 1962 showed widespread pollution from above Stockton, near French Camp Slough, to an area in the shipping channel near Fourteen Mile Slough.

Field studies were conducted during September and October 1963 to obtain data on hydraulic and physical conditions, chemical quality, oxygen relationships and the effect of waste discharges on the river. Weekly sampling provided information on short-term variations in the physical condition, and in the chemical quality of the river. Hydrologic characteristics of the river were determined from existing data and field measurements using dye tracing techniques.

During the field surveys, water samples were collected and analyzed for temperature, DO, free carbon dioxide (CO_2), alkalinity (CO_3 and HCO_3) and pH determinations. In addition, samples were collected at selected stations and tested for EC, BOD, Cl, detergent (ABS), and volatile solids.

Pollution and oxygen depletion in the San Joaquin River near Stockton were found to be functions of: (1) upstream microorganism populations, nutrients, and BOD's; (2) wastes discharged from the City of Stockton treatment plant; (3) river flows too low to sufficiently dilute and transport wastes; and (4) the change in environment that prevents the upstream autotrophic communities from existing in the ship channel.

When oxygen-demanding wastes from the Stockton discharge exceeded the receiving water BOD, that carried by San Joaquin River inflows, oxygen concentrations in the river dropped below desired levels. At the higher river inflows the oxygen deficiency near Stockton was displaced downstream and the water was diluted until desirable DO levels could be maintained.

Biologic communities upstream from the ship channel supplied oxygen to the water while producing organic material. The inability of this type of community to thrive in the ship channel reduced an important oxygen resource in the river, and at the same time increased the magnitude of oxygen demanding material in the water.

Quantities and Qualities of Future Wastes

Projections were made of quantities and qualities of wastes to be discharged in 1995. Resultant values were used to determine possible effect of the wastes on receiving waters, and to predict surface water quality in 1995.

Municipal and Industrial Wastes

Population predictions were used to project domestic wastes; future industrial wastes were estimated from industrial growth factors. It was assumed that the growth of an area would depend on its present industry and domestic population and that future growth would follow the present trend.

The possibility of developing new waste treatment methods in future years should be considered when evaluating projections of future waste loadings. Biochemical oxygen demand of a waste is the only factor effectively treated by methods in current use. BOD projections were made on the basis of both present treatment efficiencies and amount of raw BOD prior to treatment.

The data presented in Table 21 shows projected total areal loadings of major constituents under 1995 conditions.

TABLE 21

ESTIMATED 1995 MUNICIPAL AND INDUSTRIAL CONSTITUENTS DISCHARGED WITHIN THE DELTA AND SUISUN BAY

Constituent	Constituents in 1,000 pounds per day				
	Northern Delta	Southeastern Delta	Western Delta	Suisun Bay	Total
Flow (cfs)	250	120	380	240	990
Solids					
TDS	570	480	3,190	3,850	8,090
Settleable	---	---	---	30	---
Total suspended	120	30	350	90	590
Volatile suspended	---	---	170	50	---
BOD					
Present treatment	200	20	160	80	460
Raw, prior to treatment	320	190	260	140	910
COD (Chemical Oxygen Demand)	490	---	600	340	---
Grease and oil	50	7	9	22	88
Total hardness	200	120	610	760	1,690
Alkalinity					
HCO_3	330	190	240	190	950
CO_3	---	---	---	---	---
Nitrogen					
Organic	13.4	3.8	1.9	5.0	24.
NH_3	20.0	8.1	6.1	36.0	70.
NO_3	1.3	2.6	2.2	1.2	7.
Total	34.7	14.5	10.2	42.2	101.
ABS	5.5	1.6	---	1.2	---
Chloride	100	140	870	1,020	2,130
Phosphate	22	6.7	2.3	12	43

In 1995 liquid waste quantities in the northern Delta are expected to be double or triple the present flows. It is estimated that 320,000 pounds per day of untreated BOD will be discharged in the area. If present treatment methods (36 percent BOD removal) continue, about 200,000 pounds of BOD will be discharged directly into the river. This will be from a population equivalent of 880,000 persons. If 75 percent of the BOD could be removed by the dischargers in the area, the 1995 loading on the river would be about what it is presently.

Waste flow in the southeastern Delta can be expected to increase almost threefold by 1995. Presently, the degree of waste treatment in the area is high, and if current practices are continued the total BOD loading will increase to only 20,000 pounds per day. Nitrogen concentrations in the area are of major concern. Estimated future loadings of 14,500 pounds per day of nitrogen, or almost three times the present quantities, can be expected to cause problems similar to that found in the San Joaquin River near Stockton unless changes in environmental conditions enhance the assimilative capacities of southeastern Delta channels.

Waste water flows in the western Delta are expected to increase 2.5 times by 1995 and will account for a corresponding increase in constituent loadings. Present overall BOD removal efficiency is about 37 percent, but additional treatment facilities in the western Delta could reduce 1995 BOD loadings to amounts equal to or less than present values.

Quantities of waste flow will possibly double in the Suisun Bay area by 1995. At present concentrations, the total constituent waste loadings will then be approximately twice as high as they are now. Dissolved mineral concentrations will be equal to, or less than, those in the receiving water. Increased nitrogen loading could influence aquatic growth and result in unsightly conditions and unpleasant odors.

Projected increases in quantities of flow, TDS, Cl, and N discharged, and raw BOD between present and 1995 conditions are shown on Figure 31. The data from each area concerning flow and specific constituents discharged may be used to calculate waste concentrations in mg/l by dividing the total constituent loading expressed in units of lbs/day by the product of 5.39 and the flow in cfs. These concentrations determine the quantities of incremental waste loading.

Delta Agricultural Wastes

Drainage flow projections for 1995 are based on the premise that the increase in seepage will be the major cause of increased drainage. The present seepage rate of 950 cfs is expected to increase to 1500 cfs by 1995. The quality of 1995

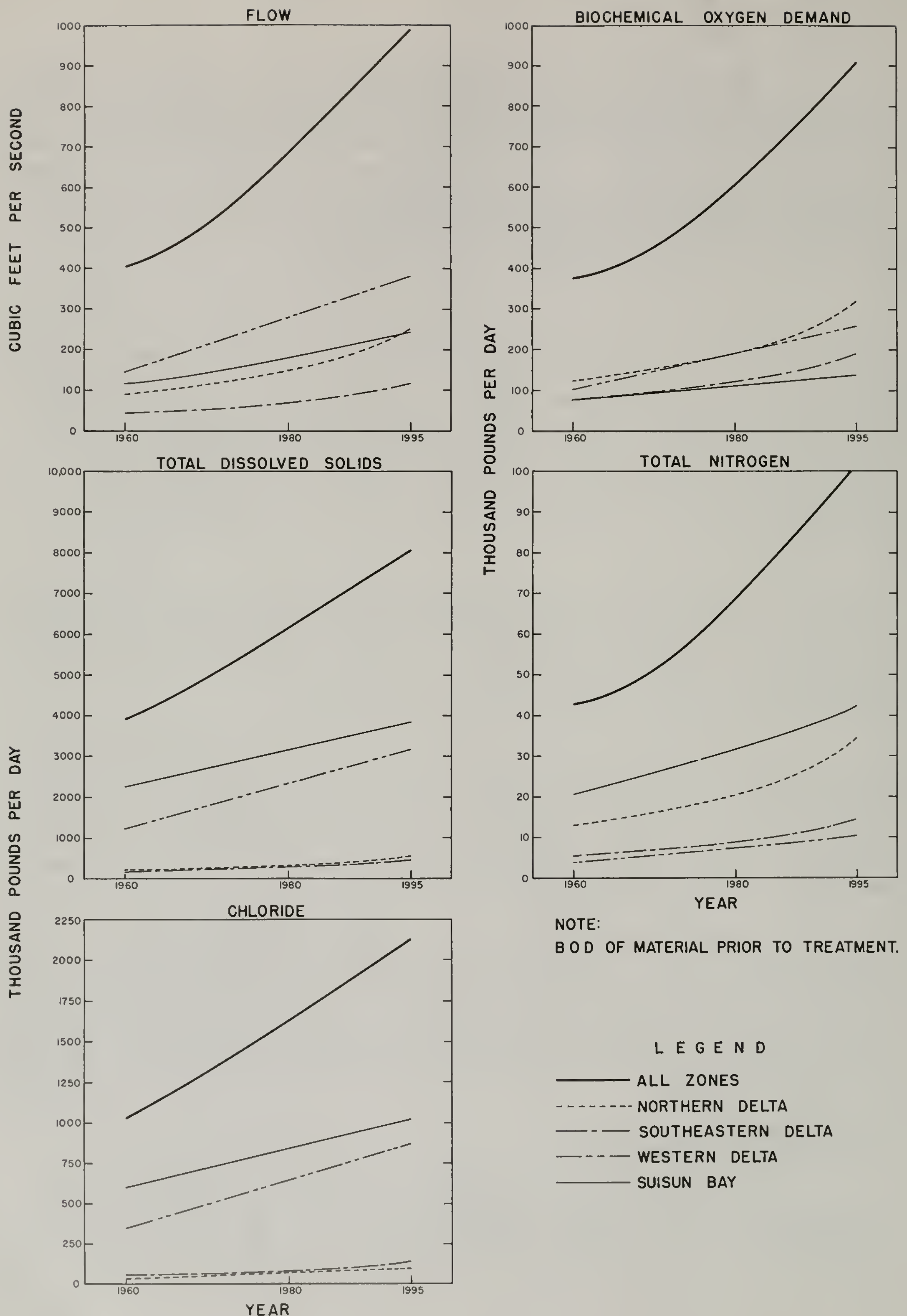


Figure 31. PRESENT AND PROJECTED TOTAL QUANTITIES OF MUNICIPAL AND INDUSTRIAL WASTE DISCHARGED IN THE DELTA AND SUISUN BAY

TABLE 22

AVERAGE SEASONAL QUANTITIES OF DELTA AGRICULTURAL DRAINAGE, 1995

Delta Area	Quantities in 1,000 pounds per day											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Northern												
Flow (cfs)	420	280	250	270	320	430	550	470	280	230	310	430
TDS	1950	1370	1060	900	720	420	590	620	500	760	1000	1920
Cl	550	440	340	300	210	90	200	170	100	210	280	630
BOD	11.5	8.7	7.0	6.2	6.5	7.2	7.4	5.7	4.0	4.9	6.9	11.1
N	9.9	7.2	5.5	4.5	3.5	1.7	3.6	2.8	3.2	3.5	6.3	10.0
Western												
Flow (cfs)	380	240	240	280	240	280	300	280	230	220	250	360
TDS	1820	1360	1360	1450	840	520	900	1020	670	680	650	1550
Cl	700	480	460	490	300	200	430	440	270	260	190	560
BOD	10.5	7.4	7.2	6.3	5.0	4.8	4.0	3.3	3.4	4.6	6.4	9.3
N	9.9	7.0	7.2	6.7	4.4	2.7	3.8	4.4	3.1	3.7	5.2	7.4
Southeastern												
Flow (cfs)	1320	700	580	600	790	980	1020	980	730	590	740	1160
TDS	6130	3610	3145	3300	3660	3590	3700	4530	3950	3850	5640	5220
Cl	2060	1220	1070	1110	1240	1200	1380	1470	1230	1220	1730	1750
BOD	95.0	39.0	24.1	22.9	25.7	26.9	22.7	19.8	18.6	24.9	17.4	36.3
N	31.4	18.8	16.3	16.9	19.2	17.4	19.4	11.6	13.5	12.7	13.0	27.1
Totals												
Flow (cfs)	2120	1220	1070	1150	1350	1690	1870	1730	1240	1040	1300	1950
TDS	9900	6340	5565	5650	5220	4530	5190	6170	5120	5290	7290	8690
Cl	3310	2140	1870	1900	1750	1490	2010	2080	1600	1690	2200	2940
BOD	117.0	55.1	38.3	35.4	37.2	38.9	34.1	28.8	26.0	34.4	30.7	56.7
N	51.2	33.0	29.0	28.1	27.1	21.8	26.8	18.8	19.8	19.8	24.5	44.5

drainage was estimated by degrading present Delta agricultural drainage qualities by the increase in consumptive use values (about 20 percent). Phosphate and BOD concentrations were projected by comparing the values obtained during the 1964 five-month study of Delta drainage with the qualities of waste discharged by drains in the Sacramento Valley, which are characteristically similar to Delta drains but discharge greater quantities of waste. This provided data on a yearly basis for conditions similar to those that might occur in the Delta in future years.

Total quantities of flow, TDS, Cl, BOD, and N projected to be discharged in 1995 from the study area were estimated by using future quantities and qualities shown in Table 22.

BOD concentrations in drainage discharged in the southern Delta will be from one to two times those discharged in the northern Delta. Minimum concentrations can be expected during the summer and maximum concentrations will probably occur in the spring. Estimated concentrations for 1995 ranged from 2.2 to 5.6 mg/l for the northern Delta, and 3.7 to 8.1 mg/l for the southern Delta.

Phosphate concentrations in surface drains probably will not fluctuate significantly either seasonally or geographicall Random variations from 0.24 to 0.69 mg/l will likely occur in 1995 Delta drainage with maximum values resulting from fertilizer applications and leaching.

