SWRCB ORDER NO. W.Q. 85-1
TECHNICAL COMMITTEE REPORT

REGULATION OF AGRICULTURAL DRAINAGE TO THE SAN JOAQUIN RIVER

FINAL REPORT

AUGUST 1987

STATE WATER RESOURCES CONTROL BOARD

Les Grober

STATE WATER RESOURCES CONTROL BOARD
RESOLUTION NO. 87- 78

APPROVAL OF THE TECHNICAL COMMITTEE REPORT
"REGULATION OF AGRICULTURAL DRAINAGE TO THE SAN JOAQUIN RIVER"

WHEREAS:

1. The State Board by Order WQ 85-1, established the San Joaquin River Basin Technical Committee and directed it to investigate agricultural drainage effects on San Joaquin River water quality.

2. The Technical Committee was directed to prepare a report to the State Board on (i) proposed water quality objectives for the San Joaquin River Basin; (ii) proposed effluent limitations for agricultural drainage discharges in the Basin to achieve these objectives; and (iii) a proposal to regulate these discharges.

3. The Technical Committee was provided guidance from six advisory groups.

4. The State Board has reviewed this report and its appendices and conducted a special workshop on June 18, 1987 to receive public comments on the report.

5. The State Board has reviewed the responses of the Technical Committee to written and oral comments received during the June 18, 1987 workshop, and while the workshop record was held open.

6. The Technical Committee has revised the Report and its Executive Summary to address the comments and concerns which were raised. The revisions were distributed for review on July 23, 1987.

7. Additional changes to the report were proposed by staff at the Board meeting.

THEREFORE BE IT RESOLVED THAT:

1. The State Board accepts the revised report of the Technical Committee as responsive to the tasks assigned in Order WQ 85-1.

2. The State Board staff is directed to prepare the Technical Committee Report for publication and transmit the report and its appendices to the Central Valley Regional Board for consideration of appropriate action in revising the San Joaquin River Basin Plan as set forth in Order WQ 85-1.

3. The recommendation contained in the Technical Committee Report should be carefully evaluated by the Regional Board. Objectives for the protection of wildlife beneficial uses in the grasslands area should result in improvements to these beneficial uses. As an alternative to the numeric water quality objective for the grasslands area, the use of a U. S. Environmental Protection Agency-developed biological monitoring or assessment method should be further evaluated by the Regional Board. The Regional Board will develop long-term objectives by 1991.

4. The State Board wishes to express its appreciation to all the State and Regional Board staff who worked on various aspects of this report.

5. The State Board wishes to thank the Grassland Water Task Force, South Delta Water Agency, U. S. Environmental Protection Agency, San Joaquin Valley Drainage Program, State Department of Water Resources, Environmental Defense Fund and Natural Resources Defense Council for the guidance they provided to the Technical Committee. Although the Technical Committee and representatives from these groups did not always agree, their participation was a key element to the success of this effort.

CERTIFICATION

The undersigned, Administrative Assistant to the Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on August 20, 1987.

Maureen Marche'
Maureen Marche'
Administrative Assistant to the Board

REGULATION OF AGRICULTURAL DRAINAGE TO THE SAN JOAQUIN RIVER

AUGUST 1987

SAN JOAQUIN RIVER BASIN TECHNICAL COMMITTEE

SWRCB ORDER NO. WQ 85-1 TECHNICAL COMMITTEE AND STAFF

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1/ Advisors and Consultants to the Technical Committee do not necessarily endorse the findings or conclusions contained in this report.

Acknowledgements

In addition to the valuable assistance provided by the Technical Committee's advisors and consultants, listed by name elsewhere in the report, others have been very helpful to the Committee in the completion of its charge. The Committee would like to offer its thanks to the following persons for providing valuable technical guidance and information:

Charles Burt, California Polytechnic State University, San Luis Obispo; Robert Gilliom, U.S. Geological Survey; Glenn Hoffman, U.S. Agricultural Research Service; John Letey, University of California, Riverside; Jim Oster, University of California, Riverside; Fred Paveglio, U.S. Fish and Wildlife Service; and Ken Tanji, University of California, Davis.

For valuable guidance regarding the regulatory and implementation plans, the Committee thanks Steven Hall of the Land Preservation Association.

For their important support activity, the Committee offers its appreciation to Adan Garcia, Ed Wilds and Dale Oliver of the State Board's Graphic Services Unit; Jim Baglin, Margaret Ledesma and Ryan Rowlands of the State Board's Reproduction Unit; Geri Young who typed a major portion of the initial draft of the report and Ellyn Sekul for her tireless word processing of the revised draft and final editions of the report.

FOREWORD

Background

In February 1985 the State Water Resources Control Board (State Board) adopted Order WQ 85-1. This order addressed the waterfowl problems at Kesterson Reservoir arising from selenium laden subsurface agricultural drainage water discharged into this facility. In this order the State Board also expressed concerns related to the discharge of agricultural drainage water into the San Joaquin River. The State Board directed the formation of the San Joaquin River Basin Technical Committee, made up of State Board and Central Valley Regional Water Quality Control Board (Regional Board) staff. The Technical Committee was to investigate water quality concerns in the San Joaquin River Basin related to agricultural drainage and to report back to the State Board on (1) proposed water quality objectives for the San Joaquin River Basin, (2) proposed effluent limitations for agricultural drainage discharges in the Basin to achieve these objectives and (3) a proposal to regulate these discharges. This report and its appendices contain the results of the Technical Committee's efforts.

Throughout this effort the Technical Committee received valuable guidance from six advisory groups. They are: (1) Grassland Water Task Force, (2) South Delta Water Agency, (3) U.S. Environmental Protection Agency, (4) Interagency San Joaquin Valley Drainage Program, (5) California Department of Water Resources, and (6) Environmental Defense Fund and Natural Resources Defense Council. These groups provided extremely valuable information and guidance to the Technical Committee. While these groups do not necessarily endorse the conclusions or recommendations of the Technical Committee, their contributions were essential to this effort.

Review of Draft Report

A draft of the Technical Committee Report was circulated for review in May. Public comments were received during a public workshop on June 18, 1987. Changes made as a result of the comments received were circulated for review, and the State Board accepted the report with appropriate changes at its August 20, 1987 regular Board Meeting.

Purpose of Report

The final Technical Committee Report is now being transmitted to the Central Valley Regional Board for its consideration, along with other information, in amending the San Joaquin River Basin Water Quality Control Plan (Basin Plan). Based on their review, draft Basin Plan amendments will be prepared. The Regional Board will hold public hearings on the draft Basin Plan amendments. According to the schedule set forth in Order WQ 85-1, the Regional Board is to complete its review of these amendments to the Basin Plan by February 20, 1988.

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I. INTRODUCTION

The southern portion of California's Central Valley is comprised of two hydrologic basins, separate except during extremely high runoff periods. Both the Tulare Lake Basin and the San Joaquin River Basin are intensively farmed. This report focuses on the regulation of agricultural drainage in the San Joaquin River Basin.

Approximately 2 million of the 7.1 million acres in the San Joaquin River Basin are devoted to irrigated agriculture. Significant water quality and water management problems have developed during the more than 100 years of agricultural growth in the Basin. Human alteration of surface water flows, ground water supplies and land use, coupled with natural hydrogeologic conditions are responsible for these problems.

Natural sources of irrigation water are plentiful on the east side of the Valley. Deep well pumping and the construction of drainage works in the 1920's and 1930's largely corrected salt load imbalances and drainage problems which developed as a result of poor water management.

Importation of water by the Central Valley Project provided an increased irrigation supply for most lands on the west side of the Valley and in the Valley trough. West side soils are of marine origin and are commonly underlain by shallow clay layers. Irrigation results in high water tables containing elevated concentrations of naturally occurring salts and trace elements. Subsurface drainage systems have been installed in many areas of the west side to lower the water table and allow needed periodic leaching of the soils. About 77,000 acres in the San Joaquin River Basin have subsurface drainage systems which eventually discharge to the San Joaquin River. About 48,000 acres of this land are upstream of Salt and Mud sloughs. The discharge of this subsurface drainage to the San Joaquin River has contributed to the downstream degradation of water quality. Claims of adversely affected water rights and fish and wildlife impacts have resulted from this water quality degradation.

During the 1960's and 1970's the U.S. Bureau of Reclamation and the California Department of Water Resources collaborated in planning for the staged construction of a master drainage canal to remove subsurface agricultural drainage from the San Joaquin Valley. Due to funding problems, political opposition, and environmental concerns, only an 85 mile stretch was completed. This portion, known as the San Luis Drain, stretches northward from near the town of Five Points to a series of twelve shallow ponds at Kesterson Reservoir near Gustine.

Operated secondarily as a wildlife refuge, Kesterson Reservoir accepted relatively good quality local surface runoff from 1972 to 1978. Between 1978 and 1981 an increasing proportion of the flow to Kesterson Reservoir was comprised of subsurface agricultural drainage. By 1981 almost the entire flow was from subsurface drains from the Westlands Water District. In 1982 extremely high concentrations of selenium were measured in water samples from the San Luis Drain and Kesterson Reservoir. Subsequently, high frequencies of waterfowl deaths and deformities were observed at Kesterson Reservoir and attributed to the accumulation of selenium to toxic concentrations.

Due to the potential risk to human consumers of fish and waterfowl, health warnings were issued to limit the consumption of fish and waterfowl from the Kesterson area and the nearby grasslands area of western Merced County. The grasslands area includes about 50,000 acres within the Grassland Water District that are cultivated and seasonally flooded to provide wintering waterfowl habitat.

The State Water Resources Control Board (State Board) held hearings and issued a Cleanup and Abatement Order (WQ 85-1) in February 1985 to the U.S. Bureau of Reclamation, operators of Kesterson Reservoir. In addition, a Technical Committee composed of State Board and Central Valley Regional Water Quality Control Board staff was established for the purpose of proposing water quality objectives for the San Joaquin River, effluent limitations for agricultural drainage discharges in the Basin, and methods to regulate these discharges.

Since the occurrence of waterfowl mortalities at Kesterson Reservoir, over 150 selenium-related studies have been undertaken by federal, state, and and local agencies, the University of California, and local agricultural entities. Beginning in early 1985, managers of waterfowl areas in the grasslands area refused to accept selenium-tainted drainage water from upslope agricultural operations as their water supply. This resulted in the bypass of the upslope drainage water to the San Joaquin River. Because incidental selenium removal arising from the impoundment of the drainage water in the Grassland Water District marshes ceased, an approximate two-fold increase in the discharge of selenium to the River from this area has occurred. As a result, a commensurate increase in the concentration of selenium has occurred in the San Joaquin River upstream of the Merced River.

The Technical Committee circulated a draft summary report for public comment in August 1986. The draft report presented a condensed review of the Committee's findings up to that time and listed tasks which remained to be completed. The Technical Committee was hampered in some areas by a lack of data from which to draw its conclusions. Nevertheless, wherever possible, the Technical Committee has attempted to fulfill its charge based on the best information available.

This report first reviews the history of agricultural and water development in the San Joaquin River Basin and the changes in the flow and quality of the River that have resulted. Then, the beneficial uses of the River and its major tributaries in the Valley trough are examined. Special emphasis has been given to examining beneficial uses related to fish and wildlife, which may be particularly sensitive to pollutant effects. Next, constituents of subsurface agricultural drainage which are of special concern are identified, and water quality criteria to protect beneficial uses in the Valley are developed for these constituents. This chapter is followed by an examination of existing water management practices and selenium loads in the areas draining to the San Joaquin River upstream of its confluence with the Merced River. After the agricultural economy of the study area is examined, the environmental and economic effects of implementing various drainage management alternatives are presented.

Lastly, water quality objectives are discussed and a program for their implementation is suggested.

Substantial technical and supporting material, which served as the basis for the Technical Committee's summary report, is included in nine appendices, available upon request. Please contact the Office of Legislative and Public Affairs at (916) 322-3132 if you wish to receive copies.

II. HISTORY OF AGRICULTURAL DEVELOPMENT AND DRAINAGE PROBLEMS IN THE SAN JOAQUIN RIVER BASIN

This chapter summarizes the history of agricultural development in the San Joaquin River Basin. Some of the factors which have contributed to current drainage and water quality problems are reviewed. A more detailed discussion is contained in Appendix A.

The approximately seven million acre San Joaquin River Basin (Basin 5C, State Water Resources Control Board, 1975) extends from the Delta, south to the upper San Joaquin River, west to the Coast Range, and east to the Sierra Nevada (see Figure II-1). Three major tributaries to the San Joaquin River, the Merced, Tuolumne, and Stanislaus rivers drain the east-side of the Basin. On the west side, ephemeral streams drain the Coast Range, rarely reaching the San Joaquin River. The climate is arid. Annual precipitation averages 8 inches and evaporation averages 50 inches (Kratzer, 1985).

Relatively large-scale agricultural development began in the San Joaquin River Basin during the 1850's to supply food for the numerous immigrants who flocked to California during the Gold Rush. Figure II-2(A-F) summarizes the growth of irrigated agriculture in the Basin. Initially, irrigation water came from ground water or instream riparian diversions. Later, flood protection structures and irrigation canals were built during reclamation of the fertile flood plain lands along the major water courses. In the 1870's extensive irrigation projects were constructed. Much of the early agricultural development took place on the east side and in the Valley trough. Miller and Lux diverted substantial San Joaquin River flows to irrigate large west side holdings. By 1880 almost 200,000 acres were irrigated (see Figure II-2A) (Department of Public Works, 1931).

By the late 1880's there was a demand for legislation allowing formation of irrigation districts by non-riparian farmers. Large riparian landowners strongly opposed water diversion by non-riparian farmers. But in 1887 the state passed the Wright Act. This act enabled landowners to form irrigation districts when irrigation water was derived from the same source and physical works. Districts had the power of eminent domain, could obtain water rights, issue bonds, and levy assessments. Many irrigation districts were created under this act and subsequent revisions (Department of Public Works, 1930b). By 1915, 800,000 acres were being irrigated in the San Joaquin Valley (Department of Public Works, 1931).

<u>Changes in the Natural Environment</u>

The growth of irrigated agriculture in the San Joaquin River Basin drastically changed the natural environment. Historically, peak flows occurred in May and June with flooding common along the major rivers. The rich silt deposited along the natural levees and deltas by annual floods supported lush, diverse riparian forests. It has been estimated that riparian vegetation once covered as much as two million acres (Gilmer et al., 1982; Katibah, 1984; Katibah et al., 1984; Warner and Hendrix, 1985). When flood flows reached the valley floor they spread over the lowlands creating several hundred thousand acres of permanent tule marshes and over a million and one half acres of seasonal wetlands (Department of Fish and Game, 1983; Warner and Hendrix, 1985).

This water-dependent environment supported abundant fish and wildlife resources. Although no historical records are available, it can be assumed, from recent records, that the San Joaquin Basin probably supported hundreds of thousands to millions of migratory and resident waterfowl. Thousands of other birds, mammals, reptiles and amphibians probably utilized the riparian forests, wetlands, and more arid uplands. Tens of thousands of chinook salmon probably spawned in the headwaters of all permanent streams and rivers. A diverse community of native, resident fishes also inhabited these watercourses.

By the late 1920's agriculture had eliminated significant amounts of riparian and wetland habitat (Warner and Hendrix, 1985, U.S. Bureau of Reclamation, 1986). The soils of riparian lands were fertile and protected from annual floods by natural levees. Riparian vegetation provided the primary source of timber, fuel and fencing (Katibah, 1984). As more irrigation storage, reclamation, and hydroelectric power projects were built, floods and high flows were reduced. The annual flow patterns changed and water was transported away from riparian and wetland zones.

Ground water pumping also lowered the water table below the root zone of riparian plants. By the 1920's the only surviving wetlands were owned by private duck clubs (Department of Fish and Game, 1983) and riparian areas were substantially reduced (Katibah, 1984).

Today, about 65,000 acres of wetlands are managed by public and private groups for migratory waterfowl primarily in the grasslands of Merced and Fresno Counties in the vicinity of Los Banos. Approximately 600,000 to one million waterfowl winter in the San Joaquin Basin. Only the Sacramento Valley's Butte Basin supports more wintering waterfowl (Department of Fish and Game, 1983). The remaining riparian woodland, representing about 2 percent of the original amount, survives only as a narrow band along the major rivers. (For further detailed discussion of of this subject, including references, see Appendix B.)

Early Drainage Problems

Salinity and drainage problems are not new to the San Joaquin Basin. They developed rapidly as irrigated agriculture spread into arid lands, areas with naturally poor drainage and high water tables, and low lying flood overflow lands. As early as 1886 elevated soil salinity and waterlogging related to agricultural operations was observed.

Much of the problem was due to application of excessive amounts of irrigation water above known specific crop requirements and the ability of the shallow ground water to move laterally out of the area. Surface water supplies were seasonally plentiful and of good quality. In some cases, farmers deliberately overirrigated during the wet season, raising the water table to provide a water supply to crops during the dry season (sub-irrigation). Furthermore, irrigation canals were unlined and significant seepage occurred. In the arid climate of the Basin, evapotranspiration resulted in the heavy accumulation of various mineral salts in the upper soil layers. More water had to be applied to leach salts below the crop root zone. By the turn of the century these conditions had reduced productivity and forced abandonment of some areas on the east side (Department of Water Resources, 1974). In an attempt to solve this problem the U.S. Department of Agriculture demonstrated the use of subsurface tile drainage lines in 1909 (Interagency Drainage Program Report, 1979). But it was not until the 1920's - 1930's when deepwell pumping was introduced, that these problems were finally corrected on the east side (Kelley and Nye, 1984; Department of Public Works, 1931).

The Central Valley Project

During the 1920's - 1930's the demand for larger, more reliable irrigation supplies resulted in the construction of several major storage projects (see Appendix A, Table A-1) as well as the first comprehensive, statewide water analysis and plan (Department of Public Works, 1930a, Rogers and Nichols, 1967). The elements of the 1929 California Water Plan were known as the Central Valley Project (CVP). The primary purpose was to store water from the northern Sacramento Valley and transport it to irrigate the west side of the San Joaquin Valley. The State approved the CVP in 1933 and issued bonds to finance its construction. However, because of the Depression, adequate funds were not raised. Federal financing was eventually obtained and construction of the CVP in Northern California began in 1937. The U.S. Bureau of Reclamation (USBR) was given responsibility for construction and operation of the CVP (Jackson and Paterson, 1977; Rogers and Nichols, 1967).

The CVP facilities serving the San Joaquin Valley were constructed between 1944 and 1951 (see Table II-1 and Figure II-2E). Friant Dam on the upper San Joaquin River was completed in 1947, although deliveries to the northeastern San Joaquin River Basin via the Madera Canal began in 1945. Good quality San Joaquin River flows had been used by growers between Mendota and Newman for many years. In order to compensate these growers who had been irrigating with San Joaquin River water under pre-1914 water rights, the USBR agreed to provide "exchange" water via the Delta-Mendota Canal (Department of Water Resources, 1960). Those receiving water by this agreement are known as "exchange contractors". Since Delta water contained more salts than San Joaquin River, approximately seven times the total dissolved solids, additional supplies above historic use levels were made available to the exchange contractors to provide for leaching. Deliveries of San Joaquin River water southwards to the Tulare Basin via the Friant-Kern Canal began in 1949. The initial CVP facilities for transferring

Sacramento River water south to the west side of the San Joaquin Valley were finished and commenced operations in 1951 (Department of Water Resources, 1960; Jackson and Paterson, 1977; Rogers and Nichols, 1967). Additional irrigation water became available when the federal San Luis Unit began delivering Delta water to the west side of the Valley in 1968 (see Table II-1). Within the San Joaquin River Basin, the San Luis Unit supplied the San Luis, Broadview, and Pacheco Water Districts and Panoche Drainage District (see Figure II-2F).

Operation of the CVP allowed more land to be irrigated in the San Joaquin Valley, including the Tulare Lake Basin. Between 1930 and 1960 irrigated land increased from 3.6 million to 4.4 million acres (Department of Water Resources, 1965). During this period, surface water diversions for irrigation in the San Joaquin River Basin increased from 2.5 to 3.5 million acre-feet (af). Between 1950 and 1957, irrigated acres on the west side rose from about 293,000 to 402,000, and from 729,000 to 861,000 on the east side. About 5,000 additional acres were brought into production on the west side by deliveries from the San Luis Canal after 1968 (Swain, 1987). The west side growth was due to both the availability of imported water from the CVP's Delta-Mendota Canal as well as development of ground water. Since deliveries from the San Luis Unit began, Delta water supplies have replaced ground water use for irrigation for much of the west side. Increased agricultural development on the east side was the result of increased ground water development and a firmer water supply from storage facilities (Department of Water Resources, 1960).

Modern Drainage Problems

The availability of CVP water, while facilitating agricultural expansion, accelerated the development of a new set of drainage and water quality problems in the Basin. Ground water pumping and CVP water deliveries enabled irrigated agriculture to spread into the arid uplands of the west side in the 1950's (Figure II-2E). Due to the hydrogeology of the area, soil drainage and water quality problems worsened following this expansion.

Prior to significant development on the west side, ground water flow was generally northeastward from the Coast Ranges toward the San Joaquin River. Except for local ground water depressions or mounds caused by ground water pumping or imported surface water, the general trend of ground water movement is still northeastward (see Figure II-3). Based on DWR ground water contour maps (California Department of Water Resources, 1985) and unpublished U.S. Geological Survey (USGS) data (Gilliom, 1987), we drew the general ground water flowlines shown on Figure II-3. This information allows a preliminary evaluation of the potential up-gradient areas to the Drainage Study Area (DSA) (see Chapter V). The direction of ground water flow in the Panoche fan between the California Aqueduct and the 225-foot ground water contour is uncertain, as is the direction of ground water flow west of the Aqueduct in the area north of Little Panoche Creek. Between the alluvial fans (Little Panoche, Panoche, and Cantua creeks), a ground water divide appears to follow the California Aqueduct. Ground water flows in opposite directions on either side of the divide (see Figure II-3). The USGS is presently working on a technical report which will describe this ground water divide in detail. This USGS report on the hydrogeology of the west side of the San Joaquin Valley should be available later this year.

Unlike a surface water flow divide, the location of this ground water divide is not constant. In fact, its location is very unstable and is in a continual state of flux. Thus, although some irrigated lands are currently west of the ground water divide, this situation could change in the near future. For example, continued irrigation on lands west of the ground water divide coupled with the implementation of water conservation measures east of the divide will move the divide westward and thus include more lands in the region up-gradient of the DSA in Figure II-3. Any quantitative estimation of this movement will require the sort of information the USGS is presently putting together.

West side soils are derived from marine sediments of the Coast Range. These soils contain large amounts of water soluble mineral salts, including calcium carbonate and calcium sulfate, as well as trace elements which have dissolved and occur at high concentrations in the ground water (Kratzer, 1985). The salts and trace elements contained in these soils have been transported by ground water and concentrated by evaporation. The poor quality of subsurface agricultural drainage from the west side is typified by drainage from western Fresno County. It is alkaline (median pH is 8.4), hard (median total hardness as calcium carbonate is 2,510 milligrams per liter (mg/l)) and very salty (about 10,000 mg/l total dissolved solids (TDS)). The dominant ions are sodium and sulfate. High levels of cadmium, chromium, copper, zinc, boron, and molybdenum are also present (Izbicki, 1985). Selenium also occurs as a natural impurity of sulfide minerals in this area (Burau, 1985). Subsurface drainage increases oxidation of these minerals and the release of selenate. Figure II-4 shows the location of ground water containing high selenium levels. High nitrates are also released in subsurface drainage.

In many areas of the west side there are dense clay lenses below the surface soil which impede deep percolation of applied irrigation water. This is known as the A clay or Hanford clay. Local mounds of shallow, salty, ground water can form above these clay lenses. Direct application of irrigation water as well as lateral seepage from upgradient have contributed to elevation of the water table in some downgradient areas to levels that can adversely affect agricultural productivity. Areas with poor drainage are shown in Figure II-5. Capillary action and evapotranspiration result in upward migration of salty subsurface water. When the water evaporates, salts accumulate in the soil in concentrations that can be toxic to plants. They must be leached below the crop root zone by application of water in excess of crop requirements. Leaching further exacerbates the high water table situation.

In order to alleviate salt build-up in the soil and high water table problems, growers began installing subsurface drainage systems in the 1950's to carry accumulated water downslope to the San Joaquin River. Originally made of clay tiles, though now usually of perforated plastic pipe, subsurface drains are still commonly referred to as tile drains.

Most subsurface systems were installed in western Fresno County between Mendota and Los Banos (see Figure II-6). Many more acres may need subsurface drainage to remain productive in the future (see Figure II-5).

Plans for a San Joaquin Valley Master Drain

In the 1950's a Valley-wide drainage and salt accumulation and disposal problem was recognized (USBR Central Valley Basin Report to 81st Congress, 1949). Both state and federal agencies realized that planned additional water importation projects would worsen these problems. The 1960 authorization for the California Department of Water Resource's (DWR's) State Water Project (SWP) and the federal San Luis Unit of the CVP included plans for a master drain to remove salty subsurface drainage from the San Joaquin Valley.

During the 1960's the USBR and DWR collaborated on plans for staged construction of a San Joaquin Valley drain that would discharge in the Delta. The State was unable to develop a method for repayment of reimbursable costs, acceptable to future drain users. Therefore, DWR withdrew from the planning process. The USBR continued with plans to build a 188 mile long San Luis Interceptor Drain. Construction of the San Luis Drain began, in 1968, to serve the federal San Luis Unit Service Area. From 1968 to 1975, an 85 mile segment was built between the town of Five Points and Kesterson Reservoir (see Figure II-5). The partially completed Kesterson Reservoir consisted of 12 holding ponds constructed to regulate future flows in the drain prior to the planned discharge of effluent to the Delta. In a 1970 cooperative agreement between the Bureau of Sport Fisheries and Wildlife and the USBR, Kesterson Reservoir was secondarily designated part of the Kesterson National Wildlife Refuge. In 1972, irrigation water began flowing into Kesterson Reservoir and the U.S. Fish and Wildlife Service (USFWS), successor to the Bureau of Sport Fisheries and Wildlife, began managing it as a wildlife refuge.

Interagency Drainage Program

San Luis Drain construction was halted in 1975 because of federal funding problems, environmental impact concerns, and lack of a final location for drain discharges. An Interagency Drainage Program (IDP) was formed to resolve some of these concerns and develop an economically, environmentally and politically acceptable plan to handle subsurface drainage water.

The IDP's recommendations were published in 1979. The preferred plan was a 290 mile long drain extending from the Tulare Basin to a discharge point near Chipps Island in Suisun Bay. The drain was to be constructed in stages as drainage requirements increased. Essentially all irrigable lands were in production by 1979, but it was anticipated that additional subsurface drains would be needed to remove the rising shallow ground water. The plan recommended by the IDP included 45,000 acres of marshes for waterfowl habitat supported by recirculated drain water and 19,000 acres of holding ponds to regulate peak drainage flows. The water quality constituents of concern in subsurface effluent at that time were recognized to be primarily salts but also included nitrate, phosphate, boron, chromium, iron, lead, mercury, certain pesticides, and arsenic. (Interagency Drainage Program Report, 1979). The IDP recommended further toxicity and water quality studies be performed prior to issuance of waste discharge requirements. In 1981 the USBR requested the State Board to issue a waste discharge permit for release of San Luis Drain effluent to Suisun Bay (Kratzer, 1985). The State Board specified nineteen issues for which the USBR should provide additional information before a permit could be issued. Federal studies of drainage were begun shortly thereafter.

Toxic Effects of Subsurface Agricultural Drainage at Kesterson Reservoir

By 1978 some subsurface agricultural drainage blended with good quality irrigation water had begun flowing in the San Luis Drain. By 1981, the entire flow came from subsurface drainage discharged from about 8,000 acres in the Westlands Water District (see Figure II-1) (Kratzer, 1985). In 1982 the USFWS observed unusually high levels of the potentially toxic trace element selenium in San Luis Drain water. In 1983, water entering Kesterson Reservoir contained about 300 parts per billion (ppb) selenium (Presser and Barnes, 1984). Studies of lower food chain organisms, fish, and waterfowl confirmed that selenium concentrations were increasing in these organisms at Kesterson Reservoir. Selenium concentrations in lower food chain organisms ranged from 6 to 32 parts per million (ppm) wet weight. Levels in mosquitofish in the Reservoir and San Luis Drain were about 30 ppm wet weight in 1982 increasing to 60 ppm wet weight in 1983. Bird eggs contained 6 to 20 ppm. By contrast, in nearby Volta Wildlife Management Area (WMA), which did not receive subsurface agricultural drainage, the water supply contained about 1 ppb or less of selenium and concentrations in mosquitofish were 0.3 ppm. Bird tissue (liver) from Kesterson contained an average of 10 ppm while that from Volta WMA was 1.4 ppm.[1] Unusually high numbers of waterfowl deaths and embryonic deformities were observed at Kesterson Reservoir. These abnormalities were similar to symptoms seen when test animals were fed 7 to 10 ppm selenium dry weight (for further discussion see Appendix A).

In 1984 food chain studies were expanded to the grasslands in western Merced County (see Figure II-1). Waterfowl habitat in the grasslands was maintained by a mixture of fresh water, tailwater, and subsurface agricultural drainage. About 50,000 af of this supply came from subsurface drainage and was used each year by duck clubs in the GWD for waterfowl habitat. Water used for wetland habitat contained about 50 ppb selenium (Presser and Barnes, 1985). Average selenium concentrations in waterfowl eggs from the grasslands were intermediate (about 1.5 ppm wet weight) between those at Kesterson Reservoir (about 5 to 10 ppm wet weight), which received all subsurface drainage, and Volta WMA, which received no subsurface drainage.

Recent sampling by the Department of Fish and Game (1987) in the San Joaquin River and tributaries to the grasslands showed that selenium concentrations in channel catfish muscle average below 1 ppm wet weight while liver concentrations average about 2 ppm wet weight. USFWS found selenium concentrations of from about 1 to slightly above 2 ppm wet weight in whole fish samples from the tributaries (Saiki, 1987).

In 1985, the grasslands duck clubs decided they would no longer accept water with more than 2 micrograms per liter (ug/l, equivalent to ppb)

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1 Data from various USFWS and USGS studies described in Kratzer, 1985. drainage) and Volta WMA (about 0.3 ppm wet weight) which received no subsurface drainage. Tissue levels in waterfowl from these areas showed a similar pattern to that found in eggs (Ohlendorf et al, 1986).

selenium. Thereafter, most of the subsurface agricultural drainage produced upslope was released to the San Joaquin River via Salt and Mud sloughs (see Figure II-1). The Department of Fish and Game estimated the pre-1985 load to be about 2,600 pounds and the Grassland Water Task Force estimated that selenium loads to the River increased to 9,200 pounds in 1985 (see Chapter V).

In June and October 1985, the Department of Health Services prepared human health risk assessments for consumption of fish and birds from Kesterson Reservoir and the grasslands. Because selenium in some muscle of whole body samples exceeded 2 ppm wet weight, it was recommended that consumption of fish from around GWD and ducks from the grasslands be limited and that women of childbearing age and that children below 15 years old not eat any fish or duck meat from the grasslands. These public health warnings were posted by Merced County.

<u>State Board Hearing on Kesterson Reservoir</u>

In May, 1984, Robert Claus, a landowner near Kesterson Reservoir and GWD, appealed to the State Board to take enforcement action against entities discharging subsurface effluent to GWD after the Regional Board declined to do so. Three evidentiary hearings were held by the State Board. On February 5, 1985 the State Board adopted Order No. WQ 85-1.

Order No. WQ 85-1 instituted a process to develop an overall program regulating agricultural drain discharges in the San Joaquin River Basin. To this end, a Technical Committee, consisting of State and Regional Board staff selected by the State Board's Executive Director, was formed. The Technical Committee was charged with the tasks of developing: (1) proposed water quality objectives for the San Joaquin River Basin; (2) proposed effluent limits for agricultural drain discharges in the basin; (3) a proposal to regulate these discharges; and (4) an estimate of the total cost of the proposed regulatory program and potential sources of funding. The State Board will receive the report of the Technical Committee and approve the report if it is judged to be complete. The Regional Board is required to adopt appropriate Basin Plan amendments for the San Joaquin River Basin (Basin 5C) following approval of the report by the State

Board. After the adoption of Basin Plan amendments, the Regional Board must undertake a program to regulate the discharge of agricultural drainage in the San Joaquin River Basin.

Historical Water Quality

In view of the many changes discussed in the preceding portion of this chapter; e.g., extensive agricultural growth, water development, importation and exportation of water, installation of subsurface drainage systems; the Technical Committee reviewed historic flow and water quality data to determine if any changes in water quality were identifiable.

Historical data on salinity at Vernalis were reviewed from 1930 to 1980 to identify significant trends. Detailed analysis of sources and loadings for salinity, boron, selenium and molybdenum was confined to the nine most recent years because data were available and significant changes in water quality were detected during the years preceding the period. The study period is water years 1977 through 1985. This period of time includes the full range of San Joaquin River hydrology from the extremely critical water year of 1977 to the extremely wet year of 1983.

Water Year Types

Water quality in the San Joaquin River system is influenced by seasonal and annual variations in river flow. The water year is a method used to classify and report these flows. The water year extends from October 1 of one year to September 30 of the next year. For example, water year 1986 extends from October 1, 1985 through September 30, 1986. The 1975 Basin Plan classifies water years into wet, normal, dry and critical as shown in Figure II-7. These classifications are based on the total annual unimpaired runoff, i.e. runoff uninfluenced by man's activities, at the four major rivers in the San Joaquin River Basin. These are the San Joaquin, Merced, Tuolumne and the Stanislaus rivers. The range of flow conditions used to classify water year types changes in years following critical years. Figure II-7 also shows the frequency of occurrence for each of the year types from 1906 to 1985. This water year classification system is used throughout this report.

Historical Trends

o Salinity

Water quality data for salinity at the downstream reach of the river near Vernalis have been reviewed to identify trends from 1930 to 1980. These data were summarized into five year running averages to facilitate visual interpretation and are shown in Figure II-8. Salinity concentrations have increased substantially since 1930. Individual monthly values within this five year period are much higher than the average, particularly during the irrigation seasons of recent years. At times they are almost twice the five year average. Figure II-8 also shows measured river flows near Vernalis for the years 1930 to 1980, as a five year running average. As one would expect, there is an inverse relationship between river flow and salinity concentrations (TDS). The increase in salinity led to the passage of legislation (Water Code Section 12230 et seq.) in 1961. This legislation requires State agencies to do nothing to cause further degradation in the lower reaches of the San Joaquin River. Two water districts near Vernalis filed water right complaints with the State Board in 1985 stating that this increase in salinity has adversely affected their water rights.

Total salt load in the River near Vernalis is also shown on Figure II-8. These data indicate that the relationship between total salt load and river flow has changed markedly since the 1930's. During the 1930's and early 1940's a very close relationship between salt load and flow held true near Vernalis. About the late 1940's, it began to diverge and the amount of divergence has increased steadily since that time. Flows and salt load are still related, i.e., at high flows the salt load is high. However, in recent years there is more salt per acre-foot discharged than occurred historically.

To determine the possible causes for the changes in relationship between the flow and salt load, we evaluated changes in unimpaired and actual flow during the period from 1930 to 1980 (Figure II-9). Our analysis indicates that the difference between unimpaired flows and measured flows near Vernalis has changed during wetter years. Because events which could potentially modify flows and water quality (e.g. completion of Friant Dam and Delta-Mendota Canal) occurred about 1950, the database for the period before that year was compared to the database after that year. The two lines in Figure II-9 showing the pre-1950 and post-1950 relationships are significantly different at the 99% confidence level. The pre-1950 period is characterized by higher median annual flows and lower median annual salt loads than the post-1950 period (Figure II-8). Before 1950, high salt loads were generated when large quantities of flow with relatively low salt concentrations were discharged from the San Joaquin River Basin near Vernalis. After 1950 these large flows and the salts they contained were captured behind reservoirs. Some of the water and salts were exported from the Basin and prevented from entering the River system. The remaining water and the accompanying salts were retained in reservoirs and released downstream in subsequent years. In recent years some other source of salt load has replaced that which used to flow out of the system only during high runoff periods. This replacement salt load is now discharged in both high flow and low flow years. This increase in salt load is a factor which has caused salinity increases in the San Joaquin River.

The concentrations for some selected ions that make up salinity have changed from 1950 to 1980 (Figure II-10). Both nitrate (NO_3^-) and sulfate (SO_4^{-2}) show steady increases through time that are statistically significant. Sulfate increases by a factor of about three and nitrate by about a factor of about five during this period. Other ions like chloride (Cl^-), sodium (Na^+) and potassium (K^+) do not show statistically significant trends.

Both nitrates and sulfates are characteristic components of land derived salts from subsurface agricultural drainage of the west side of the Valley. The increasing trends match closely with the increasing divergence of the historic flow-salt load relationship. Other sources of these salts, including sewage effluent, are known to be relatively insignificant in the San Joaquin River Basin.

o Boron and Molybdenum

Historical data for boron and molybdenum are scarce. Based on information in the previous section, it is likely that these two elements, found commonly in subsurface agricultural drainage in the San Joaquin River Basin, have also increased in the San Joaquin River over the last 30 to 50 years.

o Selenium

Selenium was not routinely monitored in surface waters prior to 1983. Data collected prior to then is of questionable reliability due to shortcomings in the analytical methodology.

Recent water management changes for wildlife areas upstream of the Merced River's influent have resulted in a marked increase of selenium loading to the San Joaquin River system. Prior to 1985, the duck clubs located in the approximately 50,000 acre GWD impounded agricultural drainage as part of their water supply for waterfowl habitat. This supply included fresh water and surface runoff combined with subsurface drainage from upslope agricultural areas. During 1983 and 1984, these privately operated duck clubs became aware that the drainage water supplied to the grasslands contained levels of selenium that could be harmful to waterfowl and other wildlife. Beginning around January 1985, almost all of these clubs and the state and federal waterfowl areas decided not to accept water which contained greater than 2 ug/l selenium. The decision to protect their wildlife areas resulted in the bypass of additional subsurface agricultural drainage directly to the San Joaquin River via Salt and/or Mud sloughs. Since that time the GWD, with the assistance of local farming interests and state agencies, has initiated actions to secure other water supplies. To date, reliable replacement sources have not been obtained.

Estimates obtained from the Department of Fish and Game and others indicate that prior to 1985 the wetlands in the grasslands area were incidentally removing large quantities of selenium from their water supply prior to its eventual discharge to the San Joaquin River. The Technical Committee estimates that the selenium loads to the San Joaquin River from this area can increase by about two and one-half times when GWD bypasses drainage water. The Regional and State Boards have expressed concern that these recent increases in selenium need to be evaluated to ensure that they do not cause adverse effects on fish and wildlife resources in the San Joaquin River and downstream areas. Later chapters of this report will address the possible effects of these increased concentrations and actions that should be considered to correct possible water quality problems.

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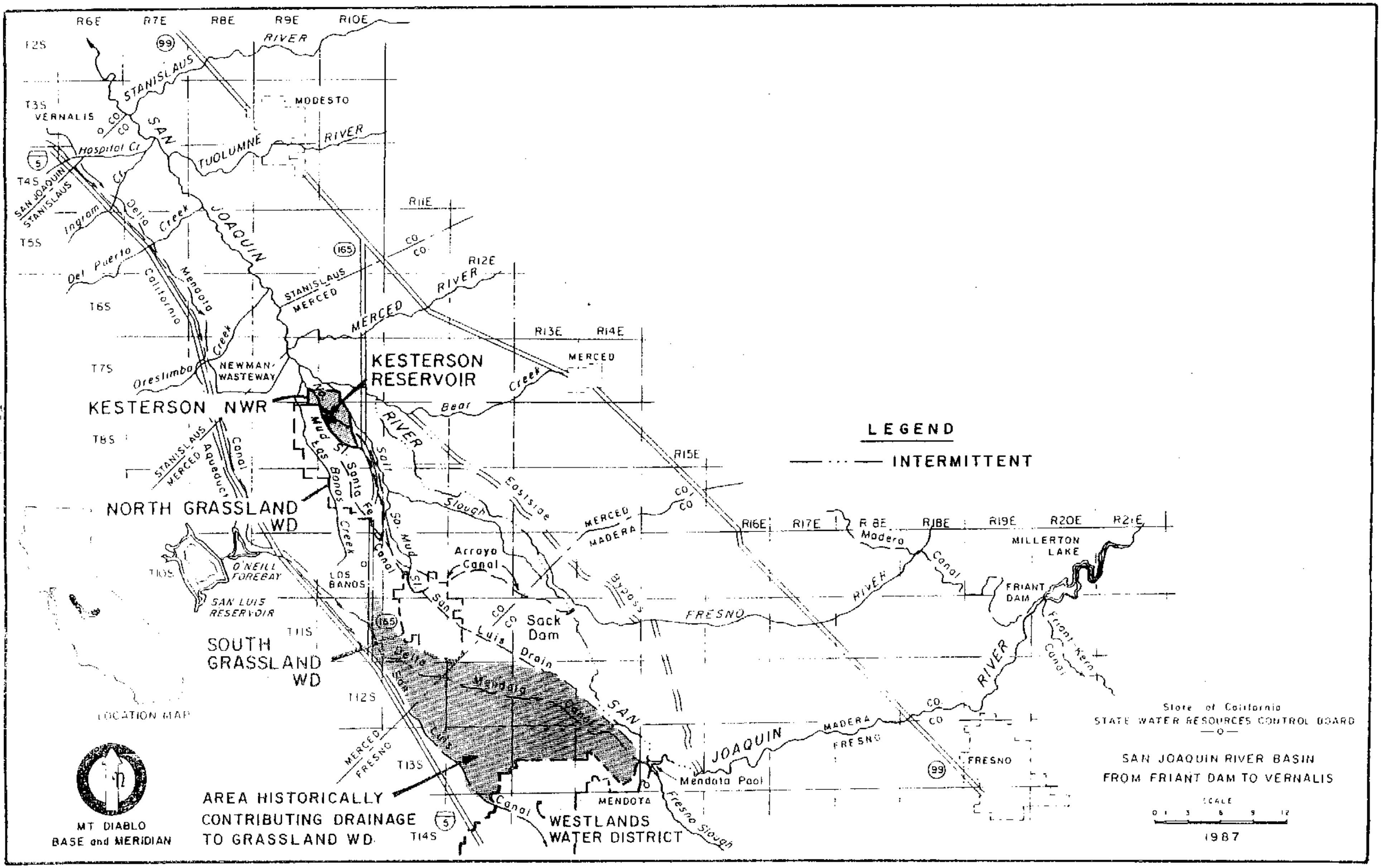
Table II-1

Central Valley Project Facilities
Serving the San Joaquin Valley

Facility Name (north to south)	Primary Purpose	Completion Date
Shasta Dam	Impound waters of the upper Sacramento River for irrigation, navigation, flood control, and hydroelectric power	1945
Tracy Pumping Plant	Pump Sacramento River water up into the Delta-Mendota Canal thence south to Mendota Pool	1951
Delta-Mendota Canal	Deliver Delta water to the west side of the San Joaquin Valley	1951
Mendota Pool	Supply Delta waters via Delta-Mendota Canal to irrigators who formerly diverted San Joaquin River water	Existing*
Friant Dam	Impound waters of the upper San Joaquin River in Millerton Lake for irrigation and flood control	1947
Madera Canal	Deliver San Joaquin River water from Millerton Lake to east side of San Joaquin River Basin (in operation prior to completion of Friant Dam)	1944
Friant-Kern Canal	Deliver San Joaquin River water from Millerton Lake southeast to the Tulare Lake Basin for irrigation	1949
San Luis Unit	Storage of water diverted from the Delta in San Luis Reservoir and O'Neill Forebay and distribute this water to the west side of the San Joaquin Valley via the San Luis Canal.	1967

* Pre-dates CVP; built for local use.