Nitrogen and phosphate will be discharged at a ratio varying from 6:1 to 20:1, with maximum loadings in spring and summer when irrigation drainage flows are highest. Nitrogen loadings will be greatest in the southeastern Delta. There, discharges will amount to approximately 50 percent of the total nitrogen discharged in agricultural drainage.

Effects of Wastes on Future Water Quality

Predictions of the water quality characteristics throughout the Delta and Suisun Bay under 1995 conditions were based on operation of a Peripheral Canal for water transfer and on previousl estimated quantities and qualities of wastes to be discharged.

Significance of Discharge Qualities

Several of the waste dischargers divert large quantities of surface water directly from the estuary. These water supplies contain significant amounts of the same constituents that are found in the discharged wastes. As a result, the quantity and quality of influent must be considered when studying waste discharges to the Delta and Suisun Bay; otherwise, an erroneously high concentration increase could be calculated.

Projecting the effect of waste discharge on constituent concentrations in receiving waters depends on the quantity and quality of the waste discharged, the assimilative characteristics of the receiving waters, and the existing constituent concentrations in the receiving waters.

Increases that might occur in a channel must be calculated on the net quantity of material added to the channel. The magnitude of the net discharge determines the extent of degradation in receiving waters after the steady-state concentration increases have been determined for specific assimilative conditions.

From results of fluorescent tracer studies, steady-state concentrations (Cs) values were determined for the San Joaquin River near Antioch and for Suisun Bay. These C_s values include the effect of tidal dispersion. The mathematical model of the Delta was used to determine increases in mineral concentrations through solution of the salt balance, or water quality program, which neglects tidal dispersion. Influence coefficients, also developed from the mathematical model, were used to estimate changes in nitrogen, phosphate, and BOD concentrations resulting from municipal, industrial, and agricultural drainage.

<u>Mineral Concentrations</u>

Twenty stations were selected to represent the mineral quality of Delta water under 1995 conditions. The basic mineral quality of the entire Delta was estimated through the mathematical model solution of the water quality program and reported as TDS in mg/l. The conditions of 1995 were simulated for the median year bimonthly periods of January-February, May-June, July-August, July-August (with the San Joaquin Master Drain discharging at Antioch Bridge), September-October, November-December, and a November-December dry year condition. The results of these 1995 simulations are shown on Figures 32 through 38.

Within the areas not affected by salinity intrusion, the 1995 TDS values from the model were used in conjunction with individual station mineral correlations to calculate EC, Cl, Ca, Na, Mg, and SO_4 concentrations and total hardness. Western Delta stations were corrected for salinity intrusion. Mineral concentrations throughout the Delta and TDS in the western Delta are shown in Tables 23 and 24.

On Figure 39 seasonal variations of TDS for present and 1995 are shown for eight different stations in the study area. The values do not reflect any changes resulting from operation of the proposed agricultural master drain.

The computed 1995 quality of Sacramento River water near Walnut Grove is related to increased population in the metropolitan area of Sacramento, resulting in larger municipal

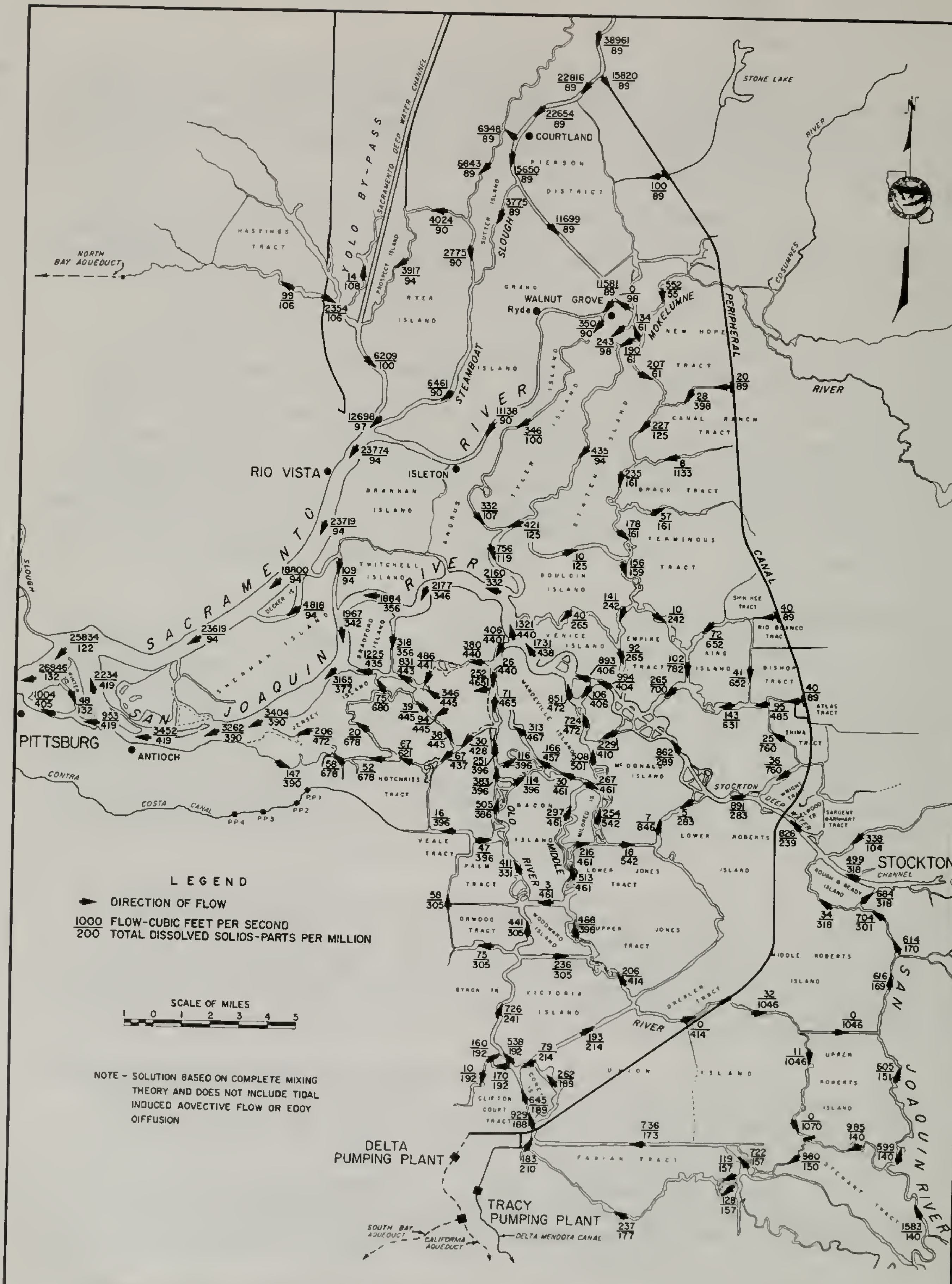


Figure 32. DIGITAL COMPUTER SIMULATION OF JAN–FEB 1995 DELTA WATER QUALITY

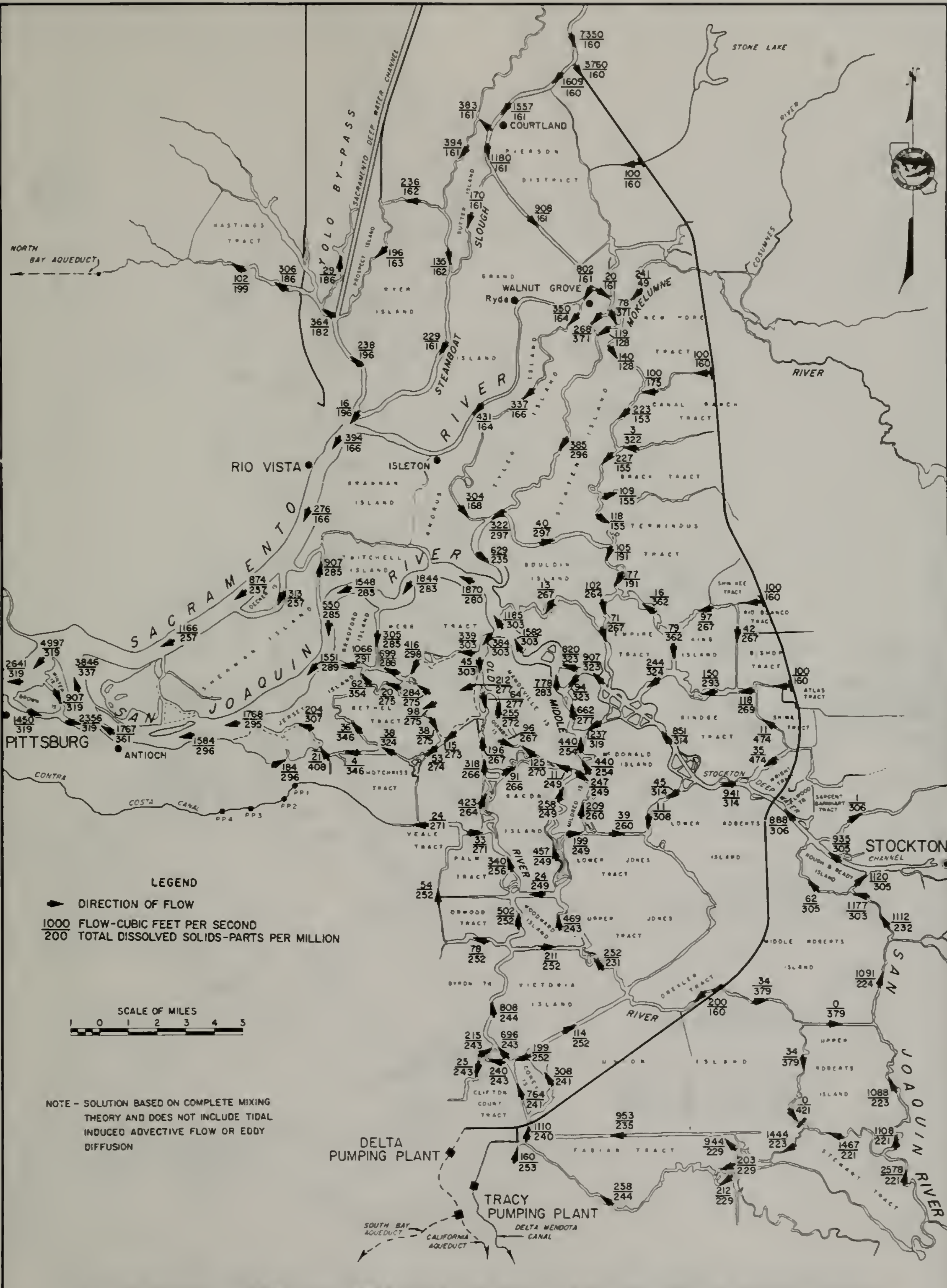


Figure 33. DIGITAL COMPUTER SIMULATION OF MAY-JUNE 1995 DELTA WATER QUALITY

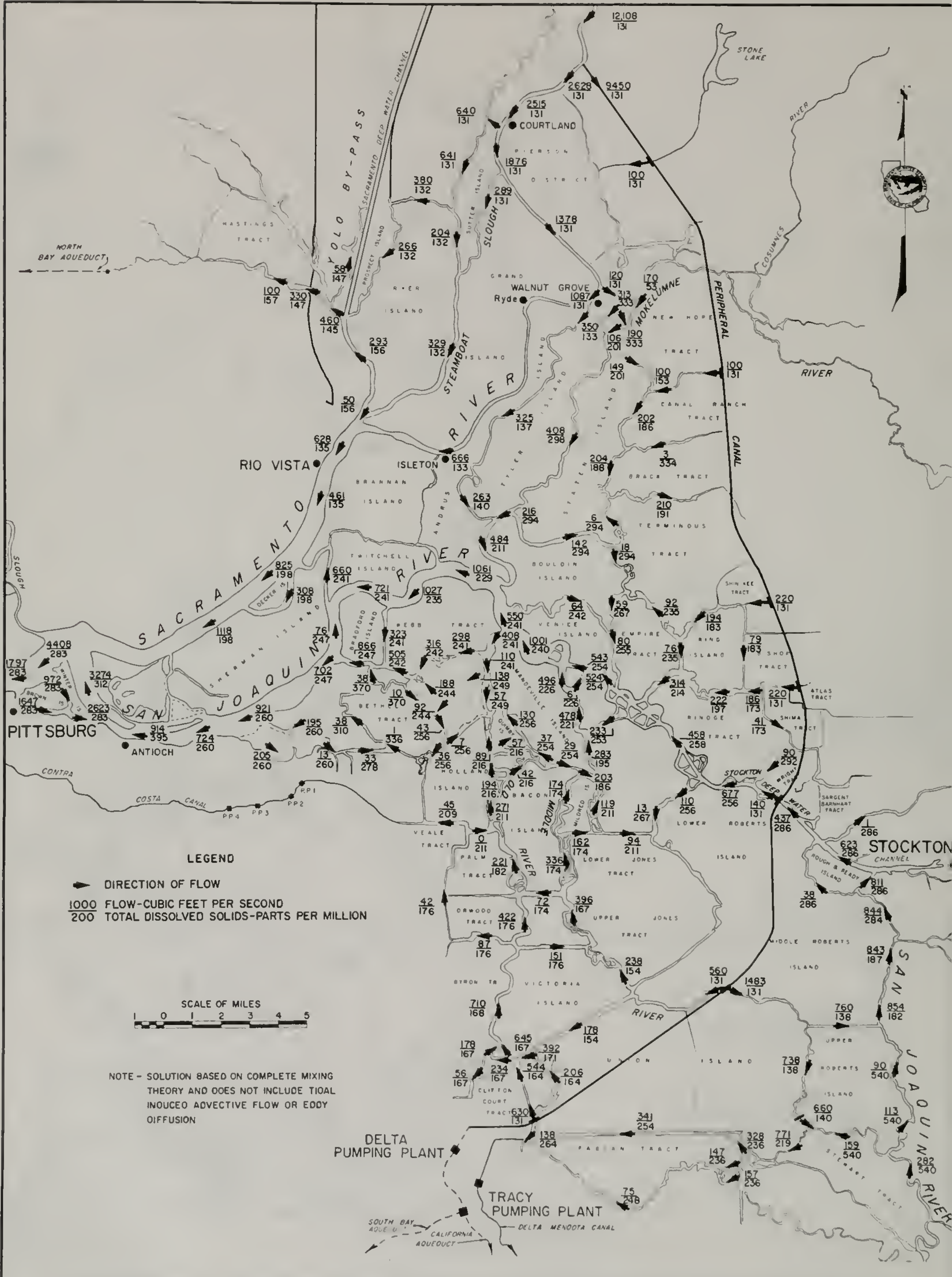


Figure 34. DIGITAL COMPUTER SIMULATION OF JULY-AUG 1995 DELTA WATER QUALITY

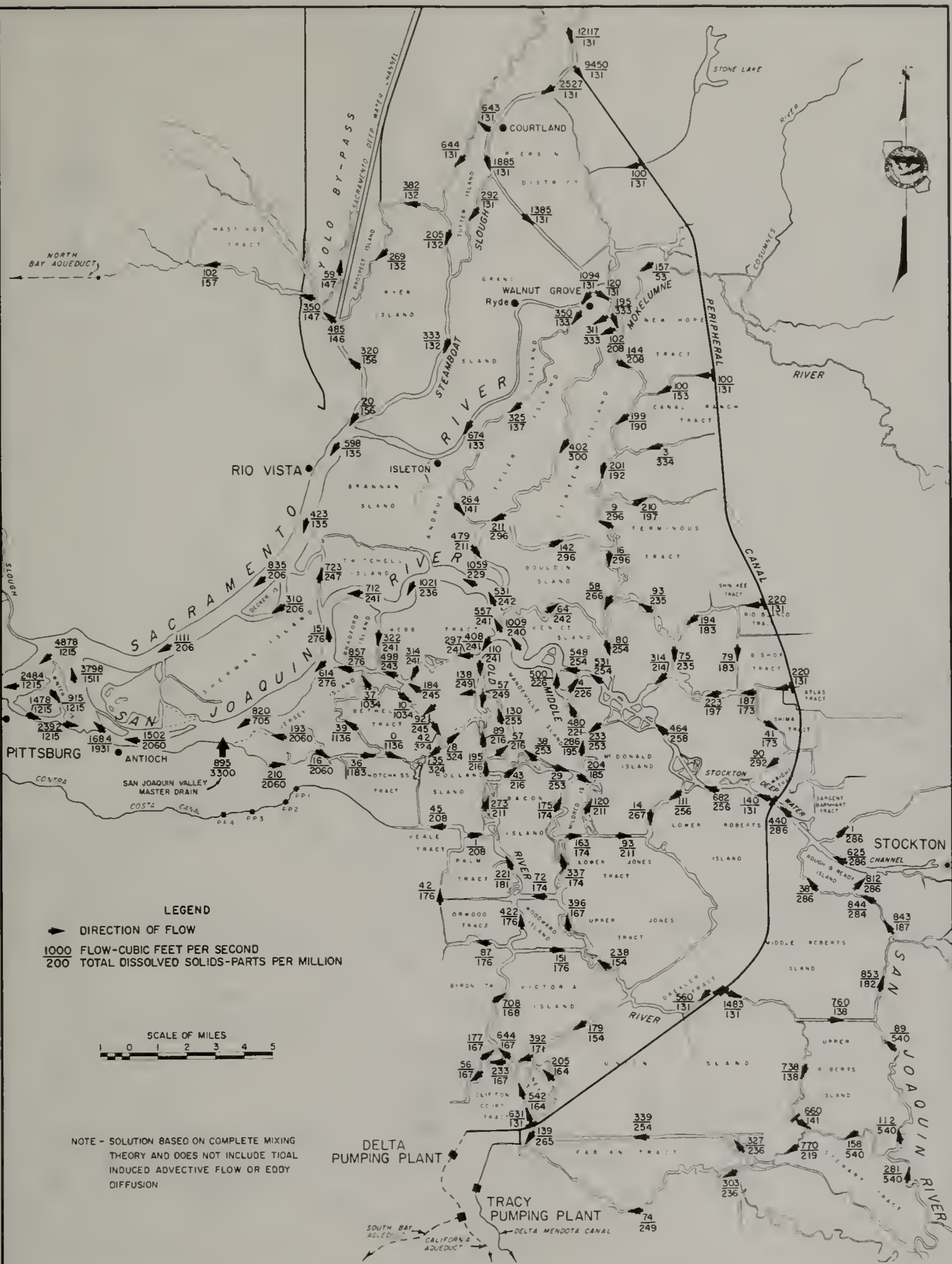


Figure 35. DIGITAL COMPUTER SIMULATION OF JULY-AUG 1995 DELTA WATER QUALITY WITH MASTER DRAIN

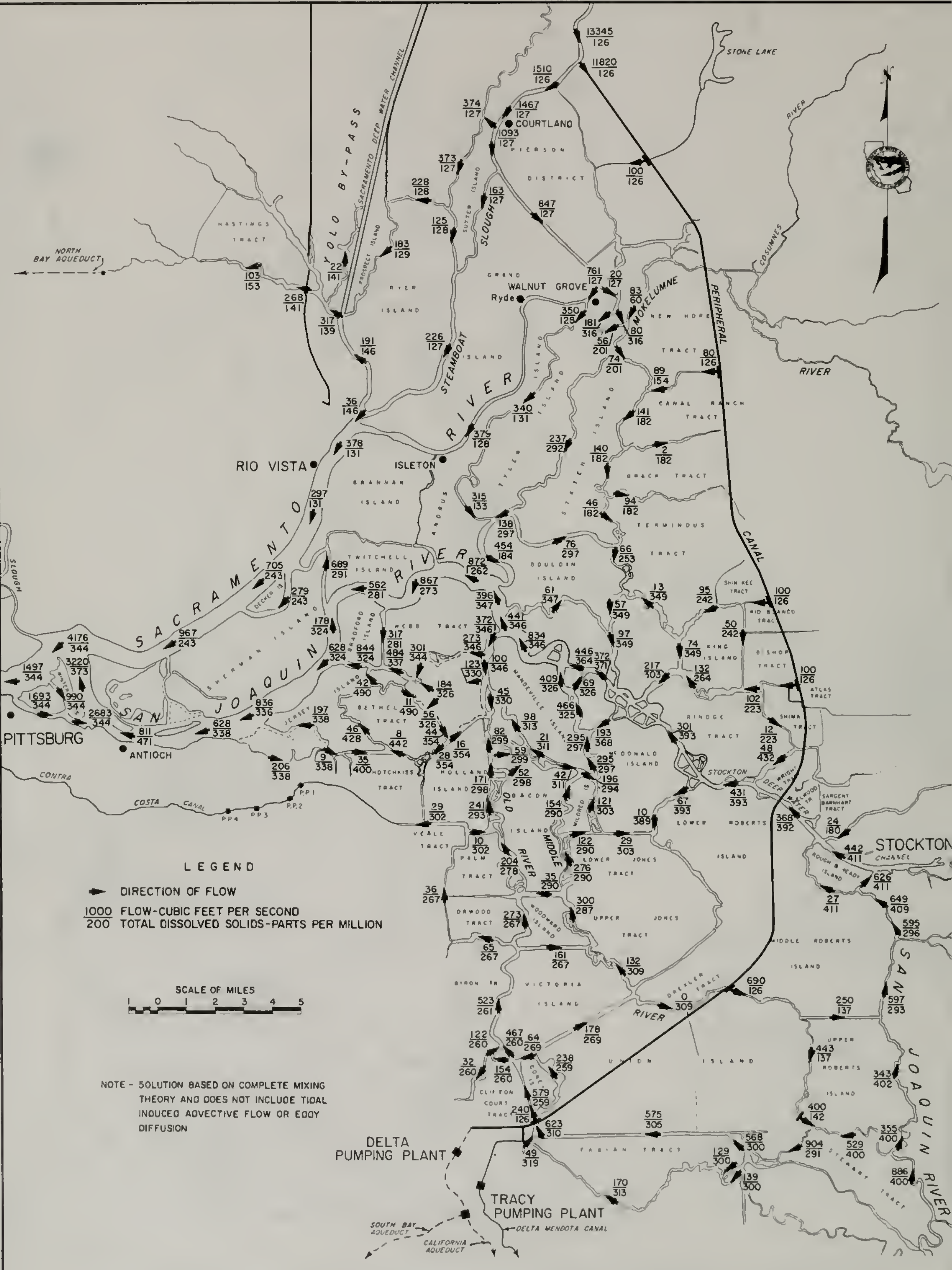


Figure 36. DIGITAL COMPUTER SIMULATION OF SEPT-OCT 1995 DELTA WATER QUALITY

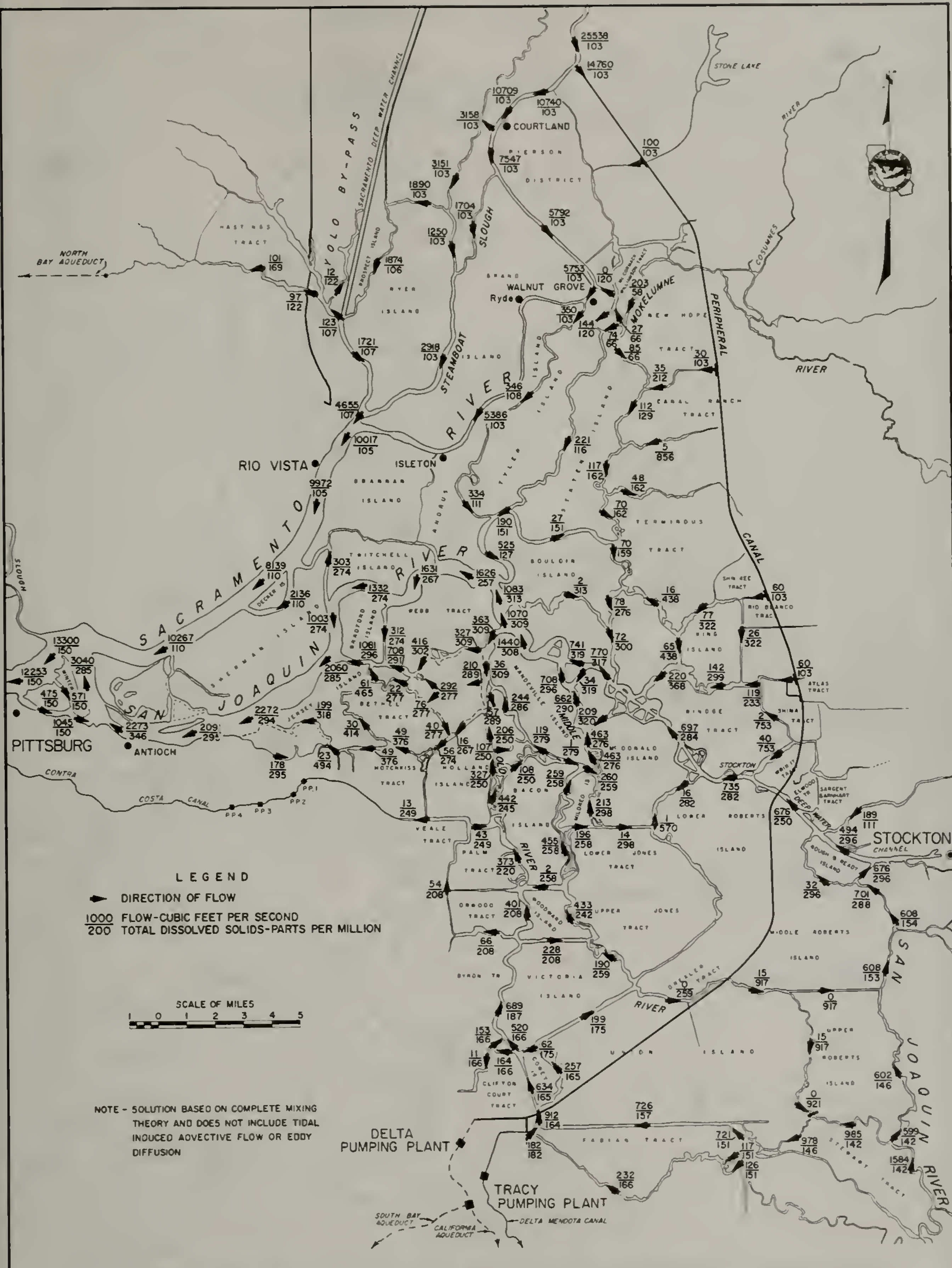


Figure 37. DIGITAL COMPUTER SIMULATION OF NOV - DEC 1995 DELTA WATER QUALITY

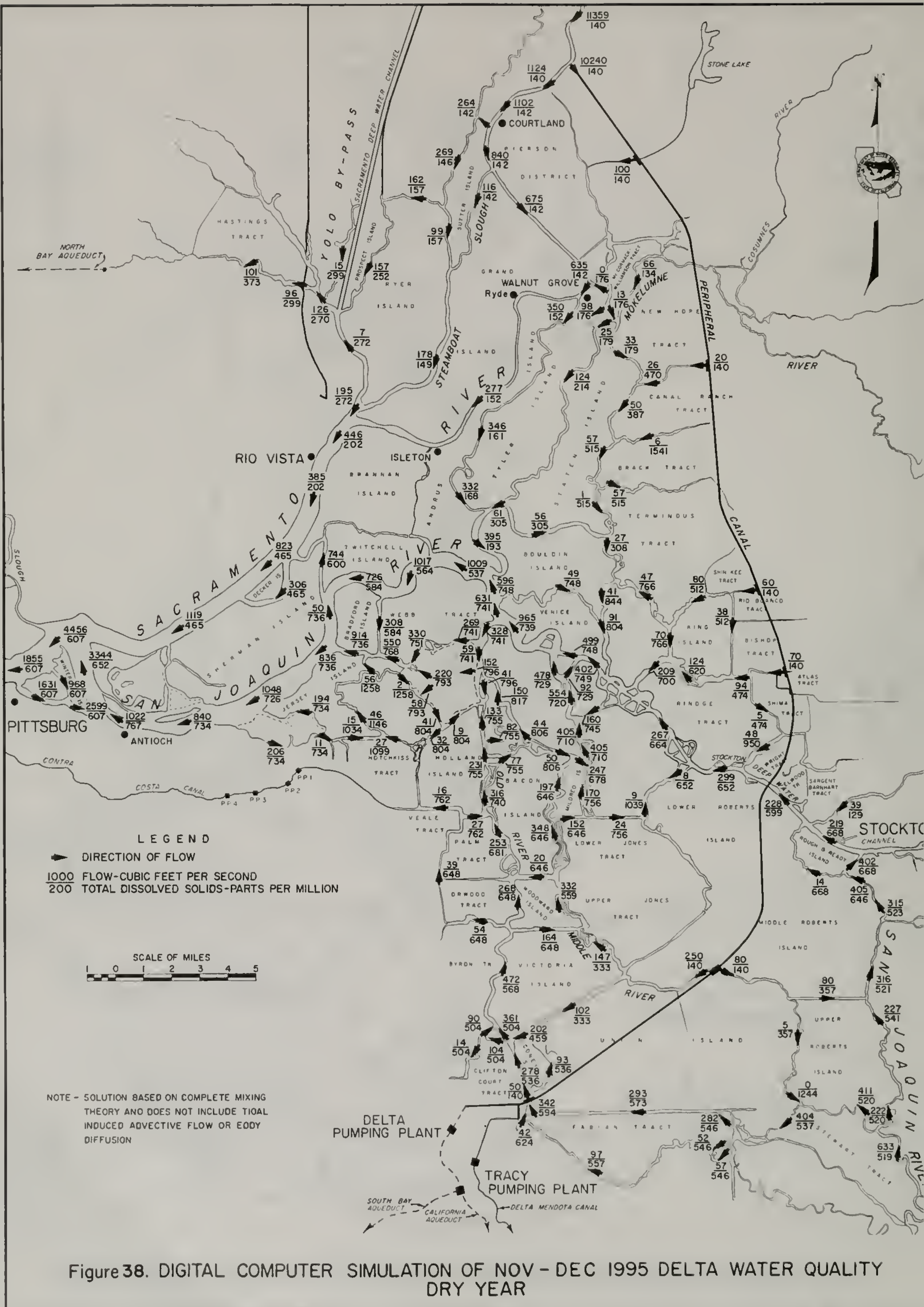


Figure 38. DIGITAL COMPUTER SIMULATION OF NOV - DEC 1995 DELTA WATER QUALITY DRY YEAR

TABLE 23

ESTIMATED 1995 MINERAL CONCENTRATIONS THROUGHOUT THE DELTA[a]

Station	Total dissolved solids					Specific conductance[b]					Total hardness					Sodium				
	Concentrations in milligrams per liter																			
			Annual 1995					Annual 1995					Annual 1995					Annual 1995		
	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average
Delta Cross Channel near Walnut Grove	100	130	160	100	130	150	210	260	150	200	60	70	90	60	70	10	15	20	10	15
Sacramento River at Hood	90	130	160	90	120	140	210	260	140	190	50	70	80	50	70	10	15	20	10	10
Lindsey Slough near Rio Vista	110	160	200	110	160	170	260	330	170	260	60	90	110	60	90	10	20	30	10	20
Sacramento River at Rio Vista	90	220	250	90	170	160	360	410	160	290	50	120	140	50	100	5	35	40	5	25
San Joaquin River at Antioch	420	7100	8000	350	4210	700	12700	14300	60	7520	70	1430	1600	60	840	50	2200	2500	40	1320
San Joaquin River at Mossdale Bridge	140	540	540	140	290	250	950	950	250	510	60	210	210	60	110	30	105	105	30	60
San Joaquin River at Garwood Bridge	170	190	300	150	210	300	300	500	270	350	70	100	130	70	90	30	25	45	30	35
Stockton Ship Channel at Rindge Island	280	260	390	260	300	510	400	670	400	530	130	130	180	130	140	50	35	65	35	50
Little Potato Slough near Mouth	270	260	350	250	290	400	380	520	380	430	110	110	150	110	120	30	30	40	30	35
Grant Line Canal at Tracy Road Bridge	170	250	300	160	220	320	470	560	320	410	70	110	130	70	90	35	55	65	35	50
Delta-Mendota Canal near Tracy	90	130	160	90	120	140	210	250	140	190	50	70	90	50	70	9	15	19	9	15
Old River at Clifton Court Ferry	190	160	260	160	200	330	270	440	270	350	80	90	120	60	90	35	20	45	20	35
Italian Slough near Mouth	190	170	260	170	200	340	290	460	290	360	90	70	100	70	90	35	25	50	25	35
Rock Slough near Knightsen	400	210	400	210	290	690	370	690	370	500	170	100	170	100	120	75	35	75	35	50
Old River at Holland Tract	400	220	400	220	290	610	320	610	320	440	110	80	110	80	90	75	30	75	30	50
Old River at Mandeville Island	470	250	470	250	320	800	430	800	430	550	130	90	130	90	100	100	50	100	50	65
Middle River at Victoria Canal	410	150	410	150	260	750	240	750	240	450	130	80	130	80	100	90	20	90	20	50
Mokelumne River at Highway 12 Bridge	120	210	240	120	180	190	350	390	200	290	60	110	120	60	90	15	25	30	15	20
San Joaquin River at Brandt Bridge	150	540	540	150	290	230	810	810	220	440	50	180	180	50	100	25	90	90	20	50
San Joaquin River at San Andreas Landing	330	230	330	230	270	530	370	530	370	440	100	90	100	90	90	65	40	65	40	50