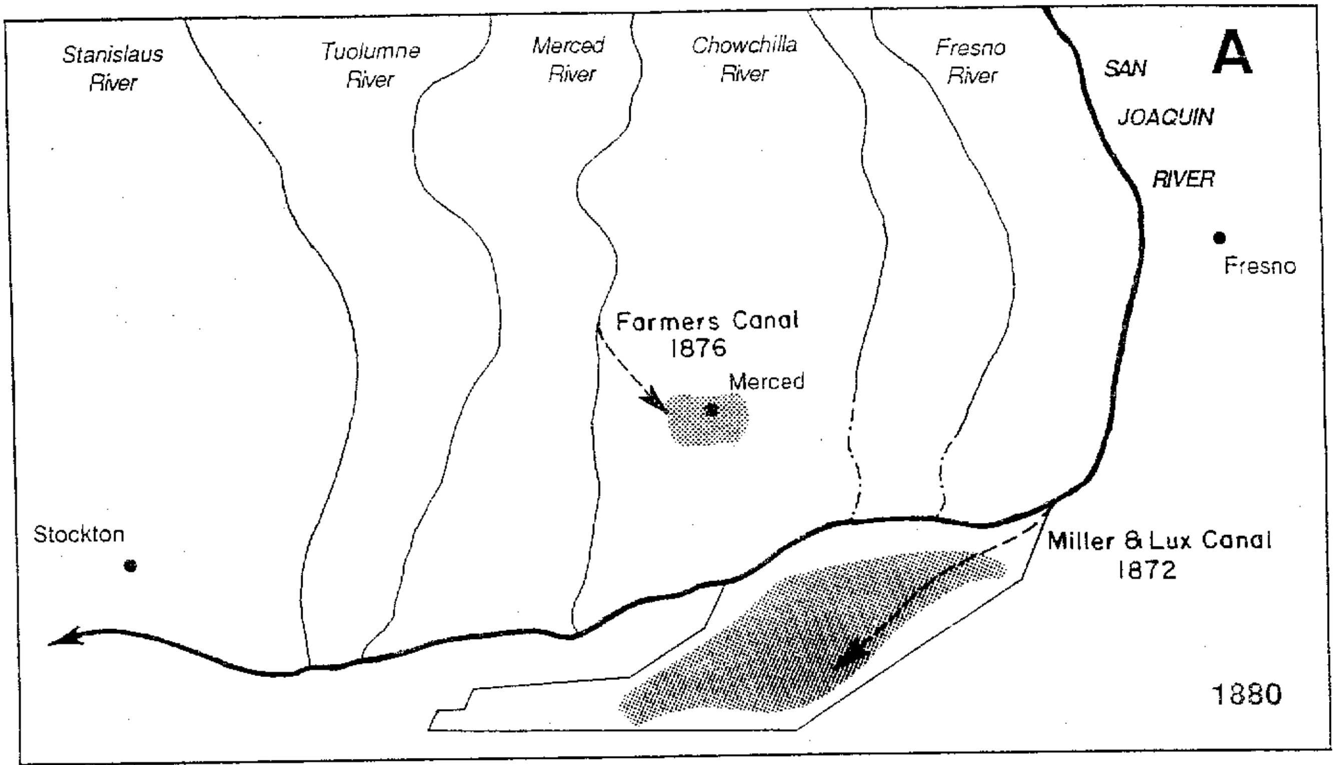
FIGURE II-1

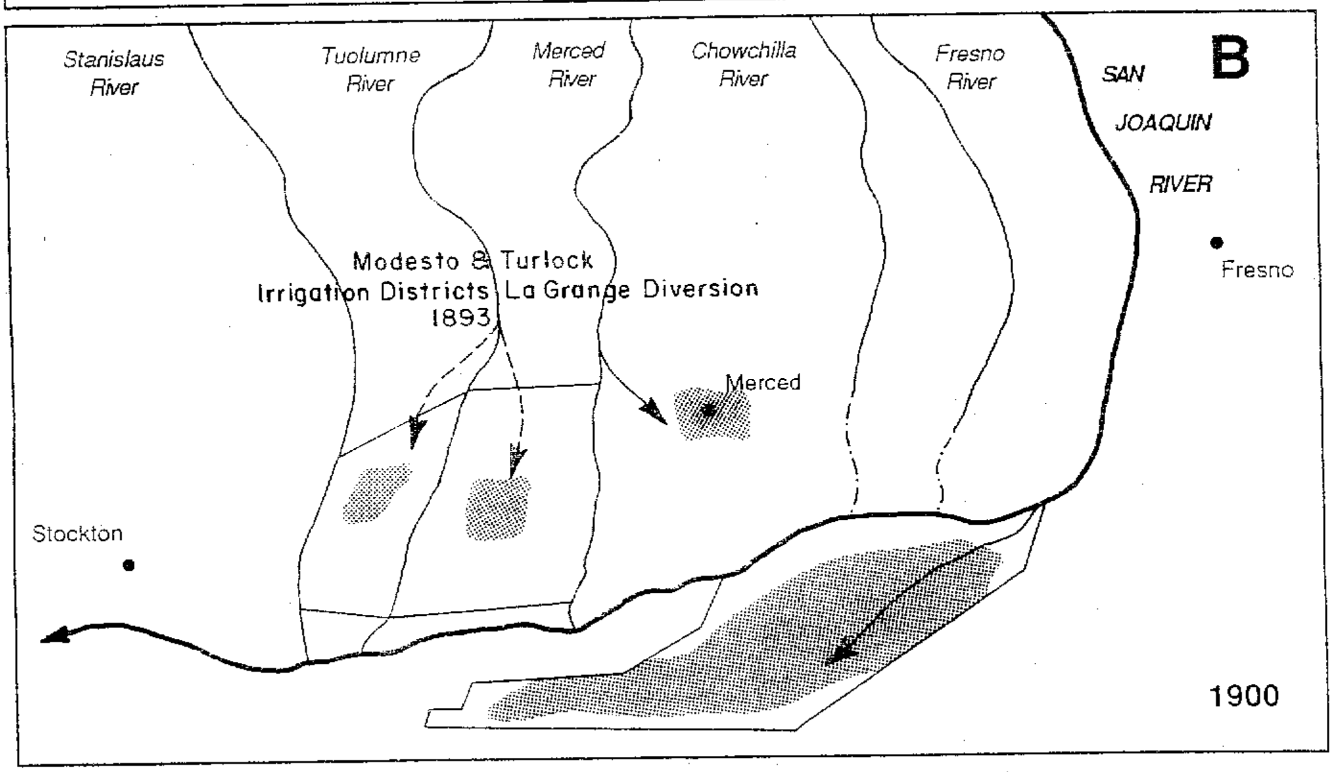


LEGEND
INTERMITTENT
KESTERSON RESERVOIR
KESTERSON NWR
NORTH GRASSLAND WD
SOUTH GRASSLAND WD
AREA HISTORICALLY CONTRIBUTING DRAINAGE TO GRASSLAND WD
WESTLANDS WATER DISTRICT
SAN JOAQUIN RIVER
STANISLAUS RIVER
TUOLUMNE RIVER
MERCED RIVER
FRESNO RIVER
MODESTO
VERNALIS
LOS BANOS
MENDOTA
FRESNO
Mendota Pool
Fresno Slough
Sack Dam
FRIANT DAM
MILLERTON LAKE
Friant-Kern Canal
Madera Canal
Eastside Bypass
Salt Slough
Mud Sl.
Santa Fe Canal
So. Mud
Las Banos Creek
San Luis Drain
Arroyo Canal
Delta Mendota Canal
California Aqueduct
O'NEILL FOREBAY
SAN LUIS RESERVOIR
NEWMAN WASTEWAY
Orestimba Creek
Del Puerto Creek
Ingram Cr
Hospital Cr
Bear Creek
LOCATION MAP
MT DIABLO BASE and MERIDIAN
State of California
STATE WATER RESOURCES CONTROL BOARD
SAN JOAQUIN RIVER BASIN FROM FRIANT DAM TO VERNALIS
SCALE
0 3 6 9 12
1987

FIGURE II-2 **SCHEMATIC REPRESENTATION OF SURFACE WATER DEVELOPEMENT IN THE SAN JOAQUIN RIVER BASIN, (1880-1900)**

(After DWR, Bulletin 89)



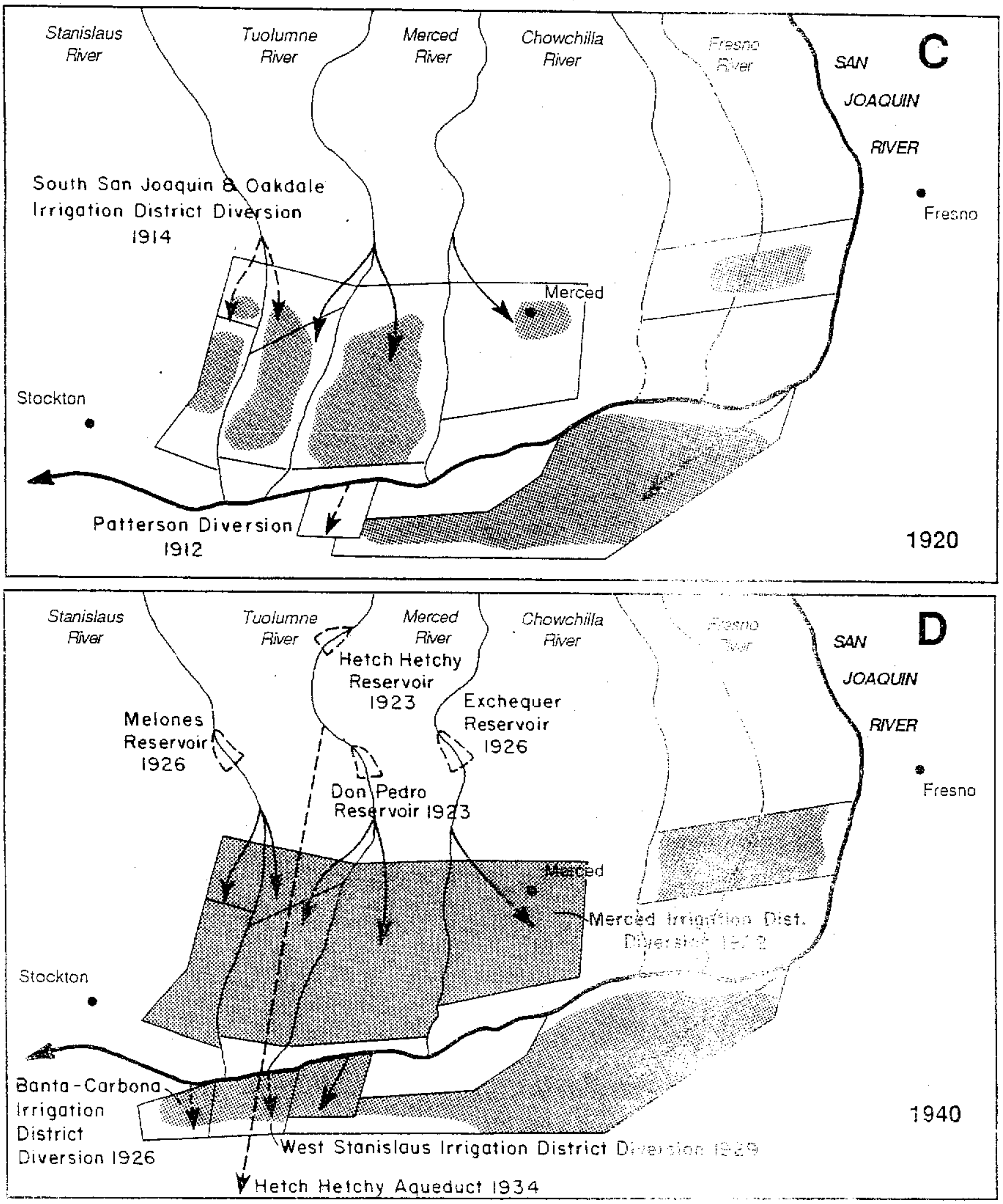


LEGEND

- RIVER
- INTERMITTENT RIVER FLOW
- PROJECT SERVICE OR IRRIGATED AREA
- PREVIOUS PROJECT ENLARGED
- NEW PROJECT, PLACED IN OPERATION DURING PERIOD SHOWN
- OLD PROJECT, IN OPERATION PRIOR TO PERIOD SHOWN

FIGURE II-2 **SCHEMATIC REPRESENTATION OF SURFACE WATER DEVELOPEMENT IN THE SAN JOAQUIN RIVER BASIN, (1920-1940)**

(After DWR, Bulletin 89)

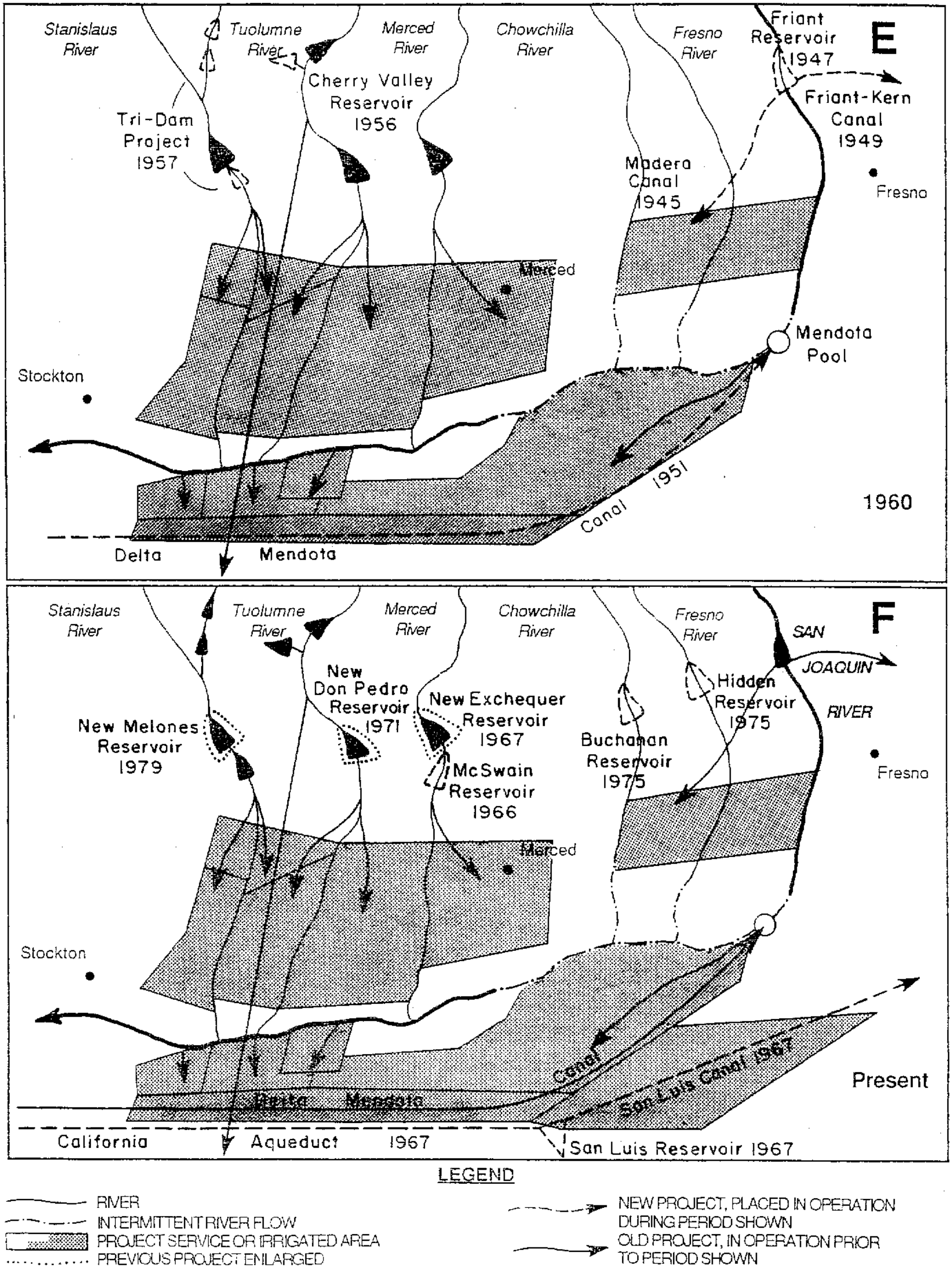


LEGEND

- RIVER
- INTERMITTENT RIVER FLOW
- PROJECT SERVICE OR IRRIGATED AREA
- PREVIOUS PROJECT ENLARGED
- ...ECT, PLACED IN OPERATION ... SHOWN
- ...ECT, IN OPERATION PRIOR ... SHOWN

FIGURE II-2 **SCHEMATIC REPRESENTATION OF SURFACE WATER DEVELOPEMENT IN THE SAN JOAQUIN RIVER BASIN, (1960-Present)**

(After DWR, Bulletin 89)



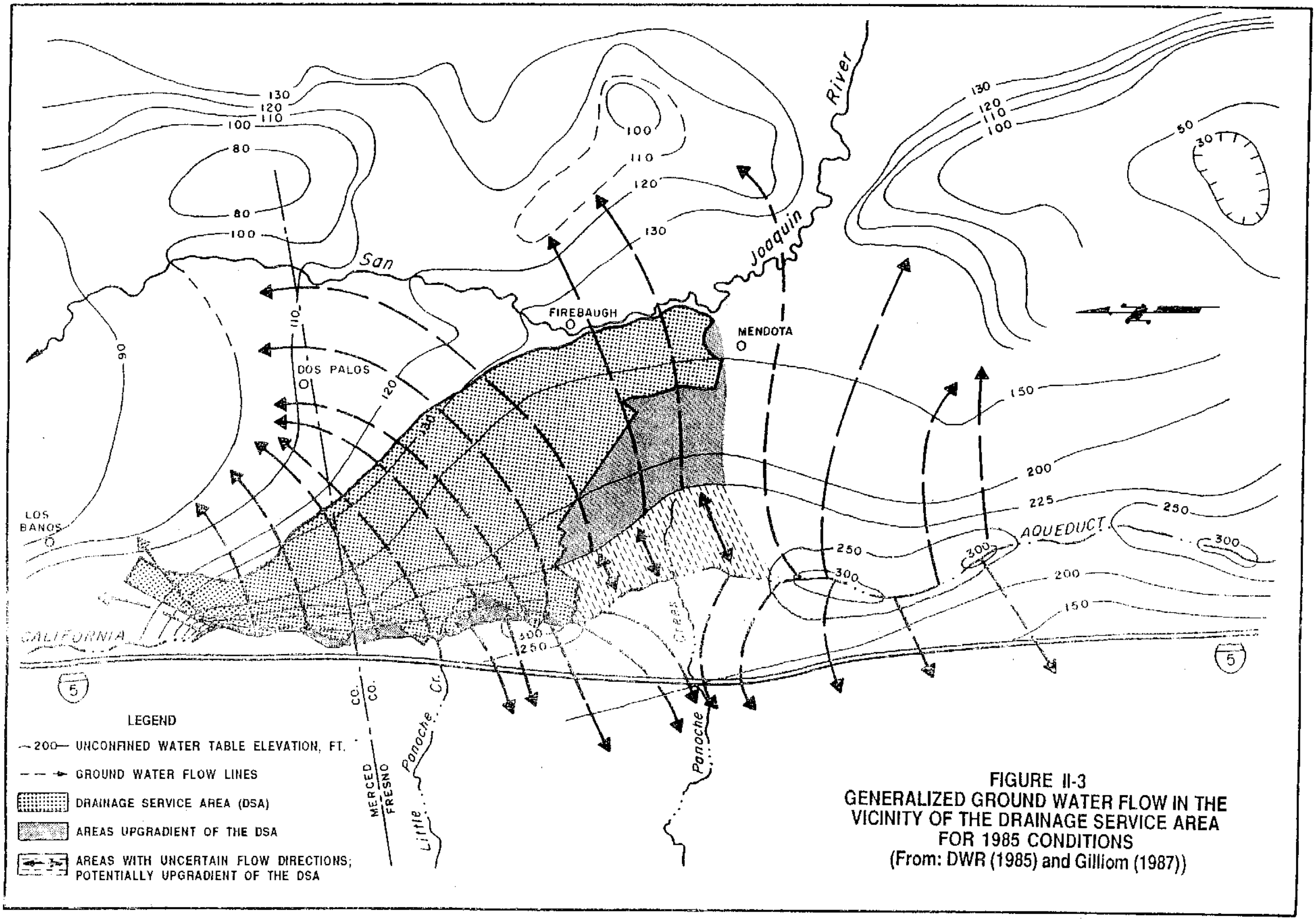


FIGURE II-3
GENERALIZED GROUND WATER FLOW IN THE VICINITY OF THE DRAINAGE SERVICE AREA FOR 1985 CONDITIONS
(From: DWR (1985) and Gilliom (1987))

FIGURE II-4 **AREAL DISTRIBUTION OF SELENIUM IN SHALLOW GROUNDWATER IN THE WESTERN SAN JOAQUIN VALLEY**

(From Kratzer 1985)

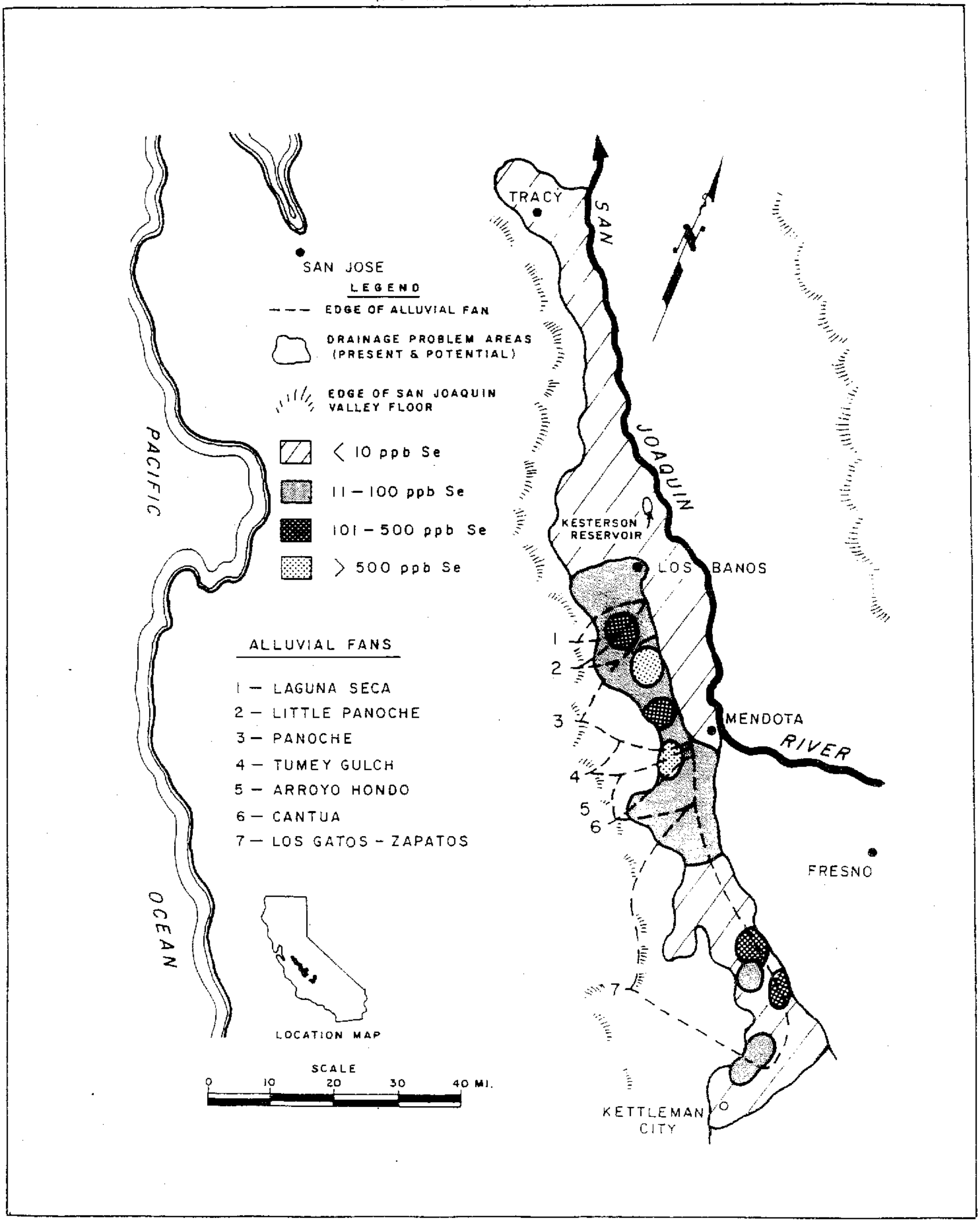


FIGURE II-5 **DRAINAGE PROBLEM AREAS AND TILE DRAINED AREAS IN THE SAN JOAQUIN RIVER BASIN**

(After Kratzer 1985)

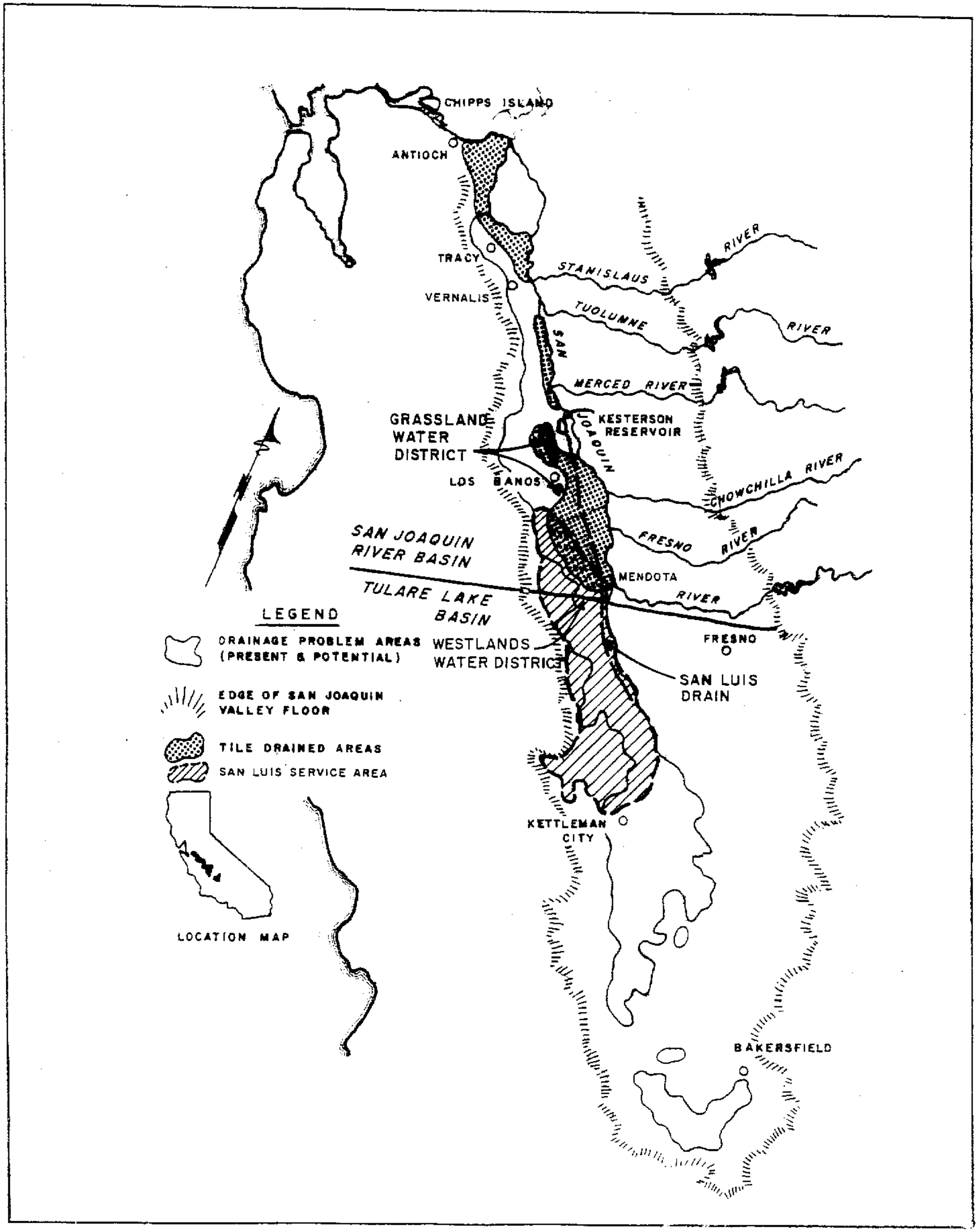
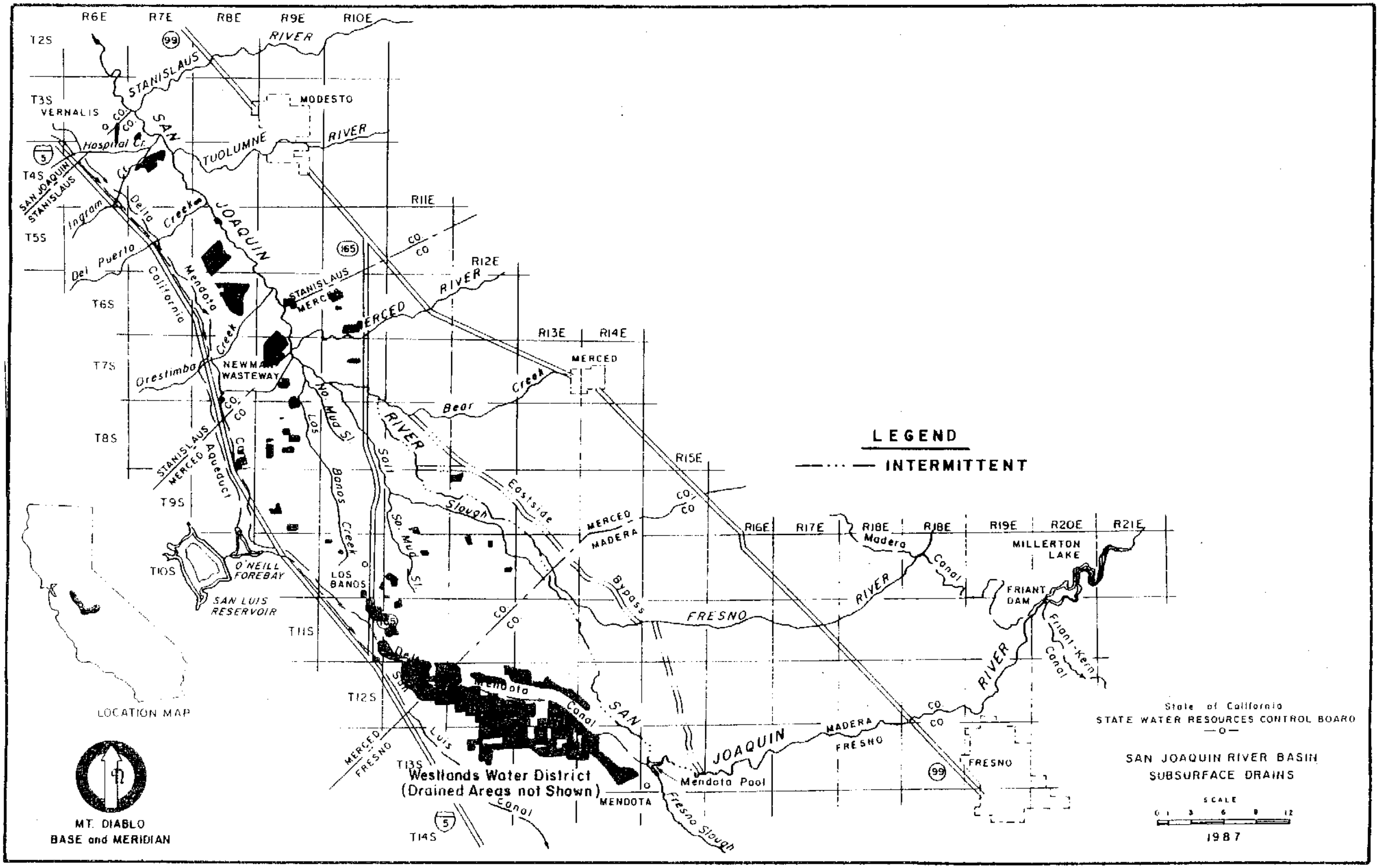


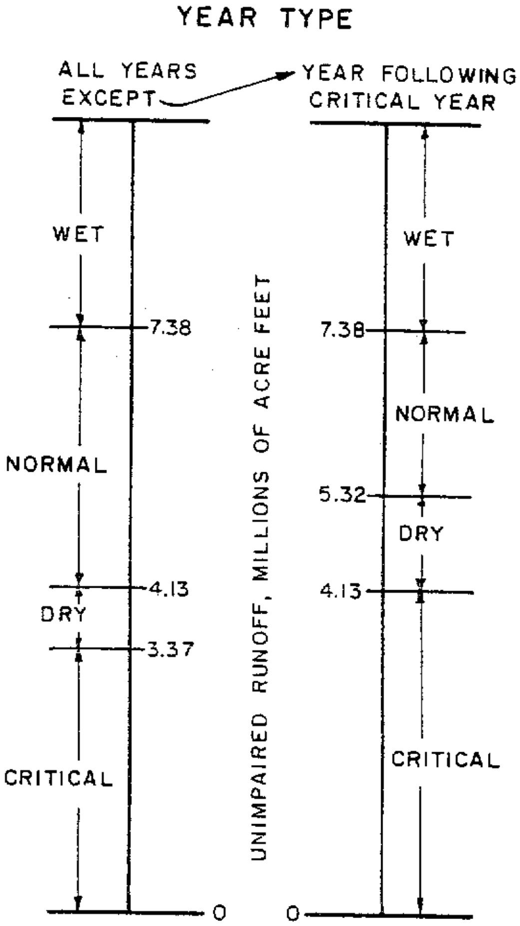
FIGURE II-6



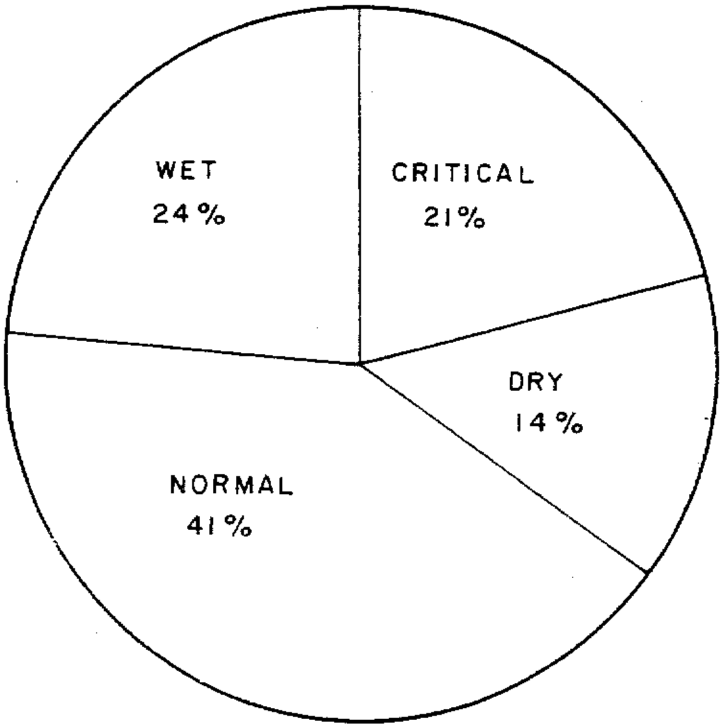
LEGEND
INTERMITTENT
State of California
STATE WATER RESOURCES CONTROL BOARD
SAN JOAQUIN RIVER BASIN
SUBSURFACE DRAINS
SCALE
1987
MT. DIABLO
BASE and MERIDIAN
LOCATION MAP
Westlands Water District
(Drained Areas not Shown)
MODESTO
MERCED
FRESNO
MENDOTA
LOS BANOS
VERNALIS
MILLERTON LAKE
FRIANT DAM
SAN LUIS RESERVOIR
O'NEILL FOREBAY
NEWMAN WASTEWAY
Mendota Pool
Friant-Kern Canal
Madera Canal
California Aqueduct
Delta Mendota Canal
Eastside Bypass
SAN JOAQUIN
STANISLAUS RIVER
TUOLUMNE RIVER
MERCED RIVER
FRESNO RIVER
Salt Slough
Fresno Slough

FIGURE II-7 Water Year Types for the San Joaquin River Basin

WATER YEAR CLASSIFICATION IS DETERMINED BY THE UNIMPAIRED RUNOFF FOR THE WATER YEAR (OCTOBER 1 OF THE PRECEDING CALENDAR YEAR THROUGH SEPTEMBER 30 OF THE SUBSEQUENT CALENDAR YEAR) AS PUBLISHED IN CALIFORNIA DEPARTMENT OF WATER RESOURCES BULLETIN 120 FOR THE SUM OF THE FOLLOWING LOCATIONS: SAN JOAQUIN RIVER AT FRIANT DAM, MERCED RIVER AT EXCHEQUER DAM, TUOLUMNE RIVER AT DON PEDRO DAM, STANISLAUS RIVER AT NEW MELONES DAM.



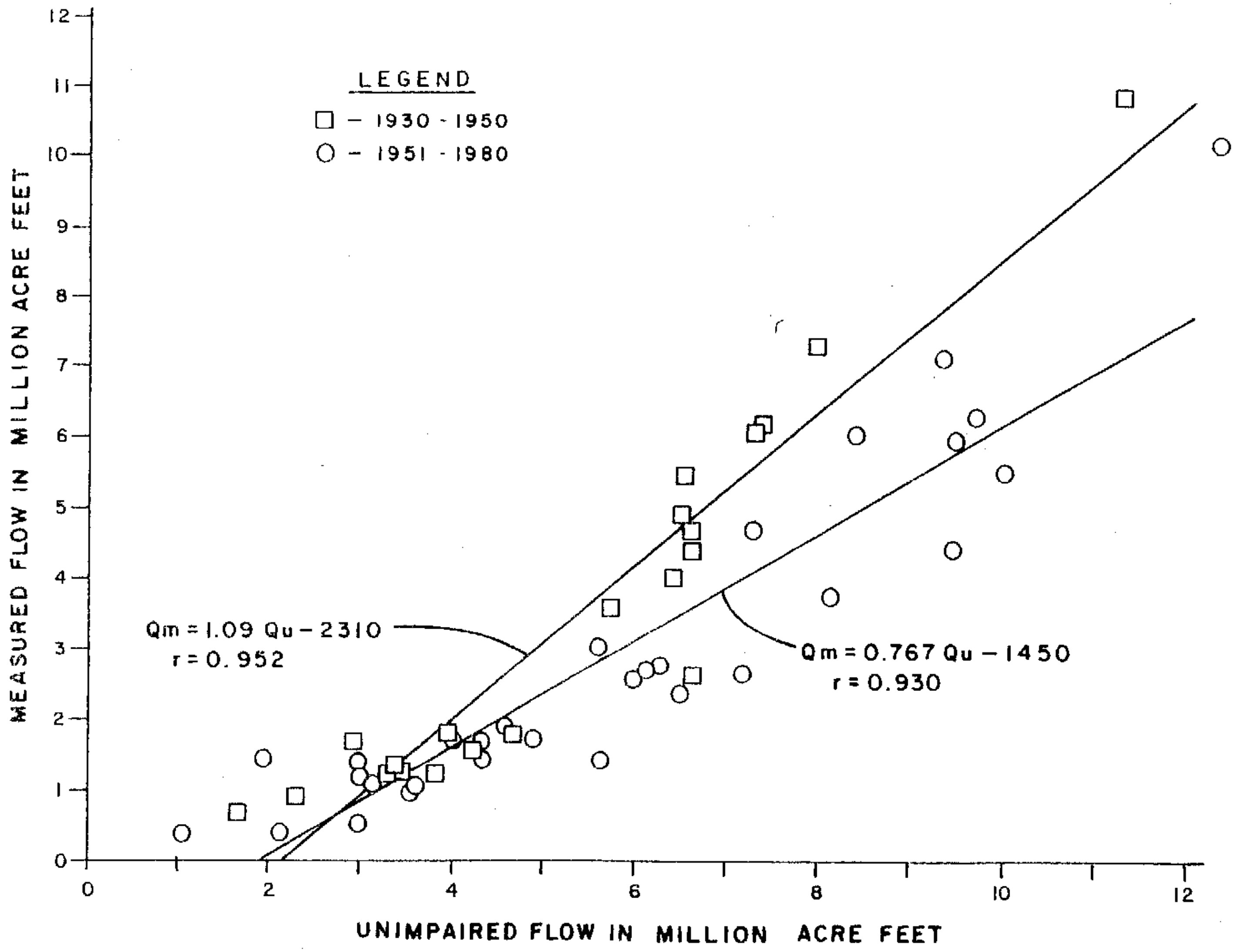
FREQUENCY OF OCCURRENCE
1906 TO 1985



1/ AS DEFINED IN THE 1975 BASIN 5C WATER QUALITY CONTROL PLAN

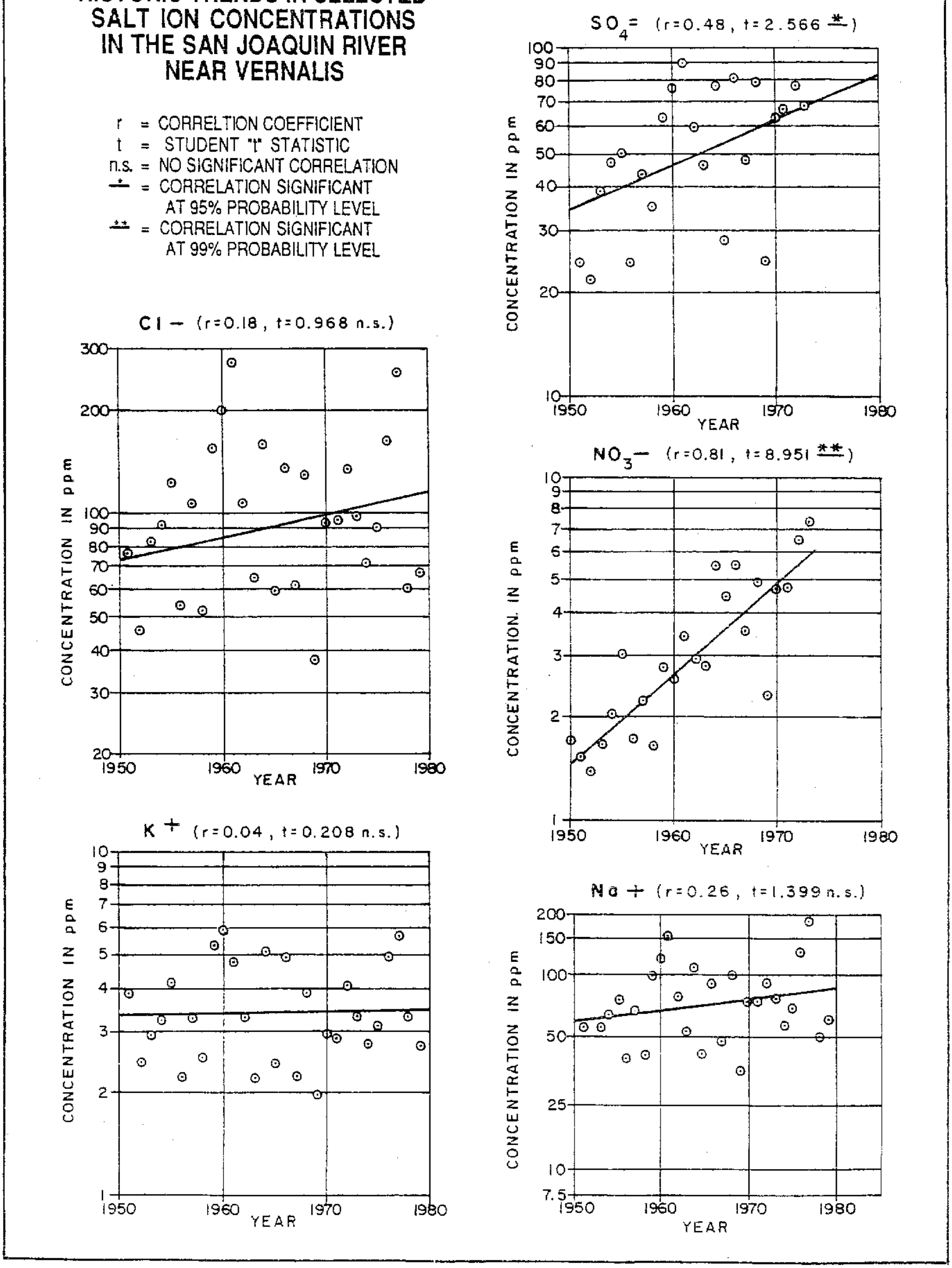
FIGURE II-8 Salinity, Flow and Salt Load in the San Joaquin River Near Vernalis
(5 Year Running Average)

FIGURE II-9 San Joaquin River Flows Near Vernalis



HISTORIC TRENDS IN SELECTED SALT ION CONCENTRATIONS IN THE SAN JOAQUIN RIVER NEAR VERNALIS

r = CORRELTION COEFFICIENT
t = STUDENT "t" STATISTIC
n.s. = NO SIGNIFICANT CORRELATION
* = CORRELATION SIGNIFICANT AT 95% PROBABILITY LEVEL
** = CORRELATION SIGNIFICANT AT 99% PROBABILITY LEVEL



III. BENEFICIAL USES

The first task of water quality control planning is the identification of beneficial uses of state waters. Because the Technical Committee report will be used by the Regional Water Quality Control Board to amend its Basin Plan, an analysis of beneficial uses was undertaken.