Station	Calcium					Magnesium					Chloride					Sulfate				
	Concentrations in milligrams per liter																			
			Annual 1995					Annual 1995					Annual 1995					Annual 1995		
	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average	Jan.-Feb.	July-Aug.	Maximum	Minimum	Average
Delta Cross Channel near Walnut Grove	12	15	18	12	14	6	8	10	6	8	8	10	13	8	10	10	12	15	10	12
Sacramento River at Hood	10	15	17	10	13	5	8	10	5	7	5	10	13	5	10	7	10	13	7	10
Lindsey Slough near Rio Vista	10	16	20	10	16	8	11	14	8	11	10	15	22	10	15	13	20	25	13	20
Sacramento River at Rio Vista	10	24	26	10	18	6	14	16	6	11	5	35	40	5	25	8	20	20	8	14
San Joaquin River at Antioch	15	105	115	15	65	20	260	300	15	160	180	4000	4500	150	2400	25	575	650	20	340
San Joaquin River at Mossdale Bridge	15	50	50	15	25	5	20	20	5	10	35	175	175	35	90	15	55	55	15	30
San Joaquin River at Garwood Bridge	16	20	30	15	20	7	12	15	6	10	40	15	60	15	40	18	18	30	15	20
Stockton Ship Channel at Rindge Island	30	25	40	25	30	13	16	21	13	16	80	20	95	20	70	30	25	40	25	30
Little Potato Slough near Mouth	25	20	30	20	25	13	12	17	12	13	55	50	80	50	60	20	20	25	20	22
Grant Line Canal at Tracy Road Bridge	15	25	30	15	20	7	11	13	7	9	45	75	90	40	60	20	30	35	18	25
Delta-Mendota Canal near Tracy	10	15	17	10	15	6	8	10	6	8	7	10	12	7	9	8	12	15	8	11
Old River at Clifton Court Ferry	20	15	25	15	20	9	9	12	7	9	45	20	60	20	45	25	15	30	15	25
Italian Slough near Mouth	20	15	25	15	20	10	9	12	9	10	45	35	70	35	50	25	20	35	20	25
Rock Slough near Knightsen	35	20	35	20	25	20	10	20	10	14	115	50	115	50	90	40	25	40	25	30
Old River at Holland Tract	20	15	20	15	17	15	10	15	10	11	120	35	120	35	70	30	18	30	18	22
Old River at Mandeville Island	20	15	20	15	16	18	11	18	11	13	180	70	180	70	110	35	20	35	20	25
Middle River at Victoria Canal	30	15	30	15	20	19	10	19	10	13	140	12	140	12	70	50	15	50	15	30
Mokelumne River at Highway 12 Bridge	15	25	30	15	20	7	12	13	7	10	10	20	20	10	15	10	15	20	10	15
San Joaquin River at Brandt Bridge	10	40	40	10	20	5	18	18	5	10	35	135	135	35	75	5	45	45	5	15
San Joaquin River at San Andreas Landing	15	15	16	15	15	14	10	14	10	11	100	50	100	50	75	20	16	20	16	18

[a]Controlled minimum Delta outflow approximately 1,800 cubic feet per second.

[b]In micromhos at 25°C.

TABLE 24

ESTIMATED 1995 TRANSIENT STATE SALINITY INTRUSION AND

TOTAL DISSOLVED SOLIDS IN THE WESTERN DELTA

	Jan.-Feb.		May-June		July-Aug.		Sept.-Oct.		Nov.-Dec.		Dry yr Nov-Dec		July-Aug w/drain	
	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l	Flow cfs	TDS mg/l
San Joaquin River														
Pittsburg	26,846	1,100	2,641	8,900	1,797	11,500	1,497	12,600	12,253	1,400	1,855	11,200	2,484	9,000
Antioch		419		5,200		7,100		8,000		346		7,000		5,400
Antioch Bridge		390		3,400		4,700		5,200		295		4,600		3,400
Blind Point		385		2,600		3,600		3,900		291		3,500		2,700
Jersey Point		377		1,600		2,200		2,500		285		2,100		1,700
Threemile Slough		356		1,000		1,300		1,500		274		1,300		1,000
San Andreas Landing		332		280		229		262		257		537		229
Sacramento River														
Pittsburg	26,846	1,100	2,641	8,900	1,797	11,500	1,497	12,600	12,253	1,400	1,855	11,200	2,484	9,000
Collinsville		94		4,400		7,200		8,200		110		6,900		4,600
Toland Landing		94		1,800		3,400		4,100		110		3,200		1,900
Rio Vista		94		200		220		250		105		220		200
Iselton		90		164		133		128		103		152		133

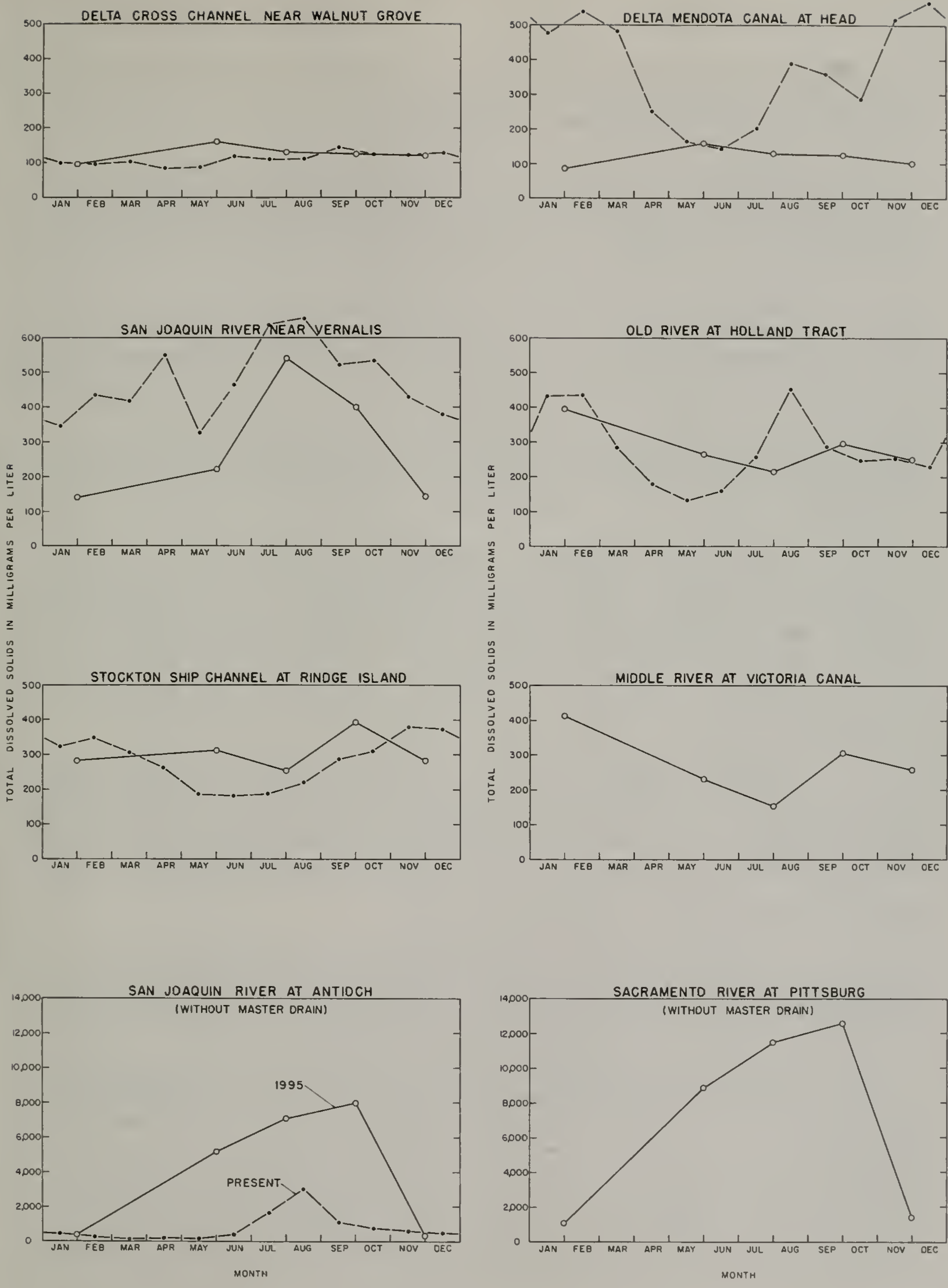


Figure 39. ESTIMATED PRESENT AND 1995 AVERAGE TOTAL DISSOLVED SOLIDS

and industrial return waste flow to the river. The increase in mos constituent concentrations is minimal, from about 1 to 15 percent, depending on the individual constituent.

In Lindsey Slough near Rio Vista, water quality will be slightly improved in 1995. High quality Sacramento River water wil be transported up the slough for use in the North Bay Aqueduct. Quality may be degraded briefly during floods when the Yolo Bypass overflows into the area.

Water quality near the north and south forks of the Mokelumne River, and in Little Potato Slough near Terminous, will be lower than at present because of reduced flow through the Delta Cross Channel and subsequent reduction in the quality of Sacramento River water moving down the Mokelumne's north and south forks. However, water quality in both areas is expected to continue to meet class I agricultural standards. The Little Potato Slough area will contain lower quality water than the Mokelumne River due to flushing of eastern dead-end sloughs by summer releases from the Peripheral Canal.

San Joaquin River water quality at Mossdale and Brandt bridges will be higher because of the influence of the Peripheral Canal and upstream water project development. Water quality at Garwood Bridge on the San Joaquin River will be improved by releases from the Peripheral Canal in July and August, while mineral concentrations at Rindge Tract will be increased about 10 percent. At other central Delta stations changes will be even smaller in magnitude.

Mineral quality of Delta waters will be generally improve by 1995. In areas where reduced flows and increased agricultural drainage might cause degradation, the water will still be suitable for most beneficial uses. The southern Delta will benefit significantly from operation of the Peripheral Canal.

Nitrogen and Phosphate Concentrations

Future conditions, including operation of the Peripheral Canal and waste discharges from municipal, industrial, and agricultural sources, will increase concentrations of nitrogen and phosphate throughout the Delta and Suisun Bay.

In the northern Delta, near metropolitan Sacramento, concentrations of nitrogen and phosphate in receiving waters are influenced more by municipal and industrial discharges than by agricultural discharges. Agricultural drainages increase the concentrations in other areas of the Delta at least as much as municipal and industrial wastes. Future quantities of municipal and industrial wastes discharged in the southern Delta will be greater than agricultural drainage. The large amount of phosphate and ammonia in wastes discharged from the City of Stockton sewage treatment plant will cause high receiving water concentrations, despite the greater net flows. Agricultural drainage will cause significant increases of nutrients in Old and Middle rivers in the area south of Stockton. Because of large volumes of dilution water from tidally induced advective flow, local internal agricultural drainage and municipal and industrial wastes will cause minimal changes in nitrogen and phosphate concentration increases in the western Delta and Suisun Bay. Projected 1995 nitrogen and phosphate concentrations for 16 stations listed in Table 25 were derived from results of the mathematical model program previously described. The periods of January-February and July-August were selected to correspond to the extreme operating criteria of the Peripheral Canal. The conditions generally found for these two periods bracket the concentration changes that might occur.

An examination of the estimated concentrations shows that nitrogen concentrations will vary almost fivefold from one area to another. In some Delta areas, total nitrogen concentrations might approach three or four mg/l.

A comparison of present conditions and projected 1995 conditions indicates that nitrogen concentrations will increase about 50 percent throughout the entire Delta. Specific areas might be expected to have increases of 110 to 160 percent. The average nitrogen concentration for 1995 is estimated to be about 1.6 to 2.2 mg/l.

One area of the Delta that presently has relatively high quality water is a segment of Middle River along the northern edge of Union Island. It will be closed at the Peripheral Canal crossing. Calculated 1995 nitrogen concentrations for this reach of the river ranged from a maximum of 5.1 mg/l during March through May, to a minimum of 1.0 mg/l during July through October. This is a local situation where a problem, if it arose, could be corrected by increasing Peripheral Canal releases into Middle River.

Estimated increases in phosphate concentrations over present values will range from 20 to about 70 percent. Increases throughout the entire Delta will average about 40 percent with the highest concentrations probably downstream from the City of Stockton. Total phosphorus concentrations, however, are not expected to increase significantly above present levels. They may increase in some areas where previous concentrations have been low.

TABLE 25

ESTIMATED 1995 NITROGEN AND PHOSPHATE CONCENTRATIONS IN THE DELTA AND SUISUN BAY[a]
(Minimum Controlled Delta Outflow of 1800 cfs)

Station	Concentration in milligrams per liter			
	Total nitrogen		Total phosphate	
	Jan-Feb	July-Aug	Jan-Feb	July-Aug
Sacramento River at Snodgrass Slough	0.8	0.9	0.3	0.5
Georgiana Slough at Mokelumne River	0.8	1.0	0.3	0.5
San Joaquin River at Brandt Bridge	1.8	1.0	0.4	0.5
San Joaquin River at Fourteenmile Slough	3.1	2.1	1.2	1.2
San Joaquin River near Disappointment Slough	3.3	2.3	1.2	1.1
Old River at Tracy	1.8	1.2	0.5	0.6
Old River at Clifton Court Ferry	1.9	1.3	0.5	0.7
Old River near Italian Slough	1.9	1.3	0.5	0.6
Middle River at Victoria Canal	3.8	0.9	0.5	0.5
Old River at Holland Tract	2.7	1.7	0.5	0.5
Connection Slough at Mandeville Island	3.1	2.3	0.5	0.6
San Joaquin River at San Andreas Landing	2.6	1.9	0.7	0.6
False River at Fisherman's Cut	3.0	2.0	0.6	0.6
Sacramento River at Rio Vista	0.8	0.9	0.4	0.5
San Joaquin River at Antioch	2.6	2.0	0.6	0.6
Suisun Bay at Port Chicago	1.2	2.3	0.5	0.7

[a] Without the master drain.

Biochemical Oxygen Demand

The estimated 1995 concentrations of BOD throughout the Delta and Suisun Bay were derived from information on future waste loadings, net travel time, dilution factors, and an assumed rate of deoxygenation. Additional information, resulting from the assimilation studies in the San Joaquin River near Antioch and in Suisun Bay was used to calculate increases in BOD concentrations caused by the discharge of organic wastes, not including the discharge from the San Joaquin Master Drain.

Present average BOD values for the surface waters in the area range from 1.0 to 4.9 mg/l, with an overall average of approximately 2.0 mg/l.

Estimated 1995 concentrations shown in Table 26 indicate that seasonal influence will probably be important in the persistence of BOD in local areas. Ranges are expected to be from 0.4 to 4.4 mg/l during January-February and 0.2 to 5.4 mg/l during July-August. Oxygen deficits can be expected in areas where net flows are low and velocities minimal.

TABLE 26

ESTIMATED 1995 BIOCHEMICAL OXYGEN DEMAND IN THE DELTA AND SUISUN BAY

Station	Concentration in mg/l	
	Jan-Feb	July-Aug
Sacramento River at Snodgrass Slough	2.2	3.5
Georgiana Slough at Mokelumne River	0.6	0.5
San Joaquin River at Brandt Bridge	2.3	4.4
San Joaquin River at Fourteenmile Slough	4.4	5.4
San Joaquin River near Disappointment Slough	1.7	1.2
Old River at Tracy	2.6	4.6
Old River at Clifton Court Ferry	1.7	3.1
Old River near Italian Slough	1.3	2.7
Middle River at Victoria Canal	2.3	2.3
Old River at Holland Tract	2.0	1.3
Connection Slough at Mandeville Island	2.8	2.2
San Joaquin River at San Andreas Landing	1.2	0.9
False River at Fisherman's Cut	0.9	0.6
Sacramento River at Rio Vista	1.8	0.2
San Joaquin River at Antioch	0.4	0.8
Suisun Bay at Port Chicago	0.5	3.4

Estimates indicate that average BOD concentrations will range from about 1.8 mg/l in winter to 2.3 mg/l in summer. An increase of 10 or 20 percent can be expected for the entire area. Specific increases could be as high as 130 percent where channels are changed by construction of the Peripheral Canal as in Middle River south of Victoria Canal.

An absolute value cannot be predicted accurately for nonconservative constituents such as BOD. Calculated values present an indication of possible increases and a guide to estimates on the future of receiving waters.

Water Temperature

One of the most simple yet most revealing measurements used to characterize aquatic environment is water temperature. Temperature affects water density, metabolic activities of plants and animals, rates of waste stabilization, and optimum productivity of some irrigated crops.

Water temperature throughout the Delta generally reflects changes in seasonal air temperatures, but is also influenced by net flows and agricultural drainage. Minimum water temperatures of 45° to 50°F occur in December and January; maximums of about 75°F occur during July through September.

By 1995, several changes will have been made in the control of inflows to the Delta. In addition, water transfer faciliti will have been constructed in the Delta. Changes of water temperat in the Delta are not expected to be significantly different than those historically experienced. Removal of agricultural drainage from the San Joaquin River by the San Joaquin Master Drain is not expected to change the San Joaquin River temperatures, either in the San Joaquin Valley or in the vicinity of the master drain discharge near Antioch.

Effects of San Joaquin Valley Drainage

Studies conducted during the San Joaquin Valley Drainage Investigation revealed that there presently is a waste water disposal problem in the San Joaquin Valley that will spread and intensify in the future. It will be necessary to remove and dispose of salts and agricultural drainage from the San Joaquin Valley in order to maintain the rich productivity of the valley.

The San Joaquin Master Drain, recommended for removing the concentrated dissolved minerals from the agricultural areas, is an authorized facility of the State Water Project. Waste water will be transported from a point south of Bakersfield to a discharge point in the western Delta, a distance of approximately 280 miles. The amount of waste to be conveyed by the drain is expected to increase from an initial quantity of approximately 60,000 AF in 1970 to about 500,000 AF by 2020. Maximum flows during peak months are expected to be about 30 percent higher than average quantities.

Concentrations of chemical constituents to be discharged from the San Joaquin Master Drain are shown in Table 27.

TABLE 27

ESTIMATED CONCENTRATIONS OF CHEMICALS
IN AGRICULTURAL WASTE DISCHARGED FROM THE
SAN JOAQUIN MASTER DRAIN

Constituents	Concentrations in milligrams per liter		
	1970	1995	2020
Calcium	220	--	160
Magnesium	160	--	90
Sodium	1,900	780	540
Potassium	20	--	10
Carbonate	0	--	0
Bicarbonate	220	--	200
Sulfate	3,500	1,260	740
Chloride	1,000	750	670
Boron	11	6.5	3
TDS	6,800	3,300	2,500
Nitrogen	21	21	21
Phosphate	0.35	--	0.35
Pesticides	0.001	--	0.001
Pehnols	0.001	--	0.001
Grease and Oil	0.5	--	0.5

Tracer Studies at Antioch Bridge

Fluorescent tracer techniques were used to predict the effect of waste discharges on receiving waters. Based on three dye studies conducted in 1964, steady-state concentrations (C_s) were developed for a conservative material injected at Antioch Bridge. Mean C_s values were also calculated for the entire area.

Hydraulic conditions existing during the field tests and the average dye concentrations observed over the period of each study at HHW and LLW slacks are shown on Table 4 and Figure 14. Concentrations reflect the influences of tidal and net flows.