Legislative and Regulatory Background

The Porter-Cologne Water Quality Control Act (Porter-Cologne Act) defines beneficial uses of state waters to be those uses that may be protected against water quality degradation (Appendix F, page 4). Beneficial uses include, but are not limited to: "domestic, municipal, agricultural, and industrial supply; power generation, recreation; esthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves." (Ibid.)

Waste disposal and assimilation are not and cannot be beneficial uses but, "are recognized as part of the necessary facts of life, to be evaluated and subject to reasonable consideration and action by the regional boards" (Appendix F, p. 4). The Porter-Cologne Act mandates the Regional Water Quality Control Boards (Regional Boards) "to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible" (Appendix F, page 5). The Porter-Cologne Act requires each Regional Board to establish water quality objectives in its Water Quality Control Plan (Basin Plan)which will ensure the reasonable protection of beneficial uses and recognizes that the quality of the water may be changed to some degree without unreasonably affecting beneficial uses (Appendix F, page 5).

The Regional Boards have the responsibility for designating beneficial uses of waters of the State during the development and adoption of Basin Plans. Beneficial use designations are to be made for all waters of the State, which include "any water, surface or underground, including saline waters, within the boundaries of the state" (Appendix F, page 13). This includes "navigable waters" and their non-navigable tributaries, as defined in the Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act), and agricultural irrigation and drainage systems (Appendix F, page 13). The status of existing drainage facilities as waters of the State cannot be changed by fencing and screening of the conveyances to preclude access by fish, wildlife, and humans. Neither can the status be changed by placing waste treatment facilities at its downstream terminus. However, a newly constructed conveyance to carry waste to a treatment facility would not be waters of the State (Appendix F, page 32).

Existing conveyance facilities assume the beneficial uses of the downstream water body segment to which they are tributary unless site specific beneficial uses have been assigned to the conveyance. The Porter-Cologne Act does allow the dividing of water bodies into segments. Beneficial uses in some segments may be deleted where the beneficial use is not existing, provided specific Environmental Protection Agency (EPA) procedural requirements are met (Appendix F, pages 7 and 8), and all downstream beneficial uses are protected. In general, the Porter-Cologne Act does not allow for the deletion of an existing instream beneficial use.

Water quality objectives reasonably protective of beneficial uses must be adopted even if they occur in ephemeral streams where the beneficial use is made possible only by the discharge of agricultural waste flow (Appendix F, page 26). If agricultural waste flows allow a beneficial use, the waste flow must be of a quality sufficient to protect that beneficial use (Appendix F, page 27).

Federal legislation also controls water quality. Section 303 of the Clean Water Act requires EPA approval of beneficial uses and water quality objectives contained in Basin Plans adopted by the Regional Boards. EPA regulations distinguish between a "designated use", i.e. uses specified for water bodies whether or not they are being attained, and an "existing use", those uses actually attained in a water body on or after November 28, 1975. EPA regulations require that existing instream water uses be maintained and protected. In general, Federal regulations prohibit the deletion of an existing use, unless a use requiring more stringent criteria is added. As previously discussed, designated uses which are not existing uses may be deleted from basin plans if the Regional Boards can show that attainment of the use is not feasible per specific Federal criteria. If the use considered for deletion involves the protection of fish, shellfish, wildlife or recreation in and on the water, the State must complete a use attainability analysis to demonstrate that its attainability is infeasible (Appendix F, pages 8, 9 and 31).

Federal regulations allow for the segmentation of water bodies and changes in beneficial use designations (per the above restriction) provided that changes are protective of downstream beneficial uses and the hydrologic unit as a whole (Appendix F, pages 9, 30, 31).

Beneficial Uses of the San Joaquin River and its Tributaries

Currently designated beneficial uses in the San Joaquin River Basin are specified in the Basin Plan for Basin 5C (SWRCB, 1975). The two segments of the River above Friant Dam are not affected by subsurface agricultural drainage and therefore are not discussed in this report.

Beneficial Uses Not Related to Fish and Wildlife Preservation

The existing beneficial uses of the San Joaquin River (SJR-1 through SJR-4) and its tributaries, Salt and Mud sloughs, were examined. A brief description of those beneficial uses and what is known about them follows:

- Municipal and Domestic Water Supply (MUN)

  This beneficial use includes use in community or military water systems and domestic uses from individual water supply systems. This is designated as an existing beneficial use in two reaches and as a potential beneficial use in the other two reaches. In actuality an existing use occurs only in SJR-1, from Friant Dam to Mendota Pool. There is no direct diversion of river water for municipal or domestic use in the three downstream reaches, from Mendota Dam to Vernalis.

  In all reaches of the River, water is pumped for domestic purposes from wells in the flood plain. Changes in river water quality could affect these wells.

o Agricultural Supply (AGR)

In the San Joaquin River Basin, more water is used for agricultural supply than for any other beneficial use. This use includes row crop, orchard and pasture irrigation, stockwatering, support of vegetation for range grazing, and all other non-domestic uses in support of farming and ranching operations. Irrigation is shown as a beneficial use for all reaches. Water may be used and reused several times for irrigation, and return flows from agriculture constitute a significant portion of the flow from Mendota Dam to Vernalis during the irrigation season.

Except during periods of high runoff, most flow in SJR-2 (Mendota Dam to Sack Dam) is irrigation supply water released from the Mendota Pool. Almost all the flow is diverted into the Arroyo Canal and intake canals for the San Luis Canal Company.

There are a few irrigation diversions in SJR-3 (Sack Dam to the Merced River confluence) by the Stevinson Water District. The majority of flow in this reach during most of the year is irrigation return flow from the Turner Island Water District and Salt and Mud sloughs.

El Solyo and Patterson water districts and West Stanislaus Irrigation District divert from SJR-4 (confluence of the Merced River to near Vernalis). Numerous farming companies, reclamation districts, and others with appropriative and riparian water rights also divert from SJR-4.

Stockwatering is designated as a beneficial use for all four segments of the San Joaquin River. The extent to which the River is actually diverted for stockwatering is unknown; but it is likely that water diverted for irrigation purposes is used incidentally by cattle. Salt Slough is used for irrigation supply water.

- Industrial Process Supply (PROC)

  This beneficial use includes water used directly for manufacturing purposes. Although this beneficial use is designated for all four reaches of the River and in Mud and Salt sloughs, little if any water is currently used for this purpose.

- Industrial Service Supply (IND)

  This beneficial use includes those which are not primarily dependent on high water quality, such as mining, cooling water supply, hydraulic conveyance, fire protection, oil well repressurization and gravel washing. At present this is not a designated beneficial use for any reach of the San Joaquin River nor Salt and Mud sloughs. However, there are a number of sand and gravel mining operations along the River, most occurring between Friant Dam and Mendota Pool (SJR-1).

- Hydroelectric Power Generation (POW)

  Although this beneficial use is not designated for the four reaches in question, power generation was recently installed at Friant Dam in SJR-1.

- Water Contact Recreation (REC-1)

  This beneficial use includes all recreation involving actual contact with the water or activities where ingestion of water is reasonably possible. Examples include swimming, wading, waterskiing, skin diving, surfing, sportfishing, and uses in therapeutic spas. This beneficial use is designated for all segments of the River and Salt and Mud sloughs and, where flows and access are adequate, water contact recreation is popular. Several state, county and local parks adjoin the River and provide fishing access and boat launching facilities. Although fish are not stocked downstream of the State Highway 41 overcrossing (SJR-1), a popular sport fishery has developed along stretches with adequate flows. The fishery is primarily composed of channel and white catfish, bullheads, largemouth and smallmouth bass, bluegill, carp, striped bass, American shad, sturgeon, and chinook salmon.

Canoeing and rafting are also included in this beneficial use in all segments of the River and Mud and Salt sloughs. Useage is not thought to be extensive at this time.

o Non-Contact Water Recreation (REC-2)

This beneficial use includes recreation which involves the presence of, but not necessarily contact with water. Examples include picnicking, sunbathing, hiking, beachcombing, camping, pleasure boating, hunting, sightseeing, and esthetic enjoyment associated with the above activities. This beneficial use also includes the protection of human consumers of fish and wildlife. A very high percentage of the sport caught fish is believed to be consumed by humans. Commercial fishing for resident warmwater fish also occurs in the Basin. All segments of the River and Salt and Mud sloughs are designated for this beneficial use, which is popular where access is available.

The Technical Committee recommends that the Regional Board make the aforementioned changes in beneficial use designations not related to fish and wildlife preservation during its Basin Plan amendment process.

Fish and Wildlife Related Beneficial Uses

A lengthy investigation was undertaken to better document the existing beneficial uses related to fish and wildlife of the San Joaquin River and its primary tributaries (Appendix B). This investigation greatly expanded upon the information available to the Regional Board in 1975 when beneficial uses were established and the Basin Plan adopted.

The beneficial uses of nine distinct segments of the San Joaquin River and its tributaries were examined (Figure III-1):

- San Joaquin River from Friant Dam to Mendota Pool (SJR-1)
- San Joaquin River from Mendota Dam to Sack Dam (SJR-2)
- San Joaquin River from Sack Dam to the Merced River (SJR-3)
- San Joaquin River from Merced River to near Vernalis (SJR-4)
- Merced River from McSwain Dam to San Joaquin River (MR)
- Tuolumne River from Don Pedro Dam to San Joaquin River (TR)
- Stanislaus River from Goodwin Dam to San Joaquin River (SR)
- Salt Slough (SS)
- Mud Slough (MS)

Beneficial uses were specifically listed in the 1975 Basin Plan for all of these segments but Salt and Mud sloughs. By default, Salt and Mud sloughs were assigned the beneficial uses of SJR-3. Specific listing of these sloughs will allow more precision in designating beneficial uses for these waters.

The 1975 Basin Plan identified the following beneficial uses for the above-mentioned reaches:

- Warm freshwater habitat (WARM);
- Cold freshwater habitat (COLD);
- Fish migration (MIGR), for both warmwater and coldwater fisheries;
- Fish spawning (SPWN), for both warmwater and coldwater fisheries;and
- Wildlife habitat (WILD).

The Basin Plan discussed the beneficial use of water for preserving rare and endangered species (RARE), but did not designate any reach for this use.

As a result of the investigation the following observations are made:

- Fisheries and wildlife habitat, particularly wetlands and riparian areas, have been greatly reduced in extent within the San Joaquin River Basin over the last one hundred years. This reduction has been caused primarily by alterations in land use and water management.

- The San Joaquin River Basin from Friant Dam to near Vernalis supports over 200 species of fish and wildlife, including threatened and endangered species.

- The riparian and impounded water wetland habitats within the grasslands and downstream areas of the San Joaquin River are essential to the maintenance of existing populations of a large majority of the fish and wildlife of the Basin and to the survival of some species. The wetlands are critical winter habitat for the second largest population of waterfowl in the State.

The following recommendations are made and summarized in Figure III-1:

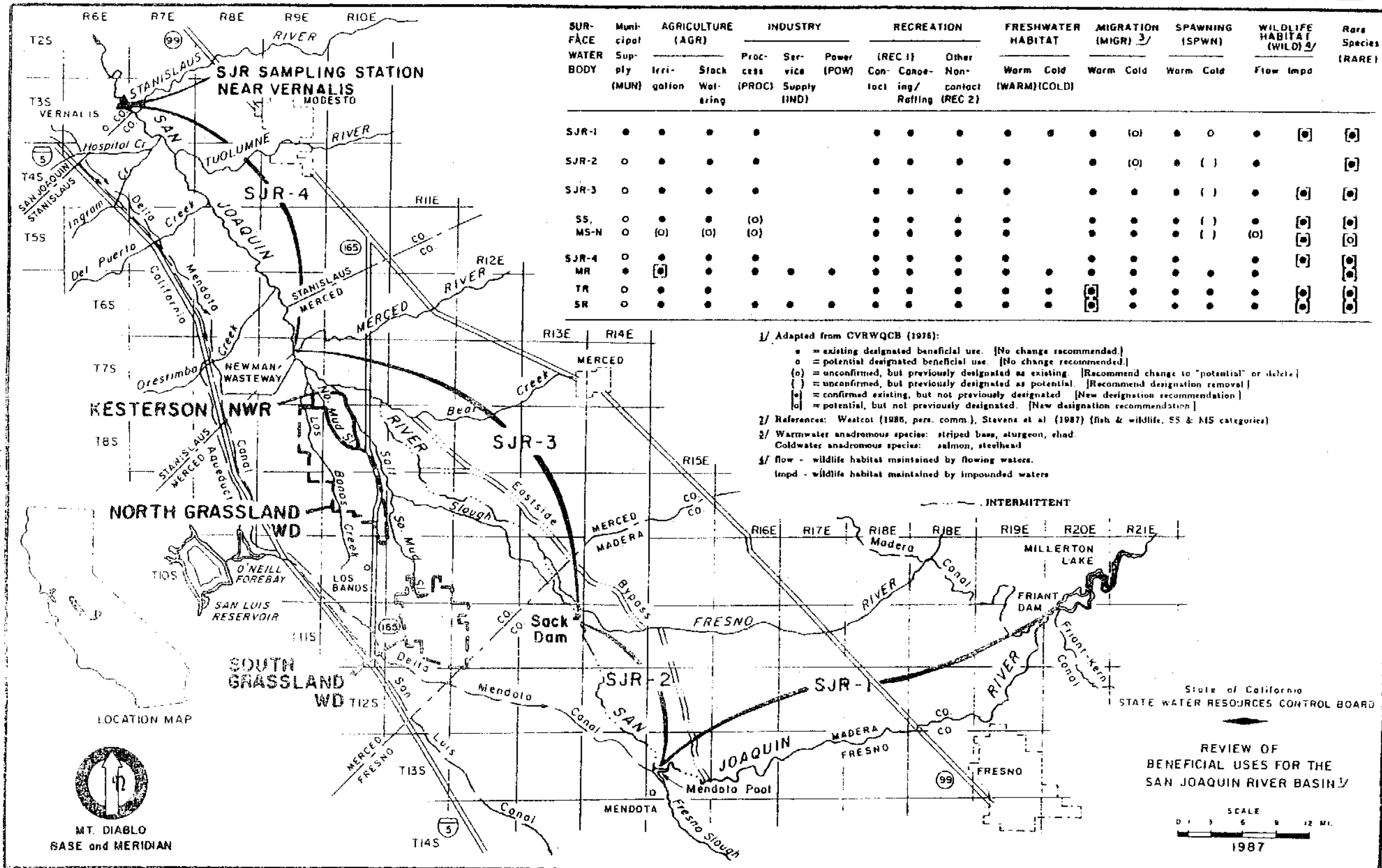
- All reaches examined should be designated as supporting RARE. This change would reflect the occurrence and dependence of rare, endangered, and threatened species on the remaining riparian and wetland habitats in the Basin.

- The WILD beneficial use should be understood to include both the maintenance of habitat for wildlife occupying or dependent on areas of flowing water, e.g. riparian habitat, and the maintenance of wildlife habitat occupying or dependent on areas of impounded waters, e.g. wetland habitat. In areas of impounded water identified in Appendix B, the WILD beneficial use should require higher protection from bioaccumulative constituents of agricultural drainage such as selenium (Appendix D).

- A MIGR beneficial use for the Tuolumne and Stanislaus rivers has been confirmed for warmwater species and should be added to the beneficial uses in the Basin Plan.

- The intent of the beneficial use designation to protect spawning habitat (SPWN) should be amended to clearly include resident as well as anadromous fish.

FIGURE III-1



SURFACE WATER BODY	Municipal Supply (MUN)	AGRICULTURE (AGR) Irrigation	AGRICULTURE (AGR) Stock Watering	INDUSTRY Process (PROC)	INDUSTRY Service Supply (IND)	INDUSTRY Power (POW)	RECREATION (REC 1) Contact	RECREATION (REC 1) Canoeing/Rafting	RECREATION Other Noncontact (REC 2)	FRESHWATER HABITAT Warm (WARM)	FRESHWATER HABITAT Cold (COLD)	MIGRATION (MIGR) 3/ Warm	MIGRATION (MIGR) 3/ Cold	SPAWNING (SPWN) Warm	SPAWNING (SPWN) Cold	WILDLIFE HABITAT (WILD) 4/ Flow	WILDLIFE HABITAT (WILD) 4/ Impd	Rare Species (RARE)
SJR-1	•	•	•	•			•	•	•	•	•	•	(o)	•	o	•	[•]	[•]
SJR-2	o	•	•	•			•	•	•	•		•	(o)	•	( )	•		[•]
SJR-3	o	•	•	•			•	•	•	•		•	•	•	( )	•	[•]	[•]
SS,	o	•	•	(o)			•	•	•	•		•	•	•	( )	•	[•]	[•]
MS-N	o	(o)	(o)	(o)			•	•	•	•		•	•	•	( )	(o)	[•]	[o]
SJR-4	o	•	•	•			•	•	•	•		•	•	•		•	[•]	[•]
MR	•	[•]	•	•	•	•	•	•	•	•	•	•	•	•	•	•		[•]
TR	o	•	•				•	•	•	•	•	[•]	•	•	•	•	[•]	[•]
SR	o	•	•	•	•	•	•	•	•	•	•	[•]	•	•	•	•	[•]	[•]

1/ Adapted from CVRWQCB (1976):
- • = existing designated beneficial use. [No change recommended.]
- o = potential designated beneficial use. [No change recommended.]
- (o) = unconfirmed, but previously designated as existing. [Recommend change to "potential" or delete]
- ( ) = unconfirmed, but previously designated as potential. [Recommend designation removal]
- [•] = confirmed existing, but not previously designated [New designation recommendation]
- [o] = potential, but not previously designated. [New designation recommendation]

2/ References: Westcot (1986, pers. comm.), Stevens et al (1987) (fish & wildlife, SS & MS categories)

3/ Warmwater anadromous species: striped bass, sturgeon, shad.
Coldwater anadromous species: salmon, steelhead

4/ flow - wildlife habitat maintained by flowing waters.
Impd - wildlife habitat maintained by impounded waters

IV. WATER QUALITY CRITERIA

Water quality criteria are defined in this report as scientifically determined concentrations of pollutants which will allow full protection of specified beneficial uses. The Environmental Protection Agency (EPA) defines water quality criteria as "constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use." (40 Code of Federal Regulations (CFR) §131.3(b)). They must be based on "sound scientific rationale and must contain sufficient parameters or constituents to protect the designated use." (40 CFR §131.3(b)) For waters with multiple use designations, the criteria must support the most sensitive use (Ibid.). Criteria recommended in this report are based on the best currently available data about the environmental effects of pollutants. They represent a risk assessment analysis for each chemical. By contrast, water quality objectives (see Chapter VIII) are a risk management tool providing reasonable protection for beneficial uses while taking into consideration other factors besides full protection of beneficial uses.

The preparation of water quality criteria is a necessary step in the process of developing water quality objectives for the San Joaquin River Basin Water Quality Control Plan (Basin Plan). The water quality criteria presented in this chapter were developed by a task force of the State Board's Division of Water Quality (DWQ) in consultation with the Technical Committee. A thorough review of the literature was performed by DWQ staff. In some cases the most current toxicological information was obtained from scientific researchers prior to publication. This chapter summarizes the detailed information and analyses presented in Appendix D.

Water quality criteria provide information and guidance in the formulation of water quality objectives. The criteria in this report are intended to indicate the highest levels of individual contaminants which may with confidence be maintained over a long period in waters of the San Joaquin Valley drainage system, without causing adverse impacts on the beneficial uses of these waters. Hereinafter, these are called continuous criteria.

Water quality criteria should be revised as signficant new information about pollutant effects becomes available. The theory and methodology of criteria development are also expected to evolve with time. Thus, water quality criteria reflect the current data base and best judgment at the time of their development. Site-specific information from the San Joaquin River Basin is lacking for most of the elements covered in this report. Studies are needed to determine actual effects of subsurface agricultural drainage waters on local sensitive species.

The EPA has developed water quality criteria for specific priority toxic pollutants listed under Section 304(a) of the Federal Water Pollution Control Act Amendments of 1972 (known as the Clean Water Act). If these pollutants are reasonably expected to interfere with designated water uses, numerical criteria must be adopted by the State when water quality standards are reviewed, revised or new standards adopted (Clean Water Act 1986, §303 and 308(a) Pub.L. 100-4). The EPA criteria may be adopted as the standards or the State may develop its own criteria during the basin planning process. When numerical criteria are not available, their development must be based upon biological monitoring or assessment methods. Under the Water Quality Act of 1987, when the Basin Plan is revised, numeric criteria will be required to be adopted for selenium, cadmium, chromium, copper, nickel and zinc. These are discussed further in the Chapter VIII sections on water quality objectives. Existing EPA criteria as well as the Technical Committee's recommended criteria are illustrated in Figures IV-1 to IV-9.

Constituents of Concern

In 1981, the State Board identified the information it would need from the U.S. Bureau of Reclamation (USBR) to prepare and issue waste discharge requirements for the proposed San Luis Drain discharge to the San Francisco Bay-Delta estuary. In 1983, while performing the required studies, the U.S. Fish and Wildlife Service (USFWS) observed that nests of waterfowl populating Kesterson Reservoir, the temporary terminus of the drain, contained many dead and deformed hatchlings and an excessive proportion of unhatched eggs. Analysis of the monitoring data and the observed symptoms indicated that selenium in subsurface agricultural drainage was the most likely cause of this problem. Agricultural drainage water samples analyzed by several agencies indicated that there were also 24 other trace constituents contained in subsurface agricultural drain water which exceeded concentrations found in most surface waters (see Table IV-1). In addition, increasing San Joaquin River salinity (measured as either electrical conductivity (EC) or total dissolved solids (TDS)) caused by subsurface agricultural drainage has been a major concern in the Basin. (The San Luis Drain was originally conceived to resolve the problem of a salt imbalance in the San Joaquin Valley.) Therefore, the Technical Committee added salts to the list of constituents of concern. At this time, pesticides have not been identified as major pollutants in subsurface agricultural drainage (Neil, 1987). Therefore, the Technical Committee will not address them in this report. Consequently, the Technical Committee has identified 26 constituents of subsurface agricultural drainage which are currently of concern because of their effects on water quality and beneficial uses (see Table IV-1).

The Technical Committee realized that it would be unable to develop site-specific water quality criteria for all 26 constituents of potential concern in the allotted time. Therefore, a list of 11 constituents of concern was developed based upon a review of the available literature and the use of the following criteria:

- Constituents which are quite toxic, are known to occur in geological formations within areas likely to generate agricultural drainage, and which have been measured in very high concentrations in agricultural drainage;

- Constituents known to exist in the San Joaquin Valley which may cause deformities or mortality in waterfowl similar to those which have been attributed to selenium at the Kesterson Reservoir;

The 11 constituents of concern are: boron, molybdenum, salinity, selenium, cadmium, chromium, copper, manganese, mercury, nickel and zinc. The methods of developing water quality criteria for these 11 constituents are addressed more specifically in the following sections of this chapter and in detail in Appendix D. The four constituents identified as primary constituents in Table IV-1 are those for which water quality objectives are developed in this report (see Chapter VIII). Although pesticides were not addressed in this report, the Technical Committee recommends future studies of their effects on beneficial uses in the San Joaquin River Basin be implemented, since they are found commonly in surface and tailwater agricultural discharges.

Methodology Used to Develop Water Quality Criteria

The Technical Committee determined that water quality criteria for the 11 constituents of concern listed in Table IV-1 were needed to protect human health and the agricultural and fish and wildlife beneficial uses in the San Joaquin River Basin. The Committee requested DWQ to prepare water quality criteria which would prevent excessive selenium bioaccumulation as well as protect beneficial uses from direct toxicity caused by selenium and the nine other elements on the list. The Regional Board staff reviewed existing agricultural criteria. Current state and federal criteria were evaluated. New data developed after these criteria were established were also reviewed. Where appropriate, existing criteria were retained. For example, the University of California Committee of Consultants (1974) and Pratt (1972) previously developed agricultural crop and stockwatering criteria for boron, molybdenum, salinity and selenium. For agricultural beneficial uses the existing criteria still appear to be appropriate. Current EPA criteria and DWQ's proposed criteria are discussed in the individual sections for each element.

At the Technical Committee's request, DWQ evaluated three methodologies for preparing criteria (see Appendix D). These were (1) a bioaccumulation method for selenium in the site specific food web, (2) the EPA method for mercury, cadmium, chromium, copper, nickel and zinc based on water hardness (EPA, 1984) and (3) the State Board's Ocean Plan method (Klapow and Lewis, 1979) for selenium, boron, manganese and molybdenum.

The EPA method was rejected by DWQ on two grounds. First (as discussed in Appendix D, Chapter 2), DWQ does not agree that a hardness based criteria such as EPA's is applicable in the San Joaquin River system. The Technical Committee concurs. Water hardness fluctuates both spatially and temporally in the San Joaquin River Basin (Table IV-2). The data in Table IV-2 are generally based on bimonthly samples. These do not permit a good estimate of the duration of low-hardness periods. The lower hardness values in the River are in the same range as the lower hardness values at which toxicity is commonly reported in the scientific literature. Thus, even though, on the average, the River contains water that is moderately hard, criteria related to hardness would have to be based on the lowest hardness reasonably expected. A water quality criterion based on the average hardness of these waters could result in seriously adverse conditions occurring at times of lowered hardness.

Temperature, pH and organic carbon content are other variables which may significantly affect the toxic action of chemicals in water. For example, Braginskiy and Shcherban (1978) reported a 10 to 100 fold increase in acute toxicity of cadmium to Daphnia magna from 25^{o}C (77^{o}F) to 30^{o}C (86^{o}F). This temperature range can occur in San Joaquin Valley surface waters. Interactions of metals with other organic or inorganic substances may also cause an increase in aquatic toxicity. Thus, criteria based on hardness alone, particularly if elevated on the basis of high hardness, may underprotect aquatic life from the effects of other independent variables. Furthermore, as shown in Figures IV-1 through IV-9, chronic effects on biota of different trophic levels have been found in low hardness waters at concentrations substantially below EPA's recent criteria.

The second reason for rejecting the EPA criteria development method is that it intentionally underprotects aquatic resources by disregarding the lowest 5 percent of toxicity values. Thus, chronic toxicity has been documented for many pollutants below the EPA criteria. Criteria developed in this manner represent a risk management approach appropriate to the water quality objective setting process but not to the risk assessment stage. In California, criteria to protect aquatic resources are developed to indicate levels of aquatic contaminants that would have no adverse ecological impacts on the most sensitive relevant species. Weighing competing beneficial uses and, if appropriate, providing less than complete protection of beneficial uses is part of the risk management or water quality objective setting stage. Therefore, the EPA method was deemed inappropriate to the criteria development process.

Two methods were selected by DWQ and the Technical Committee for determining criteria. A method based on selenium bioaccumulation through the food web was used to establish selenium criteria for human health and fish and wildlife (see Appendix D, Chapter 1). A method based on reports of chronic, reproductive, and developmental toxicity to sensitive relevant species was used to develop criteria for boron, manganese, molybdenum, cadmium, chromium, copper, nickel, zinc, and also selenium (see Appendix D, Chapter 2). This method is derived from a method that was previously used in the California Water Quality Control Plan for Ocean Waters. To protect beneficial uses in the Basin, the results of studies of chronic toxicity rather than acute toxicity studies were used. This method compares the lowest reported chemical concentrations causing chronic toxicity (lowest observed adverse effect level) with reported national background concentrations (assumed no adverse effect level). Site-specific studies and laboratory tests indicating the no effect levels and lowest effect levels in sensitive local species are generally not available. Therefore, national data from many chronic (or long term) studies were evaluated. The national background level of a given chemical was presumed to represent a no effect concentration on the assumption that organisms are adapted to such concentrations.

An attempt was made to determine San Joaquin River background concentrations for the 11 constituents of concern. The EPA's STORET data base for the San Joaquin River and east side tributaries was examined. However, for most information there was no differentiation between values of "below detection limits" and zero, and the computer program treated both situations as zero when calculating mean water quality values. This convention rendered the site-specific data base unusable for criteria development purposes. Therefore, national background values reported in the literature were used.

An "adverse effect level" was calculated as the geometric or logrithmic mean (used interchangeably in this chapter, see Glossary) of the three lowest acceptable chronic toxicity values. This value is recommended as the instantaneous maximum criterion. Water quality criteria were calculated as the log mean of the adverse effect level and the background level (see Appendix D, Chapter 2). This is consistent with the observation that organisms' responses to pollutants are generally lognormally distributed (EPA, 1984). This method assumes that a criterion should lie between the background level to which organisms are presumably adapted and a known low adverse effect level. In the present situation, use of the logarithmic mean provides an approximate ten-fold safety factor from known adverse affect levels for many pollutants. In cases where the logarithmic mean of the three lowest chronic toxicity values is greater than 100 times the background concentration, the adverse effect level is divided by ten (or multiplied by 0.1) to produce the criterion. This method provides protection against causing direct toxicity when there is uncertainty about site-specific chronic effects.

Based upon the above method, the proposed criteria should protect the aquatic ecosystem from adverse effects of the individual constituent being addressed. However, the San Joaquin River will, at any given time, contain varying proportions of all the constituents of concern addressed in this report. The data from the San Joaquin River sampling site at Vernalis, where the lowest concentration of all constituents were measured, indicate that the levels of these constituents all greatly exceed the estimates of the national background reported in the literature (see Figures IV-1 to IV-9). In many cases they also exceed the criteria. Whether the San Joaquin River ecosystem is subject to long term sublethal effects has not yet been determined.

The criteria in this report are based on the effects of the individual constituents. However, it is known that interactions of toxicants can alter their effects in the environment. These interactions may be additive, i.e., the effects of two toxic substances equal the sum of their individual effects; they may be synergistic, i.e., a mixture results in a significantly greater than additive toxicity; or they may be antagonistic, i.e., the toxicity is less than the sum of their effects (see Appendix D, Chapter 2). As an estimate of the potential for interactive toxicity, DWQ calculated the approximate additive contribution for each of the constituents of concern at the individual criterion values developed (see Appendix D, Chapter 2). This calculation indicated that a mixture of all these pollutants at the recommended criterion values may not be fully protective of the most sensitive organisms. Site-specific studies should be performed to determine if the recommended water quality criteria, in combination, for the various constituents (shown in Figures IV-I et seq.) are adequate to protect beneficial uses in the Basin. If the organisms are found to be acclimatized to naturally occurring high levels of some substances, it may be that the River system could support full beneficial uses with water quality objectives somewhat higher than the proposed criteria. However, if there are additive or synergistic effects, these criteria may be too high.

Results of site-specific studies in the San Joaquin River Basin are needed to better identify the lowest adverse effect levels and no effect levels (estimated at this time by the national background) for the constituents of concern. The Technical Committee agrees with the concept of setting an instantaneous maximum criterion equal to the adverse effect level. At no time should the concentration of the constituent of concern exceed the instantaneous maximum criterion (this is the geometric mean of the three lowest chronic effects levels). Therefore, except for mercury, criteria for the nine elements in the list of constituents of concern on Table IV-1 are based on the method outlined above and detailed in Appendix D. A criterion for mercury is not included in this report because the State Board's Priority Chemical Program is developing a water quality criterion or criteria for mercury which is anticipated to be completed by October 1987.

<u>Criteria</u>

Salinity

Salinity is measured as either total dissolved solids (TDS, in milligrams/liter = parts per million) or electrical conductivity (EC, in millimhos/centimeter). Salinity in the San Joaquin River Basin is of concern because of its effect on irrigated crops, the most salinity sensitive beneficial use. Livestock are able to tolerate somewhat more saline water without severe adverse effects (see Table IV-3). The criteria to fully protect agricultural beneficial uses is lower tha the criteria to protect other beneficial uses, and therefore should protect fish and wildlife.

The Technical Committee proposes that the concentrations of 0.7 mmhos/cm EC (415 to 430 mg/l TDS) shown in Table IV-3 be considered as the salinity water quality criterion needed to protect the identified beneficial uses. The criterion is intended to permit the use of water without any detrimental effects under the wide range of conditions encountered in irrigated agriculture in the San Joaquin Valley. An EC of 0.7 mmhos/cm permits production of all crops on all soils with adequate drainage in the San Joaquin River Basin and downstream in the southern Delta. Salinity levels above this require special cropping or water management techniques. Above an EC of 3.0 mmhos/cm (about 2,000 mg/l TDS) water quality is generally too poor to support agriculture.

Water Quality Criterion - Agricultural Supply Water = 0.7 mmhos/cm EC

Selenium

Selenium is a necessary micronutrient for animals and humans. It is commonly added to animal feeds to prevent health problems caused by a deficiency of this element. In higher doses it can cause toxicity including liver and other organ damage, nerve and skin disorders, mutations, and death to animals and humans.

The water quality criterion for agriculture which will not adversely affect normal crop growth or livestock forage supplies is 20 ppb selenium (Pratt, 1972). There are no data, at this time, to indicate that this criterion is inappropriate. Therefore, the Committee recommends continuing this selenium concentration as the water quality criterion to protect agricultural beneficial uses.

Continous Criterion - Agricultural Supply Water = 20 ppb selenium.

Recent concern has focused on selenium contained in subsurface agricultural drainage discharges in the San Joaquin River Basin, because it is believed to be the cause of widespread mortality and teratogenic effects in waterfowl at Kesterson Reservoir (see Figure II-1). Subsurface agricultural drainage water has been used to maintain wetland habitat in other areas of the grasslands on the west side. These wetlands provide critical habitat for a significant proportion of the migratory waterfowl of the Pacific Flyway. Birds, fish and other wild foods from this area are also eaten by humans. Because of selenium's known adverse effects, it is important to understand the concentrations which pose a threat to beneficial uses and develop criteria which will protect the public health and natural resources from exposure to dangerous levels of this constituent.

Studies of the cycling of selenium in aquatic ecosystems indicate that dissolved selenium is taken up by primary producers (phytoplankton and aquatic plants) and incorporated into the food chain. Higher trophic level organisms, including fish and waterfowl, feed on plants, aquatic invertebrates and other prey, accumulating organic forms of selenium such as selenomethionine. Selenate (+VI) is the major form of selenium in agricultural subsurface tile drain water discharged into the grasslands area. However, selenite (+IV) and organic selenides (-II) have also been detected in Kesterson Reservoir. More detailed discussion of selenium chemistry, partitioning and other aspects is contained in Appendix D, Chapter I.

Although selenium may be present at relatively low levels in water, it is accumulated to much higher and potentially toxic concentrations by various species in the aquatic food web. Kesterson Reservoir, where waterfowl deaths and deformities have been attributed to selenium accumulation, had freshwater inflows containing selenium concentrations as high as 300 ppb in 1983. Lower food chain organisms including plants were found with selenium levels averaging about 6 to 10 ppm, aquatic insects 7 to 30 ppm, waterfowl tissue and eggs 5 to 10 ppm, and mosquitofish 45 ppm.[1] Subsurface drainage flows in the grasslands have contained an average of 30 to 50 ppb selenium.

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[1] Except as otherwise noted, valued for selenium in this report are expressed as total selenium, with tissue values expressed in wet weight.

Tissue levels of selenium in bird eggs and fish have ranged from less than 1 ppm to over 2 ppm. Tissue concentrations of selenium ranging from about 2 to 10 ppm have been implicated in reproductive inhibition and abnormalities, and death in fish from eastern lakes, and waterfowl at Kesterson Reservoir (for further discussion of the data see Chapter II and Appendices A and D).

The Department of Health Services has determined that selenium levels of 2 ppm wet weight or more in fish or birds consumed by humans pose a potential public health risk. Public health warnings limiting the consumption of fish and/or birds from the grasslands (including Grassland Water District) were posted in 1985 because animals containing concentrations greater than 2 ppm were collected in this area.

In 1980 the EPA published a 24-hour criterion for the protection of freshwater aquatic life for selenite of 35 ppb. In spring 1986, EPA revised this criterion recommending that acid soluble selenite not exceed a four day average of 26 ppb more than once every three years and a one hour average of 190 ppb once every three years. The present EPA drinking water standard is 10 ppb selenium.

Current data indicate that selenium at levels considerably less than the EPA selenite criteria for protecting freshwater aquatic life cause significant adverse effects on the biota (see Appendix D, Chapter II). In fact, in 1984 State Board staff, using the Ocean Plan method (Klapow & Lewis, 1979), developed a draft water quality criterion of 5 ppb. Since then, additional selenium data have been analyzed to develop water quality criteria which will protect (1) human health from the consumption of sport-caught fish and wildlife; and (2) survival and reproduction of aquatic organisms.

Laboratory studies indicate that there is a relatively small amount of direct uptake of selenium from water (bioconcentration) by aquatic organisms. The bioconcentration factor (BCF) is relatively low for fish, typically less than 10 (Hodson et al., 1980; Adams, 1976; Sato et al., 1980) although sometimes it is higher (Lemly, 1982). The diet appears to contribute the majority of the tissue burden via bioaccumulation through the food chain (Birkner, 1978; Lemly, 1985; Schultz et al., 1980; Lemly, 1986; Finley, 1985; Hicks et al., 1984; Sandholm et al., 1973). It has been observed that when selenium occurs in water in parts per billion some trophic levels in the aquatic food web may contain selenium concentrations in the parts per million. Consumer species tend to contain greater amounts of selenium than plants. The available data are presented in Appendix D, Chapter I. The bioaccumulation of selenium and its effects on the biota have been evaluated in this report.

Flowing and impounded water criteria were developed separately because preliminary analysis suggests selenium may bioaccumulate to much higher levels in impounded waters such as lakes, reservoirs, and seasonally flooded wetlands. Data on the bioaccumulation of selenium for reservoirs were taken from published and unpublished studies throughout the United States for calculation of impounded water criteria. Data from the San Joaquin River and Mud and Salt sloughs were used for calculation of flowing water criteria (see Appendix D, Chapter I). Regression equations were calculated between selenium in water and selenium in food chain organisms from algae to fish for impounded waters and for fish in flowing waters (Figures 1 to 6, Appendix D). The R^2 values ranged from .67 to .88. These relationships indicate what the expected tissue selenium concentration would be in a particular type of organism for a given selenium concentration in water. The results of this analysis is discussed below.

Site-specific data for the bioaccumulation of selenium in marshland habitat such as the grasslands of the San Joaquin River Basin are being collected by the U.S. Fish and Wildlife Service but will not be available for 1 to 2 years. Elevated selenium levels present in the grasslands biota appear to be reflecting the higher selenium-containing subsurface agricultural drainage water (averaging about 40 ppb in 1984 and 1985) which was previously impounded to provide waterfowl habitat. The present water supply to the grasslands is relatively low in selenium because subsurface agricultural drainage is no longer diverted in large quantities. Instead it is bypassed to the San Joaquin River. Review of the preliminary data indicate that selenium levels in the biota and sediments of the grasslands do not reflect the selenium levels of water now being used in this area. It may take several years for the selenium in the biota and sediments of the grasslands to reach steady state with its cleaner water supply. Until that time, site-specific data on the bioaccumulation of selenium in marsh habitats of the San Joaquin River Basin will not be available unless special studies or tests are initiated under controlled conditions elsewhere in the Basin. In the interim, the Technical Committee proposes that national selenium bioaccumulation data for impounded waters be used in developing criteria to protect beneficial uses in intermittently impounded marsh habitat.

While the relative selenium tissue concentrations between the trophic levels in flowing and impounded water were generally constant, the bioaccumulation factor (BAF) from water to tissue seems to be different for flowing and impounded water. The reasons for this difference are unknown at this time. Several possibilities exist, including that (1) fish food items such as terrestrial or drift organisms have not spent much time in selenium laden waters or have been carried downstream from low selenium areas, (2) the fish sampled may not have been resident in the area long enough to reflect ambient concentrations of selenium in the food chain, or (3) other factors such as partitioning differences between water and sediments or biomass to water ratios are different. For the range of selenium concentrations studied, the bioaccumulation factor of selenium from water through the food chain to fish and waterfowl in impounded waters is about 1,000. For example, if there is 1 ppb selenium in the water, selenium will have bioaccumulated to 1,000 ppb (= 1 ppm) in fish. In flowing waters the bioaccumulation factor appears to be about 100, e.g., with 1 ppb selenium in water, 100 ppb (= 0.1 ppm) is observed in fish (see Figure IV-10 and Table IV-4). However, recent unpublished data on the concentrations of selenium in fish tissues from similar sites (Saiki, 1987) indicate that it may be much higher.

Selenium criteria presented in this report which would prevent adverse effects were developed from toxicity and feeding studies (see Appendix D, Chapter 1). Measured bioaccumulation rates of selenium from water through the various trophic levels to fish in impounded and flowing waters, and from water to waterfowl food organisms in impounded waters were evaluated to determine the concentrations of selenium in water that are associated with levels of selenium in tissue which would not pose a threat to human health or fish and wildlife. Also, calculated bioaccumulation rates for insects serving as waterfowl food organisms in flowing water were developed assuming that insect tissue to fish tissue relationships for flowing waters are similar to those in impounded waters. These assumptions should be verified through site-specific studies and the collection of field data.

The bioaccumulation criteria are set forth in Table IV-4. The human health criteria of 0.8 ppb is for food fish inhabiting impounded waters. That is to say, 0.8 ppb selenium in the water should prevent the bioaccumulation of selenium in fish to a concentration which would be deleterious to human health if consumed. This criterion is derived from the equation developed for bioaccumulation of selenium in fish from impounded waters, $\log (y/1000) = 0.075 + 0.749 \log x$, where x = the concentration in water and y = the concentration in fish. It was developed from the maximum allowable residue level (MARL) of 1 ppm (wet weight) in edible fish flesh (skeletal muscle) established by the Department of Health Services (Book, 1986) to protect human consumers of fish. When the MARL of 1 ppm in fish flesh is inserted into the bioaccumulation equation above, the corresponding selenium concentration in water is 0.8 ppb. The Department of Health Services issues health advisories when fish tissue concentrations reach 2 ppm. This has occurred in some areas of the grasslands and all of Kesterson Reservoir.

The continuous criterion for the protection of fish that live in impounded waters is 0.9 ppb and its derivation is discussed in detail in Appendix D, Chapter I. Toxic effects such as degenerative changes in fish kidneys and larval mortality associated with elevated levels of selenium in muscle and ovarian tissue have been observed between 2 and 5 ppm. The geometric mean of the three lowest toxic effect levels (or adverse effect level) is 2.77 ppm. An estimate of the no effect concentration in fish tissue is derived by calculating the geometric mean of the adverse effect level and the fish tissue background level. The geometric mean of the adverse effect level (2.77 ppm) and the background level (0.42 ppm) is 1.1 ppm. This value (1.1 ppm) is then inserted into the regression equation relating selenium concentrations in impounded water to fish tissue concentrations due to bioaccumulation (see above equation). The resulting value of 0.9 ppb indicates the concentration of selenium in water which will protect against selenium bioaccumulation in fish flesh to levels above 1.1 ppm which could cause toxic effects to their human consumers. Most of the impoundments along and adjacent to the San Joaquin River in Reach 4 are supplied, at least in part, by the River (see Appendix B). The Technical Committee recommends that appropriate site-specific studies be performed to determine if the fish in these impounded waters are being adversely affected. In the interim, the Technical Committee recommends the continuous criterion for impounded water as 1.0 ppb (0.8 ppb and 0.9 ppb rounded to 1.0).

Continuous Water Quality Criterion-Impounded Water = 1.0 ppb selenium

To determine levels safe for fish in flowing waters the regression equation, $\log (y/1000) = - 0.666 + 0.669 \log x$ was used, where x is the selenium concentration in water and y is the selenium concentration in fish tissue (see Appendix D).

Site-specific bioaccumulation data indicate that for flowing waters, selenium concentrations of 1 ppm in fish muscle would result from concentrations of of 10 ppb selenium in water. Selenium concentrations below 10 ppb in water would prevent fish tissue levels from exceeding the public health MARL (1 ppm). A continuous concentration of selenium in water of 11 ppb would be expected to produce concentrations of selenium in fish tissue through bioaccumulation of 1.1 ppm. These two criteria values for flowing water would preclude excessive bioaccumulation of selenium in fish living in the San Joaquin River Basin. These criteria do not address the direct effects, (i.e., accute or chronic non-bioaccumulation effects) of selenium.

In order to develop a selenium criterion for direct toxicity (acute or chronic effects not due to bioaccumulation), the method described in Appendix D, Chapter II was used. This is similar to the Ocean Plan method and is described on pages IV-6 through IV-13. The nationwide ambient water quality data were reviewed to determine the selenium concentration in surface waters which could be considered to be an appropriate background level. This was determined to be 0.2 ppb. Data were analyzed to determine selenium concentrations in water which cause chronic toxicity effects in North American freshwater organisms. An estimate of the lowest adverse effect level (also recommended as an instantaneous maximum) was calculated as the geometric mean of the three lowest available chronic toxicity concentrations for three sensitive species; 10 ppb (a green alga), 28 ppb (rainbow trout) and 66 ppb (coho salmon) (see Table IV-5). For selenium the lowest adverse effect level is 26.3 ppb (see Figure IV-1). Because the lowest adverse effect level was more than 100 times the background concentration, by convention it was divided by 10 to produce the criterion. Therefore, the derived criterion is 2.6 ppb. The selenium concentration derived from this method provides an estimate of a water quality criterion which will protect the most sensitive relevant species from long term or life cycle adverse effects. As indicated above, the selenium water quality criterion for direct toxic effects is developed by dividing the estimated lowest adverse effect level by a safety factor of ten. This conversion has been used with success in developing water quality criteria for the State Board's Ocean Plan. However, the use of this technique for inland waters is still being discussed.

The recommended water quality criterion for flowing water is 2.6 ppb selenium (see Figure IV-1). The instantaneous maximum concentration should not exceed 26 ppb selenium.

Continuous Water Quality Criterion - Flowing Water = 2.6 ppb selenium
Instantaneous Maximum Criterion - Flowing Water = 26 ppb selenium.

When developing water quality criteria for selenium, the values to protect humans and aquatic organisms as shown in Table IV-4 were evaluated carefully. In addition, bioaccumulation data from waterfowl were evaluated, taking into account feeding habits of different species (see Appendix D, Chapter 1). Due to a lack of sufficient data and the numerous assumptions needed to derive a water quality criterion to protect waterfowl, the Technical Committee is not at this time recommending any selenium water quality criteria based on protection of waterfowl or human consumption of waterfowl. Preliminary calculations indicated much species variation for water quality criteria for waterfowl. The water quality criteria for protection of human health ranged from 0.10 to 5.0 ppb. The criteria to protect waterfowl reproduction ranged from about 0.2 to 8.0 ppb. The median criterion for these parameters was about 1 ppb. The USFWS is carrying out several studies which are expected to provide information that can be used to develop waterfowl criteria by 1991. However, waterfowl beneficial uses should be adequately protected in the interim by the other criteria recommended in Table IV-4 (see Appendix D, Chapter 1).

Monitoring and research studies are currently being performed which will contribute to a better understanding of bioaccumulation effects in waterfowl. The Technical Committee recommends additional studies (Appendix D, Chapter 1) which will help develop site-specific water quality criteria for the San Joaquin River Basin. The Committee believes that developing water quality criteria to protect waterfowl and their consumers needs to be a top priority. Other studies are needed to determine whether a separate bioaccumulation criterion for flowing waters is needed and whether the high sulfate content or other constituents of Basin waters may affect selenium toxicity.

Boron

Boron is essential in the nutrition of higher plants. However, in excess of 500 ppb, boron is known to be deleterious to certain crops. Sensitive crops include artichokes, plums, pears, grapes and citrus fruits. These can tolerate no more than 1,000 ppb. Boron is never found in nature in its elemental form, generally occurring as sodium borate (borax) or as calcium borate (colemanite) in mineral deposits and some natural waters (McKee and Wolf, 1963). There is no evidence that it performs any vital function in human or animal nutrition.

The agricultural criteria for boron were developed to take into account the wide range of climate and soil conditions in the San Joaquin Valley (Table IV-6). Boron concentrations below 500 ppb will protect all crops. Above this, detrimental effects will begin to occur and special management practices will be required (Pratt, 1972).

There are no data at this time to indicate that the water quality criterion to protect all crops, i.e. 500 ppb, is inappropriate. Therefore, the Technical Committee recommends retaining this criterion to protect agricultural beneficial uses (see Figure IV-2).

Continuous Criterion - Agricultural Supply Water = 500 ppb boron

Aquatic toxicity data on boron are sparse (see Appendix D, Chapter 2, Table II-4). When setting water quality criteria which will be protective of the beneficial use, an LC_{50} (the concentration which kills 50% of the test population) does not provide an accurate estimate of a no effect level. Unfortunately most of the chronic toxicity data on boron use 50% lethality as the study endpoint.

The EPA has not proposed a water quality criterion for boron to protect aquatic life. Using the method outlined previously and the LC_{50} data mentioned above, the lowest adverse effect level was calculated to be 5,800 ppb. This is the geometric mean of the three lowest toxic concentrations on the three most sensitive species; 1,020 ppb (rainbow trout), 8,800 ppb (Daphnia magna) and 22,000 ppb (channel catfish). Based upon the less than ideal estimate of chronic toxicity (5,800 ppb) and the national background level (100 ppb) the recommended water quality criterion is 760 ppb (see Figure IV-2). To provide a criterion which is not based on 50% mortality of test organisms, reliable data from long-term tests of sensitive relevant species should be developed.

Continuous Water Quality Criterion = 760 ppb boron

Instantaneous Maximum Criterion = 5,800 ppb boron

Molybdenum

In very low concentrations this element has been found to be essential for healthy growth of many plants and an essential trace element for rats (and most likely for all animals). At higher concentrations molybdenum has been injurious to the growth of many kinds of plants in solution or sand culture. This metal and its salts are not widely distributed in nature. It has been used as a constituent in fertilizers for leguminous crops (McKee & Wolf, 1963). Molybdenum is not one of EPA's priority chemicals; therefore, there is no EPA criterion for molybdenum.

The agricultural criterion for molybdenum was developed to take into account the range of climate and soil conditions in the San Joaquin Valley. Molybdenum can be toxic to livestock through bioaccumulation. For waters used continuously for irrigation on all soils and livestock forage supplies the water quality criterion which will protect all uses is 10 ppb (see Figure IV-3). There are no data at this time to indicate that this criterion is inappropriate. Therefore, the Technical Committee recommends retaining this criterion to protect agricultural beneficial uses.

Continuous Criterion - Agricultural Supply Water = 10 ppb molybdenum

There are very few acute or long-term (chronic) aquatic toxicity test results available for molybdenum (Appendix D, Chapter 2, Table II-6). Unfortunately, the chronic data all involve lethal endpoints. Further, data for three different species are not available. Thus, there is uncertainty as to whether the calculated criterion value will protect against adverse effects.

The existing test data are less than ideal because the calculated lowest adverse effect level of 440 ppb is an estimate of toxicity based upon lethal end points. The three lowest toxic concentrations produced an LC_{10} of 120 ppb (rainbow trout), and LC_{50}'s of 730 ppb (rainbow trout), and 960 ppb (narrow mouthed toad). Since the average background concentration (0.68 ppb) is less than .01 of the adverse effect level (440 ppb), the criterion is calculated as 0.1 times the adverse effect level.

The Committee recommends that priority should be given to developing data from long term, early life stage tests of sensitive relevant species using non-lethal endpoints, in order to refine this criterion.

Continuous Water Quality Criterion = 44 ppb molybdenum
Instantaneous Maximum Criterion = 440 ppb molybdenum

Manganese

This element is essential for plant growth. This metal, or its salts, has been used in agriculture to enrich manganese deficient soils but in some concentrations it may be phytotoxic. In an oxidized state it is seldom present in natural surface waters. However, in ground water subject to reducing conditions, manganese can be leached from the soil and occur in high concentrations (McKee & Wolf, 1963).

Acute and chronic aquatic toxicity data for manganese are not plentiful (Appendix D, Chapter 2, Table II-5). There is no EPA freshwater aquatic life criterion for manganese. Chronic tests using lethal endpoints had to be included in the criterion development process because of the limited data base. The lowest adverse effect level was calculated as 1,600 ppb which is the logarithmic mean of 960 ppb (rainbow trout), 1,420 ppb (narrow-mouthed toad) and 3,100 ppb (the green alga, *Selenastrum capricornutum*). The estimate of natural background concentration from a national average is 20 ppb. Therefore, the derived criterion value is 180 ppb (the logarithmic mean of 1,600 ppb and 20 ppb) (Figure IV-4).

Because the data base for manganese is relatively small, and two of the three data points used for criterion calculation are based on lethality, data from long-term tests of more sensitive endpoints need to be developed to refine this criterion. More ambient testing is also needed to determine background levels of manganese in the various river reaches.

Continuous Water Quality Criterion = 180 ppb manganese
Instantaneous Maximum Criterion = 1,600 ppb manganese

Cadmium

In the elemental form, cadmium is insoluble in water. It occurs in nature largely as the sulfide salt, greenockite or cadmium blend, often as an impurity in zinc-lead ores. Cadmium salts are sometimes employed as insecticides and antihelmenthics (McKee & Wolf, 1963).

In 1980, EPA published water quality criteria for cadmium, using a hardness-dependent relationship which gave a continuous (24-hour) criterion ranging from 0.012 ppb at a hardness of 50 ppm to 0.051 ppb at a hardness of 200 ppm as $CaCO_3$. These criteria were revised in 1984 to 0.66 ppb and 2.0 ppb at hardness values of 50 and 200 ppm, respectively (Figure IV-5). This was an increase of more than 30 times over the 1980 criteria. The 1984 EPA Water Quality Criteria document for cadmium states, "If brook trout, brown trout and striped bass are as sensitive as some data indicate, they might not be protected by this criterion". Available data indicate that this may be the case not only with salmonids and striped bass, but also with Daphnia spp. and other sensitive and important freshwater invertebrates. As indicated in Appendix D, Table II-7, adverse effects have been demonstrated in such organisms at levels well below EPA's 1984 criteria. These factors are considered grounds for developing a cadmium criterion more protective than EPA's in surface waters of the San Joaquin River Basin using the method outlined above.

Based upon the best available data, the lowest adverse effect level (geometric mean of the three lowest chronic effect levels in the three most sensitive species) is 0.2 ppb. This is the geometric mean of 0.15 ppb (Daphnia magna), 0.2 ppb (rainbow trout) and 0.28 ppb (Moina macrocopa, a crustacean). The national background concentration of cadmium is 0.01 ppb. The logarithmic mean of the lowest adverse effect level and the background level is 0.05 ppb which is the recommended criterion for cadmium.

Many studies of the chronic effects of cadmium are based on mortality. Two of the three lowest available data points representing chronic adverse effects use lethality as the endpoint of the test. The Technical Committee recommends that additional toxicity studies and site specific monitoring be performed. Chronic tests are needed using sensitive relevant species which do not use lethality as an endpoint to determine effects.

Continuous Water Quality Criterion = 0.05 ppb cadmium
Instantaneous Maximum Criterion = 0.2 ppb cadmium

Chromium

Chromium has several valence states but the two that are environmentally significant are the trivalent and hexavalent forms. Hexavalent chromium can be reduced to the trivalent form by heat, by organic matter, or by reducing agents. Chromium is present in trace amounts in soils and in plants, but there is no evidence that chromium is essential or beneficial to plant nutrition (McKee & Wolf, 1963).

The EPA has developed separate criteria for tri- and hexavalent chromium. In 1985 EPA proposed a hardness related criterion for the trivalent form. At hardnesses of 50 and 200 ppm as $CaCO_3$, criteria of 120 ppb and 370 ppb trivalent chromium, respectively, were proposed (see Figure IV-6). The available data were reviewed by DWQ and no relationship between toxic effects and water hardness could be concluded. It appears (see Appendix D, Chapter 2, Table II-8) that several species may be adversely affected by levels of trivalent chromium at or below the EPA criteria.

Toxicological data on chronic and developmental adverse effects for trivalent chromium are shown in Appendix D, Table II-8. The three lowest values are 44 ppb, 89 ppb, and 397 ppb for three sensitive species. The logarithmic mean of the three lowest chronic toxicity values is 116 ppb. The ambient background concentration of trivalent chromium is 5 ppb. The geometric mean of these two numbers provides a criterion of 24 ppb. The tri- and hexavalent forms of chromium easily transform into the other valence form. Therefore, at no time should the combination of tri- and hexavalent chromium exceed the trivalent criterion. The recommended criteria for trivalent chromium are:

Continuous Water Quality Criterion = 24 ppb trivalent chromium
Instantaneous Maximum Criterion = 116 ppb trivalent chromium

In 1980, EPA published a non-hardness based freshwater ambient water quality criterion for hexavalent chromium of 0.29 ppb. In 1985 this criterion was raised to 11 ppb (see Figure IV-6). As shown in Appendix D, Table II-9, _Daphnia_ spp. and other invertebrates appear to be exceptionally sensitive to low levels of hexavalent chromium. Also, certain green algae and salmonids appear to be quite sensitive. Toxic effects for some species have been shown to occur between about 2 and 10 ppb.

The lowest adverse effect level for hexavalent chromium is calculated as 4.5 ppb. This is the geometric mean of 2.5 ppb, 6.1 ppb, and 6.1 ppb, the three lowest chronic toxicity values in three sensitive species. The background concentration is 0.5 ppb. The logarithmic mean of these levels produce a criterion of 1.5 ppb. The recommended water quality criteria for hexavalent chromium are:

Continuous Water Quality Criterion = 1.5 ppb hexavalent chromium
Instantaneous Maximum Criterion = 4.5 ppb hexavalent chromium

Copper

Copper salts occur in natural surface waters only in trace amounts and their presence is generally the result of pollution, e.g., the use of copper compounds for the control of undesirable plankton organisms or from mining waste. Minute quantities of copper are essential for plant and animal growth. However, relatively small increases in concentration can become toxic (McKee & Wolf, 1963).

EPA's 1980 water quality criterion for copper was 5.6 ppb. In 1984 this was revised using a hardness-related equation yielding criteria of 6.5 ppb, 12 ppb and 21 ppb at hardnesses of 50 ppm, 100 ppm and 200 ppm as $CaCO_3$, respectively (see Figure IV-7).

Numerous studies have shown toxic effects below EPA's criteria (see Appendix D, Table II-10). _Daphnia magna_, freshwater crustaceans, and immature salmonids appear to be particularly sensitive to copper. The lowest adverse effect level was determined to be 1.41 ppb (the log mean of

1 ppb, 1.4 ppb, and 2 ppb). The ambient background level is 1.0 ppb. The geometric mean of these two levels yields a criterion of 1.2 ppb. The recommended criteria are:

Continuous Water Quality Criterion = 1.2 ppb copper
Instantaneous Maximum Criterion = 1.4 ppb copper

Nickel

Elemental nickel seldom occurs in nature, but nickel compounds are found in many ores and minerals. Many nickel salts are highly soluble in water. This element is extremely toxic to citrus plants. Nickel is found in many California soils, generally in insoluble form. Excessive acidification of such soil may render it soluble, causing severe injury or death to plants (McKee & Wolf, 1963).

In 1980, EPA's published water quality criteria for the protection of aquatic life from nickel ranged from 50 to 160 ppb, at respective water hardnesses of 50 to 200 ppm as $CaCO_3$. In 1986 these criteria were adjusted to 88 and 280 ppb at the same hardness values (see Figure IV-8). EPA's criterion for nickel for the protection of human health from the effects of ingesting aquatic organisms and water is 13.4 ppb.

The toxicological data set for nickel is contained in Appendix D, Table II-11. Toxic effects below the EPA criteria and hardness values were observed in aquatic vertebrates and invertebrates in all studies listed. The logarithmic mean of the three lowest chronic effect levels was 6.7 ppb (adverse effect level). The three lowest toxicity values (based on mortality of test organisms) were 4.1 ppb, 7 ppb, and 10.6 ppb. Background concentration is 1.0 ppb. The recommended criterion is therefore 2.6 ppb (see Figure IV-8).

Water Quality Criterion = 2.6 ppb nickel
Instantaneous Maximum Criterion = 6.7 ppb nickel

Zinc

Zinc occurs abundantly in rocks and ore, but is present in most surface and ground waters only in trace amounts. Zinc is an essential and beneficial element for animals and plants. However, unlike mammals, toxicity results in plants when concentrations exceed a very low level. Furthermore, zinc exhibits its greatest toxicity in aquatic life. Aquatic organisms may acclimatize somewhat to zinc and become less susceptible to future exposures. However, aquatic organisms may exhibit a delayed response to zinc poisoning. Copper appears to have a synergistic effect on the toxicity of zinc (see Appendix D, Chapter II). Recent studies indicate that certain species of green algae may be at least as sensitive to the toxic effects of zinc as other sensitive aquatic organisms (Appendix D, Table II-12).

The 1980 ambient water quality criteria for zinc have not been revised by EPA. Their 24-hour criterion for the protection of freshwater aquatic life is 47 ppb (see Figure IV-9). However, while this criterion is not hardness based, the one hour maximum criterion is. This criterion ranges from 180 to 570 ppb at 50 to 200 ppm as $CaCO_3$, respectively.

The toxicological data for zinc are contained in Appendix D, Table II-12. Green algae and some aquatic invertebrates have exhibited toxic effects below the 24-hour EPA criterion of 47 ppb. The three lowest values are 30 ppb, 37 ppb, and 47 ppb. The logarithmic mean of the three lowest toxicity values produces an estimated lowest adverse effect level of 37 ppb. The national background zinc concentration is 2 ppb. Therefore, the geometric mean of these values produces a recommended criterion of 8.6 ppb (see Figure IV-9).

Continuous Water Quality Criterion = 8.6 ppb zinc
Instantaneous Maximum Criterion = 37 ppb zinc

Summary

The water quality criteria developed by the Division of Water Quality (DWQ) and the Technical Committee and recommended by the latter are summarized below in the first three columns of Table IV-7. Current EPA criteria are shown in the last column for comparison. As shown in this table, median concentrations of the constituents of concern in the San Joaquin River and/or its tributaries often exceed the criteria recommended by the Technical Committee. Some exceed EPA criteria as well. DWQ and the Committee agree that site-specific chronic toxicity tests for the top priority subsurface drainwater constituents are needed to refine these criteria. DWQ is developing plans for site-specific chronic toxicity and bioaccumulation studies of selenium. The effects of sulfate and carbonate on selenium toxicity and bioaccumulation will be examined. The individual and interactive effects of boron, cadmium, chromium, copper, nickel and zinc are also proposed to be evaluated during 1988-89. Additional details of such studies are discussed in Chapter VIII and Appendix D.

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Table IV-1

Water Quality Constituents of Concern
In Subsurface Agricultural Drainage

Constituents of Potential Concern	Tech. Comm. Constituents of Concern*	Tech. Comm. Primary Constituents of Concern	Beneficial Use Affected at Lowest Concentration
Aluminum	Boron	Boron	Agriculture
Arsenic	Cadmium	Molybdenum	Agriculture
Barium	Chromium	Salts	Agriculture
Beryllium	Copper	Selenium	Fish & Wildlife (including Human Consumption of Fish & Wildlife)
Bismuth	Manganese		
Boron	Mercury		
Cadmium	Molybdenum		
Chromium	Nickel		
Copper	Salts		
Fluorine	Selenium		
Iron	Zinc		
Lead			
Lithium			
Magnesium			
Manganese			
Mercury			
Molybdenum			
Nickel			
Nitrogen			
Phosphorous			
Salts			
Selenium			
Silver			
Strontium			
Vanadium			
Zinc			

* Constituents for which water quality objectives are recommended for adoption.

Table IV-2
San Joaquin River Drainage 1975-85
Water Hardness as $CaCO_3$ (ppm)[1/]

Location	Avg. Hardness	Std. Dev.	Lowest Values	Sampling Dates
Mendota	68	27	14	6/78
			19	5/82
			20	8/83
Stevinson	142	80	40	3/83
			35	1/84
Fremont Ford	142	51	32	5/78
			41	6/82
			39	1/84
Patterson	131	51	44	10/82
			25	8/83
Grayson	134	51	54	10/82
			53	3/83
Maze Rd. Bridge	108	48	33	10/82
			43	1/84
Mossdale Bridge	106	52	33	6/75
			30	3/80
			28	5/80

1/ Data from California Department of Water Resources

TABLE IV-3

Salinity Water Quality Criteria and Irrigation and Stockwatering Supply Needs1/

Needs	Constituent Concentration EC2/	TDS3/
Water which permits full production of all crops on all soils with adequate drainage in the San Joaquin River Basin and Southern Delta	0.7*	415-430*
Water which can have detrimental effects on crops	0.8-3.0	470-2,000
Water that may have severe effects on crops	>3.0	>2,000
Excellent for stockwatering	1.5	950
Very satisfactory for stockwatering	1.5-5.0	950-3,200

1/ University of California Committee of Consultants, 1974, and Pratt, 1972
2/ Electrical Conductivity (EC) mmhos/cm
3/ Total Dissolved Solids (TDS) mg/l

*The water quality criterion which will protect all uses

TABLE IV-4
WATER QUALITY CRITERIA FOR SELENIUM
Total selenium in ppb

METHOD OF CALCULATION	IMPOUNDED WATERS		FLOWING WATERS	
	HUMAN HEALTH FISH	AQUATIC LIFE FISH	HUMAN HEALTH FISH	AQUATIC LIFE FISH
Bioaccumulation				
(1) Public Health criteria(1 ppm) in flesh ÷ measured BAF*	0.8		10	
(2) Log mean of NOAEL* & LOAEL* (1.4 ppm) in tissue ÷ measured BAF		0.9		11
Chronic Toxicity				
(3) Chronic toxicity to fish modified Ocean Plan method		2.6		2.6

* BAF - Bioaccumulation Factor
* NOAEL - No Observable Adverse Effect Level
* LOAEL - Lowest Observable Adverse Effect Level

Table IV-5
Freshwater Adverse Effects from Selenium

Species	Selenium (ppb)	Effect	Duration	Reference (App. D - Chpt 2)
Ankistrodesmus falcatus (Chlorophyte)	10	Inhibition	2 wks	Vocke et al., 1980
Rainbow trout (eyed eggs)	28	Significant Increased Mortality	44 wks	Hodson et al., 1980
Coho salmon (fry)	66*	LC_{50} 1/	43 day	Adams 1976
Rainbow trout (young)	88	MATC 2/	27 mos	Goettl and Davies 1977
Daphnia magna (full life cycle)	90	MATC	28 day	Kimball, manuscript
Scenedesmus obliquus (Chlorophyte)	100	Inhibition	2 wks	Vocke et al, 1980
Fathead minnow (embryo-larval)	113	MATC	28 day	Kimball, manuscript
Rainbow trout (fry)	117*	LC_{50}	96 day	Adams 1976
Bluegill	167*	LC_{50}	48 day	Adams 1976
Rainbow trout (fry)	192*	LC_{50}	21 day	Adams 1976

* The original concentration reported as the test chemical has been converted and reported as selenium.

1/ Concentration lethal to 50% of organism during test period.
2/ Maximum allowable toxicant concentration

TABLE IV-6

Agricultural Criteria and Crop Tolerance
for Boron

Boron	ppb
Water which will protect all crops	500*
Water which can have detrimental effects on sensitive crops	500-1,000
Water which can have detrimental effects on semi-tolerant crops	1,000-2,000
Water which can have detrimental effects on tolerant crops	2,000-10,000

* Agricultural criterion

Table IV-7

Water Quality Criteria
(in parts per billion
except where noted)

Constituent	Technical Committee Water Quality Criteria Aquatic Life: Continuous (Long-term)	Technical Committee Water Quality Criteria Aquatic Life: Instantaneous Maximum[1]	Agricultural[2]	EPA Freshwater Criteria[3]
Salinity (TDS)		--	500 mg/l*	--
Selenium		--	20	
Impounded Water	1.0[4]*	--	--	10* [drinking water]
Flowing Water	2.6*	26.	--	26* [aquatic life]
Boron	760.*	5800.	500*	--
Molybdenum	44.	440.	10	--
Manganese	180 *	1600.	--	--
Cadmium	0.05	0.2	--	0.66(50) 2.0(200)
Chromium				
Trivalent	24.	116.	--	120(50) 370(200)
Hexavalent	1.5	4.5	--	11
Copper	1.2*	1.4	--	6.5(50)* 12(100)* 21(200)
Nickel	2.6*	6.7	--	88(50) 280(200) 13.4 [public health]
Zinc	8.6*	37.	--	47*

1 Instantaneous Maximum = adverse effect level.
2 Water Quality Criteria values for agriculture are continous criteria.
3 Hardness values in mg/l are shown in parentheses for hardness based criteria.
4 Water quality criterion for impounded water is a continuous criterion.

* Measured median values exceed criterion at some or all stations. Note that detection limit for cadmium exceeds criterion and only total chromium is reported in site-specific water quality data.

FIGURE IV-1
Ambient / biological data and criteria
Selenium

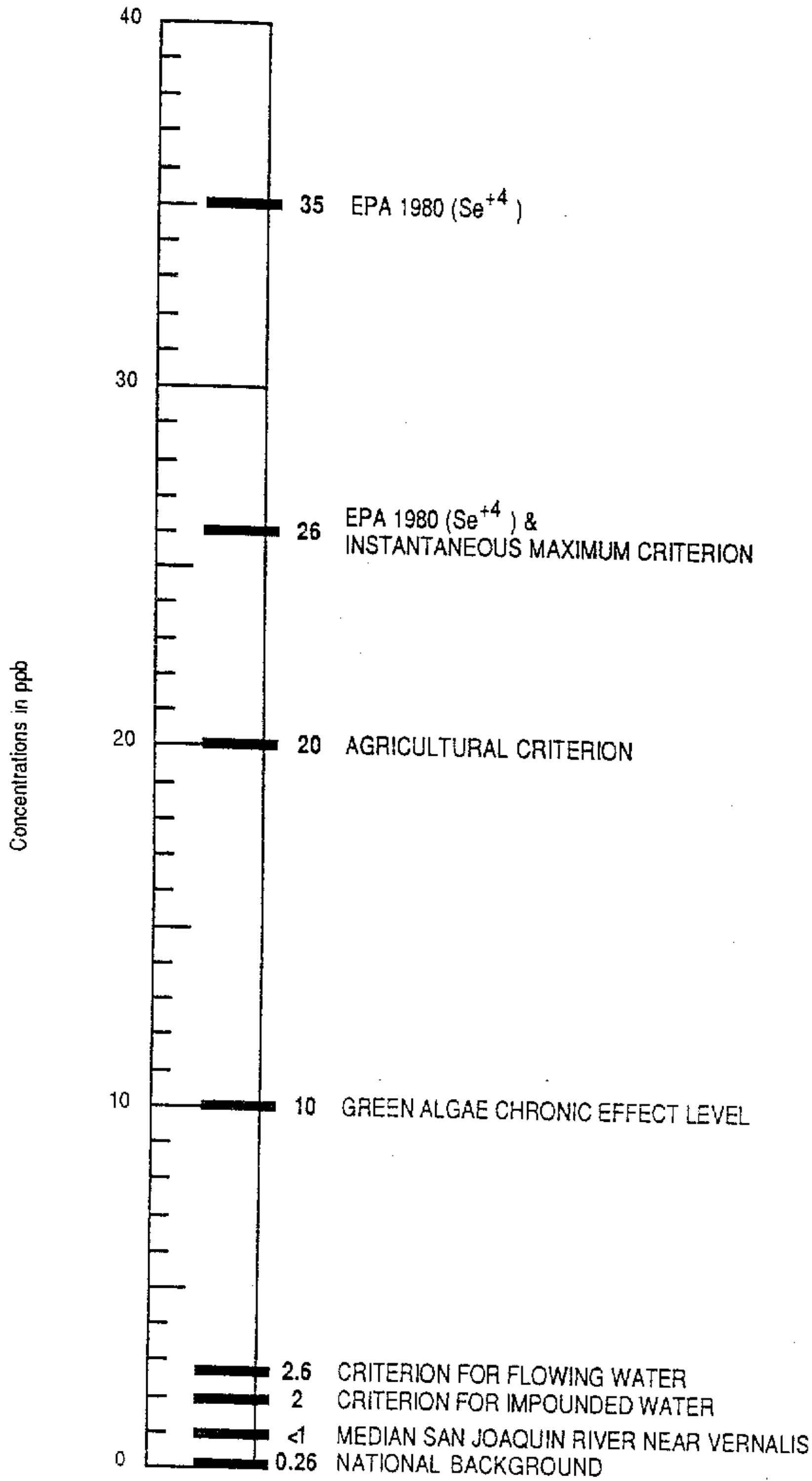


FIGURE IV-2
Ambient / biological data and criteria
Boron

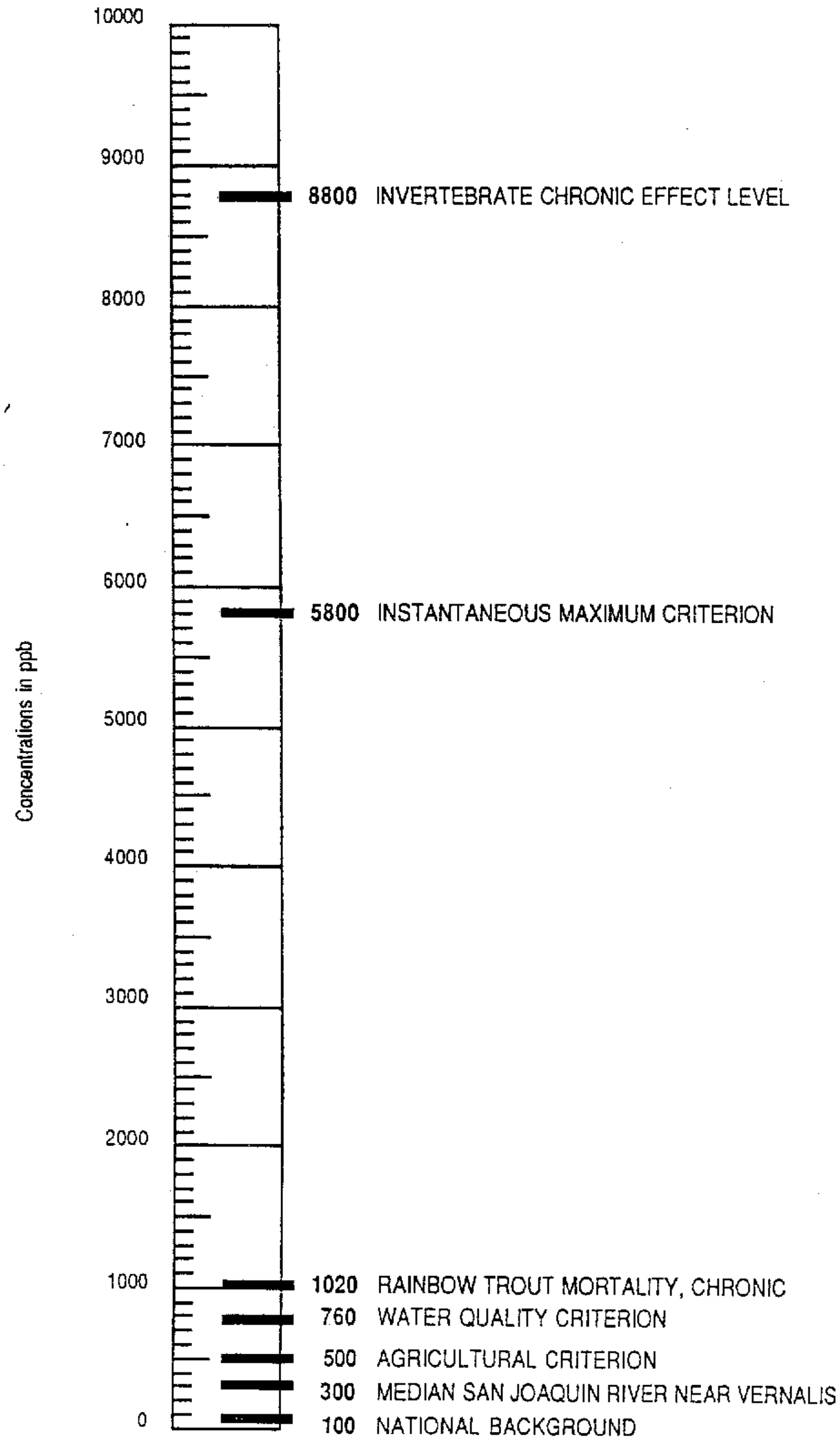
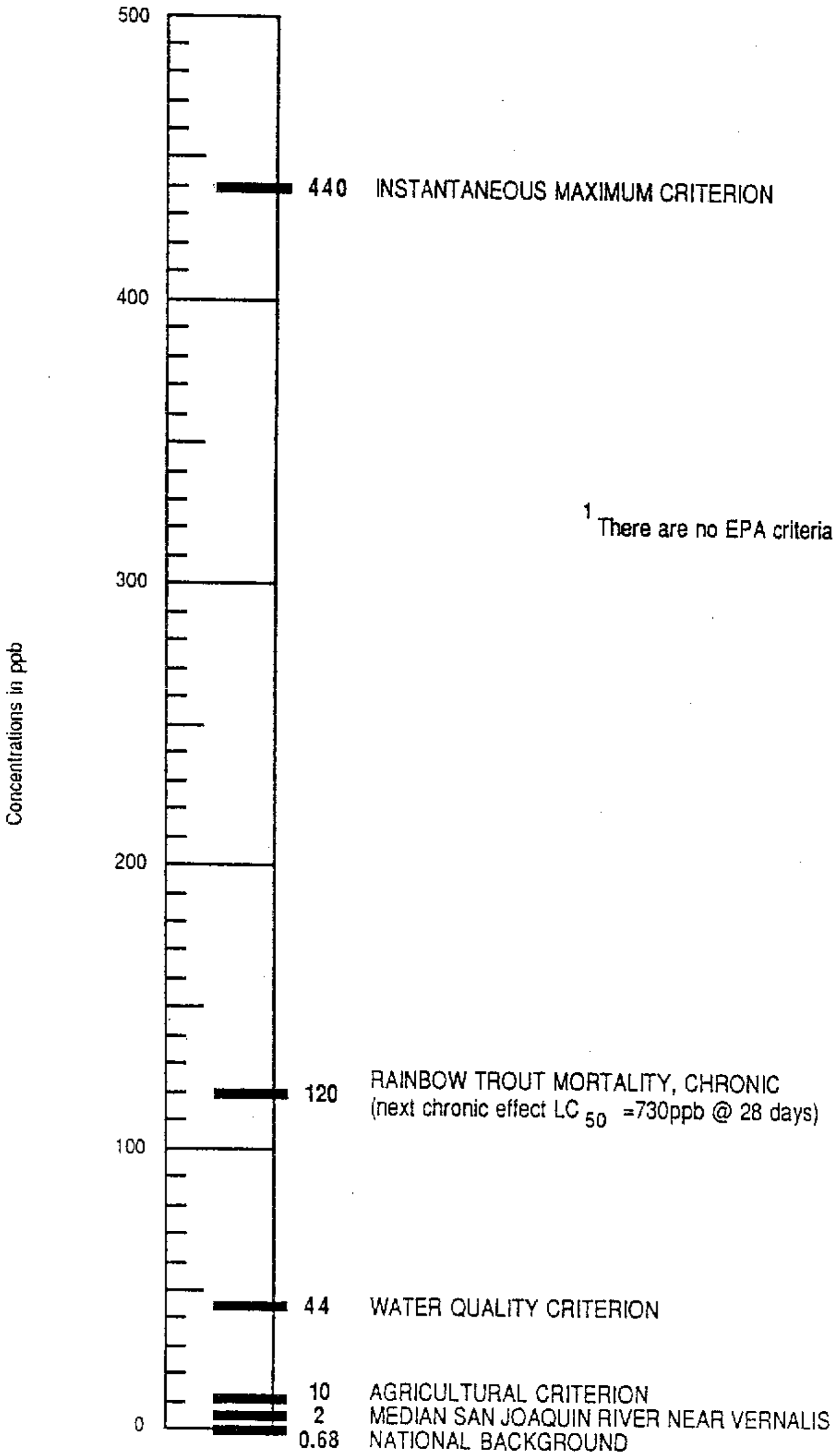


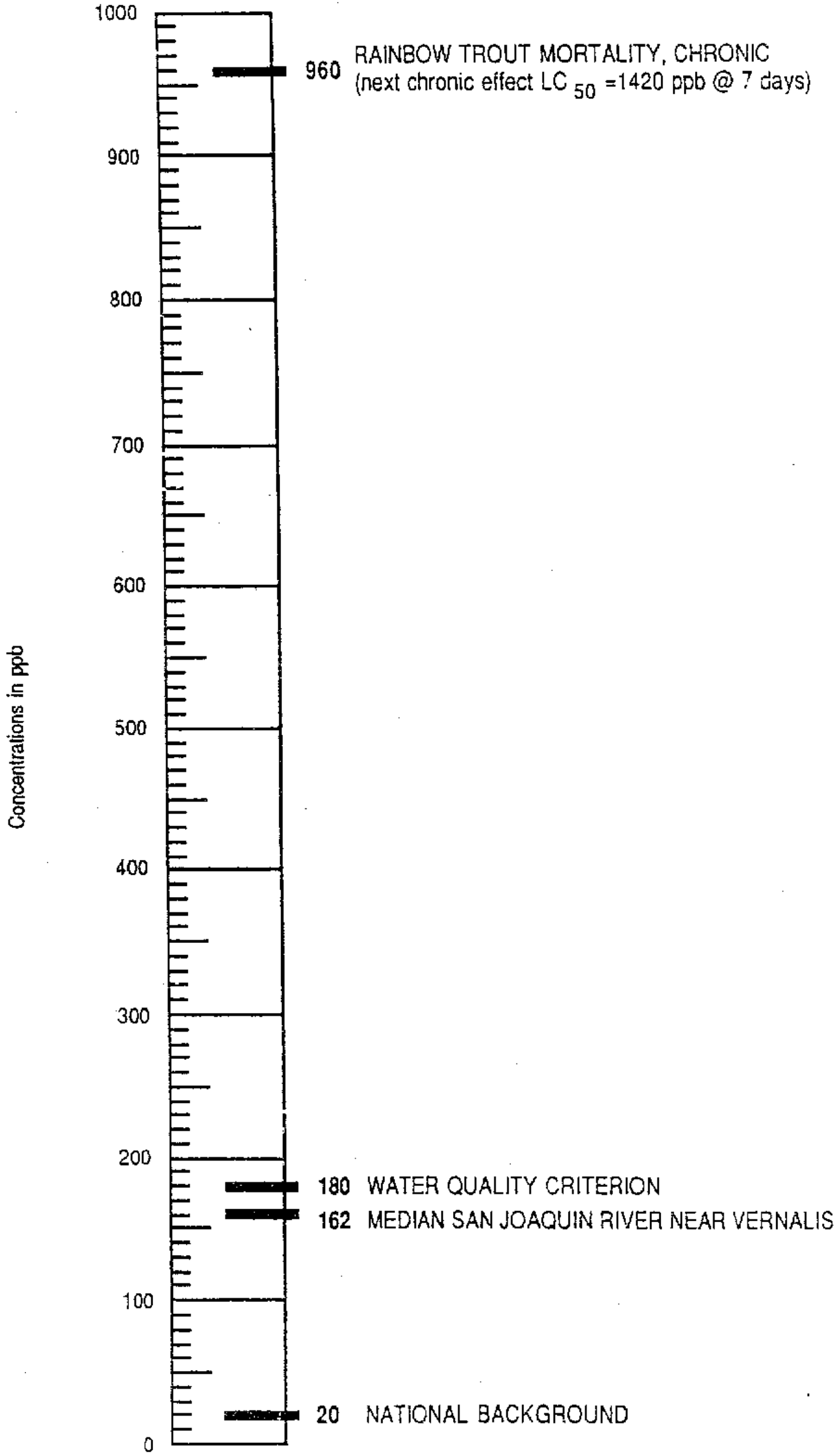
FIGURE IV-3
Ambient / biological data and criteria
Molybdenum [1]



[1] There are no EPA criteria for this element.

FIGURE IV-4
Ambient / biological data and criteria
Manganese [1]

NOTE: INSTANTANEOUS MAXIMUM CRITERION = 1600 ppb



[1] There are no EPA criteria for this element.