An estimated C_s was computed for a condition of zero net flow past Antioch, at a tidal flushing rate equal to the average of the net flushing rates determined for the two continuous dye release studies. Steady-state concentrations will theoretically approach waste water concentrations if a conservative waste is introduced into a system of zero net flow with only tidal activity present. An approximation was made to define an absolute maximum mean C_s at various net flows. The relationship of C_s vs net flow was determined (Figure 40) and used to make predictions of resultant concentration from discharges for net flows other than those found during the dye studies.

Changes in Receiving Water near Antioch

The determination, or prediction, of changes in chemical constituent concentrations due to a discharge of wastes is possible when the quantities and qualities of the waste are known, the receiving water qualities are known or determinable, the environmental features of the receiving water can be related to appropriate levels of development, and when the assimilative capacity and dilution and flushing rates of the receiving water can be quantitatively characterized in relation to independent variables.

Differences between waste and receiving water qualities determine the incremental loading of the waste water on the receiving water. The level of development influences the physical and chemical characteristics of the waters that are affected. Similarly, the level of development determines the approximate quantities and qualities of waste. Relationships obtained between C_s values and net flows represent the assimilative capacity of the river near Antioch. These relationships, and the incremental waste loadings, can be used to estimate the effect of San Joaquin Master Drain wastes on receiving waters in terms of changes in constituent concentrations.

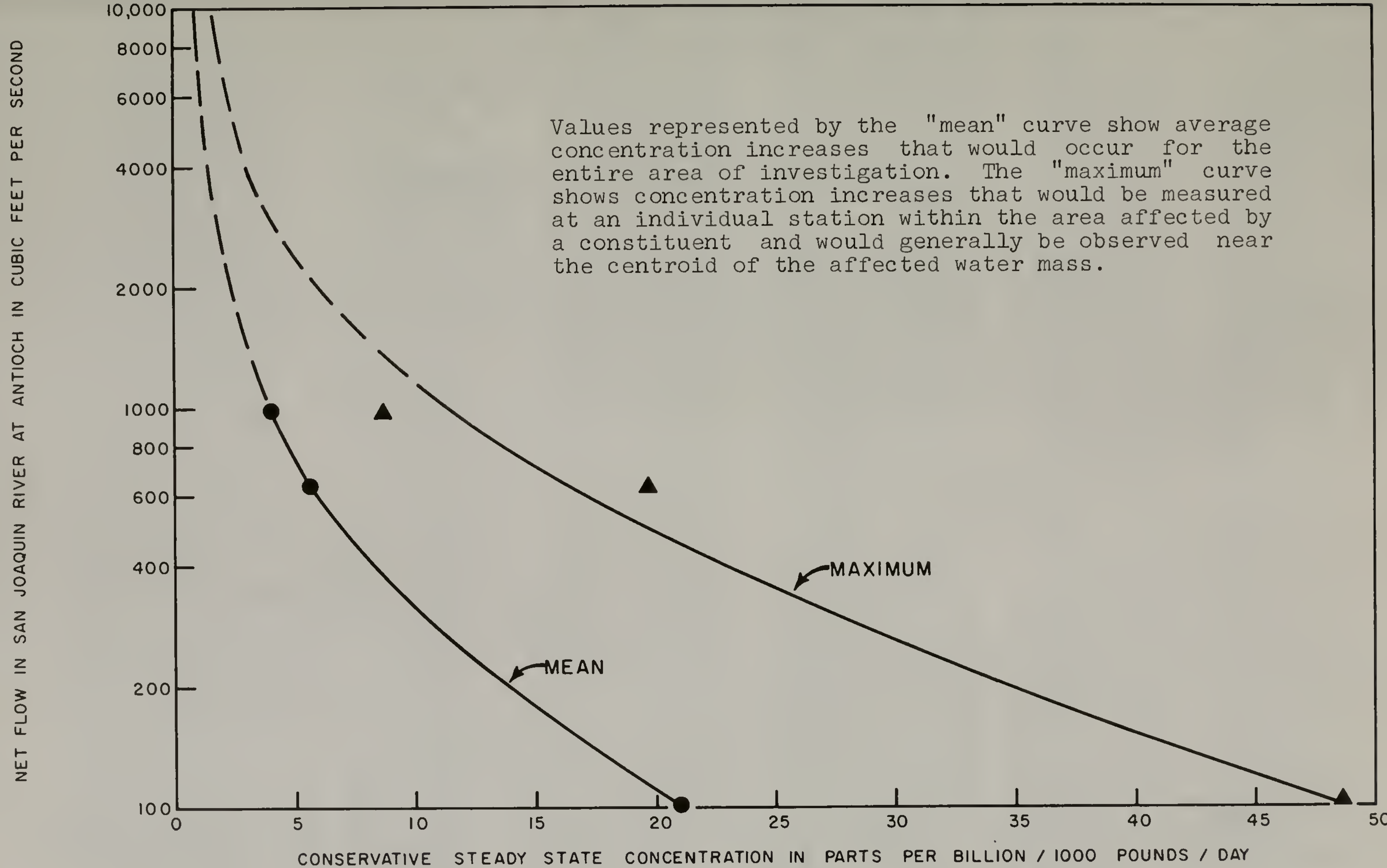


Figure 40. MAXIMUM AND MEAN STEADY STATE CONCENTRATIONS RESULTING FROM A DISCHARGE AT ANTIOCH BRIDGE AT DIFFERENT NET FLOWS

Present patterns of flow distribution at the confluence of the Sacramento and San Joaquin rivers will change significantly after the Delta water facilities are constructed. This change will alter the present flow vs quality relationship at Antioch. Determinations of probable future quality were made based on results of the digital computer simulation.

Increases in concentrations of TDS, Cl, SO_4, Na, B, and N were calculated for four different flows at Antioch under present and future conditions. Figures used were for the peak master drain flows which might be expected during the summer. Average annual drain flows would be approximately 23 percent less. Receiving water background concentrations of minerals were estimated from transient state salinity intrusion curves.

Predicted effects of the drain, shown in Tables 28 and 2 indicate that the only significant changes in concentrations will occur in the sulfate, boron, and nitrogen constituents. The initi mean increase in sulfate will be 6 percent or less, while the maxi- mum might be 12 to 17 percent. Increases in boron will range from 13 to 40 percent in 1970. Boron concentrations will probably not degrade receiving waters below usable levels, even in 1995 when in- creases are estimated to be about 0.2 or 0.3 mg/l. Maximum increa during the summer could cause a total boron concentration as high 0.76 mg/l in 1995.

Initial increases in mean nitrogen concentrations might vary from about 3 to 7 percent. The 1995 increases are expected t be approximately 10 to 30 percent of the concentrations in the absence of the drain. Maximum increases in 1970 could be as high as 0.32 mg/l, or about 21 percent of present receiving water conce trations. Future maximum nitrogen concentrations near Antioch, as a result of drainage discharge, could possibly range from 2.5 to 3.8 mg/l, or almost double the future receiving water concentratio without the master drain.

Results of the analysis indicate that initially the drainage will not degrade receiving water concentrations to the extent that prior beneficial uses will be reduced. Although increases in constituent concentrations apparently will be below various quality objectives for beneficial uses, their associated effects may result in changes in the chemical and biological environment.

<u>Mathematical Model Simulation</u>

The mathematical model of Delta hydraulics and water quality was used to simulate 1995 July-August conditions with the master drain discharging at Antioch. Because the model used a salt balance equation, without the ability to determine nonconservative constituent concentrations or diffusion processes, only TDS concentrations were computed (Figure 35). The model did not simulate salinity intrusion so adjustments were made for intrusion of western salts from Suisun Bay.

TABLE 28

ESTIMATED INCREASE IN TDS, Cl, AND SO_4 IN THE SAN JOAQUIN RIVER NEAR ANTIOCH DUE TO MASTER DRAIN DISCHARGING AT ANTIOCH BRIDGE[a]

Year	Flow in cfs: S.J. River	Flow in cfs: Drain	Qualities: Drain mg/l	Qualities: Antioch mg/l	Qualities: Net mg/l	Qualities: Net 1000 lb/day	Mean: Increases ppb/1000 lb/day	Mean: Increases mg/l	Mean: Total mg/l	Mean: Percent increase	Maximum: Increases ppb/1000 lb/day	Maximum: Increases mg/l	Maximum: Total mg/l	Maximum: Percent increase
Total Dissolved Solids														
1970	500	150	6,500	2,900	3,600	2,910	7.2	21	2,900	1	20	58	3,000	2
	1,000			2,100	4,400	3,560	4.0	14	2,100	1	11.5	41	2,100	2
	1,500			1,600	4,900	3,960	3.1	12	1,600	1	8	32	1,600	2
	2,000			1,280	5,220	4,220	2.2	9	1,300	1	6	25	1,300	2
1995	500	895	3,300	9,300	-6,000	-28,900	7.2	-208	9,100	-2	20	-578	8,700	-6
	1,000			7,100	-3,800	-18,300	4.0	- 73	7,000	-1	11.5	-210	6,900	-3
	1,500			6,300	-3,000	-14,500	3.1	- 45	6,250	-1	8	-116	6,200	-2
	2,000			1,900	1,400	6,750	2.2	15	1,900	1	6	40	1,900	2
Chloride														
1970	500	150	1,200	1,490	- 290	- 230	7.2	- 2	1,500	0	20	- 5	1,500	0
	1,000			1,060	140	110	4.0	0	1,060	0	11.5	1	1,060	0
	1,500			800	400	320	3.1	1	800	0	8	3	800	0
	2,000			630	570	460	2.2	1	630	0	6	3	630	0
1995	500	895	750	4,880	-4,130	-19,900	7.2	-143	4,740	-3	20	-398	4,480	-8
	1,000			3,710	-2,960	-14,300	4.0	- 57	3,650	-2	11.5	-164	3,550	-4
	1,500			3,290	-2,540	-12,300	3.1	- 38	3,250	-1	8	- 98	3,190	-3
	2,000			1,000	- 250	- 1,200	2.2	- 3	1,000	0	6	- 7	1,000	-1
Sulfate														
1970	500	150	3,100	265	2,835	2,290	7.2	16	281	6	20	46	311	17
	1,000			190	2,910	2,350	4.0	9	199	5	11.5	27	217	14
	1,500			145	2,955	2,390	3.1	7	152	5	8	19	164	13
	2,000			115	2,985	2,410	2.2	5	120	4	6	14	129	12
1995	500	895	1,260	845	415	2,000	7.2	14	859	2	20	40	885	5
	1,000			645	615	2,970	4.0	12	657	2	11.5	34	679	5
	1,500			575	685	3,300	3.1	10	585	2	8	26	601	5
	2,000			175	1,085	5,240	2.2	12	187	7	6	31	206	18

[a] Based on results of dye dispersion studies conducted in 1964.

TABLE 29

ESTIMATED INCREASE IN Na, B, AND N IN THE SAN JOAQUIN RIVER NEAR ANTIOCH DUE TO MASTER DRAIN DISCHARGING AT ANTIOCH BRIDGE[a]

	Flow in cfs		Qualities				Mean				Maximum			
							Increases				Increases			
Year	S. J. River	Drain	Drain mg/l	Antioch mg/l	Net mg/l	1000 lb/day	ppb/1000 lb/day	mg/l	Total mg/l	Percent increase	ppb/1000 lb/day	mg/l	Total mg/l	Percent increase
Sodium														
1970	500	150	1,600	770	830	670	7.2	5	775	1	20	13	783	2
	1,000			550	1,050	850	4.0	3	553	1	11.5	10	560	2
	1,500			415	1,185	960	3.1	3	418	1	8	8	423	2
	2,000			330	1,270	1,030	2.2	2	332	1	6	6	336	2
1995	500	895	780	2,540	-1,760	-8,490	7.2	-61	2,480	-2	20	-170	2,370	-7
	1,000			1,930	-1,150	-5,550	4.0	-22	1,910	-1	11.5	- 64	1,870	-3
	1,500			1,710	- 930	-4,490	3.1	-14	1,700	-1	8	- 36	1,670	-2
	2,000			500	280	1,350	2.2	3	503	1	6	8	508	2
Boron														
1970	500	150	10.0	0.15	9.85	8.0	7.2	0.06	0.21	40	20	0.16	0.31	107
	1,000						4.0	0.03	0.18	20	11.5	0.09	0.24	60
	1,500						3.1	0.02	0.17	13	8	0.06	0.21	40
	2,000						2.2	0.02	0.17	13	6	0.05	0.20	33
1995	500	895	6.5	0.15	6.35	30.6	7.2	0.22	0.37	147	20	0.61	0.76	407
	1,000						4.0	0.12	0.27	80	11.5	0.35	0.50	234
	1,500						3.1	0.09	0.24	60	8	0.24	0.39	160
	2,000						2.2	0.07	0.22	47	6	0.18	0.33	120
Total Nitrogen														
1970	500	150	21.0	1.5	19.5	15.8	7.2	0.11	1.61	7	20	0.32	1.82	21
	1,000						4.0	0.06	1.56	4	11.5	0.18	1.68	12
	1,500						3.1	0.05	1.55	3	8	0.12	1.62	8
	2,000						2.2	0.04	1.54	3	6	0.09	1.59	6
1995	500	895	21.0	2.0	19.0	91.7	7.2	0.66	2.66	33	20	1.83	3.83	92
	1,000						4.0	0.37	2.37	18	11.5	1.05	3.05	52
	1,500						3.1	0.28	2.28	14	8	0.73	2.73	36
	2,000						2.2	0.20	2.20	10	6	0.55	2.55	23

[a] Based on results of dye dispersion studies conducted in 1964.