FIGURE IV-5
Ambient / biological data and criteria
Cadmium

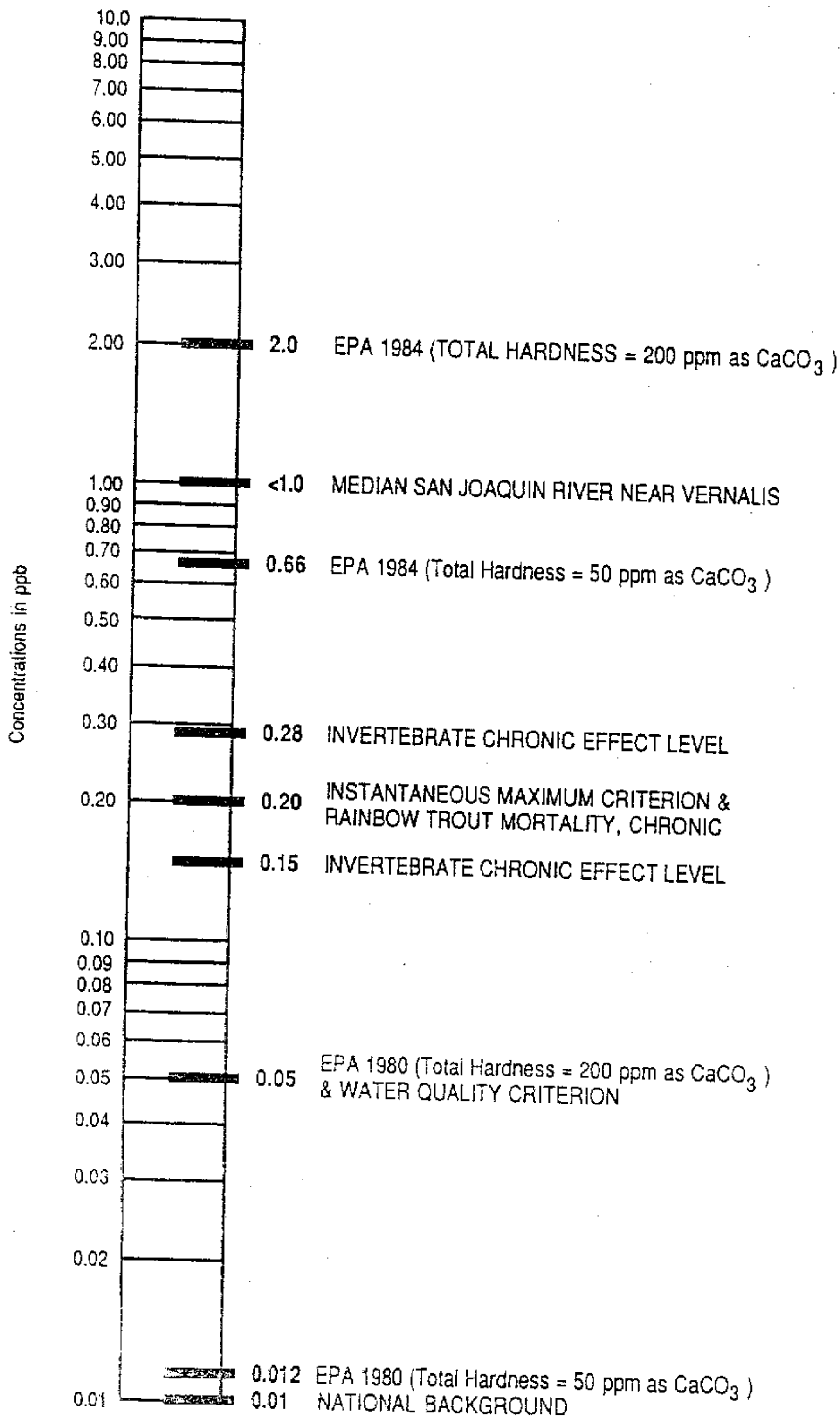


FIGURE IV-6
Ambient / biological data and criteria
Chromium

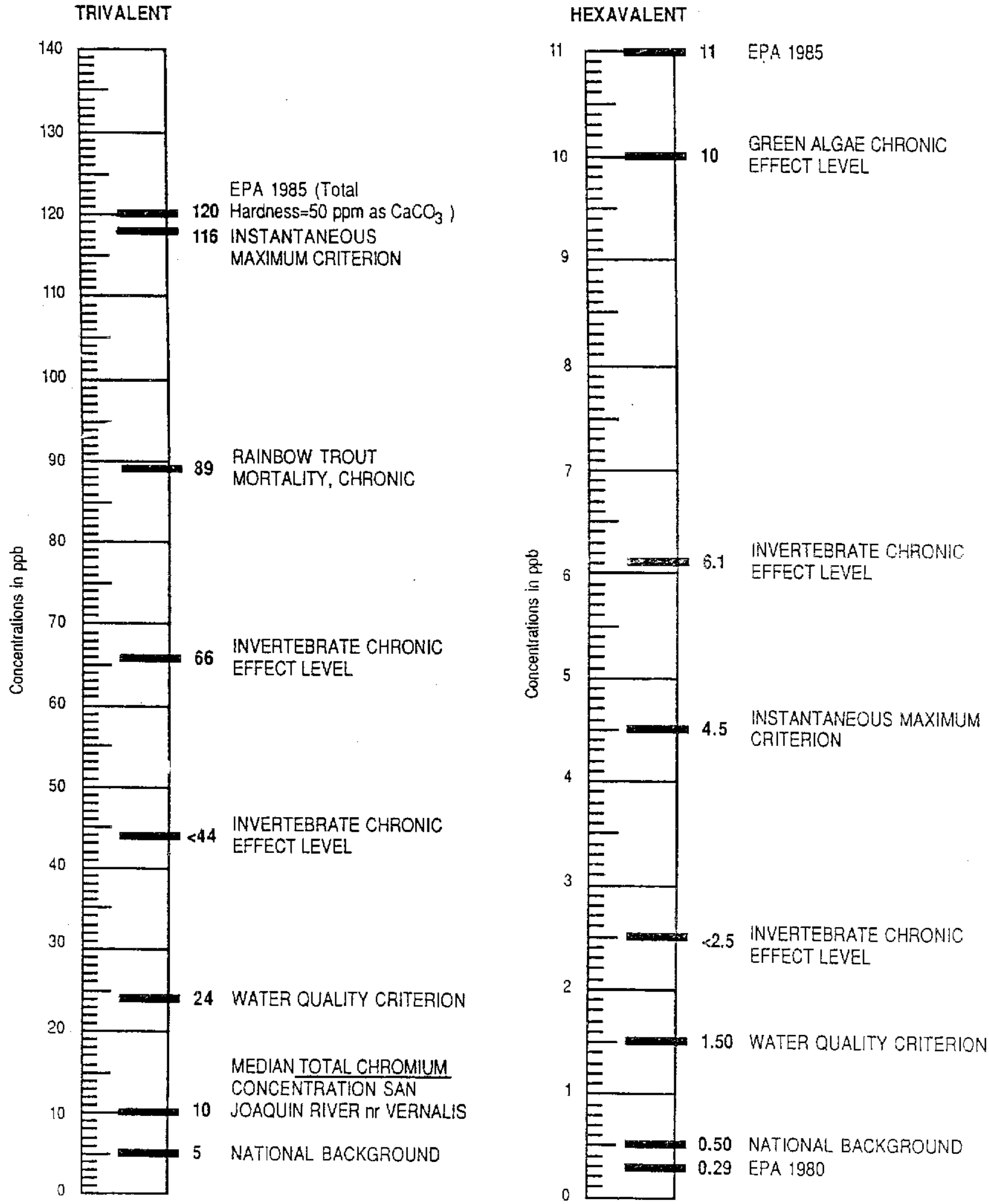


FIGURE IV-7
Ambient / biological data and criteria
Copper

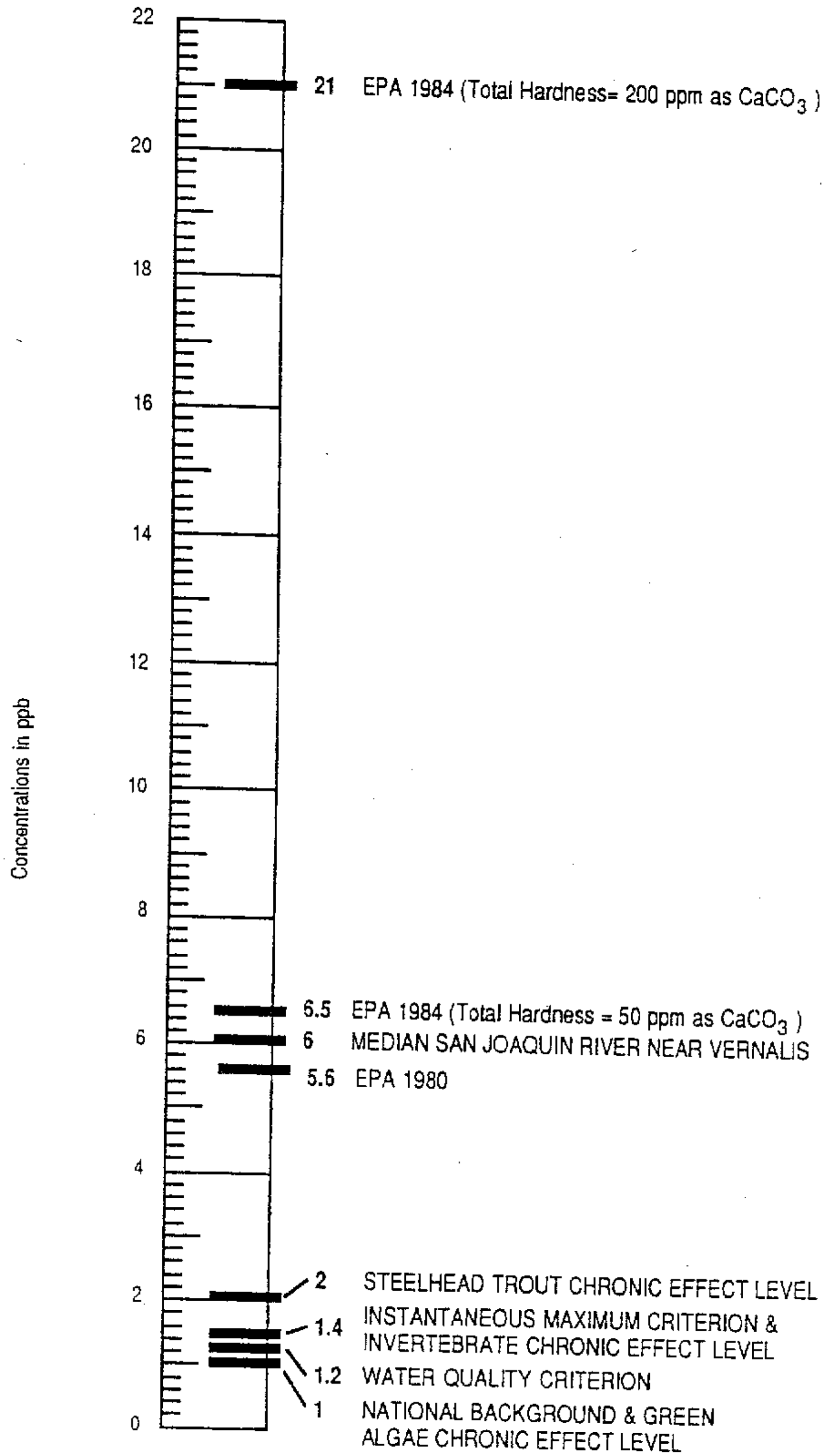
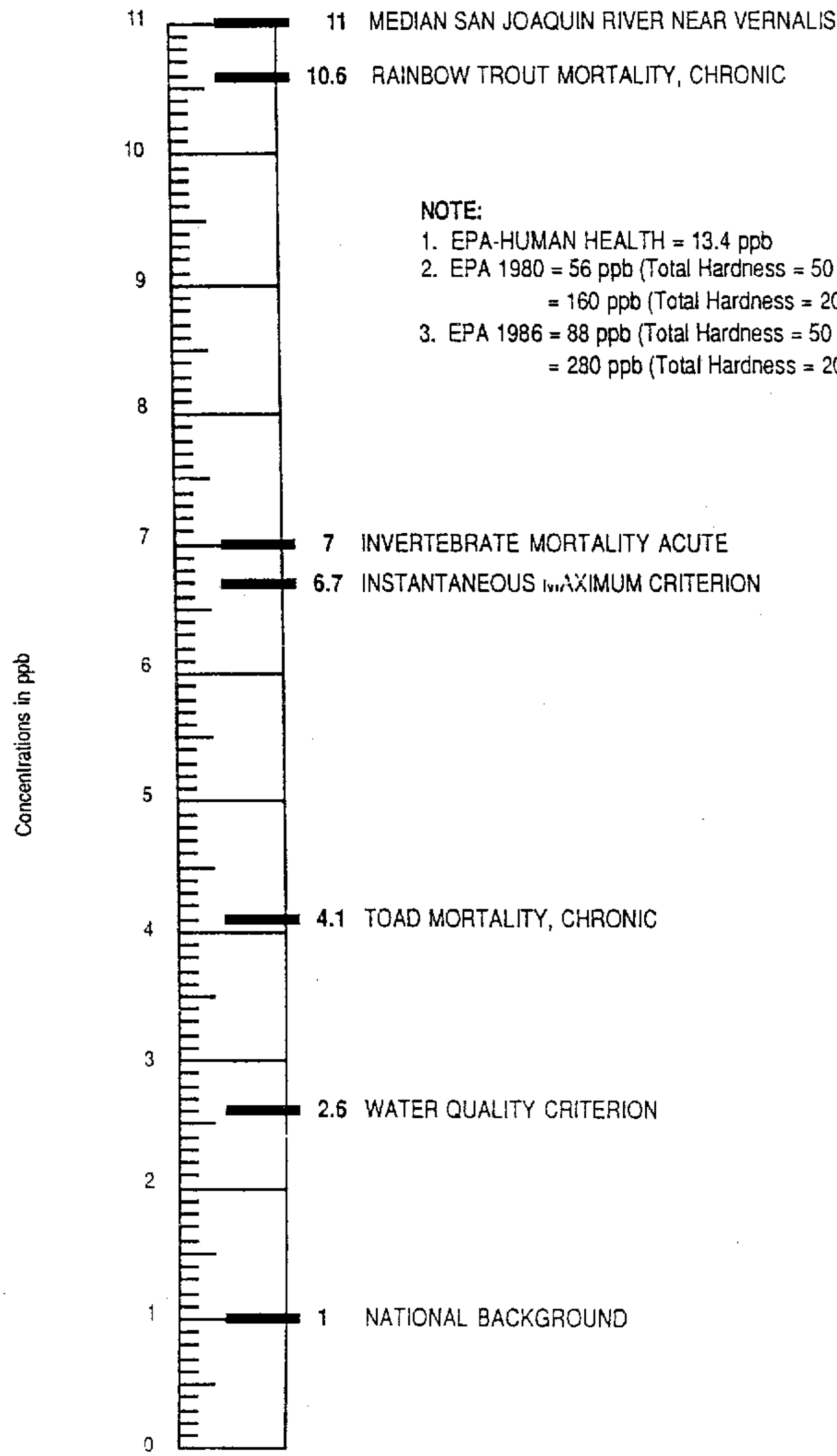


FIGURE IV-8
Ambient / biological data and criteria
Nickel



NOTE:
1. EPA-HUMAN HEALTH = 13.4 ppb
2. EPA 1980 = 56 ppb (Total Hardness = 50 ppm as $CaCO_3$)
   = 160 ppb (Total Hardness = 200 ppm as $CaCO_3$)
3. EPA 1986 = 88 ppb (Total Hardness = 50 ppm as $CaCO_3$)
   = 280 ppb (Total Hardness = 200 ppm as $CaCO_3$)

FIGURE IV-9
Ambient / biological data and criteria
Zinc

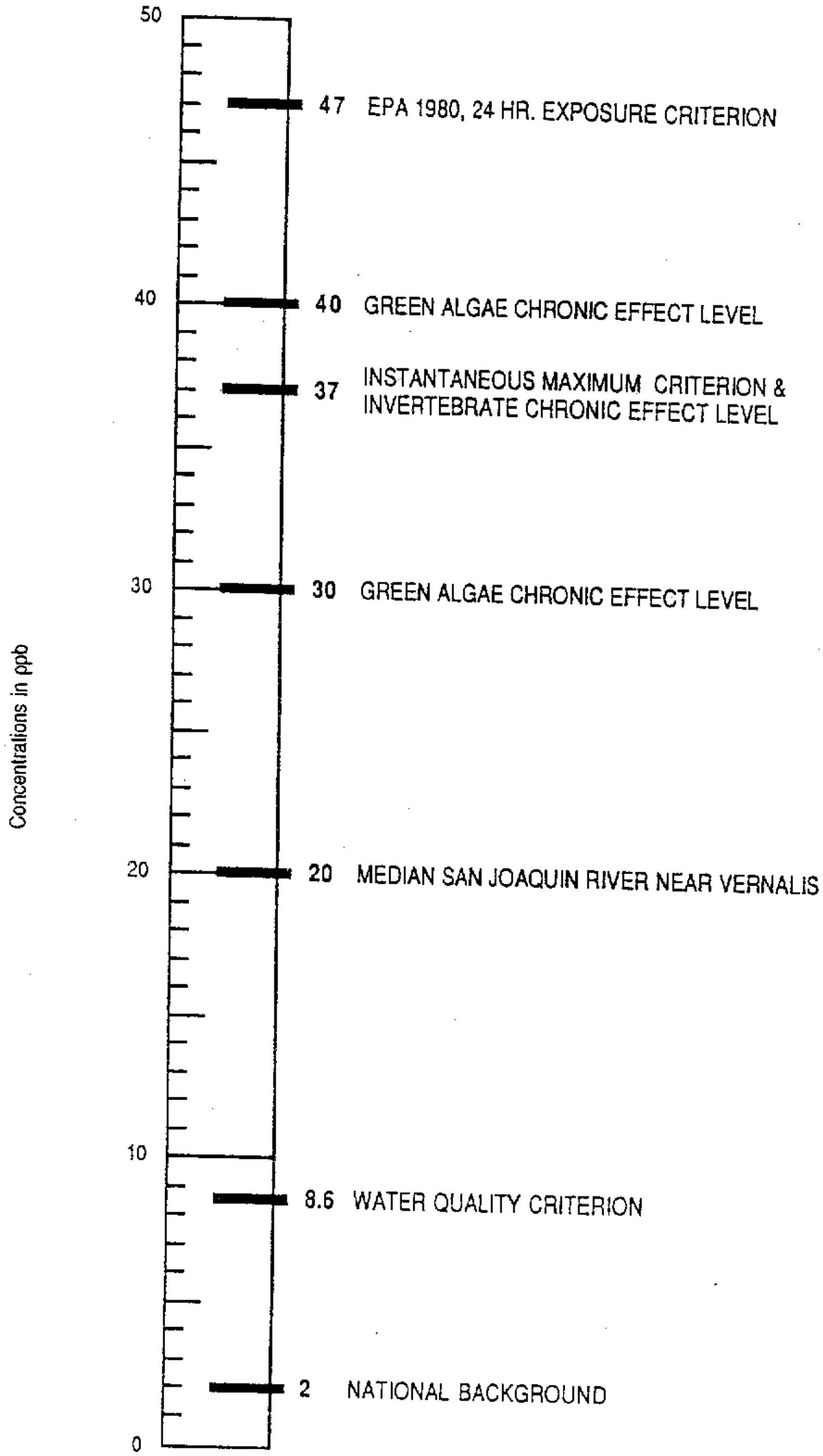
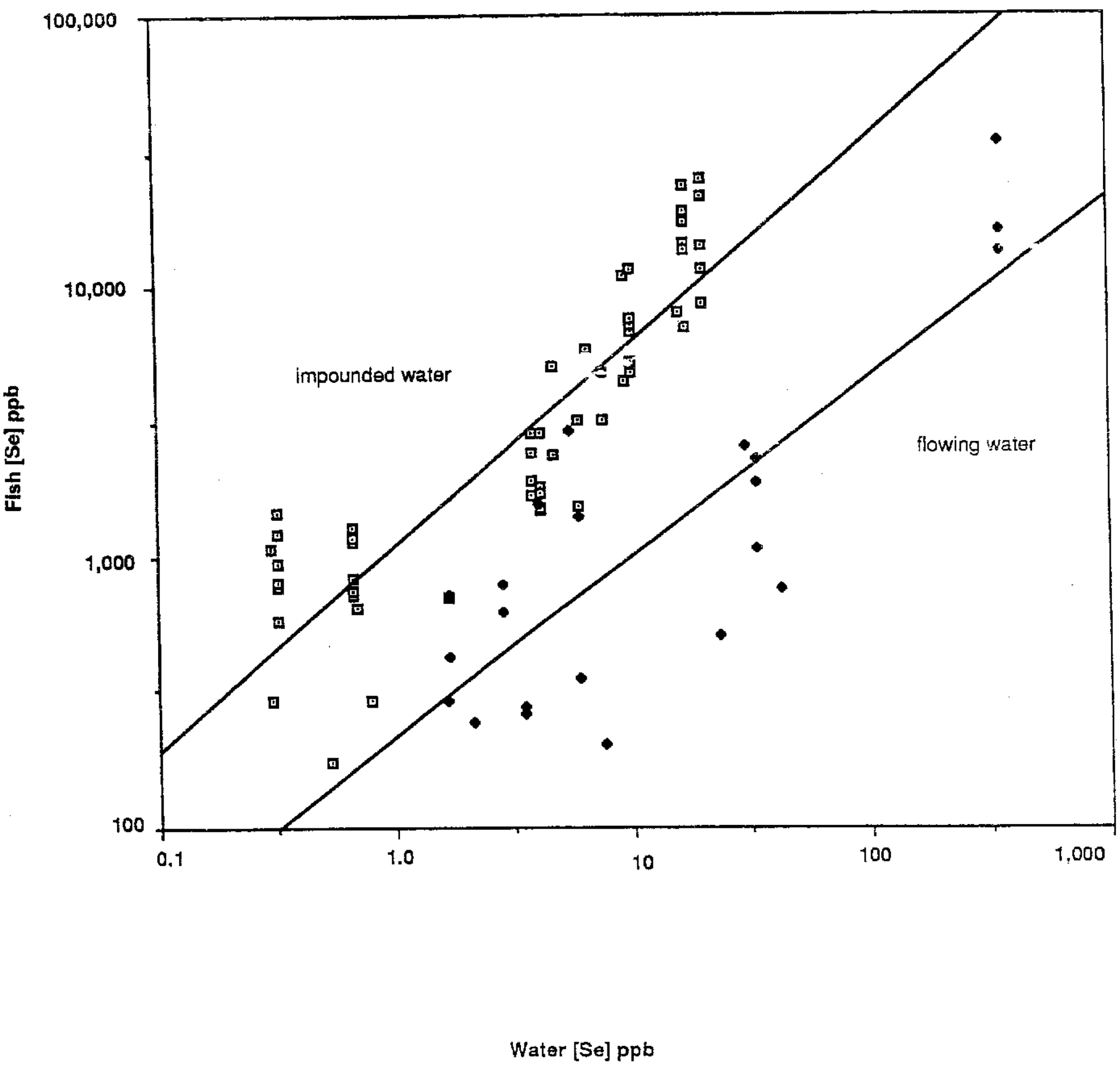


FIGURE IV-10

Bioaccumulation of selenium in fish from impounded and flowing waters



V. POLLUTANT SOURCES AND WATER MANAGEMENT IN THE SAN JOAQUIN RIVER BELOW LANDER AVENUE

Previous chapters have presented information on the entire San Joaquin River Basin. This chapter begins a discussion which focuses attention on a specific area which serves as a significant source of the constituents of concern. It also discusses the water management in this area and how these water management practices affect the load of selenium discharged to the San Joaquin River Basin. The sections discussed in this chapter are (1) water quality trends by River mile for each constituent of concern, (2) water management in the west side of the San Joaquin River Basin, (3) water use in the Drainage Study Area (DSA), (4) surface and subsurface flows and selenium loads in the DSA, (5) water balance for the DSA, (6) water use in the Grassland Water District (GWD), (7) estimated selenium loads from the DSA and GWD to the San Joaquin River system and (8) estimated selenium levels due to changes in management practices.

Water Quality Trends by River Mile

Figures V-1 through V-4 show the concentrations of salinity, boron, selenium and molybdenum at specific locations, moving downstream along the San Joaquin River from near Stevinson (Lander Avenue) to the station near Vernalis. Concentrations generally decrease downstream due to dilution from tributaries. Because of the location of some monitoring stations, some water quality changes are masked by the large dilution flows from the east side tributaries. These inflows occur just upstream of several of the historical monitoring stations thereby diluting the concentrations of these constituents at these sites. To help evaluate water quality changes in the San Joaquin River between these large inflows, an input-output model was developed to assess the proportion of the total constituent loads which can be attributed to subsurface agricultural discharges (Appendix C). All inputs and outputs in a 60-mile stretch of the River were quantified to the greatest extent possible in the San Joaquin River Input-Output (SJRIO-1) model. These include subsurface agricultural discharges, surface agricultural discharges, municipal and industrial discharges, diversions, ground water accretions and depletions, net evaporation, riparian vegetation water use, and tributary inflows.

Several extrapolations, correlations, and assumptions were required to complete the data base for all inputs and outputs for the 1977 through 1985 study period. The unaccounted for flows at River reach endpoints were attributed to the various inputs and outputs based on uncertainty factors assigned to each input and output. The ground water component of the data base was assigned a substantially larger uncertainty factor than the other components due to the uncertainty in the hydraulic conductivity values used to calculate ground water flows. The model was calibrated for flows, salinity, and boron at three River stations. The calibrated model provides an accounting of River flows, and salt, boron, selenium and molybdenum concentrations and loads at every River mile between Lander Avenue and near Vernalis. The calibrated model can be used to predict the effects of future water quality management practices on these parameters.

Sources of Loads to the San Joaquin River

The poorest water quality in the San Joaquin River is exhibited upstream of its confluence with the Merced River. The sources of salts, boron, selenium and molybdenum have been evaluated for the River between Lander Avenue and near Vernalis.

- Salinity

  The salt loads and flows in the San Joaquin River upstream of the Merced River calculated by the calibrated SJRIO-1 model are identified by source for water years 1979 and 1981 in Figures V-5 and V-6, respectively. The constituent loads in Mud and Salt sloughs are primarily from subsurface and surface agricultural drainage, although the sloughs (particularly Mud Slough) also contain some natural stream flows. In the normal water year 1979, Mud and Salt sloughs accounted for about 44% of the San Joaquin River flow above the Merced River and about 72% of the salt load (see Figure V-5). In the critical water year 1981, the sloughs accounted for 70% of the river flow and 80% of the salt load (see Figure V-6). Ground water accretions accounted for about 9% of the salt load in 1979 and 13% in 1981 according to the calibrated SJRIO-1 model. The salinities in the River at Hills Ferry and in Mud and Salt sloughs calculated by the calibrated SJRIO-1 model for water years 1979 and 1981 are shown in Figures V-7 and V-8, respectively. The model calibrates to TDS loads at the Patterson gage. The TDS concentrations at Patterson are converted from the continuous EC data using an EC/TDS ratio of 0.615 (see Appendix C). The maximum calculated River salinities are 647 ppm in water year 1979 and 1291 ppm in water year 1981.

The flow and salt load inputs to the River between Lander Avenue and near Vernalis calculated by the calibrated SJRIO-1 model are shown by source for water years 1981, 1984, and 1985 in Figures V-9, V-10, and V-11, respectively. These bar graphs differ from Figures V-5 and V-6 in that they show only the inputs to the River in a reach, whereas Figures V-5 and V-6 show the total flows and loads in the River at a reach end, including the flows and loads from Lander Avenue. For these three water years, Mud and Salt sloughs accounted for 5 to 12% of the input flows and 34 to 46% of the input salt loads. East side tributaries accounted for 69 to 85% of the input flows and 14 to 32% of the input salt loads.

o Boron

The boron loads in the San Joaquin River upstream of the Merced River calculated by the calibrated SJRIO-1 model are identified by source for water years 1979 and 1981 in Figures V-5 and V-6, respectively. Mud and Salt sloughs accounted for 86% of the boron loads in the normal water year 1979, and 88% in the critical water year 1981.

The boron concentrations in the River at Hills Ferry and in Mud and Salt sloughs calculated by the calibrated SJRIO-1 model for water years 1979 and 1981 are shown in Figures V-12 and V-13, respectively. The model calibrates to boron levels at the Patterson gage which are derived from a regression with TDS values (see Appendix C). The maximum calculated boron concentrations in the River at Hills Ferry are 725 ppb in water year 1979 and 1781 ppb in water year 1981. Salt Slough boron concentrations are generally between 1000 and 2000 ppb, while Mud Slough levels are generally between 3000 and 5000 ppb.

The boron load inputs to the River between Lander Avenue and near Vernalis calculated by the calibrated SJRIO-1 model are shown by source for water years 1981, 1984, and 1985 in Figures V-9, V-10, and V-11, respectively. For these three water years, Mud and Salt sloughs accounted for 52 to 69% of the input boron loads. Ground water accretions accounted for 12 to 17% and surface agricultural discharges accounted for 11 to 13% of the input boron loads.

- Selenium

The selenium load inputs to the River between Lander Avenue and near Vernalis calculated by the calibrated SJRIO-1 model are shown by source for water year 1985 in Figure V-14. For this dry water year, Mud and Salt sloughs accounted for about 81% of the input selenium load. Surface agricultural discharges accounted for about 9% of the input load, east side tributaries for about 5%, and ground water accretions for about 5%. The median selenium concentration in the San Joaquin River at Lander Avenue is less than one ppb (see Figure V-3). Thus, most of the selenium load in the River originates from agricultural sources draining to Mud and Salt sloughs.

The Technical Committee has estimated selenium loads and concentrations in subsurface agricultural drainage from areas tributary to the southern portion of GWD. Prior to 1985 the GWD diverted most of these drainage flows for waterfowl management. This use removed more than one-half of the total selenium load which otherwise would have reached the San Joaquin River. However, in 1985 GWD decided to bypass most drainage flows directly to the River due to selenium concentrations above 2 ppb in the drainage. The effect of GWD operations on selenium levels in the River are discussed in more detail in the last section of this chapter.

o Molybdenum

Sources of molybdenum loadings to the River are more diverse than boron or selenium. Ground water chemical analysis data from the USGS and USBR show elevated molybdenum levels (up to 40 ppb) upstream of the Merced River. Several relatively high readings at Lander Avenue suggest an upstream source of molybdenum. The early summer peak in river concentrations and the relatively high ground water flows and concentrations in the area at that time suggest ground water accretions may be the upstream source.

The molybdenum load inputs to the River between Lander Avenue and near Vernalis calculated by the calibrated SJRIO-1 model are shown by source for water year 1985 in Figure V-14. For this dry water year, Mud and Salt sloughs accounted for about 44% of the input molybdenum load. The east side tributaries accounted for about 39% of the input load, surface agricultural discharges for about 8%, and ground water accretions for about 8%. Thus, although the molybdenum concentrations in the east side tributaries are generally low (see Figure V-4), due to their large flows they make up a major portion of the total molybdenum load to the River.

Water Management in the West Side of the San Joaquin River Basin

It is clear from the above analyses that significant loadings of salt, selenium and boron to the San Joaquin River originate from the west side of the River Basin, upstream of its confluence with the Merced River. Discharges in this area can be divided into three groups.

(1) Mud and Salt Slough Drainage Area (MSSDA)

This large area of irrigated land on the west side of the Valley encompasses all lands draining to the San Joaquin River via Mud and Salt sloughs and some lands which drain directly to the River. This area includes all of Grassland, Pacheco, Broadview and Widren Water Districts; all of the land served by the Firebaugh Canal Company and Panoche Drainage District; the vast majority of the San Luis Water District and San Luis Canal Company service area; and about half of the Central California Irrigation District. The MSSDA totals 303,776 acres.

(2) Drainage Study Area (DSA)

This subset of the MSSDA includes water districts which discharge agricultural drainage water that, prior to 1985, was discharged either directly into Mud and Salt sloughs or diverted by Grassland Water District (GWD). After use in GWD, these waters were discharged to Mud and Salt sloughs through which they flowed into the San Joaquin River. Beginning in February 1985, only a relatively small quantity of drainage waters from these districts has been used by the GWD. Since that time most of the drainage water has passed directly to Mud and Salt sloughs. This area includes all of Broadview, Pacheco, and Widren Water Districts; all of the Panoche Drainage District and lands served by the Firebaugh Canal Company; and about seven percent of both the San Luis Water District and the Central California Irrigation District. The DSA totals 94,480 acres.

(3) Grassland Water District (GWD)

Historically, the GWD has depended on agricultural drainage from agricultural districts principally in the DSA for about half of its water supply. The remainder of its water supply came from the Central Valley Project. The GWD consists of approximately 52,000 acres. Agricultural drainage (both surface and subsurface) and fresh water supplies are used to seasonally flood duck hunting lands, to maintain waterfowl habitat, and irrigate forage for cattle grazing and food for migratory birds. About half of the water diverted for use within the GWD evapotranspires or seeps into the ground water. The other half, approximately 65,000 af/year, is discharged back into Mud and Salt sloughs which flow to the San Joaquin River.

Table V-1 shows the acreages which make up these three areas. Figure V-15 shows where these areas are located.

The remainder of this chapter briefly discusses water management practices and estimates of drainage and selenium loads in each of these areas. For more information on each of the water districts and their history, please refer to Appendix G, Chapter 2.

Water Use in the Drainage Study Area

As stated in Chapter II of this report, irrigated agriculture within the DSA commenced around 1872. By the 1920's it became apparent that in order to maintain productive irrigated agriculture on the west side of the Valley, better drainage had to be provided. Therefore, subsurface drains were introduced in the DSA during the 1950's and 1960's. There was a significant increase in the use of subsurface drains during the middle and late 1970's. For example, Broadview Water District increased its subsurface drained acreage from about 5 percent of the total district acreage in 1970 to 75 percent by 1980. Table V-2 summarizes the present subsurface drained acreages in the DSA by district. Currently approximately 47,820 of the 94,480 acres (51%) in the DSA have subsurface drain systems. These areas are shown on Figure V-16. These drains discharge into approximately 100 sumps located throughout the drained area. The extent of the drainage problem area can be seen in Figure V-17 which shows lands where the ground water is less than 5, 10, and 20 feet from the surface in relation to the areas where subsurface drains are located. If the depth to shallow ground water rises in areas without drains there may be interest in installing new drains in the future.

Water is used within the DSA to grow a variety of crops. The main crop produced in the DSA is cotton, which is grown on about 52 percent of the DSA acreage. Barley and wheat are grown primarily for rotation with cotton on about 11.5 percent of the acreage. Tomatoes are grown on about 6.5 percent of the acreage, dry beans and other vegetables on about 8.5 percent, melons and sugar beets on about 11 percent, and alfalfa on about 5 percent of the acreage.

Surface Water Supplies

The primary source of irrigation water within the DSA is surface water delivered from the Delta-Mendota and San Luis units of the U. S. Bureau of Reclamation's (USBR) Central Valley Project (CVP). Two water agencies within the DSA (Central California Irrigation District and Firebaugh Canal Company) and two agencies outside it (San Luis Canal Company, to the west of the San Joaquin River, and Columbia Canal Company, to the east of the River) are exchange contractors (Chapter II). They are successors to landowners Miller and Lux, or affiliated companies, which made agreements with the USBR to exchange their pre-1914 appropriative rights to San Joaquin River water for water to be delivered at no cost from the Delta-Mendota Unit. The other agencies within the DSA contracted with the USBR to purchase water from CVP units. The deliveries of CVP water in recent years to these districts are shown in Table V-3. The annual delivery of CVP water to the districts in this area from 1981 through 1985 ranges from 1.8 to 3.6 af/acre and averages 2.7 af/acre (see Table 2.4 in Appendix G).

Precipitation

Precipitation plays a role in the water availability within the DSA. Average annual precipitation measured at the Los Banos Station is 9 inches per year, but varied from 5.1" to 18.7" from 1977 to 1985. In the years studied in this report, the annual precipitation was as follows:

	Inches of Rainfall
Water year 1979 (normal)	9.4
Water year 1981 (critical)	6.9
Water year 1984 (normal)	5.2
Water year 1985 (dry)	7.0

Note that local precipitation is often not closely related to water year type. This is because runoff for the entire basin, which determines the water year type, depends mostly on precipitation quantities in the Sierra Nevada to the east of the valley floor.

The average annual precipitation of 9 inches (0.75 af/acre) can be divided into four categories: (1) effective precipitation, (2) rainfall runoff, (3) precipitation which evaporates from the land surface, and (4) precipitation which percolates to the ground water table. The portion used by crops is referred to as "effective precipitation." Most of that which falls during the growing season is effective precipitation. In addition, the portion that falls during the rest of the year which is stored in the soil profile and is available for use in the next growing season is also effective. Estimates of effective precipitation in an average year for crops commonly grown in the DSA are presented in Appendix G. The average effective precipitation for the crops grown in this area is between three and four inches (about 0.3 af/acre).

Rainfall runoff is assumed to be 20% of the total precipitation, or 0.15 af/acre. This assumption is based on a Soil Conservation Service method of estimating direct runoff from storm rainfall (Overton and Meadows, 1976). This rainfall runoff is combined with tailwater runoff and operational spills in a "surface runoff" term. This water is not reused and is lost from the system.

The remaining precipitation (0.3 af/acre) is assumed to evaporate from the land surface or the soil column, and not reach the ground water table. This assumption will be true for soils which are not highly permeable and for seasonal precipitation which is well-distributed over time (Linsley _et al_, 1975). This is usually true for the DSA. Thus, as with rainfall runoff, this component of precipitation constitutes a loss of water from the system and is unavailable for irrigation uses.

Ground Water

In addition to precipitation and surface water delivered by the CVP to irrigation districts, pumped ground water also plays a limited role in the DSA. As noted in Chapter II, prior to the advent of the CVP, ground water was the main source of irrigation water in the areas outside the exchange contractor districts on the west side of the River Basin. In those areas, the ground water was of poor quality and typically was pumped from relatively deep wells. For these reasons, its use immediately declined when good quality surface water became available. Nevertheless, it appears that some ground water pumping continues. Because this pumping is performed by individual growers, with no monitoring by water districts, little direct information is available to evaluate the importance of ground water as an irrigation supply.

The information on ground water pumping (Diamond and Williamson, 1983) is based on records of electrical consumption supplied to USGS by PG&E, from which estimates of pumping were obtained by making estimates of pump efficiency. The data are somewhat unreliable, because USGS had no way of separating ground water pumping from electrical use for farm water distribution systems. For this reason, the data may overestimate the extent of ground water pumping. According to the USGS, the average ground water use for the entire DSA is about .43 af/acre. For our analysis we assume ground water use for irrigation to be 0.4 af/acre.

Reuse

The reuse of commingled tail and tile drain water is a striking feature of the DSA. An intricate network of water distribution and drainwater collection canals, depicted schematically in Figure V-18, traverse the entire area. This provides enormous flexibility in the management of water flows and greatly facilitates the commingling and reuse of drain waters. Unfortunately, there are no systematic data on the volume of water reused: only scattered pieces of information exist in the literature. Tanji, et al (1977) report that lands served by Panoche Drainage District received 128,749 af of water from the CVP in 1975 (approximately 3.2 af/acre), and generated a combined tail and tile drain flow of 41,082 af, of which 1,455 af were reused within the District, 6,904 af were reused by farmers in CCID, and the remaining 32,723 af were discharged to GWD. In this case about six percent of the applied water was recycled for irrigation use. An unquantified amount of drainwater reuse occurs on lands within the Central California Irrigation District (CCID) and the Firebaugh Canal Company service area. However, reuse of water in the DSA is not a new water supply. It simply makes better use of supplies already within the districts. For this reason reuse has been excluded as a new source of water supply within the DSA.

Summary of DSA Water Supplies

On the average, the water supplies in the DSA are as follows:

Source	Amount af/a	Percent of Total
Central Valley Project	2.7	70
Precipitation	0.75	20
Ground water	0.4	10
Total	3.85	100

These averages can vary greatly from district to district and year to year; but, they provide a general idea of the sources of irrigation supplies within the DSA.

Surface and Subsurface Flows and Selenium Loads in the Drainage Study Area (DSA)

Farming operations in the DSA and elsewhere on the west side of the San Joaquin Valley tend to generate significant quantities of both surface and subsurface drainage water. The surface drainage consists of tailwater running off fields within individual farms, operational spills from the water districts' gravity distribution systems, and rainfall runoff. The subsurface drainage consists of flows infiltrating so-called tile drains, perforated (now usually plastic) pipes laid five feet to nine feet below ground and usually 400 feet to 800 feet apart. In this chapter tile drains and subsurface drains are used synonymously. These subsurface drains discharge into approximately 100 sumps located throughout the DSA. Commingling occurs when subsurface drainage is pumped from these sumps to ditches carrying tailwater. A portion of the combined surface and subsurface drainage is reused within the DSA but, ultimately, all drainage flows out of the DSA and into the San Joaquin River via Mud and Salt sloughs.

The best available estimates for drainage from the entire DSA come from Summers Engineering (1986) and cover the period July 1984 - August 1985 (Table V-4). Selenium concentrations measured in the River are closely approximated by those estimated to occur based on Summers' calculations. The table shows the monthly drain flow (in af) and selenium load (in pounds) from the DSA. The locations of these discharges are illustrated schematically in Figure V-18. The selenium loads in Table V-4 can be converted into concentrations (in ppb) by dividing them by the monthly drain flow and multiplying by a factor of 368. For example, for Panoche Drainage District in July the selenium concentration was 25 ppb = (325/4,780) x 368.

It is difficult to divide the combined flows described in Table V-4 into their separate surface and subsurface components because there is no direct information on either component. However, estimates of these components were made by (1) developing an estimate of the subsurface drain flow per tile drained acre, (2) multiplying this estimate by the total tile drained area, and (3) subtracting this derived value from the total flow in Table V-4 in order to obtain an estimate of the surface drainage as a residual. Estimates of the tile drained area in each district, required for step (2) are presented in Table V-2, and a map depicting the tile drained areas is presented in Figure V-16. It must be emphasized that there is some imprecision in the estimates of tile drained areas because the districts do not possess complete records on the extent of drains or their spacing when individual farmers install them. In Broadview Water District, for example, a recent reassessment of the data collected during the summer of 1986 led the District Manager to reduce his estimate of the tile drained area from 8,000 to 7,410 acres. This change accounts for the discrepancy between the estimated total of 48,410 tile drained acres in Summers Engineering (1986) and the figure of 47,820 acres presented in Table V-2.

Data on the seasonal pattern of flows from various subsurface drainage sumps or aggregates of sumps for different districts are presented in Table V-5. Estimates made by the Central Valley Regional Board staff are also presented. The development of these data is discussed in detail in Appendix G, Section 2.4. Because of the variation in the drain flow patterns and per acre estimates, JM Lord, Inc. was retained to review these data and recommend subsurface drainage flow factors for use in the DSA. The recommended monthly and annual tile drainage flow factors for each district are shown in Table V-6.

Given the subsurface drainage flow factors in Table V-6 and the subsurface drained acreages (Table V-2), the monthly subsurface drain flows were computed for each district. The difference between these estimates for 1984-85 and the combined surface and subsurface drain flows for 1984-85 developed by Summers Engineering (1986) in Table V-4 was assumed to be due to surface drain flows. It was also assumed that all surface drainage has a constant selenium concentration of 1 ppb. The remaining selenium loads from Table V-4 were attributed entirely to subsurface drainage. The resulting pattern of surface and subsurface drain flows and selenium concentrations for 1984-85 is presented in Table V-7.

The drain flow and selenium loading data from Table V-7 for the dry water year 1985 can be adjusted for other water year types. In Appendix G, the drain flows in the Panoche Water District were evaluated for the water years 1977 to 1985. This evaluation did not reveal any clear uniformity in yearly patterns. However, it was decided to assume that drain flows for water year 1981 (critical year) were the same as water year 1985 (dry year). For the two normal water years, 1979 and 1984, it was assumed that surface and tile drain flows were about 10 percent higher than in water year 1985. Further, it was assumed that the monthly selenium concentrations in surface and tile drainage were the same in all years. Therefore, the drain flows (both surface and tile) in Table V-7 were increased by 10 percent to represent drain flows in normal years, while the selenium concentrations were left unchanged.

Water Balance for the Drainage Study Area (DSA)

In order to get a better appreciation of water movement within the DSA the Technical Committee has attempted to perform a water balance for this area. Such a water balance is difficult to perform due to the lack of data on some very key components of the equation. The information presented in this section should be considered an initial attempt to understand water movement within the DSA. Other agencies should refine these estimates as they continue to work on drainage problems within the DSA. Both the University of California's newly reconstituted Committee of Consultants and the San Joaquin Valley Drainage Program are working on on-farm methods to help address drainage problems. In order for these efforts to be successful, a credible water balance needs to be assembled. This water balance is needed so that the improvements in on-farm water use can be related to reductions in deep water percolation below these lands and subsurface drain flow rates from the area. Also, the U.S. Geological Survey is working on a ground water flow model for this area. This model will help identify flows in the shallow aquifer and how changes in inputs could effect subsurface drainage volumes from the area. The results from these efforts will lead to improvements in the water balance presented below. We look forward to these improvements.

Water Supply

The first component of a water balance is water supply. In this chapter we discussed that the water supply to this area is made up of the following components:

AF/ACRE	SOURCE
2.7	CVP deliveries
0.75	Precipitation
0.4	Ground water pumping
3.85	

Canal Seepage Losses

Canal seepage losses in this area have been estimated by the Central Valley Water Use Study Committee (1986) at about 0.1 af/acre.

Evapotranspiration

The acreages for the various crops grown in the DSA are shown in Appendix G, Table 2.14. The average evapotranspiration rate for the DSA is 2.4 af/acre. However, because of the high water table in the DSA and the low permeable soils in some of this area, part of this demand is made up by the crop actually taking water from the shallow ground water table. This deficit irrigation can take place for deep-rooted crops like cotton, safflower and alfalfa. These crops make up about 60% of the DSA acreage. For cotton 20% to 50% of the evapotranspiration can be made up from the ground water table. Safflower can take even more. Based on 20% ground water use, we have estimated the evapotranspiration being satisfied from the ground water table for these crops and then spread over the acreage in the entire DSA to be about 0.3 af/acre. Therefore, the net evapotranspiration needed to be satisfied by surface waters is 2.4 - 0.3 = 2.1 af/acre.

Surface Runoff

Surface runoff out of the DSA is estimated in Table V-7 as 53,355 af/year in dry years and 10% greater in wetter years. For the entire DSA of 94,480 acres this equals about 0.6 af/acre/year of surface drainage from the DSA. This includes tailwater runoff, operational spills, and rainfall runoff. Rainfall runoff is estimated to be 0.15 af/acre. Therefore, the tailwater runoff and operational spills together are 0.45 af/acre, which is about 15% of the applied irrigation water.

Deep Percolation

From the above information deep percolation past the crop root zone can be calculated from equation 1 below.

(1) Deep percolation = water supply - seepage losses - surface runoff
- crop evapotranspiration - precipitation lost to evaporation
= 3.85 - 0.1 - 0.6 - 2.1 - 0.3
= 0.75 af/acre

Deep percolation is the amount of water which passes below the root zone. Seepage losses are not included in deep percolation since this represents water which does not reach the specific field. The 0.75 af/acre of deep percolation can be thought of as being made up of two components. The first is water flowing past the root zone due to the irrigation techniques used causing non-uniform application of water, plus any over irrigation which can occur during pre-irrigation. No irrigation system is 100% efficient in applying water uniformly across the field. Therefore, all irrigation systems overirrigate some parts of the field so that the required amount of water will reach the other parts of the field. The second component of deep percolation is that water provided to leach salts from the soil. This is called leaching water.

Irrigation Efficiency

The Westlands Water District defines annual irrigation efficiency in terms of a seasonal application efficiency (SAE) (Westlands Water District, 1987). In order to calculate the SAE in the DSA we must first calculate applied water and the evapotranspiration of applied water as shown below.

(2) Applied water = water supply - precipitation
= 3.85 - 0.75
= 3.1 af/acre

(3) Evapotranspiration of applied water = crop evapotranspiration
- effective precipitation - crop use of ground water
= 2.4 - 0.3 - 0.3
= 1.8 af/acre

The SAE for the DSA is shown in equation 4.

(4) SAE = ET of applied water ÷ applied water
= 1.8 ÷ 3.1
= 58%

Efficiency of Infiltrated Water Use

In order to calculate the efficiency of infiltrated water use we must first calculate the depth of applied water which is available for infiltration on a particular field. This calculation recognizes that some of the applied water runs off or never reaches the particular field due to canal seepage losses, and thus does not seep into the ground. The depth of applied water available for infiltration is calculated below.

(5) Depth of applied water available for infiltration = water supply - seepage losses - surface runoff - effective precipitation - precipitation lost to evaporation

$$= 3.85 - 0.1 - 0.6 - 0.3 - 0.3$$

$$= 2.55 \text{ af/acre}$$

(6) Efficiency of infiltrated water use = ET of applied water ÷ depth of applied water available for infiltration

$$= 1.8 \div 2.55$$

$$= 71\%$$

Reduction in Deep Percolation by Improving the Efficiency of Infiltrated Water Use

Furrow irrigation, managed extremely well, can result in an efficiency of infiltrated water use of 80%. Highly efficient water application methods could probably increase this efficiency to 90%. The effect of 80 to 90% efficiencies on deep percolation is shown below. Given that deep percolation is equal to the depth of applied water available for infiltration minus the ET of applied water, equation 7 can be derived from equation 6.

(7) Deep percolation = [ET of applied water x (1 - efficiency of infiltrated water use)] ÷ efficiency of infiltrated water use

At 80% efficiency of infiltrated water use:

$$\text{Deep percolation} = 1.8 \times 0.2 \div 0.8$$

$$= 0.45 \text{ af/acre}$$

At 90% efficiency of infiltrated water use:

$$\text{Deep percolation} = 1.8 \times 0.1 \div 0.9$$
$$= 0.2 \text{ af/acre}$$

The deep percolation resulting from present practices is calculated in equation (1) as 0.75 af/acre. Based on the above analysis, this could be reduced by about 40% (to 0.45 af/acre) with better water management of existing furrow systems. It could probably be reduced by more than 70% (to 0.2 af/acre) if the best available technology in irrigation systems were employed to increase the efficiency of infiltrated water use to 90%. This 0.2 af/acre of deep percolation represents an average leaching fraction of 8% over the entire DSA. This should be sufficient to prevent the accumulation of salts in the soils of this area according to the Central Valley Water Use Study Committee (1986) and the U.C. Committee of Consultants (1987). The Water Use Committee recommended a minimum leaching fraction of 2.6% (0.06 af/acre) and the Committee of Consultants recommended a minimum of 5% (0.12 af/acre). Also, in their review of our analysis the Committee of Consultants indicated that deep percolation could probably be reduced to 0.5 af/acre with best management of existing irrigation systems and to 0.2 af/acre with a pressurized system.

Possible Reductions in Tile Drain Flow Resulting from Improved Efficiencies of Infiltrated Water Use

Tile drained lands comprise about one-half of the DSA. The drainage flow can be calculated for these lands with the following equation:

(8) Drainage flow per tile drained acre = deep percolation
- crop use of ground water + drainage from upgradient

For present conditions the drainage flow for tile drained lands in the DSA is about 0.7 af/acre (see Table V-7). Thus, the upgradient drainage component can be calculated by difference from equation 8 as follows:

0.7 = 0.75 - 0.3 + upgradient drainage
upgradient drainage = 0.25 af/acre

For the approximately 47,000 acres of tile drained lands in the DSA this equals 11,750 af. Along the approximately 30 linear miles of upslope boundary to the DSA (see Figure II-3) this equals a flow rate of about 390 af/mile/year. For comparison, in a field study of lateral ground water flow rates to Firebaugh Canal Company and Broadview Water District, Schmidt (1987) calculated flow rates of 250 af/mile/year and 300 af/mile/year, respectively. Also, Grismer and Woodring (1987) estimated lateral ground water flow rates in Westlands Water District from 4.4 to 220 af/mile/year. In the SWRCB analysis of ground water accretions and depletions to the San Joaquin River (see Appendix C) the lateral ground water flow rates on the west side ranged from one (1) af/mile/year to 762 af/mile/year. Thus, the estimate of 0.25 af/acre for upgradient drainage appears to be reasonable.

If we assume the crop use of ground water and upslope drainage components remain constant, we can estimate changes in drainage flow from the tile drained lands due to improved efficiencies of infiltrated water use from equation 8. Estimates of present-day flow rates and flow rates for increases in efficiency to 80% and 90% are presented below.

Drainage flow at present efficiency = 0.75 - 0.3 + 0.25 = 0.7 af/acre

Drainage flow at 80% efficiency = 0.45 - 0.3 + 0.25 = 0.4 af/acre

Drainage flow at 90% efficiency = 0.2 - 0.3 + 0.25 = 0.15 af/acre

As shown above, an increase in the efficiency of infiltrated water use could have a dramatic effect on drainage flow rates. We must emphasize that these are estimates that should be evaluated through practical experience, proper monitoring and further studies. The estimates of crop use of ground water and upgradient drainage are particularly tenuous. They will most likely not remain constant as assumed above. The crop use of ground water should decrease somewhat as a decrease in deep percolation causes a drop in the water table. However, as long as there is tile drainage from these lands, deep-rooted crops such as cotton and safflower will continue to use some ground water since their roots extend down to the depth of tile drains. The crop use of ground water could be kept at the present level or even increased by not pumping the tile drain sumps periodically to allow the water table to rise and permit greater crop use of this resource.

The amount of water table decline is also dependent upon the upgradient drainage component. If upslope areas do not reduce their deep percolation then the upgradient drainage will increase due to an increased hydraulic gradient between upslope and downslope areas. However, if upslope areas reduce their deep percolation to the same degree as downslope areas, the upgradient drainage should remain fairly constant.

Leakage from the shallow water table to a deeper aquifer has not been included in Equation 8. Based on our representation of tile drainage flow (see Figure VII-1), this factor would represent deep percolation which is not picked up by tile drains through increased head on the shallow water table. This factor would be subtracted from deep percolation in the same manner as crop use of ground water in Equation 8. However, this leakage factor cannot be quantified at present and would remain fairly constant as deep percolation is reduced. Since the upgradient drainage value used in Equation 8 is consistent with other calculations for the area, the leakage factor is probably implicitly included in our estimates of crop use of ground water and deep percolation. Nevertheless, based on our water balance, a leakage factor would not have a significant impact on drainage flow reductions.

Therefore, in order for the drainage reductions for 80% and 90% efficiencies of infiltrated water use to be realized, the following two management actions would be required: (1) all upslope areas would need to increase their efficiencies the same as the downslope areas, and (2) the tile drained lands would need to manage their water table to allow the continued use or increased use of the water table by crops.

At this juncture it is important to rate the observations made by Day and Nelson (1986) regarding water conservation in the Broadview Water District.

> "...there is potential for considerable drainage flow reduction through improved on-farm water management. Furthermore, and even more significant, a reduction in drainage flow can be obtained by a single farm regardless of whether a management plan is implemented in the entire region. Control and treatment of peak flows through regional management plans has (sic) potential for significant savings. Winter peak flows can be minimized if pre-irrigations are spaced evenly throughout the winter on a regional basis. ...Relationships of current irrigation applications with the drainage effluent produced indicate that minimizing and managing drainage flows through irrigation management is feasible. This implies that irrigation management is a potentially significant tool in addressing the drainage problem on the west side of the San Joaquin Valley as drainage flow reduction and management can be used to reduce the costs of implementing all of the proposed solution alternatives including evaporation, treatment, deep well injection, dilution, and ocean discharge."

Water Use in the Grassland Water District (GWD)

Immediately downstream of the DSA lies the GWD, which consists of 51,575 acres of seasonal wetlands and agricultural lands, divided into two sub-units. The Southern Division consists of about 21,000 acres adjacent to the DSA; the Northern Division, about 31,000 acres, lies between Gustine and Los Banos (see Figure V-15).

Most of the GWD lies within the Grassland Resource Conservation District (GRCD). The GRCD consists of 46,000 acres of privately owned wetlands, about 17 percent of the wetland acreage remaining in California and state and federal refuges provide an additional 18,900 acres of wetlands. These wetlands are the remnants of a much larger seasonal wetlands area, which existed when the region was first farmed by Henry Miller.

Recreational activities in the grasslands area include waterfowl hunting, fishing, upland game hunting, birdwatching, and nature tours. Within the GWD as a whole there are about 160 private hunting clubs.

The number of waterfowl hunters using the GWD is unknown, but is estimated at 2,500 to 3,000 per hunting day (U.S. Fish and Wildlife Service, 1978a). Almost all of the duck clubs in the GWD allow hunting only on Saturdays, Sundays, and Wednesdays, a schedule that yields an average of 40 shooting days per season. An estimated 495,000 activity hours of waterfowl hunting occur annually within the district (U.S. Fish and Wildlife Service, 1978b).

Most of the 51,575 acres within the GWD are managed to provide habitat for wintering waterfowl. Presently, there are about 2,000 acres in agricultural use in GWD. These acres receive drain water only and are managed for permanent pasture and crops such as sugar beets, alfalfa and cotton. Some duck club owners lease their land for seasonal cattle pasture.

GWD has also played an important role in drainage management in the area. Prior to 1985 GWD received water from two sources: approximately 50,000 af delivered annually by the CVP, and a slightly larger quantity of commingled surface and subsurface drainwater delivered at no charge by upslope agricultural water districts. Altogether 18 agricultural entities, including some outside the DSA (e.g., CCID) delivered drain water. In addition to the 50,000 af of CVP water, GWD receives another 3,500 af of CVP water which it delivers without prior use to Kesterson National Wildlife Refuge. Since February 1985, GWD ceased diverting large quantities of drainage flows from the DSA due to its concerns about selenium contamination. This reduction in supply water has been partly offset with water from other sources.

In short, it is evident that the GWD relied on drainage waters for a significant portion of its water supply, and the pollution of these supply waters has led to a substantial disruption of GWD operations. Because of the lack of precise data, determining exactly how much drain water the district received is not easy. With the help of Mr. Donald "Pete" Blake, manager of the California Department of Fish and Game's Los Banos Wildlife Management Area, our consultants were able to generate some estimates of drainage flows into and out of the GWD both before and after GWD's 1985 changes in operations. Using the Summers Engineering (1986) estimates of drainage flows and selenium loads discharged from the DSA and historically available to the GWD (Table V-4), and data provided by Blake (1986), estimates were made of the amount of drainwater historically used by GWD from the DSA. (see Appendix G - Table 3.3). These calculations suggest that prior to 1985 GWD diverted about 67,000 af/yr of drainage waters from the DSA if the drain water was there for them to divert. This is only an approximation, and is clearly subject to many qualifications. It is also estimated that the District's diversions of drainage flows from outside the DSA, which would not have a high selenium content, may have amounted to about 6,000 af/yr. The resulting estimates of GWD's total water supply under normal conditions prior to 1985 are presented in Table V-8.

The operations within the GWD have a profound effect on the discharge of water from this area. A schedule of the monthly patterns of discharges from the grasslands area was developed based on Blake's estimates(Table V-9). Of the approximate 122,884 af/year used within GWD historically, about half (51,600 af) is returned to Mud and Salt sloughs. The rest percolates to ground water or is lost to evapotranspiration.

Estimated Selenium Loads From the DSA and GWD to the San Joaquin River System

To evaluate the various assumptions on drainage volume, selenium content and GWD operations made thus far, these data were used to estimate historical selenium concentrations for the water years 1979 (normal), 1981 (critical), 1984 (normal) and 1985 (dry). The estimates for 1984 and 1985 were then compared with those generated from the SWRCB San Joaquin River Input-Output Model (SJRIO-1) discussed earlier in this chapter.

Tables V-10 through V-13 contain monthly flow and selenium estimates calculated for water years 1979, 1981, 1984 and 1985 based on the estimates of drain flows and selenium concentrations set forth in the previous section. One change was made to these values. Broadview Water District did not discharge into the River Basin until 1983. Therefore, the flows and selenium loads from Broadview were subtracted to obtain revised estimates for 1979 and 1981. This change affects the amount of drainage flow from the DSA and the amount of this flow available for diversion by the GWD.

The estimated historical selenium concentrations in Table V-10 to V-13 indicate that the monthly selenium levels in the San Joaquin River at Hills Ferry were usually less than 2 ppb until 1985, when GWD decreased its diversion of drainage from the DSA.

To evaluate the accuracy of these estimates we compared them with monitoring data available for 1984 and 1985. Table V-14 compares the predicted selenium levels developed in Tables V-10 to V-13 with values from the calibrated SJRIO-1 model (Appendix C) and data collected for Hills Ferry by the U.S. Geological Survey (USGS). Selenium data from upstream sampling stations which drive the SJRIO-1 model are available beginning in May 1984. Data from USGS are available beginning in June 1985. The USGS and SJRIO-1 results for the last four months of water year 1985 are in extremely close agreement. However, while the predicted selenium concentrations (Column 1) (based on loads) for water year 1985 follow the same seasonal trends as the SJRIO-1 results, the concentrations are generally higher in January through September of 1985 than those based on monitoring data and integrated by the SJRIO-1 model. By comparing measured values with predicted values for selenium, this overestimate in these months was determined to be due likely to an underestimate of drainage flows from the DSA that were taken by GWD during that period. The data in Table V-15 reflect the best estimate of GWD's operation during this period. Using these flow data, the predicted values closely match the selenium levels monitored in the River (Column 2, Table V-14).

Estimated Selenium Levels Due to Changes in Management Practices

Tables V-10, V-11, V-12 and V-15 show additional information beyond estimated historic selenium concentrations at Hills Ferry. They also show in Column 12 the levels of selenium at this location if the GWD were to bypass all drainage water from the DSA. This is the stated operation goal of the GWD. Figures V-19 through V-22 show comparison of the estimated historic selenium levels in the San Joaquin River at Hills Ferry to those expected under future GWD operation. The largest differences are for the years prior to the introduction of loads from the Broadview Water District (1983) and the change in the operation in GWD. For the years 1979 and 1981 between 50% and 65% of the selenium load would have to be removed to reach the levels experienced historically in those years.

Tables V-10, V-11, V-12 and V-15 also show the amount of water that would be needed to dilute the drainage from the DSA to 5 ppb at Hills Ferry on the San Joaquin River. This is shown in Column 14 on these tables. Approximately 150,000 af would be needed in normal years and over 200,000 af would be needed in dry years.

The last six columns in Tables V-10, V-11, V-12 and V-15 show the pounds of selenium that would need to be removed to attain water quality objectives of 5 ppb and 2 ppb in the San Joaquin River at Hills Ferry. To obtain an objective of 5 ppb between 15% and 39% of the selenium load from the DSA would have to be removed depending on the hydrology of the specific year. To obtain 2 ppb between 48% and 84% of the selenium load from the DSA would need to be removed. These removal percentages are annual averages. Individual monthly removal percentages are often much higher. To effectively remove this amount of selenium, either large treatment plants would be needed or the districts within the DSA would need to control not only the monthly volume of drainage through on-farm regulation,but also the annual volume of drainage. As discussed in the previous section, reduction in drainage volumes can be achieved through better water management of existing irrigation systems and if necessary, use of more efficient irrigation techniques.

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TABLE V-1 WATER DISTRICTS WITHIN THE DSA AND MSSDA

District	Total Area (acres)	Acreage Discharging to Mud & Salt Sloughs (MSSDA)	Acreage Within Drainage Study (DSA)
Central California Irrigation District (CCID)	144,075	75,000	9,804
Firebaugh Canal Company	22,640	22,640	22,640
Widren WD	470	470	470
Broadview WD	9,515	9,515	9,515
Panoche Drainage District	42,300	42,300	42,300
Pacheco WD	5,851	5,851	5,851
San Luis WD	56,713	54,000	3,900
San Luis Canal Co.	47,285	42,000	0
Grassland WD	52,000	52,000	0
TOTAL		303,776	94,480

Source: Grassland Water Task Force

TABLE V-2 TILED ACREAGE IN DSA

Districts	Total Area (acres)	Approximate Area Tiled (acres)	Percent Tiled
CCID, Firebaugh CC, Widren WD	29,000	13,100	45.2
Broadview WD	9,515	7,410	77.8
Panoche DD	42,300	22,000	52.0
Pacheco WD	5,851	3,550	60.7
Charleston DD	4,314	1,100	25.5
CCID at Almond Drive	3,500	660	18.9
TOTAL	94,480	47,820	50.6

TABLE V-3 WATER DELIVERIES FROM CVP FOR AGRICULTURAL USE (AF/YR), 1976-1985

District	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Broadview WD	15,053	13,322	8,995	17,634	14,499	15,622	15,150	17,479	24,913	26,152
CCID	534,771	411,967	456,927	527,197	524,597	533,073	514,251	457,190	530,780	530,885
Firebaugh CC	85,379	65,772	72,950	84,169	83,754	85,107	82,103	72,992	84,741	94,758
Mercy Springs WD	11,994	2,008	11,276	14,130	13,921	13,451	11,469	7,628	10,247	8,490
Oro Loma WD	4,995	1,239	5,242	5,640	5,479	5,959		4,641	6,230	6,158
Pacheco WD	9,950	8,844	6,877	9,184	7,942	12,497	9,583	9,612	10,757	8,837
Panoche WD	118,386	26,159	76,357	100,937	97,732	97,332	86,579	82,285	101,885	91,766
San Luis WD	115,123	38,901	86,576	120,884	131,542	142,973	104,746	103,324	144,394	124,196

Source: USBR

TABLE V-4 ESTIMATED DRAINAGE OUTFLOW FROM DSA

	Panoche D.D.		Firebaugh C.C.+ Widren W.D.+ CCID		Broadview W.D.		Pacheco W.D.		Charleston D.D.		CCID Almond Drive		Total	
	Outflow AF	Load lbs	Outflow AF	Load lbs	Outflow AF	Load lbs	Outflow AF	Load lbs	Outflow AF	Load lbs	Outflow AF	Load lbs	Outflow AF	Load lbs
July	4,780	325	453 [2]	46	275 [2]	29	1,119 [2]	106	242*	27	594*	7	7,463	540
August	4,250	220	1,434 [2]	117	682 [2]	73	821 [2]	87	235*	15	578*	6	8,000	518
September	2,240	116	2,003*	58*	1,125	61	729*	24	176*	4	432*	5	6,705	268
October	1,144	188	1,603*	68*	1,393	95	583*	25	141*	8	346*	4	5,210	318
November	1,894	242	1,753*	181*	1,333	149	638*	78	154*	6	378*	4	6,150	660
December	2,261	522	1,302*	187*	1,236	175	474*	85	114*	3	280*	4	5,667	976
January	1,492	320	1,202*	140*	1,414	154	438*	58	106*	18	259*	4	4,911	694
February	1,837	320	1,227*	97*	1,447	142	447*	41	108*	15	265*	4	5,331	619
March	3,312	504	2,529*	278*	2,632	365	921*	113	222*	66	545*	4	10,161	1,330
April	2,569	510	2,730*	304*	2,779	257	893	133	240*	56	589*	8	9,800	1,268
May	3,507	372	2,630*	332*	1,878	276	1,030	151	231*	52	567*	8	9,843	1,191
June	4,219	447	1,346	102	893	129	960	124	231*	30	567*	8	8,216	840
	33,505	4,016	20,212	1,910	17,087	1,905	9,053	1,025	2,200	300	5,400	66	87,457	9,222
Average Se(μg/ℓ)	44		35		41		42		50		4		39	
Acreage with subsurface drainage systems	22,000		13,100		8,000		3,550		1,100		660		48,410	
Acreage with both surface and subsurface drainage systems	42,300		29,000		9,515		5,851		4,314		3,500		94,480	

* Estimated, not based on actual data.

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1 Period from July 1984 to June 1985 except where noted. Includes both surface and subsurface drainage water.

2 July and August 1985

Source: Summers Engineering Inc. (1986)

TABLE V-5 TILE DRAIN FLOW PATTERNS: PERCENTAGE OF ANNUAL FLOWS OCCURRING IN EACH MONTH

DWR - DMP DATA, 1984

District	BWD	CCID	Firebaugh			PC	Panoche			9-Sump	Broadview Data		Regional Boar
Sump	BVS 6016	DPS 4616	BVS [illegible]	FBH 2016	FBH 8061	DPS 1367	DPS 2535	DPS 3465	HMH 7516	Total	1985 - 1986		Estimate
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Crop	Beans	Rice	Cotton	Cotton	Cotton	Cotton	Cotton	Wheat/Corn	Tomatoes				
January	10.6	5.0	9.3	4.9	7.3	16.0	7.0	10.2	3.1	7.9	7.8[1]	6.0[2]	8.0
February	3.8	2.8	12.3	14.4	11.0	6.8	18.7	9.1	4.6	7.6	14.1	13.0	8.0
March	2.2	2.0	5.5	16.4	4.4	4.5	8.7	7.8	2.5	4.5	12.9	13.2	10.0
April	13.2	6.3	12.3	10.2	9.5	10.5	9.9	8.8	17.9	12.7	10.2	10.2	10.0
May	3.4	9.7	16.1	5.0	3.0	4.5	6.6	5.9	8.6	5.8	10.7	7.7	10.0
June	11.0	12.9	12.1	8.6	9.6	9.5	3.0	8.7	13.0	10.3	9.5	11.6	11.0
July	19.7	20.4	20.7	16.2	17.6	17.9	26.6	14.9	16.9	18.6	10.5	13.7	13.0
August	14.9	14.1	8.1	8.6	18.2	15.0	9.8	10.4	8.9	12.6	8.5	8.2	10.0
September	4.1	12.4	1.9	4.8	1.6	6.1	2.7	5.2	6.2	4.8	2.3	2.7	6.0
October	8.4	8.1	0.4	5.0	13.0	7.4	2.2	7.4	2.9	6.5	2.7	2.4	4.0
November	3.6	1.6	0.2	5.9	1.6	1.9	0.6	1.8	1.3	2.1	4.1	3.8	4.0
December	5.1	4.8	1.1	n.a.	3.3	0	4.1	9.5	14.0	6.5	6.8	7.5	6.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Peak Mo/ Av. Mo	2.36	2.45	2.48	1.94	2.18	2.15	3.19	1.79	2.15	2.23	1.69	1.64	1.56

NOTES: [1] Column 11 is based on May 1985 - April 1986
[2] Column 12 is based on November 1985 - October 1986, and involves a slightly different assignment of weekly flows to monthly totals.

SOURCES: Columns (1) - (9): DWR-DMP (1984)
Columns (11) - (12): Broadview WD
Column (13): Westcott (1985)

TABLE V-6 · ASSUMED TILE DRAINAGE FLOW (AF/A/MO) – BASE CASE

	Firebaugh, CCID Broadview, Widren (20,510 tiled acres)	Panoche, Pacheco Charleston (26,650 tiled acres)	CCID at Almond Drive (660 tiled acres)
January	0.0476	0.0609	0.2341
February	0.0859	0.1098	0.4223
March	0.0788	0.1008	0.3876
April	0.0623	0.0797	0.3064
May	0.0651	0.0833	0.3204
June	0.0577	0.0738	0.2840
July	0.0638	0.0816	0.3137
August	0.0517	0.0661	0.2543
September	0.0140	0.0179	0.0689
October	0.0163	0.0208	0.0801
November	0.0253	0.0323	0.1243
December	0.0416	0.0532	0.2044
Annual	0.61	0.78	3.0

TABLE V-7

BASE CASE ASSUMPTIONS REGARDING SURFACE AND TILE DRAIN FLOWS IN THE DSA, 1984/5

	Annual	Jan. 1985	Feb. 1985	Mar. 1985	Apr. 1985	May 1985	June 1985	July 1984	Aug. 1984	Sept. 1984	Oct. 1984	Nov. 1984	Dec. 1984
Panoche (22,000 TA)													
Tile flow (AF)	16584	1339	1837	2217	1753	1833	1624	1794	1455	394	458	711	1169
Surface flow (AF)	16921	153	0	1095	816	1674	2595	2986	2795	1846	686	1183	1092
Total Flow	33505	1492	1837	3312	2569	3507	4218	4730	4250	2240	1144	1894	2261
Se in tile (ppb)	86.8	88	49	84	107	74	100	65	54	104	94	124	164
Firebaugh Widren CCID (13,000 TA)													
Tile flow (AF)	7609	624	1125	1032	816	853	756	453	677	184	213	331	545
Surface flow (AF)	12603	578	102	1497	1914	1777	590	0	757	1819	1390	1422	757
Total flow	20212	1202	1227	2529	2730	2630	1346	453	1434	2003	1603	1753	1302
Se in tile (ppb)	90.2	82	32	98	135	142	49	21	63	107	111	198	126
Broadview (7,410)													
Tile flow (AF)	4324	353	636	584	462	483	428	275	383	104	121	187	308
Surface flow (AF)	12763	1061	811	2048	2317	1395	465	0	299	1021	1272	1146	928
Total flow	17087	1414	1447	2632	2779	1878	893	275	682	1125	1393	1333	1236
Se in tile (ppb)	159.1	159	81	228	201	209	110	23	70	208	281	288	207
Pacheco (3,550 TA)													
Tile flow (AF)	2772	216	390	358	283	296	262	290	235	64	74	115	189
Surface flow (AF)	6281	222	57	563	610	734	698	829	586	665	509	523	285
Total flow	9053	438	447	921	893	1030	960	1119	821	729	583	638	474
Se in tile (ppb)	134.6	98	39	115	172	186	172	133	135	129	118	247	165
Charleston (1100 TA)													
Tile flow (AF)	847	67	108	111	88	92	81	90	73	20	23	36	58
Surface flow (AF)	1353	39	0	111	152	139	150	152	162	156	118	118	56
Total flow	2200	106	108	222	240	231	231	242	235	176	141	154	114
Se in tile (ppb)	129.1	99	46	219	235	208	135	110	74	67	124	59	18
CCID-Almond Drive (660 TA)													
Tile flow (AF)	1966	155	265	256	202	211	187	207	168	45	53	82	135
Surface flow (AF)	3434	104	0	289	387	356	380	387	410	387	293	296	145
Total flow	5400	259	265	545	585	567	567	594	578	432	346	378	280
Se in tile (ppb)	10.7	9	5	5	13	12	14	11	11	32	22	14	10
TOTAL													
Tile Flow	34102	2754	4361	4558	3604	3768	3338	3109	2991	811	942	1462	2404
Surface Flow	53355	2157	970	5603	6196	6075	4878	4354	5009	5894	4268	4688	3263
Total Flow	87457	4911	5331	10161	9800	9843	8216	7463	13000	6705	5210	6150	5667
Se in tile (ppb) Flow Weighted		92	52	106	129	116	92	63	63	117	123	165	150
x̄ Se in Combined Flow		52	38	49	48	45	38	25	24	15	23	40	64

TABLE V-8 TOTAL WATER SUPPLY (AF) FROM GWD UNDER HISTORICAL CONDITIONS

Month	Diversion of Drainage from DSA	Diversion of Other Drainage	Total Drain Water Use	Deliveries From CVP	Total Water Supply to GWD
August	4,896	3,000	7,869		7,896
September	5,454	1,000	6,454	17,000	23,954
October	4,555		4,555	32,500	37,005
November	5,462		5,462		5,462
December	5,238		5,238		5,238
January	4,660		4,660		4,660
February	2,889		2,889		2,889
March	7,995		7,995		7,995
April	8,490		8,490		8,490
May	9,441	500	9,941		9,941
June	5,452	1,500	6,952		6,952
July	2,352		2,352		2,352
	66,884	6,000	72,884	50,000	122,884

Source: Col (1) = Appendix G, Table 4.3 Col (6).
Col (2) = Pete Blake, California Fish and Game.

TABLE V-9 DISCHARGES FROM GWD TO THE SAN JOAQUIN RIVER UNDER HISTORICAL CONDITIONS

Month	Total Water Supply to GWD	Discharge from GWD to San Joaquin River	Comments
August September October	7,895 23,954 37,005	0 0 0	No discharges during initial flood up of about 68,000 AF, or about 1-1/3 AF/A on 50,000 acres.
November December	5,462 5,238	1,925 1,925	Apply an additional 10,000 AF for a total flood up of about 78,000 AF. In each of these months, spill about 2-1/2 percent of water applied over the period August-December.
January	4,660	6,000	In this month release water from 5,000 acres.
February March	2,889 7,995	16,000 16,000	In each of these months release water from 20,000 acres; 40 percent of the water delivered (1-1/3 AF/A) is lost; the remaining 60 percent is discharged to the River.
April	8,490	6,000	In this month release water from 5,000 acres.
May June July	9,941 6,952 2,352	1,943 1,354 453	In each of these months, discharge 20 percent of any water applied in that month; the rest is lost to ET.
Total	112,884	51,600	

Table V-10(a)

ESTIMATED SAN JOAQUIN RIVER SELENIUM CONCENTRATIONS BASED ON LOAD ESTIMATES W/Y 1979 (NORMAL)

(1) Month	(2) Historic SJR River Bl. Mer. (af/m)	(3) Total DSA Drain Flows (af/m)	(4) Div. of Drn. Fl. by GWD (af/m)	(5) Direct Dist. By DSA Drns. (af/m)	(6) DSA Drain Ave. Se. Conc. (ug/l)	(7) GWD Discharge Flow (af/m)	(8) GWD Discharge Se. Conc. (ug/l)	(9) SJR Flows w/o GWD & DSA (af/m)	(10) Bkgnd. Se. Conc. w/o GWD & DSA (ug/l)	(11) Est. Hist. SJR Se. w/ GWD & DSA (ug/l)	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)
OCTOBER	102,800	4,338	4,338	0	22	0	5.0	102,800	0.5	0.50	1.69
NOVEMBER	79,370	5,432	5,432	0	40	1,925	5.0	77,445	0.5	0.61	3.70
DECEMBER	42,810	5,001	5,001	0	67	1,925	5.0	40,885	0.5	0.70	8.75
JANUARY	102,700	3,988	3,998	0	56	6,000	5.0	96,700	0.5	0.76	3.32
FEBRUARY	152,700	4,417	2,889	1,528	45	16,000	5.0	135,172	0.5	1.42	2.55
MARCH	207,200	8,545	7,995	550	47	16,000	5.0	190,650	0.5	0.97	3.27
APRIL	74,510	8,001	8,001	0	53	6,000	5.0	68,510	0.5	0.86	6.82
MAY	58,360	8,949	8,949	0	43	1,942	5.0	56,418	0.5	0.65	7.59
JUNE	49,090	8,145	5,452	2,693	36	1,354	5.0	45,043	0.5	2.57	6.72
JULY	32,560	7,934	2,352	5,582	27	453	5.0	26,525	0.5	5.11	6.74
AUGUST	31,470	8,118	4,896	3,222	23	0	5.0	28,248	0.5	2.80	6.08
SEPTEMBER	47,580	6,251	5,454	797	14	0	5.0	46,783	0.5	0.73	2.47
TOTAL	981,150	79,119	64,757	14,372		51,599		915,179			
AVERAGE					39		5.0		0.5	1.47	4.98

Column 2 - the San Joaquin River Flow measured by USGS at Hills Ferry (a sampling station just below its confluence with the Merced River).

Column 3 - total drain flows from the DSA assuming no regulation by GWD (Table V-7 times 1.1) and no discharges from Broadview WD.

Column 4 - estimated diversions of drainage water from the DSA by GWD (up to Table V-8 provided drain flow was available that month).

Column 5 - estimated amount of drainage water from the DSA which was not taken for use within the GWD. ((3) - (4))

Column 6 - average monthly selenium concentrations of combined surface drainage from the DSA as developed by Summers Engineers (1986) and shown in Table V-4 (minus discharge from Broadview WD) times 1.10 to reflect higher flows in normal years than dry years.

Column 7 - estimated discharge from the GWD (see Table V-9).

Column 8 - estimated historical selenium concentration in the GWD discharge based on past observations by Fish and Game staff and available monitoring data.

Column 9 - San Joaquin River flows minus the effects of drainage discharge from the DSA or GWD. ((2) - (5) - (7))

Column 10 - estimated background concentration of selenium in the San Joaquin River at Hills Ferry without drainage from GWD and the DSA.

Column 11 - estimated historic levels of selenium at Hills Ferry assuming the flows and selenium concentrations for the DSA and GWD set forth previously. ((5) x (6)) + ((7) x (8)) + ((9) x (10)) ÷ (2)

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((15) x (16)) + ((7) x (8)) ÷ ((9) + (16) + (7))

Table V-10(b)

Additional Estimates W/Y 1979 (Normal)

(1) Month	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)	(13) Est. Present SJR Fl w/ Byps (af/m)	(14) New Fl to get 5 ppb Se (af/m)	(15) All Drain Se (ug/l)	(16) All Drain Flow (af/m)	(17) All Drain Se (lbs)	(18) Broad-view Flow (af/m)	(19) Broad-view Se (lbs)	(20) Drain Fl. w/o Brdview (af/m)	(21) Drain Se w/o Brdview (ug/l)	(22) Minus Lbs to get Hist. Se (lbs)	(23) % Se Load Red To Hist (%)
OCTOBER	1.69	108,531	0	23	5,731	358	1,393	95	4,338	22	0	0
NOVEMBER	3.70	86,135	0	40	6,765	735	1,333	149	5,432	40	420	57
DECEMBER	8.75	49,047	38,333	64	6,237	1,085	1,236	175	5,001	67	929	86
JANUARY	3.32	108,102	0	52	5,402	763	1,414	154	3,988	56	404	53
FEBRUARY	2.55	157,036	0	43	5,864	685	1,447	142	4,417	45	244	36
MARCH	3.27	217,827	0	48	11,177	1,458	2,632	365	8,545	47	783	54
APRIL	6.82	85,290	32,343	48	10,780	1,406	2,779	257	8,001	53	1,166	83
MAY	7.59	69,187	37,333	45	10,827	1,324	1,878	276	8,949	43	1,100	83
JUNE	6.72	55,435	19,908	38	9,038	933	893	129	8,145	36	457	49
JULY	6.74	35,187	12,757	27	8,209	602	275	29	7,934	27	308	51
AUGUST	6.08	37,048	8,351	24	8,800	574	682	73	8,118	23	252	44
SEPTEMBER	2.47	54,159	0	15	7,376	301	1,125	61	6,251	14	81	27
TOTAL		1,062,984	149,026		96,206	10,225	17,087	1,905	79,119		6,144	
AVERAGE	4.98			39		852				39		60

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((15) x (16)) + ((7) x (8)) ÷ ((9) + (16) + (7))

Column 13 - estimated San Joaquin River flows at Hills Ferry assuming the bypass of DSA drainage by Grassland WD. (9) + (16) + (7)

Column 14 - additional dilution flows needed to attain 5 ppb at Hills Ferry. ((13) x ((12) - 5.0) ÷ (5.0 - 0.2)

Column 15 - average monthly selenium concentrations of combined surface and subsurface drainage from the DSA as developed by Summer's Engineers (1986) and shown in Table V-4.

Column 16 - estimated surface and subsurface drainage from DSA assuming no regulation by GWD from Table V-4 times 1.1 for normal year flows.

Column 17 - pounds of selenium from DSA. ((15) x (16) ÷368)

Column 18 - total flow from Broadview WD - Table V-4.

Column 19 - pounds of selenium from Broadview WD calculated from Table V-4.

Column 20 - total drain flow from DSA without Broadview WD. (16) - (17)

Column 21 - total drain flow selenium concentrations without Broadview. ((17) - (19)) ÷ (20) x 368

Column 22 - reduction in pounds of selenium to achieve historic levels of selenium. ((12) - a) ÷ ((15) - a) x (13) x (15) ÷ 368, a = 4 June, July & Aug & 2 other months

Column 23 - reduction in selenium load as a percent of total selenium load from the DSA. ((22) ÷ (20)) x 100

Table V-10(c)

(1) Month	(24) Minus Lbs to get 5 ppb Se (lbs)	(25) % Se Load Red to 5 ppb (%)	(26) Minus Lbs to get 2 ppb Se (lbs)	(27) % Se Load Red to 2 ppb (%)	(28) Effluent Limit to 5ppb (lbs)	(29) Effluent Limit to 2 ppb (lbs)
OCTOBER	0	0	0	0	358	358
NOVEMBER	0	0	420	57	735	316
DECEMBER	547	50	[illegible]	86	541	156
JANUARY	0	0	404	53	763	359
FEBRUARY	0	0	244	36	685	441
MARCH	0	0	783	54	1,458	675
APRIL	471	33	1,166	83	935	240
MAY	548	41	1,100	83	776	224
JUNE	299	32	751	80	634	182
JULY	204	34	490	81	398	113
AUGUST	138	24	448	78	436	126
SEPTEMBER	0	0	81	27	301	220
TOTAL	2,202		6,815			
AVERAGE		22		67		

Column 24 - reduction in selenium load at Hills Ferry on the San Joaquin River needed to achieve 5 ppb assuming the bypass of drainage by GWD. ((12) - 5.0) ÷ ((15) - 5.0) x (13) x (15) ÷ 368

Column 25 - percent reduction in selenium load from the DSA to achieve 5 ppb at Hills Ferry. ((24) ÷ (20)) x 100

Column 26 - reduction in selenium load needed to achieve 2 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 2.0) ÷ ((15) - 2.0) x (13) x (15) ÷ 368

Column 27 - percent reduction in selenium load from the DSA to achieve 2 ppb selenium at Hills Ferry. ((26) ÷ (20)) x 100

Column 28 - allowable load of selenium from DSA to achieve 5 ppb selenium at Hills Ferry. (17) - (24)

Column 29 - allowable load of selenium from DSA to achieve 2 ppb selenium at Hills Ferry. (17) - (26)

Table V-11(a)

ESTIMATED SAN JOAQUIN RIVER SELENIUM CONCENTRATIONS BASED ON LOAD ESTIMATES W/Y 1981 (CRITICAL)

(1) Month	(2) Historic SJR River Bl. Mer. (af/m)	(3) Total DSA Drain Flows (af/m)	(4) Div. of Drn. Fl. by GWD (af/m)	(5) Direct Dist. By DSA Drns. (af/m)	(6) DSA Drain Ave. Se. Conc. (ug/l)	(7) GWD Discharge Flow (af/m)	(8) GWD Discharge Se. Conc. (ug/l)	(9) SJR Flows w/o GWD & DSA (af/m)	(10) Bkgnd. Se. Conc. w/o GWD & DSA (ug/l)	(11) Est. Hist. SJR Se. w/ GWD & DSA (ug/l)	(12) Est. Prese SJR Se Dr Byp (ug/l)
OCTOBER	62,830	3,817	3,817	0	22	0	5.0	62,830	0.5	0.50	2
NOVEMBER	47,180	4,817	4,817	0	39	1,925	5.0	45,255	0.5	0.68	5
DECEMBER	45,360	4,431	4,431	0	67	1,925	5.0	43,435	0.5	0.69	7
JANUARY	48,580	3,497	3,497	0	57	6,000	5.0	42,580	0.5	1.06	5
FEBRUARY	53,510	3,884	2,889	995	45	16,000	5.0	36,515	0.5	2.67	[illegible]
MARCH	80,140	7,529	7,529	0	47	16,000	5.0	64,140	0.5	1.40	6
APRIL	43,530	7,021	7,021	0	53	6,000	5.0	37,530	0.5	1.12	9
MAY	35,080	7,965	7,965	0	43	1,942	5.0	33,138	0.5	0.75	10
JUNE	24,220	7,323	5,452	1,871	36	1,354	5.0	20,995	0.5	3.49	10
JULY	23,810	7,188	2,352	4,836	26	453	5.0	18,521	0.5	5.76	5.
AUGUST	25,720	7,318	4,896	2,422	22	0	5.0	23,298	0.5	2.52	6.
SEPTEMBER	22,240	5,580	5,454	126	14	0	5.0	22,114	0.5	0.58	3.
TOTAL	512,200	70,370	60,120	10,250		51,599		450,351			
AVERAGE					39		5.0		0.5	1.77	6.

Column 2 - the San Joaquin River Flow measured by USGS at Hills Ferry (a sampling station just below its confluence with the Merced River).

Column 3 - total drain flows from the DSA assuming no regulation by GWD (Table V-7) and no discharges from Broadview WD.

Column 4 - estimated diversions of drainage water from the DSA by GWD (up to Table V-8 provided drain flow was available that month).

Column 5 - estimated amount of drainage water from the DSA which was not taken for use within the GWD. ((3) - (4))

Column 6 - average monthly selenium concentrations of combined surface drainage from the DSA as developed by Summers Engineers (1986) and shown in Table V-4 (minus discharge from Broadview WD).

Column 7 - estimated discharge from the GWD (see Table V-9).

Column 8 - estimated historical selenium concentration in the GWD discharge based on past observations by Fish and Game staff and available monitoring data.

Column 9 - San Joaquin River flows minus the effects of drainage discharge from the DSA or GWD. ((2) - (5) - (7))

Column 10 - estimated background concentration of selenium in the San Joaquin River at Hills Ferry without drainage from GWD and the DSA.

Column 11 - estimated historic levels of selenium at Hills Ferry assuming the flows and selenium concentrations for the DSA and GWD set forth previously. ((5) x (6)) + ((7) x (8)) + ((9) x (10)) ÷ (2)

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((15) x (16)) + ((7) x (8)) ÷ ((9) + (16) + (7))

Table V-11(b)

Additional Estimates W/Y 1981 (Critical)

(1) Month	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)	(13) Est. Present SJR Fl w/ Byps (af/m)	(14) New Fl to get 5 ppb Se (af/m)	(15) All Drain Se (ug/l)	(16) All Drain Flow (af/m)	(17) All Drain Se (lbs)	(18) Broad-view Flow (af/m)	(19) Broad-view Se (lbs)	(20) Drain Fl. w/o Brdview (af/m)	(21) Drain Se w/o Brdview (ug/l)	(22) Minus Lbs to get Hist Se (lbs)	(23) % Se Load Red to Hist (%)
OCTOBER	2.22	68,040	0	23	5,210	318	1,393	95	3,817	22	45	14
NOVEMBER	5.22	53,330	2,417	40	6,150	660	1,333	149	4,817	39	491	74
DECEMBER	7.72	51,027	28,937	64	5,667	976	1,236	175	4,431	67	819	84
JANUARY	5.73	53,491	8,168	52	4,911	694	1,414	154	3,497	57	564	81
FEBRUARY	5.66	57,846	7,971	43	5,331	619	1,447	142	3,884	45	604	98
MARCH	6.64	90,301	30,894	48	10,161	1,330	2,632	365	7,529	47	1,189	89
APRIL	9.73	53,330	52,607	48	9,800	1,268	2,779	257	7,021	53	1,170	92
MAY	10.44	44,923	50,958	45	9,843	1,191	1,878	276	7,965	43	1,079	91
JUNE	10.78	30,565	36,802	38	8,216	840	893	129	7,323	36	629	75
JULY	8.06	26,437	16,842	27	7,463	540	275	29	7,188	26	342	63
AUGUST	6.51	31,298	9,825	24	8,000	518	682	73	7,318	22	256	49
SEPTEMBER	3.87	28,819	0	15	6,705	268	1,125	61	5,580	14	169	63
TOTAL		589,407	245,422		87,457	9,222	17,087	1,905	70,370		7,357	
AVERAGE	6.88			39		769				39		80

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((15) x (16)) + ((7) x (8)) ÷ ((9) + (16) + (7))

Column 13 - estimated San Joaquin River flows at Hills Ferry assuming the bypass of DSA drainage by Grassland WD. (9) + (16) + (7)

Column 14 - additional dilution flows needed to attain 5 ppb at Hills Ferry. ((13) x (12) - 5.0) ÷ (5.0 - 0.2)

Column 15 - average monthly selenium concentrations of combined surface and subsurface drainage from the DSA as developed by Summer's Engineers (1986) and shown in Table V-4.