Discharge of drainage at a TDS of 3300 mg/l into the more saline receiving waters would not cause degradation, but would improve the mineral quality of the receiving water. The major effect of the drain discharging at Antioch would be increased Delta outflow and decreased salinity intrusion.

Effects on Water Quality in Suisun Bay

The prototype and hydraulic model studies provided data to determine effects of wastes from municipal, industrial and agricultural discharges. The influences of the drain were evaluated at four different inflows for a discharge representing a continuous release of conservative constituents at Martinez.

Water quality data showed that the present TDS and Cl concentrations in Suisun Bay are usually equal to, or greater than, concentrations that will be discharged from the drain. Therefore, the agricultural drainage discharge will cause a negligible increase in concentrations at high Delta outflows or will reduce the concentrations at low Delta outflows.

Constituents investigated for drainage effects were sulfate, nitrogen, and boron. These constituents were chosen because expected drainage concentrations are higher than those of the estuary, and therefore could possibly degrade the surface water. Some other drainage constituents may also be important, but present knowledge precludes adequate evaluation of their effect on the receiving water. Present concentrations of sulfate, nitrogen, and boron in Suisun Bay represent the average for the area from Pittsburg to Carquinez Strait. Calculated increases presented in Table 30 show that the average increase in Suisun Bay is a function of net flow at Chipps Island.

Increases in sulfate are expected to be minimal, ranging between 15 and 20 mg/l. No detrimental effects are expected because of sulfate concentration increases.

Nitrogen concentrations are expected to increase about 10 percent initially and up to 48 percent over background by 1995. Increases in concentrations of total nitrogen will range from 0.09 to 0.16 mg/l initially, to 0.6 to over 0.9 mg/l by 1995. The calculated nitrogen increases appear nominal, although greater local increases will probably occur near the outfall.

The only significant influence that boron displays is the reduction of agricultural productivity at concentrations above 0.5 mg/l; so apparently boron will not cause problems. Although increases are expected to be relatively large (between 0.30 and 0.46 mg/l by 1995) the resultant boron concentrations will not materially affect any existing beneficial use of the surface waters in Suisun Bay.

TABLE 30

ESTIMATED AVERAGE INCREASE IN SULFATE, NITROGEN AND BORON IN SUISUN BAY DUE TO DISCHARGE FROM THE SAN JOAQUIN MASTER DRAIN WITH TERMINOUS AT MARTINEZ

Year	Flow in cfs: Chipps Island	Flow in cfs: Drain	Qualities: Drain mg/l	Qualities: Suisun Bay mg/l	Qualities: Net mg/l	Qualities: Net 1000 lb/day	Average Increase: ppb/1000 lb/day	Average Increase: mg/l	Average: Total mg/l	Average: Percent increase
Sulfate										
1970	1,000	150	3,100	1,270	1,830	1,480	10	15	1,290	1
	2,000			1,050	2,050	1,660	9	15	1,060	1
	9,000			530	2,570	2,080	8	17	540	3
	16,000			370	2,730	2,210	6	13	390	3
1995	1,000	895	1,260	1,850	- 590	-2,850	10	-28	1,820	-1
	2,000			1,500	- 240	-1,160	9	-10	1,490	-1
	9,000			710	550	2,650	8	22	730	2
	16,000			560	700	3,380	6	20	580	4
Total Nitrogen										
1970	1,000	150	21	1.4	19.6	15.8	10	0.16	1.56	11
	2,000						9	0.14	1.54	11
	9,000						8	0.13	1.53	9
	16,000						6	0.09	1.49	6
1995	1,000	895	21	1.9	19.1	92.2	10	0.92	2.82	48
	2,000						9	0.83	2.73	44
	9,000						8	0.74	2.64	39
	16,000						6	0.55	2.45	29
Boron										
1970	1,000	150	10.0	0.15	9.85	7.96	10	0.08	0.23	53
	2,000						9	0.07	0.22	47
	9,000						8	0.06	0.21	40
	16,000						6	0.05	0.20	33
1995	1,000	895	6.5	0.15	6.35	30.64	10	0.31	0.46	207
	2,000						9	0.28	0.43	187
	9,000						8	0.25	0.40	167
	16,000						6	0.18	0.34	120

Salton Sea Comparison

A study was undertaken to compare present environmental conditions in the Delta and Bay system with those observed in the Imperial Valley. It was envisioned that such a comparison would assist in evaluating the possible effects of the San Joaquin Master Drain.

The Salton Sink, an extension of the depression between Baja, California, and the mainland of Mexico, is separated from the Gulf of California by ancient alluvial deposits from the Colorado River. In the geologic past, the basin has been inundated numerous times by the Colorado River.

At the beginning of this century, the basin was almost dry. Irrigation was provided by canals from the Colorado River near Yuma, and agricultural development of the Imperial Valley began. By 1904, 150,000 acres of the Imperial Valley were under cultivation. Between 1904 and 1907, flood waters of the Colorado followed the irrigation canals, deepened existing channels of the Alamo and New rivers and created the Salton Sea. Since 1907, major inflow to the Salton Sea has been salt-laden agricultural drainage. The level of the lake has fluctuated through the years and salinity has increased.

Because of saline soil and the quality of the irrigation supply, leaching and subsurface drainage has become necessary throughout the Imperial Valley in order to prevent reduced crop production. There are presently about 600,000 acres of tilled land, with 450,000 acres served by drainage systems tributary to the Salton Sea. In addition, after various degrees of treatment, the waste of a population of approximately 200,000 persons is drained north to the Salton Sea by the Alamo and New rivers.

The necessity for soil drainage in the Imperial and San Joaquin valleys is well understood. Subsurface tile drains, in which net downward movement of water is maintained by over-irrigation are used and provide the most effective method for highly saline soils. Further salt concentration in the root zone is reduced by soil leaching during fallow seasons. These drainage systems are designed to remove soluble compounds from the soil and therein lies the potential problem. Included in solution with soil "salts" are nitrogen and phosphorus compounds and pesticides.

During August and September 1964, samples of tile drain effluent were collected from eight Imperial Valley drainage systems, and in 1962, tile drains in the Firebaugh area of the San Joaquin Valley were sampled for mineral content. All pesticide sampling was done in 1964. A comparison of data is shown in Table 31.

TABLE 31

WATER QUALITY COMPARISON OF THE SALTON SEA-
IMPERIAL VALLEY AND DELTA-BAY SYSTEMS[1]

Water Supply	Specific Conductance EC x 10^6 at 25°C	Total dissolved solids, in mg/l	Nitrogen in mg/l	Phosphorus in mg/l	Plankton per ml	5-day BOD in mg/l	MCHt, in ug/l[2]
Irrigation Supply[3]							
All-American Canal	1,220	610	1.02	0.06	410	1.3	0.09
Delta-Mendota Canal	450	250	1.32	0.16	7,180	1.0	0.07
Tile Drainage							
Imperial Valley							
Maximum	71,600	63,000	14.8	1.4	550	4.3	0.35
Minimum	10,700	3,800	1.9	0.01	2	0.2	0.05
Average	22,250	17,600	8.6	0.23	120	1.5	0.14
Firebaugh Area							
Maximum	11,000						3.0
Minimum	3,770						0.05
Average	6,670	6,500	21.0	0.15	0	1	0.41
Surface Water							
New River	5,890	3,890	3.19	0.30	3,630	4.3	0.40
Alamo River	3,620	2,700	4.86	0.23	2,340	2.7	0.60
San Joaquin River	1,200	700	1.68	0.38	8,780	5.6	0.35
Salton Sea	39,200	33,100	0.91	0.06	2,840	3.0	0.08
Antioch	5,830	3,540	0.95	0.22	8,310	3.1	0.11
Chipps Island	3,280	1,760	2.51	0.25	20,500	1.8	0.08
Roe Island	7,050	4,120	1.48	0.22	19,400	2.0	0.08
Martinez	24,600	16,000	4.83	0.19	17,300	1.7	0.08
Golden Gate	39,400	31,900	0.73	0.19	900	0.5	0.07
San Mateo	40,600	33,900	0.84	0.40	4,700	0.6	0.05

1 Based on field studies, August-October 1964.

2 1 ug/l is approximately equal to 1 ppb.

3 Quality of water supplies vary throughout the year.

TDS concentrations from tile drainage were found to be about 25 to 30 times those of the supply water. Plankton populations in tile drainage effluents were low because the effluent had not been exposed to sunlight. Samples taken from open drain ditches downstream from the Imperial valley tile drain outfalls were found to have a plankton count ranging from 800 to 6800 and averaging 2500 per ml.

The potential for algae production appears to be present in drain water. The San Joaquin Master Drain will have much greater retention time than the Imperial Valley tile drains and will also have relatively stable conditions of temperature and salinity. This would allow algae to reach maximum levels and impose an organic loading in receiving waters of yet unknown magnitude. Regulating and detention reservoirs, proposed for construction along the drain, may permit removal of some of the organic material.

Chlorinated hydrocarbon concentrations in the Firebaugh area ranged from 0.05 to 3.00 ppb as MCH_t. The cyclic pattern of tile drain flow, differences in soil type and permeability, types of pesticides and times of application, all apparently contributed to the wide range. Extensive use of organo-phosphate pesticides has developed in the Imperial Valley in the past few years. This change in use could be responsible for a lower residual MCH_t in the drains in the Imperial Valley than were found in the San Joaquin Valley. No thiophosphate pesticides were found in the effluent samples.

Imperial Valley soils are so saline and the irrigation supply of such poor quality that water can be used only once; in the San Joaquin Valley, water can be recycled a number of times before drainage disposal is necessary. This recycle capability is another possible reason for higher nitrogen and pesticide concentrations in the San Joaquin Valley.

Values for salt constituents found in samples taken from rivers into which agricultural drains of the two areas discharge reflect the differences in overall salinity as approximately four to five times as high in the Imperial Valley area. Nutrient plankton relationships were not conclusive because of differences in temperature, velocity, and turbidity in the two areas. Oxygen demand (BOD) for both areas was high for surface waters.

Chlorinated hydrocarbon concentrations in the Alamo and New rivers were higher than the maximum detected in Imperial

Valley drainage. This may be due to high pesticide concentrations in surface tailwater, or may indicate that the tile drains sampled were not truly representative. High turbidity in these rivers was indicative of topsoil erosion which could account for higher pesticide residues in the water.

Use of the Salton Sea as an irrigation waste sump, with evaporation providing the only outlet, has resulted in steadily increasing salinity. In 1907, the salinity (TDS) was reported as 3,600 mg/l; by 1948, salinity increased to 40,400. Since then, inflow has exceeded evaporation resulting in dilution to an approximate average salinity of 33,000 mg/l. Eventually, the Salton Sea should stabilize at a point where surface evaporation equals inflow; at that time salinity is expected to again increase. Salinity intrusion from the ocean is the main source of Delta-Bay system salts. Controlled releases of fresh water to the Delta keep salinities at safe levels for Delta irrigation and export.

Average nutrient concentrations in mid-depth water samples from the Salton Sea are lower than Delta-Bay system samples. Mid-depth plankton populations are also lower in the Salton Sea due to radically different environmental conditions in the two areas; a shallow, warm, static lake (Salton Sea), opposed to a very complex system (Delta-Bay), with a constantly changing depth, velocity, temperature, and water chemistry. The greatest biological activity in the Salton Sea is on the bottom; the vast tidal flats are the most productive in the Delta-Bay system. Any changes in Delta-Bay system plankton populations, due to master drain discharge, cannot be predicted from this limited comparative study.

Specific pesticide residues in fish flesh from the two areas were of the same magnitude, and were predominantly of the DDT group. No detrimental effect of pesticide concentrations on the aquatic life was detected; no conclusions can be made.

Sediment samples indicated that high concentrations of pesticides are available to benthic organisms. This could be the critical point of ecological balance in the Salton Sea. Loss of the benthic worm population would probably eliminate the Corvina sport fishery.

The complex biota of Suisun Bay would also be changed by pesticides in the bottom material and this would exert a toxic effect on important food chain items.

Effects of Water Quality Changes

Although changes in physical and chemical constituent concentrations can be predicted with some degree of certainty, biological effects of these changes on the environment and aquatic life cannot be precisely determined at this time. Work is in progress under the "Delta Fish and Wildlife Protection Study" program to evaluate some of the aspects of water quality changes.

Nutrients and Algae

Nitrogen increases, although estimated to be relatively small during the next few years and during early years of a master agricultural drain operation, will become significant in 1995. Nitrogen and phosphorus are the major nutrients which can stimulate algae growth in receiving waters, and algae in sufficient quantity are unsightly and can cause odors.

Phytoplankton populations in the study area are controlled, it is believed, by a complex interaction of physical, chemical, and biological parameters. Nutrients, particularly nitrogen and phosphorus, are essential to plant life, but the difference between nuisance conditions and an acceptable environment is subjective, depending on the use of the water.