Column 16 - estimated surface and subsurface drainage from DSA assuming no regulation by GWD from Table V-4.

Column 17 - pounds of selenium from DSA. ((15) x (16) ÷368)

Column 18 - total flow from Broadview WD. Table V-4.

Column 19 - pounds of selenium from Broadview WD calculated from Table V-4.

Column 20 - total drain flow from DSA without Broadview WD. (16) - (17)

Column 21 - total drain flow selenium concentrations without Broadview. ((17) - (19)) ÷ (20) x 368

Column 22 - reduction in pounds of selenium to achieve historic levels of selenium. ((12) - a) ÷ ((15) - a) x (13) x (15) ÷ 368, a = 4 June, July & Aug & 2 other months

Column 23 - reduction in selenium load as a percent of total selenium load from the DSA. ((22) ÷ (20)) x 100

Table V-11(c)

(1) Month	(24) Minus Lbs to get 5 ppb Se (lbs)	(25) % Se Load Red to 5ppb (%)	(26) Minus Lbs to get 2 ppb Se (lbs)	(27) % Se Load Red to 2 ppb (%)	(28) Effluent Limits to 5ppb (lbs)	(29) Effluent Limits to 2 ppb (lbs)
OCTOBER	0	0	45	14	318	273
NOVEMBER	36	5	491	74	624	169
DECEMBER	409	42	819	84	567	157
JANUARY	118	17	564	81	576	130
FEBRUARY	118	19	604	98	501	15
MARCH	450	34	1,189	89	880	141
APRIL	766	60	1,170	92	502	98
MAY	748	63	1,079	91	443	112
JUNE	553	66	770	92	287	70
JULY	270	50	470	87	270	70
AUGUST	162	31	418	81	356	100
SEPTEMBER	0	0	169	63	268	99
TOTAL	3,629		7,787			
AVERAGE		39		84		

Column 24 - reduction in selenium load at Hills Ferry on the San Joaquin River needed to achieve 5 ppb assuming the bypass of drainage by GWD. ((12) - 5.0) ÷ ((15) - 5.0) x (13) x (15) ÷ 368

Column 25 - percent reduction in selenium load from the DSA to achieve 5 ppb at Hills Ferry. ((24) ÷ (20)) x 100

Column 26 - reduction in selenium load needed to achieve 2 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 2.0) ÷ ((15) - 2.0) x (13) x (15) ÷ 368

Column 27 - percent reduction in selenium load from the DSA to achieve 2 ppb selenium at Hills Ferry. ((26) ÷ (20)) x 100

Column 28 - allowable load of selenium from DSA to achieve 5 ppb selenium at Hills Ferry. (17) - (24)

Column 29 - allowable load of selenium from DSA to achieve 2 ppb selenium at Hills Ferry. (17) - (26)

Table V-12(a)

ESTIMATED SAN JOAQUIN RIVER SELENIUM CONCENTRATIONS BASED ON LOAD ESTIMATES W/Y 1984 (NORMAL)

(1) Month	(2) Historic SJR River Bl. Mer. (af/m)	(3) Total DSA Drain Flows (af/m)	(4) Div. of Drn. Fl. by GWD (af/m)	(5) Direct Dist. By DSA Drns. (af/m)	(6) DSA Drain Ave. Se. Conc. (ug/l)	(7) GWD Discharge Flow (af/m)	(8) GWD Discharge Se. Conc. (ug/l)	(9) SJR Flows w/o GWD & DSA (af/m)	(10) Bkgnd. Se. Conc. w/o GWD & DSA (ug/l)	(11) Est. Hist. SJR Se. w/ GWD & DSA (ug/l)	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)
OCTOBER	358,500	5,731	4,555	1,176	23	0	5.0	357,324	0.5	0.57	0.86
NOVEMBER	240,300	6,765	5,462	1,303	40	1,925	5.0	237,072	0.5	0.75	1.62
DECEMBER	498,600	6,237	5,238	999	64	1,925	5.0	495,676	0.5	0.64	1.30
JANUARY	704,000	5,402	4,660	742	52	6,000	5.0	697,258	0.5	0.59	0.93
FEBRUARY	145,600	5,864	2,889	2,975	43	16,000	5.0	126,625	0.5	1.86	2.66
MARCH	84,280	11,177	7,995	3,182	48	16,000	5.0	65,098	0.5	3.15	7.03
APRIL	64,790	10,780	8,490	2,290	48	6,000	5.0	56,500	0.5	2.60	7.86
MAY	52,860	10,827	9,441	1,386	45	1,942	5.0	49,532	0.5	1.83	8.37
JUNE	47,860	9,038	5,452	3,586	38	1,354	5.0	42,920	0.5	3.44	6.97
JULY	39,270	8,209	2,352	5,857	27	453	5.0	32,960	0.5	4.50	5.78
AUGUST	41,840	8,800	4,896	3,904	24	0	5.0	37,936	0.5	2.69	4.92
SEPTEMBER	39,680	7,376	5,454	1,922	15	0	5.0	37,758	0.5	1.20	2.87
TOTAL	2,317,580	96,206	66,884	29,322		51,599		2,236,659			
AVERAGE					39		5.0		0.5	1.99	4.27

Column 2 - the San Joaquin River Flow measured by USGS at Hills Ferry (a sampling station just below its confluence with the Merced River).

Column 3 - total drain flows from the DSA assuming no regulation by GWD (Table V-7 times 1.1).

Column 4 - estimated diversions of drainage water from the DSA by GWD (Table V-8).

Column 5 - estimated amount of drainage water from the DSA which was not taken for use within the GWD. ((3) - (4))

Column 6 - average monthly selenium concentrations of combined surface drainage from the DSA as developed by Summers Engineers (1986) and shown in Table V-4 times 1.10 to reflect higher flows in normal years than dry years.

Column 7 - estimated discharge from the GWD (see Table V-9).

Column 8 - estimated historical selenium concentration in the GWD discharge based on past observations by Fish and Game staff and available monitoring data.

Column 9 - San Joaquin River flows minus the effects of drainage discharge from the DSA or GWD. ((2) - (5) - (7))

Column 10 - estimated background concentration of selenium in the San Joaquin River at Hills Ferry without drainage from GWD and the DSA.

Column 11 - estimated historic levels of selenium at Hills Ferry assuming the flows and selenium concentrations for the DSA and GWD set forth previously. ((5) x (6)) + ((7) x (8)) + ((9) x (10)) ÷ (2)

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((3) x (6)) + ((7) x (8)) ÷ ((9) + (3) + (7))

Table V-12(b)

Additional Estimates W Y 1984 (Normal)

(1) Month	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)	(13) Est. Present SJR Fl w/ Byps (af/m)	(14) New Fl to get 5 ppb Se (af/m)	(15) All Drain Se (ug/l)	(16) All Drain Se (lbs)	(17) Minus Lbs to get 5 ppb Se (lbs)	(18) % Se Load Red to 5 ppb (%)	(19) Minus Lbs to get 2 ppb Se (lbs)	(20) % Se Load Red to 2 pbb (%)	(21) Effiunt Limits to 5 ppb (lbs)	(22) Effluent Limits to 2 ppb (lbs)
OCTOBER	0.86	363,055	0	23	358	0	0	0	0	358	358
NOVEMBER	1.62	245,762	0	40	735	0	0	0	0	735	735
DECEMBER	1.30	503,838	0	64	1,085	0	0	0	0	1,085	1,085
JANUARY	0.93	708,660	0	52	763	0	0	0	0	763	763
FEBRUARY	2.66	148,489	0	43	685	0	0	281	41	685	405
MARCH	7.03	92,275	39,098	48	1,458	569	39	1,317	90	889	141
APRIL	7.86	73,280	43,602	48	1,406	635	45	1,217	87	771	189
MAY	8.37	62,301	43,789	45	1,324	643	49	1,129	85	681	195
JUNE	6.97	53,312	21,899	38	933	329	35	760	81	604	173
JULY	5.78	41,622	6,725	27	602	108	18	461	77	495	141
AUGUST	4.92	46,736	0	24	574	0	0	405	71	574	169
SEPTEMBER	2.87	45,134	0	15	301	0	0	123	41	301	178
TOTAL		2,384,464	155,112		10,225	2,283		5,694			
AVERAGE	4.27			39			15		48		

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((3) x (6)) + ((7) x (8)) ÷ ((9) + (3) + (7))

Column 13 - estimated San Joaquin River flows at Hills Ferry assuming the bypass of DSA drainage by Grassland WD. (9) + (3) + (7)

Column 14 - additional dilution flows needed to attain 5 ppb at Hills Ferry. ((13) x (12) - 5.0) ÷ (5.0 - 0.2)

Column 15 - average monthly selenium concentrations of combined surface and subsurface drainage from the DSA as developed by Summer's Engineers (1986) and shown in Table V-4.

Column 16 - pounds of selenium from DSA. ((3) x (6)) ÷ 368

Column 17 - reduction in selenium load needed to achieve 5 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 5.0) ÷ ((6) - 5.0) x (13) x (6) ÷ 368

Column 18 - percent reduction in selenium load from the DSA to achieve 5 ppb at Hills Ferry. ((17) ÷ (16)) x 100

Column 19 - reduction in selenium load needed to achieve 2 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 2.0) ÷ ((6) - 2.0) x (13) x (6) ÷ 368

Column 20 - percent reduction in selenium load from the DSA to achieve 2 ppb selenium at Hills Ferry. ((19) ÷ (16)) x 100

Column 21 - allowable load of selenium from DSA to achieve 5 ppb selenium at Hills Ferry. (16) - (17)

Column 22 - allowable load of selenium from DSA to achieve 2 ppb selenium at Hills Ferry. (16) - (19)

Table V-13

ESTIMATED SAN JOAQUIN RIVER SELENIUM CONCENTRATIONS BASED ON LOAD ESTIMATES W/Y 1985 (DRY)

(1) Month	(2) Historic SJR River Bl. Mer. (af/m)	(3) Total DSA Drain Flows (af/m)	(4) Div. of Drn. Fl. by GWD (af/m)	(5) Direct Dist. By DSA Drns. (af/m)	(6) DSA Drain Ave. Se. Conc. (ug/l)	(7) GWD Discharge Flow (af/m)	(8) GWD Discharge Se. Conc. (ug/l)	(9) SJR Flows w/o GWD & DSA (af/m)	(10) Bkgnd. Se. Conc. w/o GWD & DSA (ug/l)	(11) Est. Hist. SJR Se. w/ GWD & DSA (ug/l)	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)
OCTOBER	53,080	5,210	4,555	655	23	0	5.0	52,425	0.5	0.78	2.53
NOVEMBER	42,170	6,150	5,462	688	40	1,925	5.0	39,557	0.5	1.35	5.78
DECEMBER	77,480	5,667	5,238	429	64	1,925	5.0	75,126	0.5	0.96	4.96
JANUARY	55,500	4,911	0	4,911	52	6,000	5.0	44,589	0.5	5.54	5.54
FEBRUARY	42,600	5,331	0	5,331	43	16,000	5.0	21,269	0.5	7.51	7.51
MARCH	57,470	10,161	1,000	9,161	48	16,000	5.0	32,309	0.5	9.32	9.99
APRIL	54,420	9,800	1,000	8,800	48	6,000	5.0	39,620	0.5	8.68	9.39
MAY	44,950	9,843	1,400	8,443	45	280	5.0	36,227	0.5	8.89	9.98
JUNE	37,450	8,216	1,400	6,816	38	280	5.0	30,354	0.5	7.36	8.46
JULY	36,090	7,463	1,000	6,463	27	200	5.0	29,427	0.5	5.27	5.86
AUGUST	38,520	8,000	0	8,000	24	0	5.0	30,520	0.5	5.38	5.38
SEPTEMBER	37,940	6,705	0	6,705	15	0	5.0	31,235	0.5	3.06	3.06
TOTAL	577,670	87,457	21,055	66,402		48,610		462,658			
AVERAGE					39		5.0		0.5	5.34	6.54

Column 2 - the San Joaquin River Flow measured by USGS at Hills Ferry (a sampling station just below its confluence with the Merced River).

Column 3 - total drain flows from the DSA assuming no regulation by GWD (Table V-7).

Column 4 - estimated diversions of drainage water from the DSA by GWD (Table V-8).

Column 5 - estimated amount of drainage water from the DSA which was not taken for use within the GWD. ((3) - (4))

Column 6 - average monthly selenium concentrations of combined surface drainage from the DSA as developed by Summers Engineers (1986) and shown in Table V-4.

Column 7 - estimated discharge from the GWD (see Table V-9).

Column 8 - estimated historical selenium concentration in the GWD discharge based on past observations by Fish and Game staff and available monitoring data.

Column 9 - San Joaquin River flows minus the effects of drainage discharge from the DSA or GWD. ((2) - (5) - (7))

Column 10 - estimated background concentration of selenium in the San Joaquin River at Hills Ferry without drainage from GWD and the DSA.

Column 11 - estimated historic levels of selenium at Hills Ferry assuming the flows and selenium concentrations for the DSA and GWD set forth previously. ((5) x (6)) + ((7) x (8)) + ((9) x (10)) ÷ (2)

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((3) x (6)) + ((7) x (8)) ÷ ((9) + (3) + (7))

Table V-14
Comparison of Estimated Selenium Concentrations
in the San Joaquin River at Hills Ferry (below Merced River)
Based on Loading Estimates with
Water Quality Sampling Data

Month	(1) Estimated Historic SJR Se w/ GWD & DSA Drain. Flows ug/L	(2) Revised Estimated Historic SJR Se w/revised GWD & DSA Dr. Flows ug/L	(3) SJR Se Conc. from Calibrated SJRIO-1 ug/L	(4) Measured SJR Se Conc. from USGS ug/L
WY 1984				
May	1.83	---	0.8	---
June	3.44	---	1.9	---
July	4.50	---	3.1	---
August	2.69	---	2.9	---
Sept.	1.20	---	0.6	---
WY 1985				
Oct.	0.78	0.78	0.8	---
Nov.	1.35	1.35	1.1	---
Dec.	0.96	0.96	1.2	---
Jan.	5.54	2.48	2.5	---
Feb.	7.51	7.51	7.4	---
March	9.32	6.85	6.4	---
April	8.68	6.93	7.2	---
May	8.89	5.82	5.8	---
June	7.36	6.36	6.6	6.5
July	5.27	4.54	5.0	6.5
Aug.	5.38	4.47	3.9	4.0
Sept.	3.06	2.3	1.5	2.0

(1) From Table V-13, Column 11
(2) From Table V-15, Column 11
(3) SJRIO-1 is the SWRCB San Joaquin River Input-Output Model

Table V-15(a)

REVISED
ESTIMATED SAN JOAQUIN RIVER SELENIUM CONCENTRATIONS BASED ON LOAD ESTIMATES W/Y 1985 (DRY)

(1) Month	(2) Historic SJR River Bl. Mer. (af/m)	(3) Total DSA Drain Flows (af/m)	(4) Div. of Drn. Fl. by GWD (af/m)	(5) Direct Dist. By DSA Drns. (af/m)	(6) DSA Drain Ave. Se. Conc. (ug/l)	(7) GWD Discharge Flow (af/m)	(8) GWD Discharge Se. Conc. (ug/l)	(9) SJR Flows w/o GWD & DSA (af/m)	(10) Bkgnd. Se. Conc. w/o GWD & DSA (ug/l)	(11) Est. Hist. SJR Se. w/ GWD & DSA (ug/l)	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)
OCTOBER	53,080	5,210	4,555	655	23	0	5.0	52,425	0.5	0.78	2.53
NOVEMBER	42,170	6,150	5,462	688	40	1,925	5.0	39,557	0.5	1.35	5.78
DECEMBER	77,480	5,667	5,238	429	64	1,925	5.0	75,126	0.5	0.96	4.96
JANUARY	55,500	4,911	3,300	1,611	52	6,000	5.0	47,889	0.5	2.48	5.26
FEBRUARY	42,600	5,331	0	5,331	43	16,000	5.0	21,269	0.5	7.51	5.26
MARCH	57,470	10,161	4,000	6,161	48	16,000	5.0	35,309	0.5	7.51	7.51
APRIL	54,420	9,800	3,000	6,800	48	6,000	5.0	41,620	0.5	6.85	9.52
MAY	44,950	9,843	4,500	5,343	45	280	5.0	39,327	0.5	6.93	9.08
JUNE	37,450	8,216	2,400	5,816	38	280	5.0	31,354	0.5	5.82	9.38
JULY	36,090	7,463	2,000	5,463	27	200	5.0	30,427	0.5	6.36	8.26
AUGUST	38,520	8,000	1,500	6,500	24	0	5.0	32,020	0.5	4.54	5.72
SEPTEMBER	37,940	6,705	2,000	4,705	15	0	5.0	33,235	0.5	4.47	5.20
TOTAL	577,670	87,457	37,955	49,502		48,610		479,558			
AVERAGE					39		5.0		0.5	4.19	6.34

Column 2 - the San Joaquin River Flow measured by USGS at Hills Ferry (a sampling station just below its confluence with the Merced River).

Column 3 - total drain flows from the DSA assuming no regulation by GWD (Table V-7).

Column 4 - estimated diversions of drainage water from the DSA by GWD (Table V-8).

Column 5 - estimated amount of drainage water from the DSA which was not taken for use within the GWD. ((3) - (4))

Column 6 - average monthly selenium concentrations of combined surface drainage from the DSA as developed by Summers Engineers (1986) and shown in Table V-4.

Column 7 - estimated discharge from the GWD (see Table V-9).

Column 8 - estimated historical selenium concentration in the GWD discharge based on past observations by Fish and Game staff and available monitoring data.

Column 9 - San Joaquin River flows minus the effects of drainage discharge from the DSA or GWD. ((2) - (5) - (7))

Column 10 - estimated background concentration of selenium in the San Joaquin River at Hills Ferry without drainage from GWD and the DSA.

Column 11 - estimated historic levels of selenium at Hills Ferry assuming the flows and selenium concentrations for the DSA and GWD set forth previously. ((5) x (6)) + ((7) x (8)) + ((9) x (10)) ÷ (2)

Column 12 - estimated selenium concentration at Hills Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((3) x (6)) + ((7) x (8)) ÷ ((9) + (3) + (7))

Table V-15(b)

Additional Estimates W.Y. 1985 (Dry)

(1) Month	(12) Est. Present SJR Se w/ Dr Bypass (ug/l)	(13) Est. Present SJR Fl w/ Byps (af/m)	(14) New Fl to get 5 ppb Se (af/m)	(15) All Drain Se (ug/l)	(16) All Drain Se. (lbs)	(17) Minus Lbs to get 5 ppb Se (lbs)	(18) % Se Load Red to 5 ppb (%)	(19) Minus Lbs to get 2 ppb Se (lbs)	(20) % Se Load Red to 2 ppb (%)	(21) Effluent Limits to 5 ppb (lbs)	(22) Effluent Limits to 2 ppb (lbs)
OCTOBER	2.53	57,635	0	23	326	0	0	92	28	326	234
NOVEMBER	5.78	47,632	7,759	40	668	116	17	515	77	553	153
DECEMBER	4.96	82,718	0	64	986	0	0	686	70	986	300
JANUARY	5.26	58,800	3,191	52	694	46	7	542	78	648	152
FEBRUARY	7.51	42,600	22,264	43	623	329	53	669	107	294	0
MARCH	9.52	61,470	57,923	48	1,325	843	64	1,311	99	482	14
APRIL	9.08	57,420	48,773	48	1,278	710	56	1,152	90	568	126
MAY	9.38	49,450	45,156	45	1,204	663	55	1,038	86	541	165
JUNE	8.26	39,850	27,091	38	848	407	48	716	84	441	132
JULY	5.72	38,090	5,680	27	548	91	17	415	76	457	132
AUGUST	5.20	40,020	1,648	24	522	27	5	379	73	495	142
SEPTEMBER	2.93	39,940	0	15	273	0	0	117	43	273	156
TOTAL		615,625	219,485		9,295	3,231		7,633			
AVERAGE	6.34			39			.27		76		

Column 12 - estimated selenium concentration at Hi''s Ferry (below the Merced River) assuming that drainage from the DSA is bypassed directly to the River. ((9) x (10)) + ((3) x (6)) + ((7) x (8)) ÷ ((9) + (3) + (7))

Column 13 - estimated San Joaquin River flows at Hills Ferry assuming the bypass of DSA drainage by Grassland WD. (9) + (3) + (7)

Column 14 - additional dilution flows needed to attain 5 ppb at Hills Ferry. ((13) x (12) - 5.0) ÷ (5.0 - 0.2)

Column 15 - average monthly selenium concentrations of combined surface and subsurface drainage from the DSA as developed by Summer's Engineers (1986) and shown in Table V-4.

Column 16 - pounds of selenium from DSA. ((3) x (6)) ÷ 368

Column 17 - reduction in selenium load needed to achieve 5 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 5.0) ÷ ((6) - 5.0) x (13) x (6) ÷ 368

Column 18 - percent reduction in selenium load from the DSA to achieve 5 ppb at Hills Ferry. ((17) ÷ (16)) x 100

Column 19 - reduction in selenium load needed to achieve 2 ppb at Hills Ferry on the San Joaquin River assuming the bypass of drainage by GWD. ((12) - 2.0) ÷ ((6) - 2.0) x (13) x (6) ÷ 368

Column 20 - percent reduction in selenium load from the DSA to achieve 2 ppb selenium at Hills Ferry. ((19) ÷ (16)) x 100

Column 21 - allowable load of selenium from DSA to achieve 5 ppb selenium at Hills Ferry (16) - (17)

Column 22 - allowable load of selenium from DSA to achieve 2 ppb selenium at Hills Ferry (16) - (19)

FIGURE V-1 Selected San Joaquin River Basin Total Dissolved Solids Concentrations

NOTE:
The data used are from the San Joaquin River Input - Output model data base (See Appendix C) for WYs 1977 through 1985 and the USBR (July 1986) data base for the period from May 1984 through July 1986. For the USBR stations electrical conductivity measurements (in umho/cm) were converted to total disolved solids concentrations (in ppm) by multiplying by 0.64.

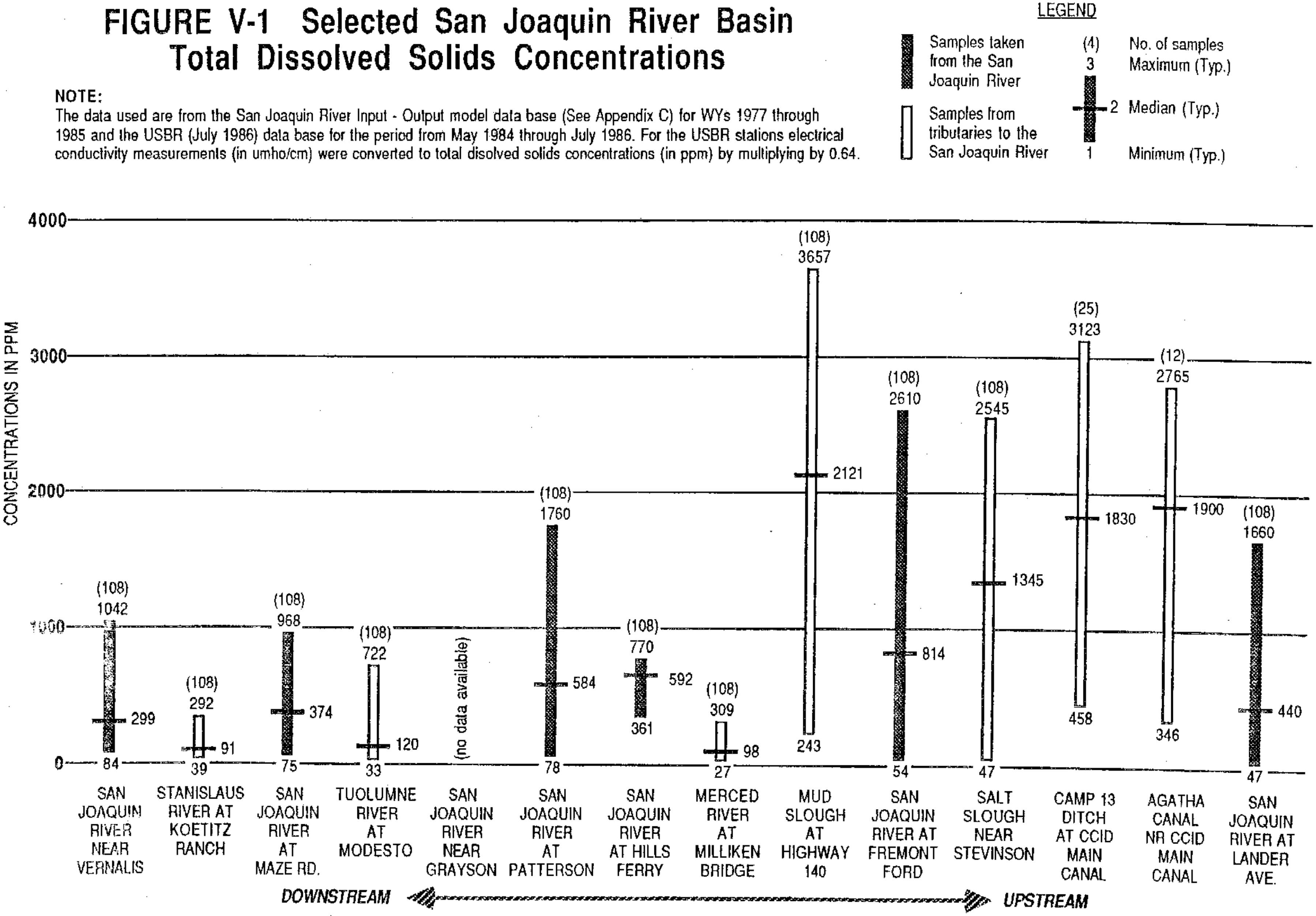


FIGURE V-2 Selected San Joaquin River Basin Boron Concentrations

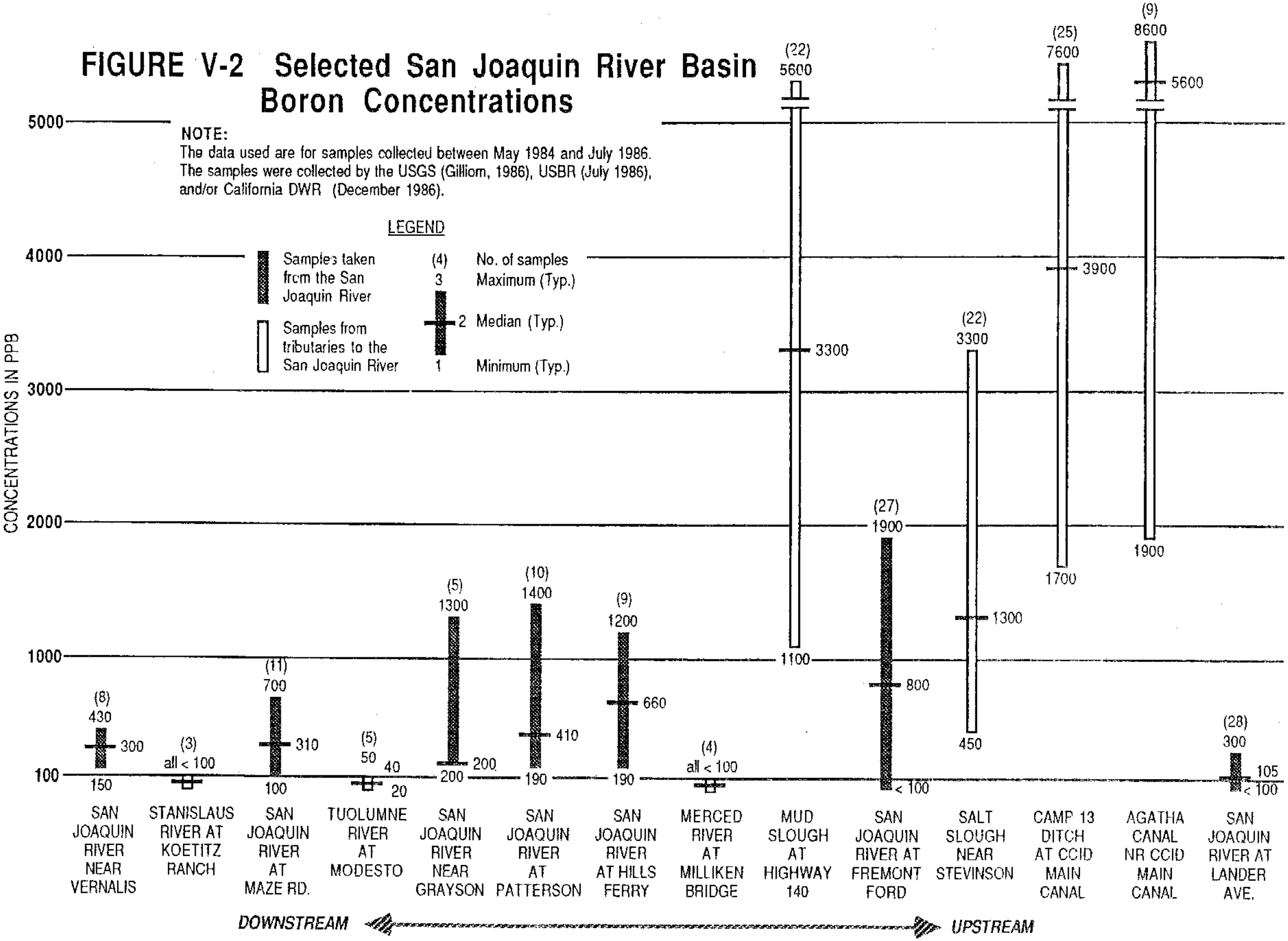


FIGURE V-3 Selected San Joaquin River Basin Selenium Concentrations

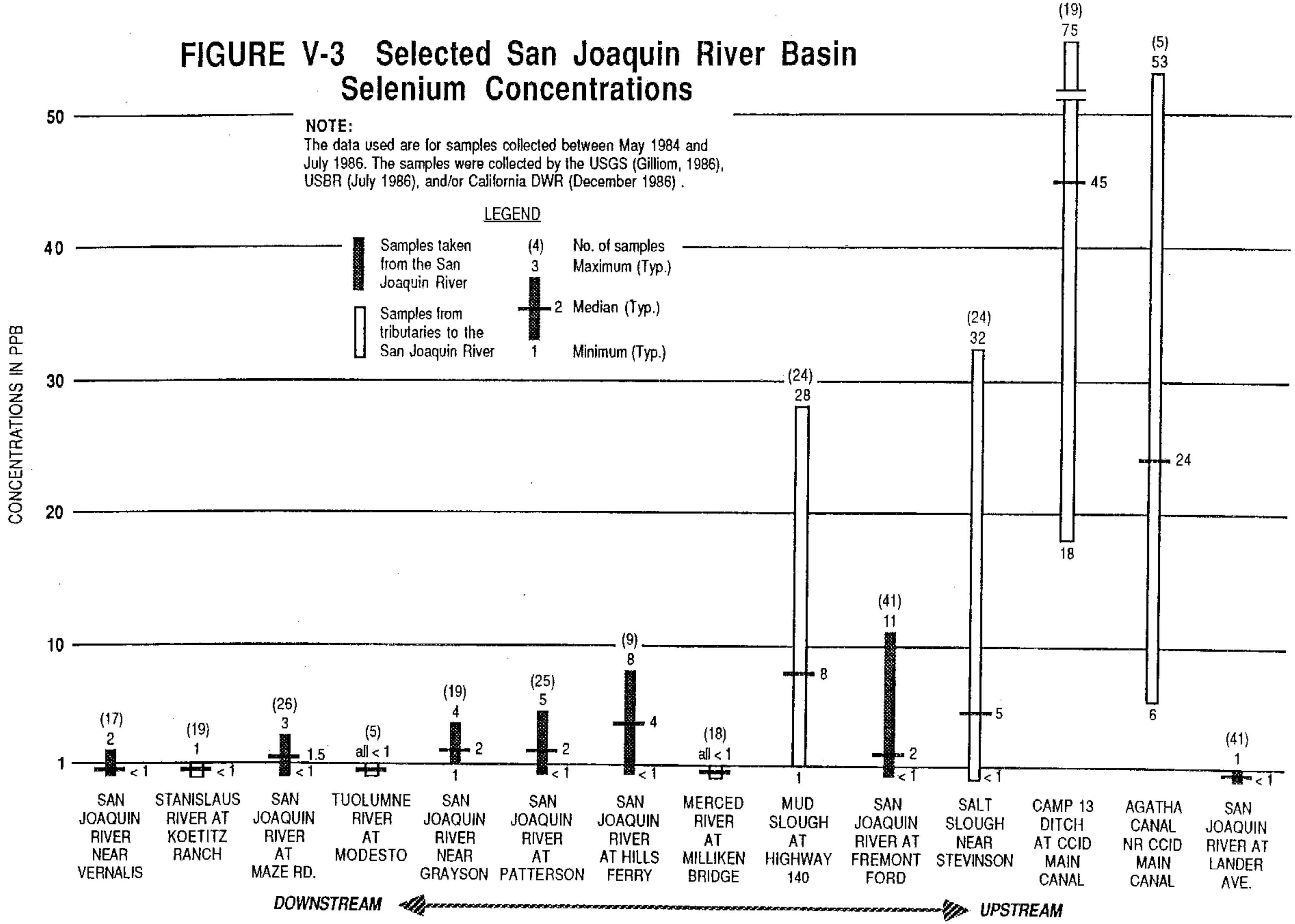


FIGURE V-4 Selected San Joaquin River Basin Molybdenum Concentrations

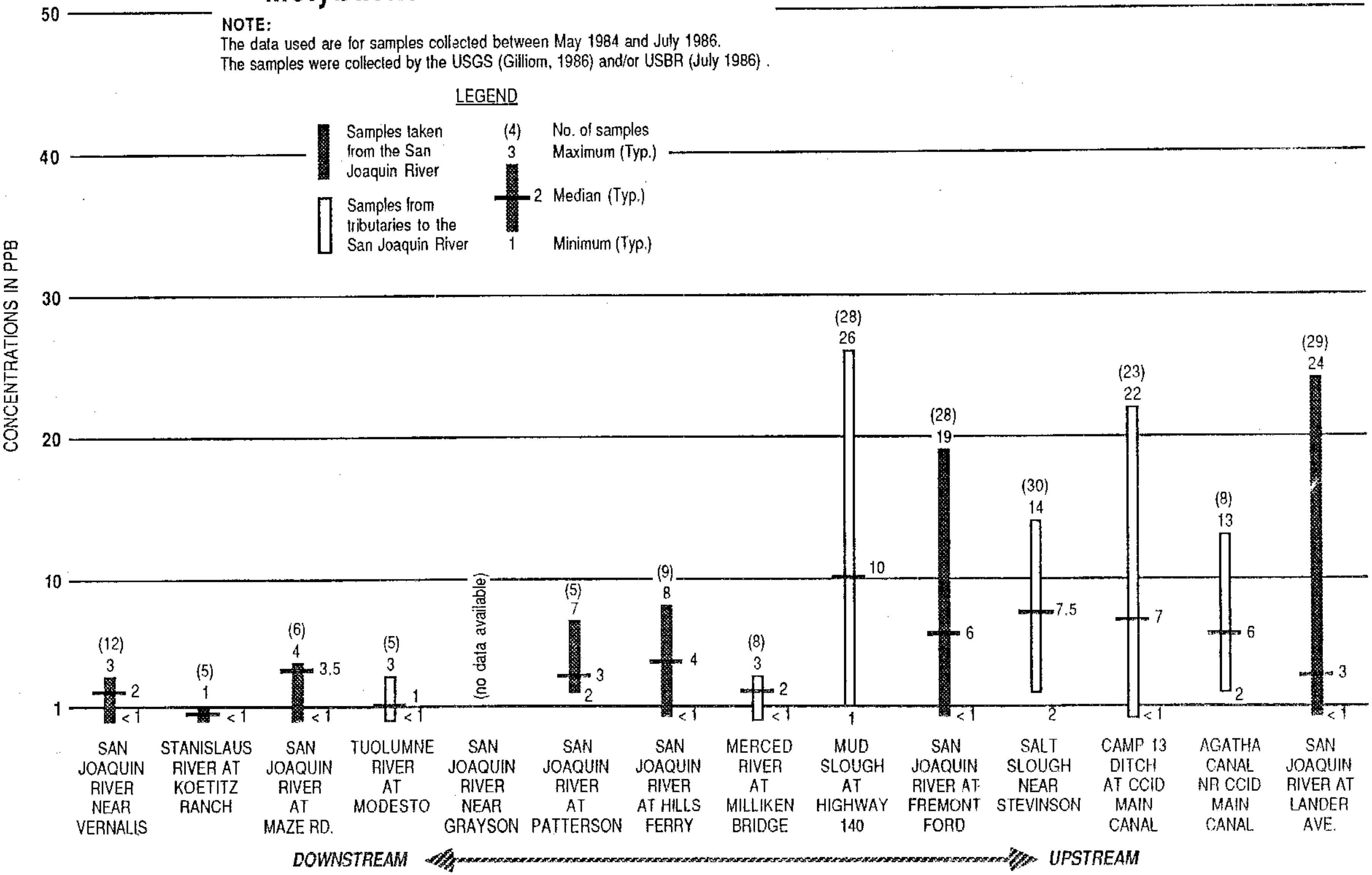


FIGURE V-5 Sources of Flow, Salinity, and Boron in the San Joaquin River upstream of the Merced River (WY1979)

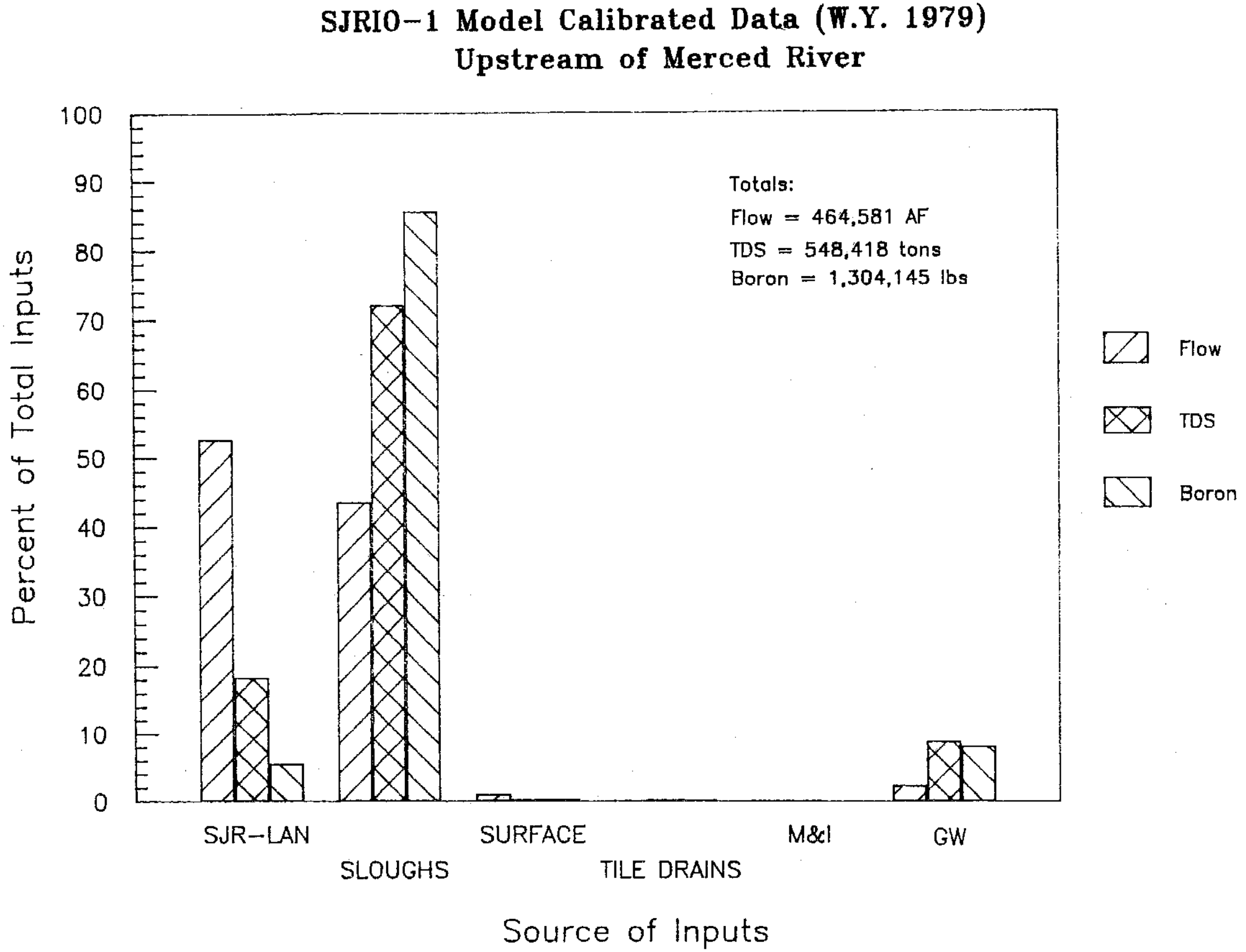


FIGURE V-6 Sources of Flow, Salinity, and Boron in the San Joaquin River upstream of the Merced River (WY1981)

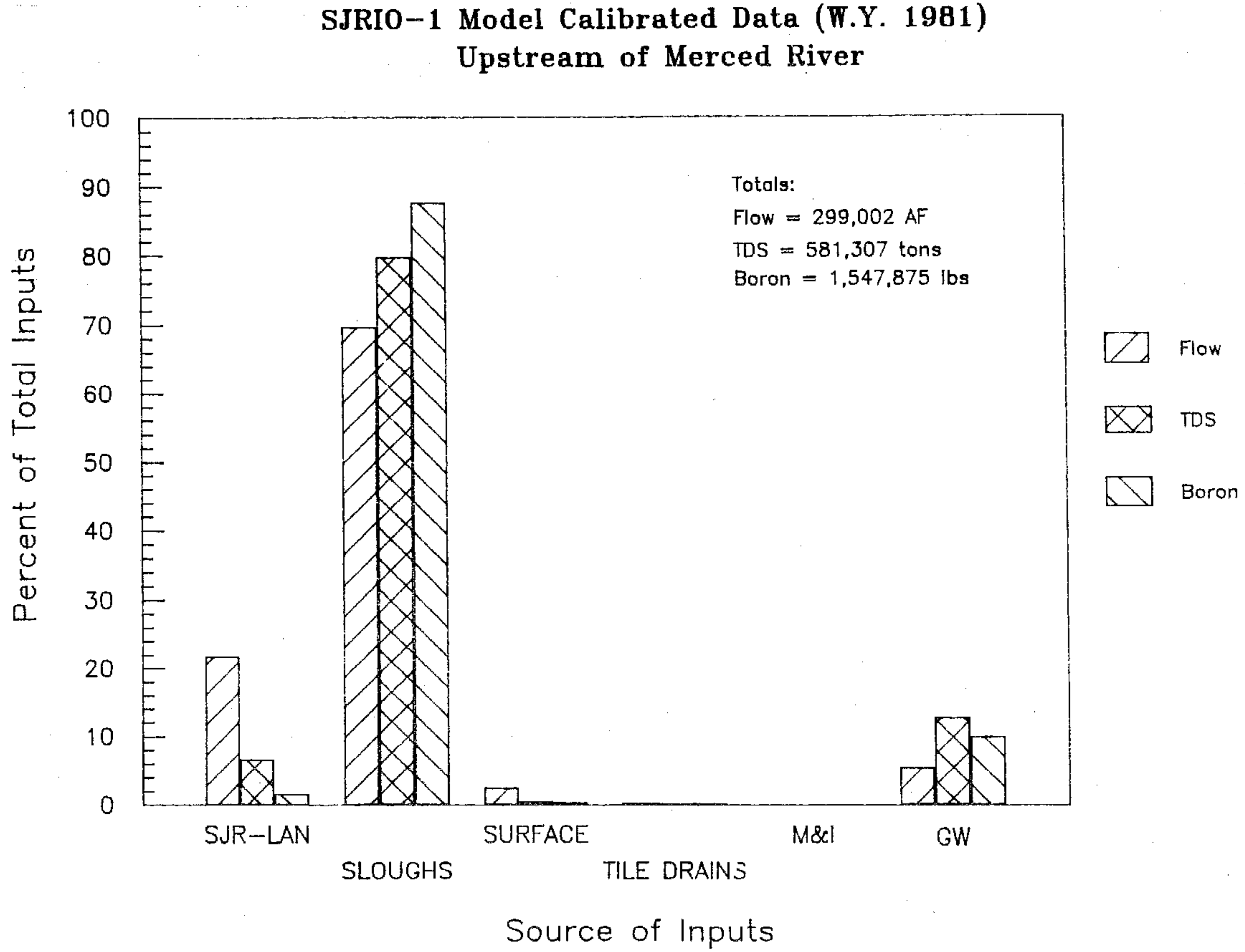


FIGURE V-7 Salinities in the San Joaquin River at Hills Ferry and in Mud and Salt Sloughs as calculated by the calibrated SJRIO-1 model (WY 1979)