Some effort was made during this study to determine the effect of nutrients on the production of algae in the Delta and San Francisco Bay system, and the efforts of others toward the same determination were reviewed. Part of the effort was expressed in the study of the relation of agricultural drainage to the Salton Sea where agricultural drainage, clearly identifiable as such, is introduced into a large body of saline water.

There is a good deal of literature available on observations of the concentrations of nutrients that are considered to trigger undesirable phytoplankton blooms in eastern lakes. The concentrations that can trigger such occurrences have been stated to approximate 0.3 mg/l of inorganic nitrogen and 0.01 mg/l of phosphorus. These clear fresh water lakes with these concentrations of nutrients have been observed to produce obnoxious algae blooms fairly consistently.

In California there is no lack of occurrence of algae blooms. Clear Lake is particularly notable, and in recent years it has had a bloom almost every summer. Other lakes, particularly those along the eastern slope of the Sierra Nevada such as Bridgeport Reservoir, frequently have distinctly visible blooms, but there may have been a time when these blooms did not occur through lack of nutrients. In these California lakes information has not been developed with which the initial nutrient levels could be ascertained.

The contrast of the Delta and San Francisco Bay with the lakes is striking. While some literature contains reports of blooms, almost without exception, it is found that the definition is based on an increase in number of organisms found in the water through counts taken from samples rather than through the visual observation of undesirable conditions directly related to profusion in numbers of algae in the water. The exceptions to this are the very strong blooms of a red form of algae and a yellow form of algae in the highly saline water of salt ponds in the south San Francisco Bay area.

In contrast with the lack of bloom conditions, the analysis of the nutrients in the water show that at almost any time and in any part of the Delta or San Francisco Bay the nutrient concentration in the water may exceed those that were earlier cited as the initial levels leading to algae blooms in eastern lakes. In many cases these concentrations (Tables 12 and 13) have become several times as great as experienced in the eastern lakes.

From this evidence, it is not reasonable to say that algae blooms will not occur with increased fertilization in the Delta and Suisun Bay. It is possible that there are inhibiting circumstances, not well understood, that make the environment much less sensitive to the effect of nutrients than most other bodies of water. The most commonly discussed condition is the presence of large amounts of suspended material, or turbidity, which inhibits the penetration of light. While concern must continue about the possible effects of high concentrations of nutrients in the receiving water, it also must be recognized that the predictions of adverse consequences made by other observers have no foundation in any observations or analytical work that has been of sufficient status to be reported in scientific literature.

CHAPTER VI

SUMMARY OF CONCLUSIONS

Summary

The Delta and Suisun Bay Water Quality Investigation was composed of several studies, each designed to yield information to meet one or more specific objectives. Field dye tracer studies were used to develop data on flow distribution, circulation patterns, diffusion characteristics, and residence times in the major channels and waterways of the Delta-Suisun Bay system. Present water quality was determined throughout the area of investigation primarily from data collected by other investigators and augmented by limited supplemental sampling at certain locations. Sources and amounts of natural and man-made water quality degradation were examined to evaluate their present and future effect on the quality of receiving waters. Estimates of changes in water quality were made with respect to one assumed method of operating the Peripheral Canal. A San Joaquin Master Drain discharge was considered at several alternative outfall locations.

Hydraulic Characteristics

The use of fluorescent dye tracers in studies designed to investigate mixing, dispersion, travel time, and flow distribution characteristics within the study area was moderately successful. Precise quantitative determination of diffusion was limited by photochemical and biochemical decay of the dye, variations in background fluorescence, and the magnitude of experimental errors in measurements and analysis.

Water Quality

Studies of the interrelationships of surface water mineral quality showed that the distribution and composition of waters throughout the Delta were influenced by the magnitude of perimeter inflows, pumping demand of the Delta-Mendota Canal, irrigation drainage, seawater intrusion, and variations in base exchange capacities caused by seasonal and hydrologic changes.

Analysis of over 500 samples taken from surface waters and irrigation drains, sediments and aquatic life, and collected from October 1963 through December 1964, indicated concentrations of specific pesticides in practically every sector of the aquatic environment. Chlorinated hydrocarbons were found in all samples analyzed and thiophosphates generally were found in samples collected in surface drains near cultivated fields.

Water Quality Degradation

Degradation of water quality was found to be caused by natural as well as man-made processes, including the life cycles of aquatic organisms, land surface runoff, sediment transport by high water flows, biochemical cycles, and highly mineralized surface or ground waters. Any of these causes can transform high-quality water into water which is unsuitable for one or more of the several beneficial uses of water.

Salinity intrusion from the San Francisco Bay system increases concentrations in the western Delta and in Suisun Bay. Variation in net outflow past Chipps Island is the primary influence on the extent of this increase.

Prior to construction of Shasta Dam, salinity intrusion into the Delta was not an unusual occurrence. Moderate to extreme salinity intrusion occurred every two or three years on the average In 1931, saline water intruded into the Delta to a point dangerously near Stockton. Since 1944, releases from Shasta Reservoir have helped repel the summer salinity threat to the Delta. There has been no year since completion of the Shasta Dam that a severe salinity intrusion problem has been experienced within the interior Delta. Had there been no releases for salinity control, salt water would have intruded well into the interior Delta.

Delta agricultural drainage wastes are discharged through more than 200 pump installations ranging in capacity from about 5 to almost 80 cfs. Most of the drainage waters are highly mineralized and contain high concentrations of nitrogen compounds. Total seasonal waste flows range from a minimum of about 500 cfs in October and March, to a maximum of 1,600 cfs in January. Estimated BOD loadings vary from 15,000 pounds per day in September to 58,000 pounds per day in January. Nitrogen is discharged at an estimated rate of 10,000 pounds per day in October and 38,000 pounds per day in January.

Fifty-four municipal and industrial waste dischargers dump ever-increasing quantities of waste contributed by approximately 1,500,000 people, plus associated industries, into the surface waters of the Delta and Suisun Bay. The quantities of waste discharged from individual works range from less than 1 cfs to over 85 cfs with varying concentrations of minerals, organics, and bacteria. Municipal and industrial dischargers with a total average daily flow of approximately 400 cfs, put an estimated 194,000 pounds per day of BOD and 43,000 pounds per day of nitrogen into the receiving waters during 1960.

Projections of the quantity and quality of waste discharged from municipal and industrial facilities indicate that between two and three times as much waste will be discharged in 1995 as at present. Total waste discharges will be approximately 1,000 cfs; assuming that waste treatment practices do not change, BOD loadings are estimated to be about 460,000 and nitrogen loadings about 100,000 pounds per day.

A special study conducted during September and October 1963, in the area of the San Joaquin River near Stockton, provided data on the hydraulic, physical, and chemical environment, and the effect of waste discharges on water quality. Pollution and oxygen depletion were found to be functions of the dieoff of upstream microorganism populations, high concentrations of nutrients and BOD, large quantities of wastes discharged from the City of Stockton waste treatment plant in the form of organic and inorganic (nitrogen potential) BOD, low river flows with no dilution and/or waste transport capabilities, and a change in environment that prevented upstream autotrophic (plant) communities from surviving in the Stockton Ship Channel.

Modeling Studies

The Corps of Engineers' hydraulic model of the San Francisco Bay system was found to adequately reproduce tides, salinities, and current velocities of the prototype for inflows of 2,000 cfs and to reproduce dispersion characteristics at 16,000 cfs. Hydraulic model studies of the San Pablo-Suisun Bay system were conducted to estimate changes in constituent concentrations resulting from future discharge of municipal, industrial, and agricultural wastes. Results from the model tests were generally effective in determining depression patterns and mixing characteristics at various Delta outflows.

A mathematical model was used to simulate the hydraulic characteristics of the Delta. Solution of the model program by digital computer provided hydraulic parameters for flow conditions existing in 1955, and those anticipated to exist in 1995. One solution for 1995 was a simulation of the anticipated mean dry year; another was the characterization of conditions with the San Joaquin Master Drain discharging at Antioch Bridge.

The net flows in Delta channels estimated from the hydraulic solution of the mathematical model were fed into a mineral quality routing program. The model solution for hydraulic and mineral characteristics of the Delta, simulated for 1955 conditions, was compared with observed prototype data to determine the model's ability to reproduce the actual environment. These comparisons showed that although the model did not simulate salinity intrusion during low flow periods, reasonable agreement was obtained in areas of net flow downstream where tidal diffusion of ocean salts was nonexistent. On the basis of the correlation between model and prototype results, conditions in 1995 were simulated incorporating flow and quality data for perimeter inflows, agricultural drains, municipal and industrial waste discharges, and water supply diversions anticipated for 1995.

Delta Water Facilities

Operation of the Peripheral Canal will enable better water quality control within the Delta. The degree of control in a given area will depend on location with respect to Peripheral Canal release works and the operation criteria of the facilities.

Plans indicate several changes in the hydraulics of the northern Delta. Water for the Peripheral Canal will be diverted from the Sacramento River near Hood (Figure 2) a short distance upstream from Snodgrass Slough. Release structures will be built along the Peripheral Canal. Operation of the Delta Cross Channel will be modified and a new control facility will be constructed in Georgiana Slough.

The influence that flow releases in the dead-end sloughs at the eastern perimeter of the Delta will have on acquatic life cannot be determined at this time. However, a physical result of the releases will be the continuous flushing so that mineralized and fertilized waters will not build up in these channels and slugs will not be released into the large river channels during times of storm runoff.

Evaluation of the studies on water flow and quality conditions estimated for 1995 shows that variations in flow conditi and increased waste loadings will generally be responsible for chan from present water quality. Some channels can be expected to have higher BOD, nitrogen, and phosphate concentrations. Areas that sho be given special attention are in the central Delta from a point ne Victoria Canal in Middle River, north to the San Joaquin River, and from Rindge Tract, west to Jersey Island.

With the completion of the Peripheral Canal, net flow reversals that presently occur during the summer near Stockton can be eliminated and greater control can be exerted over the environme of that area. Changes in flow quantities, direction, point of orig etc., could make the southern Delta one of the better quality-controlled segments of the system. Elimination of net flow reversa near Stockton will not eliminate degradation caused by the expected increases in municipal and industrial wastes. The point of maximum oxygen deficit will be displaced downstream from its present locati near the Calaveras River to a point near Rindge Island. Dissolved oxygen depletions will probably not be as great, due to changes in net velocities and flows, and minimums will be maintained above tho required by the Delta fishery.

The portion of Middle River along the north side of Union Island should be monitored carefully to assure that water released from the Peripheral Canal will produce suitable quality. The assum 1995 operation criteria used in this study for the Peripheral Canal calls for discharge into the northern reach of Middle River from Ma through August and maintenance of a flushing flow for the other eight months of the year. Controlled releases to the river will be necessary to control quality.

Distribution of controlled flows between the San Joaquin and Sacramento rivers will be different in 1995 than under present conditions. The San Joaquin River and southern Delta channels will contribute a greater proportion of water to western Delta outflow than they do presently, and will be relatively more important determinants of environmental conditions in the western Delta.

San Joaquin Master Drain

The San Joaquin Master Drain has been found to be the most practical means of protecting the water supplies and agricultural soils of the San Joaquin Valley. Quantity and quality of drainage waters to be discharged from the San Joaquin Valley were estimated during the San Joaquin Valley Drainage Investigation. Probable changes in constituents concentrations resulting from discharging this drainage water into the western Delta and parts of the San Francisco Bay system were estimated during the Delta and Suisun Bay Water Quality Investigation.

Studies to measure the effects of discharging the master drain at Antioch Bridge, Port Chicago, Martinez, Crockett, and Pinole Point, generally have shown that significant changes in concentrations will occur only for sulfate, boron, and nitrogen. These studies were predicated on discharging agricultural drainage as it developes and under minimum Delta outflow conditions. Results do not reflect the advantages that might be realized with operation controls including detention storage, dilution, of treatment prior to discharge.

Evaluation of dye tracer studies, conducted to estimate the changes in surface water quality which would result from the discharge of agricultural drainage near Antioch, indicate that the initial master drain discharge should not create any problems. Initial increases in total dissolved solids, chloride, and sodium will be insignificant, 2 percent or less. Sulfate concentrations could be increased by 5 to 18 percent initially and in the future. Increases in nitrogen concentrations during the early years of drain operation will not exceed 10 percent except possibly during extremely low flow periods in the San Joaquin River and then only near the discharge point. Boron concentrations are expected to be considerably below 0.5 mg/l.

Under 1995 conditions, operation of the master drain should result in a small improvement in the receiving water concentrations of TDS, Cl, and Na because it will help in controlling salinity intrusion. Future increases in the boron level resulting from drainage discharge near Antioch could approach the 0.5 mg/l level, but do not pose a problem to agriculture since substitute water facilities can be provided for the western Delta.

Nitrogen concentrations in the San Joaquin River near Antioch are projected to range between 2 and 3 mg/l under estimated 1995 conditions. Alghough increases in nitrogen concentratio in conjunction with other nutrients, have been reported as being responsible for excessive biological growths, there are no data presently available to indicate the nitrogen concentration in the Delta and San Francisco Bay at which this might occur. Large nitrogen concentrations in the Delta and Bay have not caused excessive biological growths to date. The surveillance program proposed in conjunction with operation of the State Water Project, should provide sufficient warning of possible problems in the estuary so that remedial action can be taken.

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