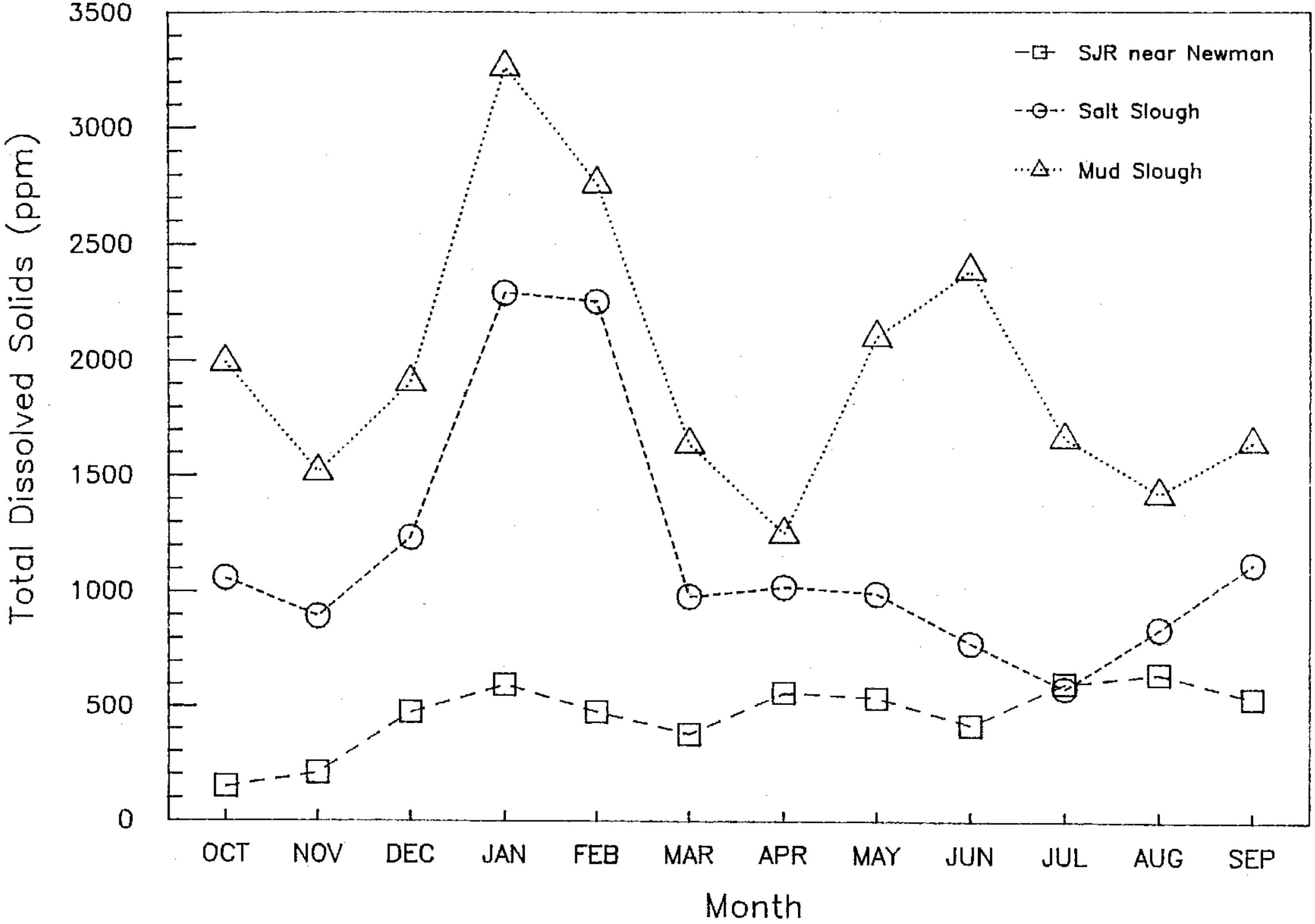


FIGURE V-8 Salinities in the San Joaquin River at Hills Ferry and in Mud and Salt Sloughs as calculated by the calibrated SJRIO-1 model (WY 1981)

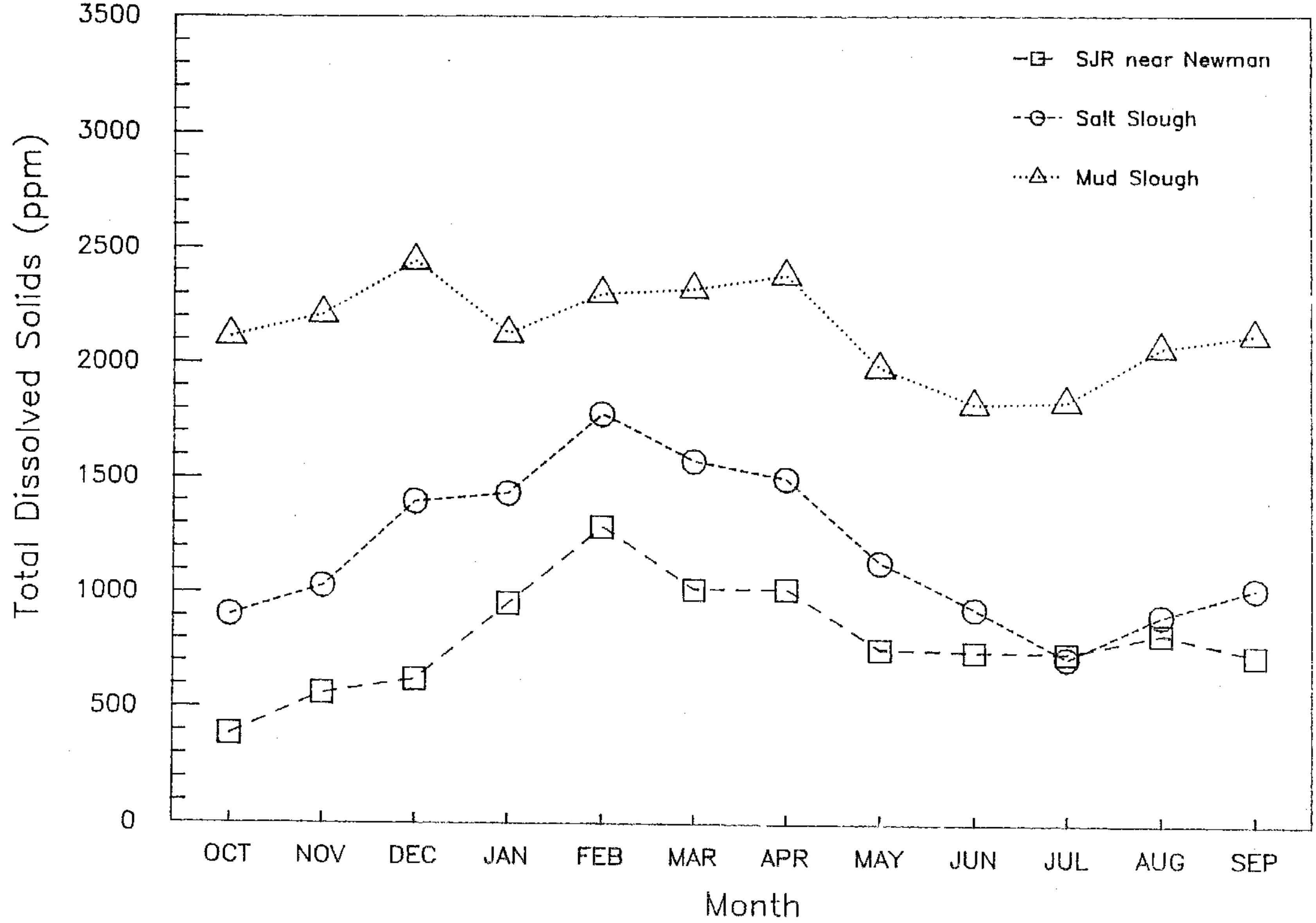


FIGURE V-9 Flow, Salinity, and Boron Inputs to the San Joaquin River (WY 1981)

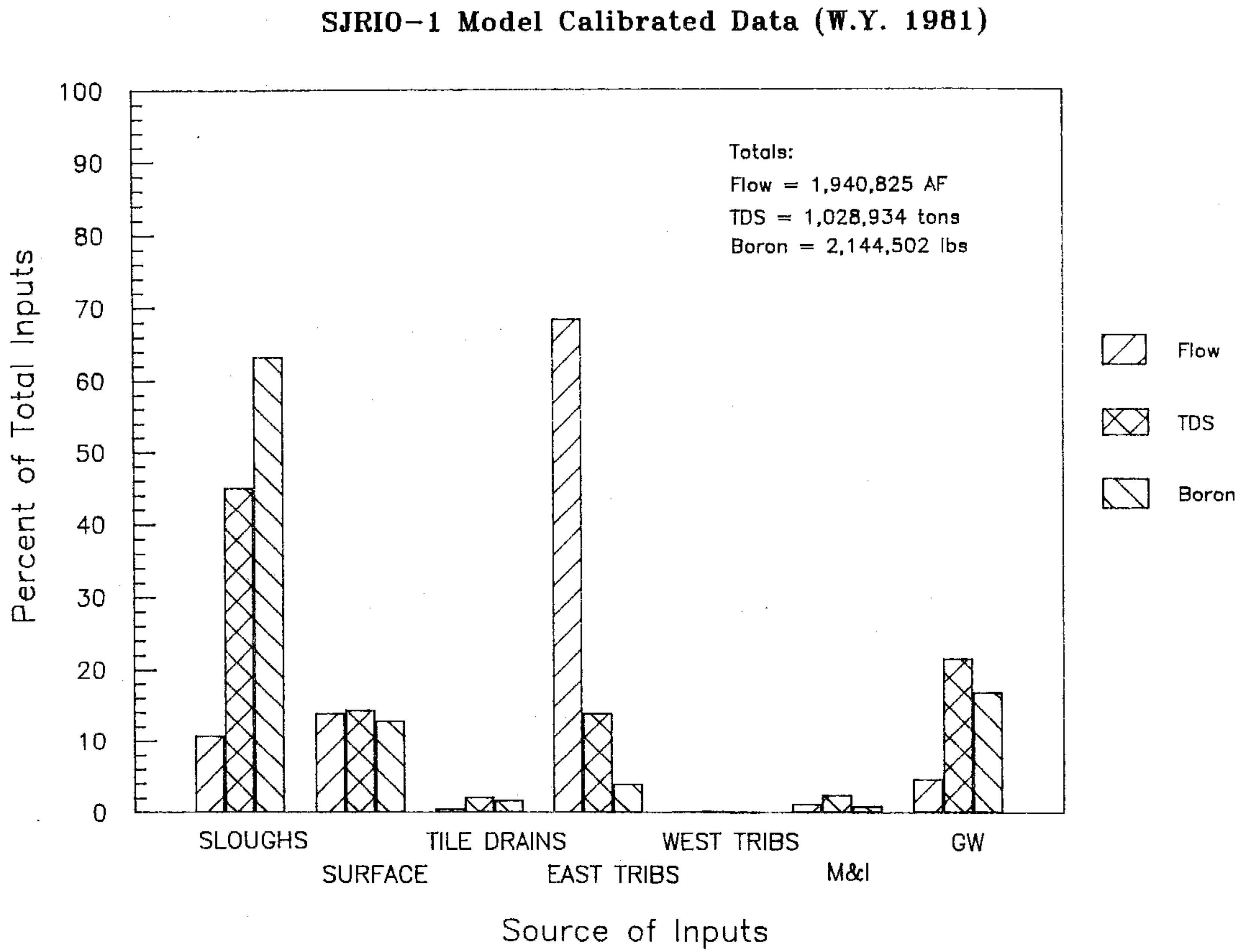


FIGURE V-10 Flow, Salinity, and Boron Inputs to the San Joaquin River (WY 1984)

SJRIO−1 Model Calibrated Data (W.Y. 1984)

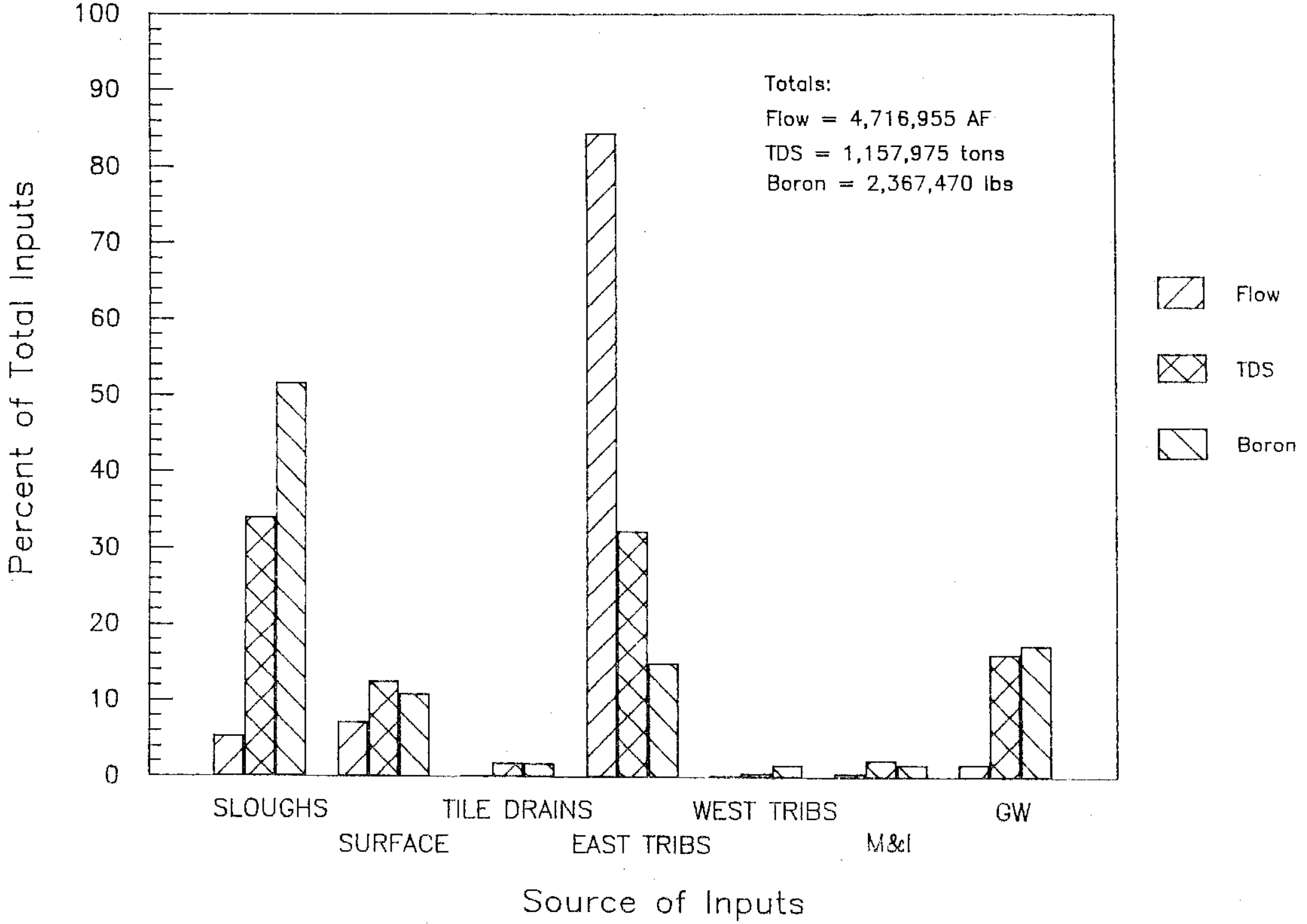


FIGURE V-11 Flow, Salinity, and Boron Inputs to the San Joaquin River (WY 1985)

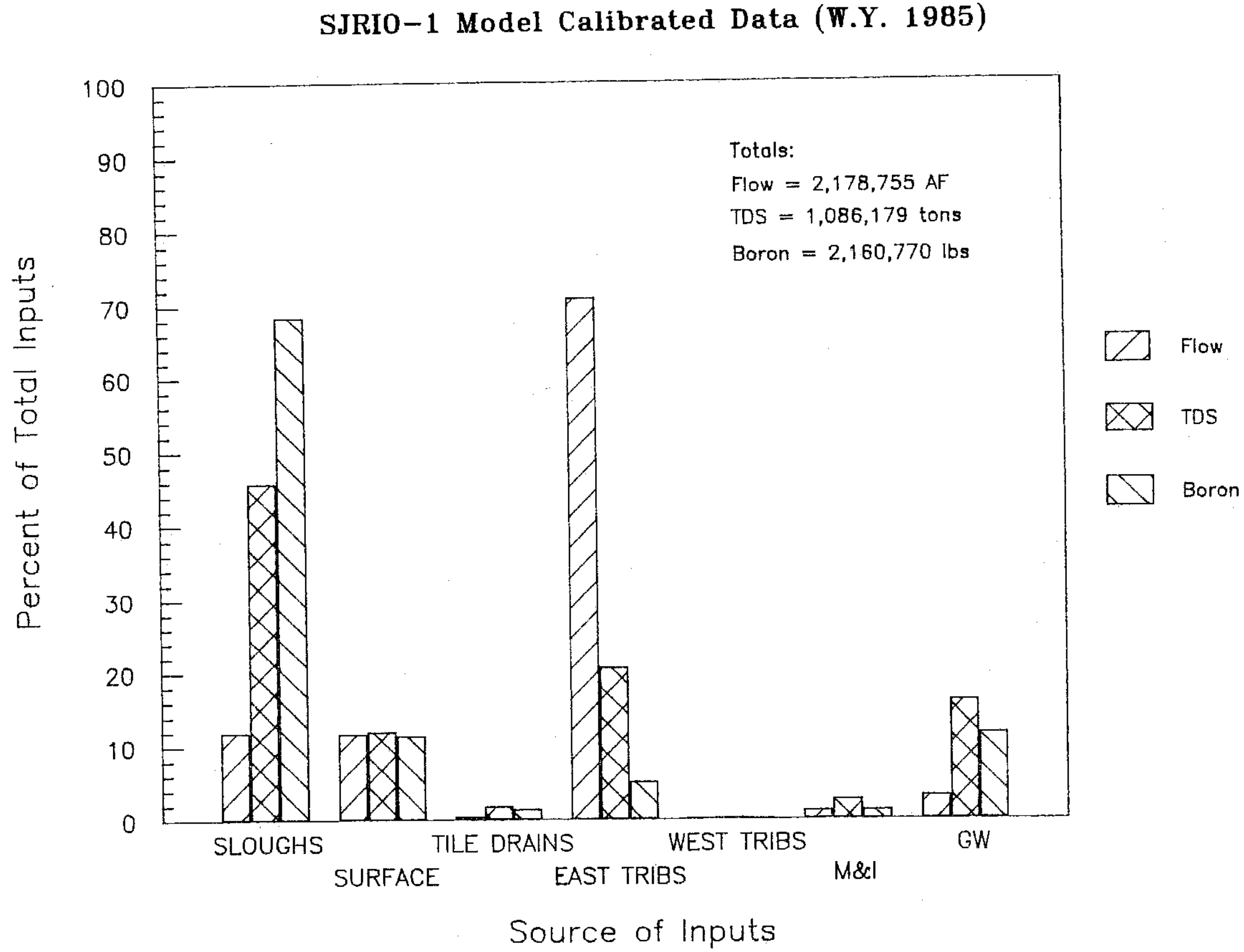


FIGURE V-12 Boron concentrations in the San Joaquin River at Hills Ferry and in Mud and Salt Sloughs as calculated by the calibrated SJRIO-1 model (WY 1979)

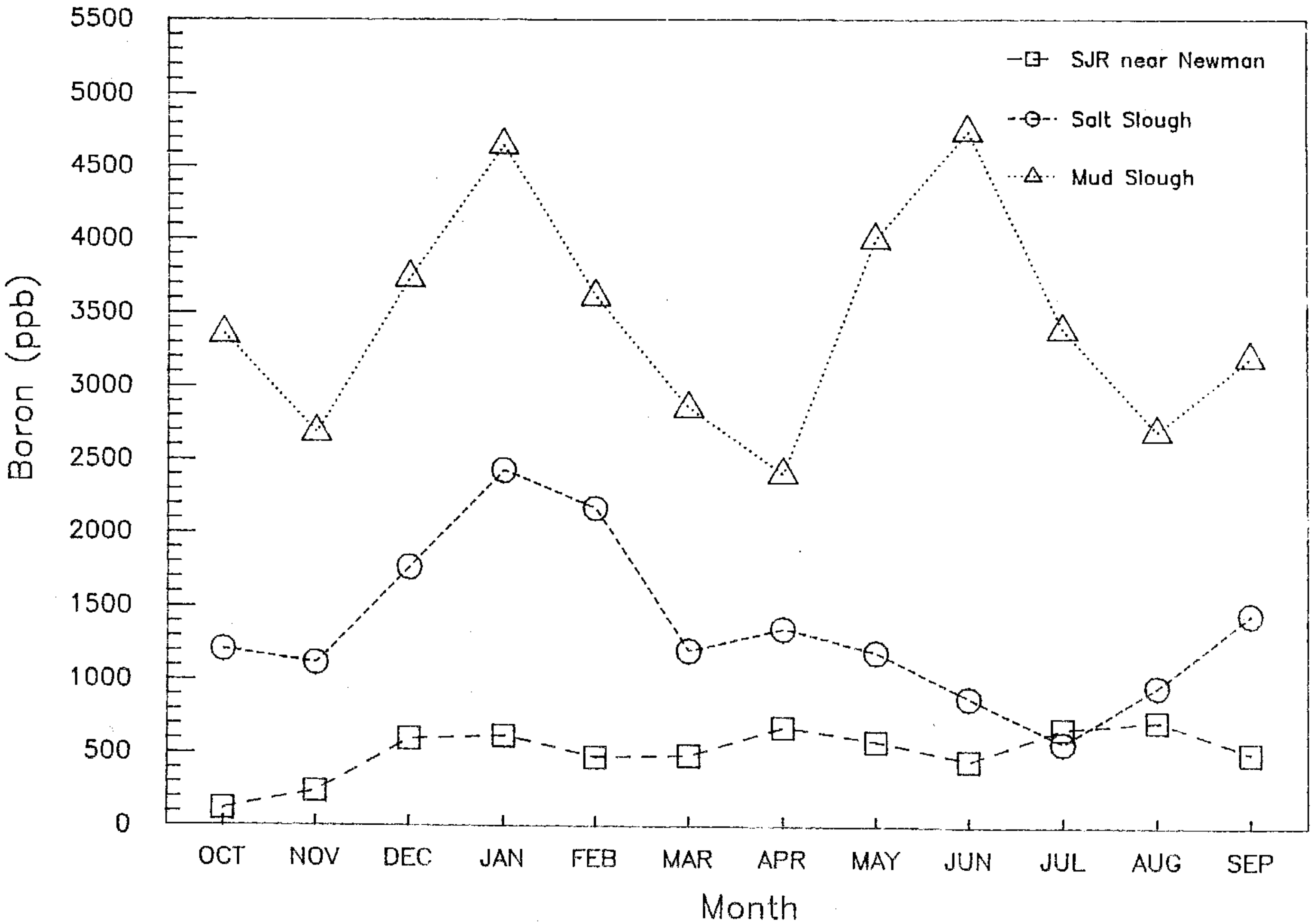


FIGURE V-13 Boron concentrations in the San Joaquin River at Hills Ferry and in Mud and Salt Sloughs as calculated by the calibrated SJRIO-1 model (WY 1981)

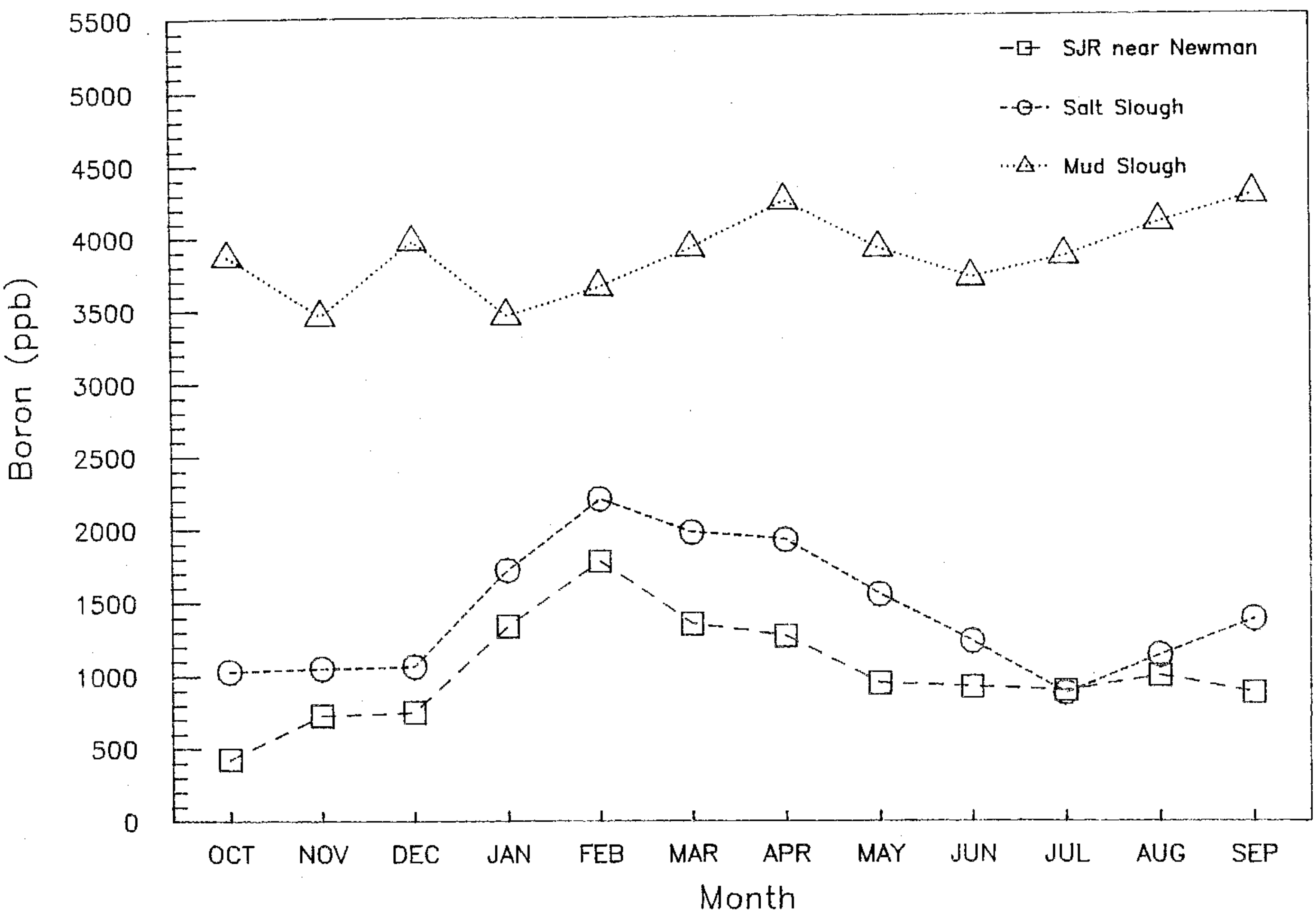


FIGURE V-14 Flow, Selenium, and Molybdenum Inputs to the San Joaquin River (WY 1985)

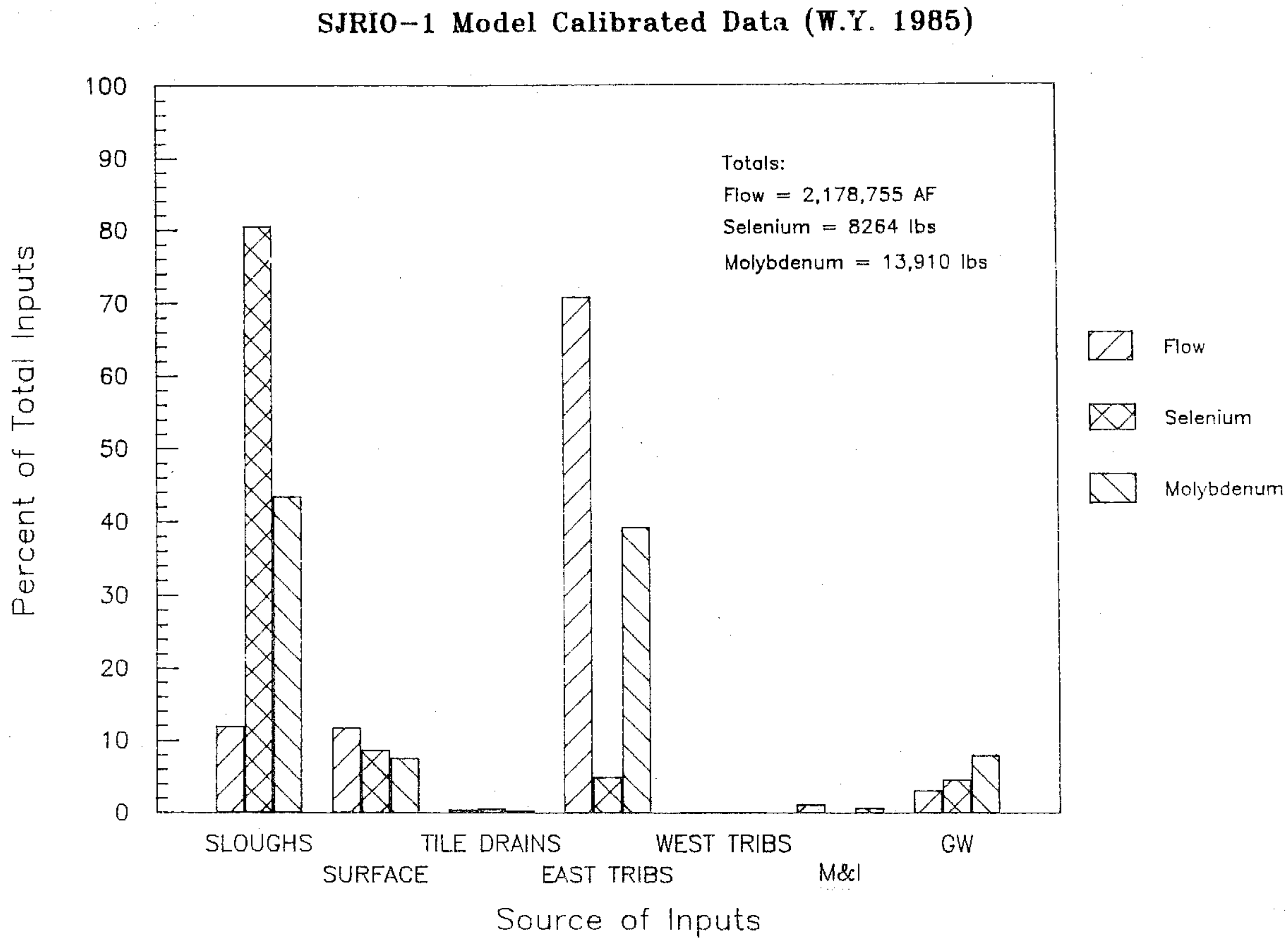


FIGURE V-15 Drainage Study Areas

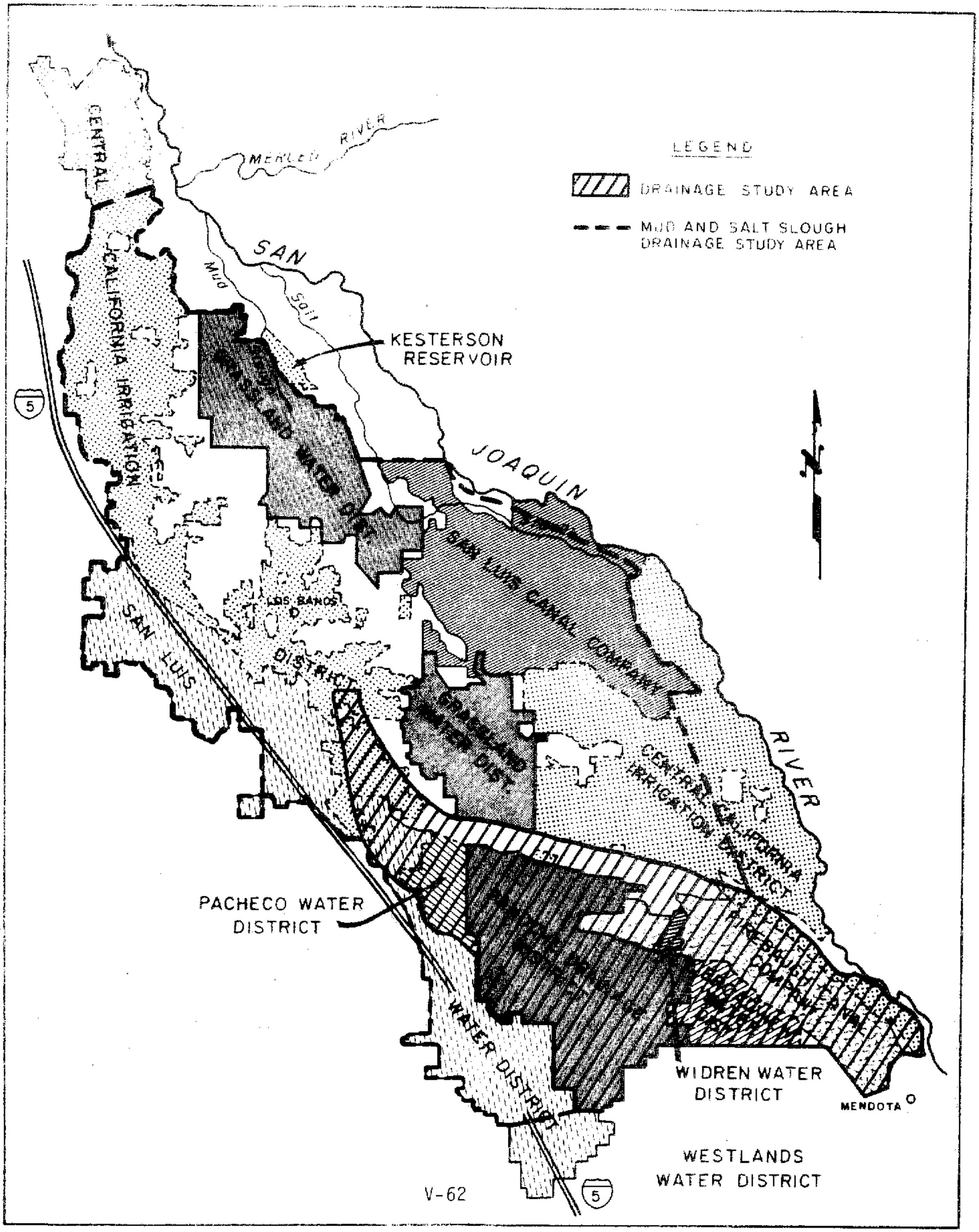


FIGURE V-16 Tile Drained Lands in the Mud and Salt Slough Drainage Areas

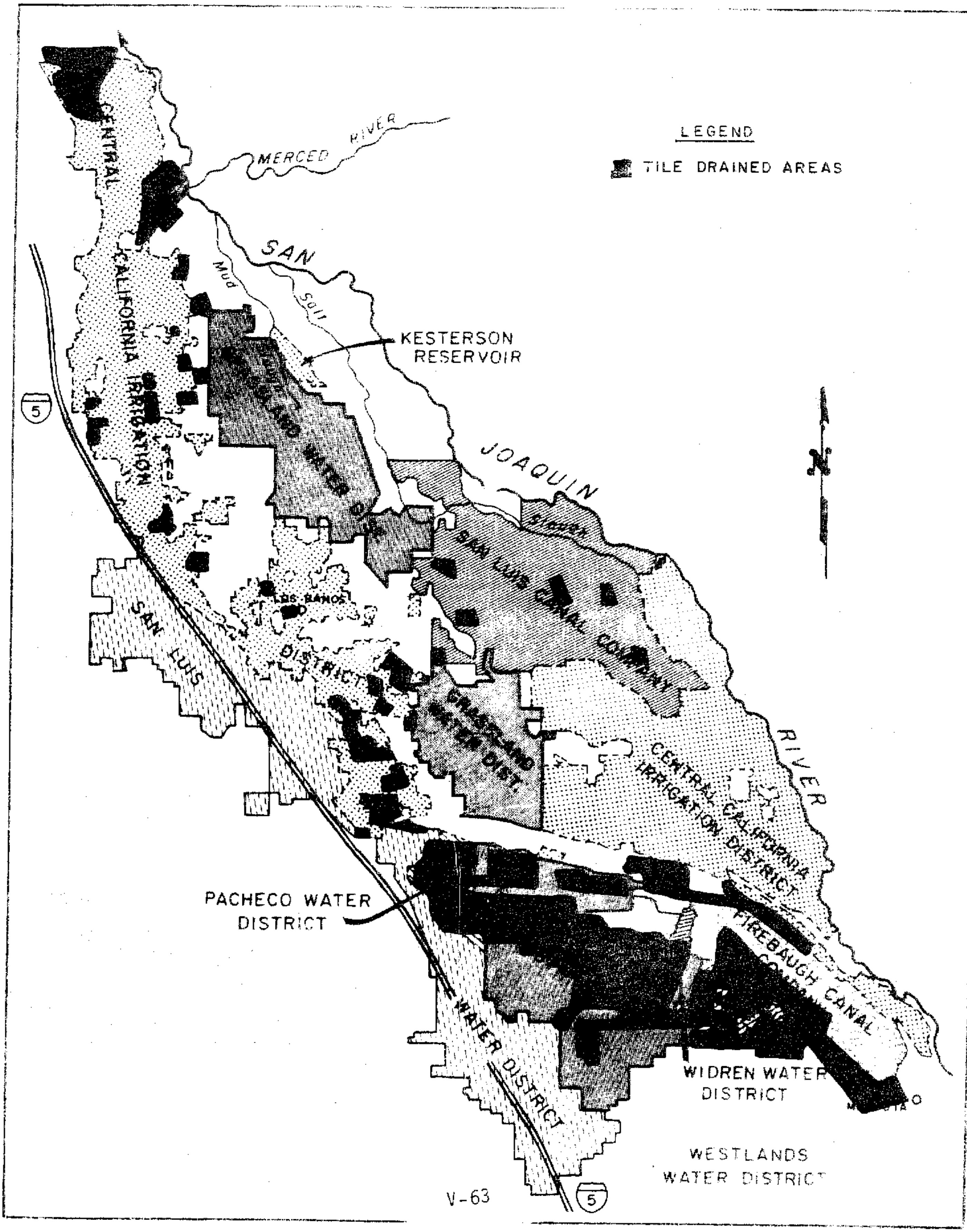
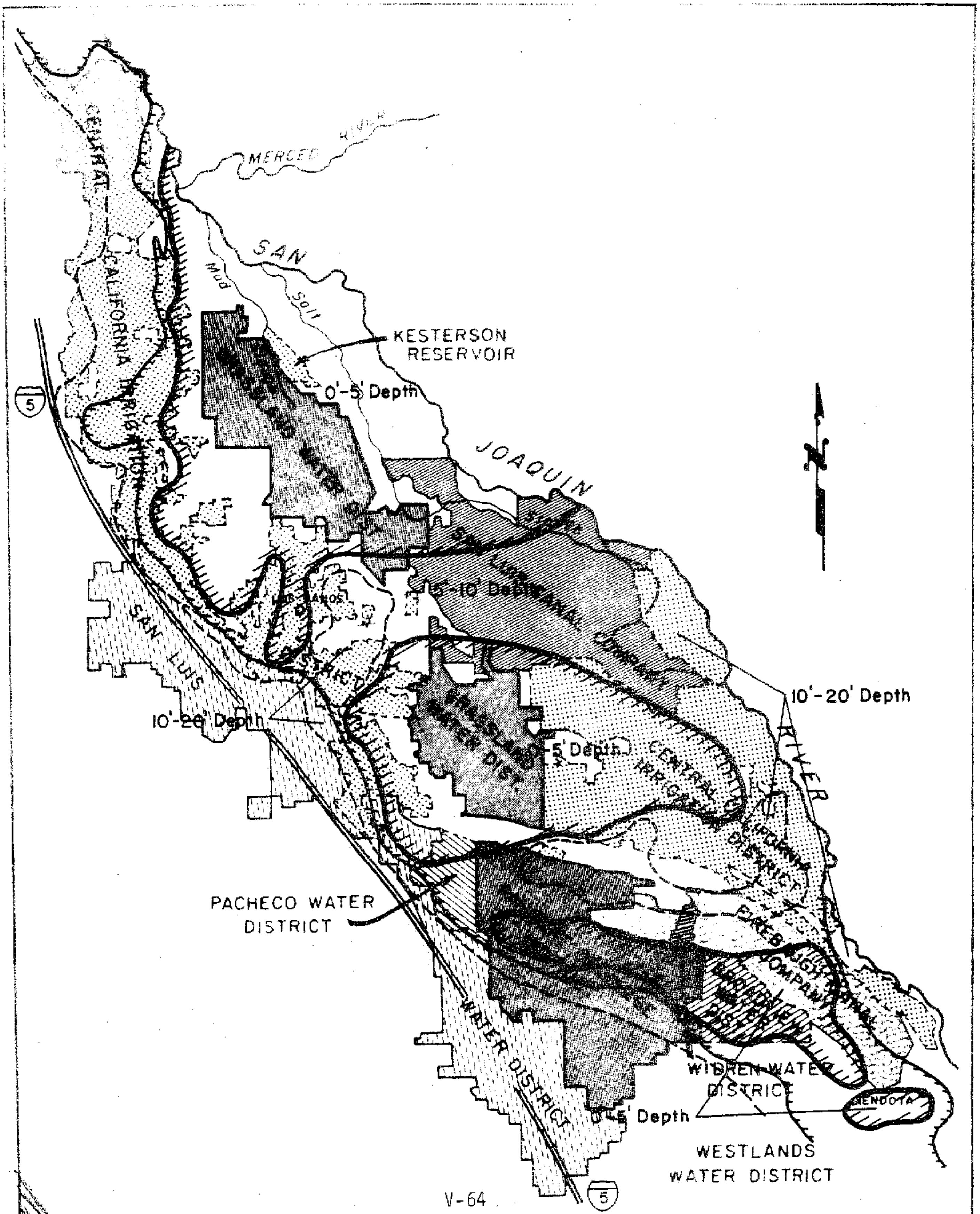


FIGURE V-17 Depth to Free Water in the Mud and Salt Slough Drainage Areas



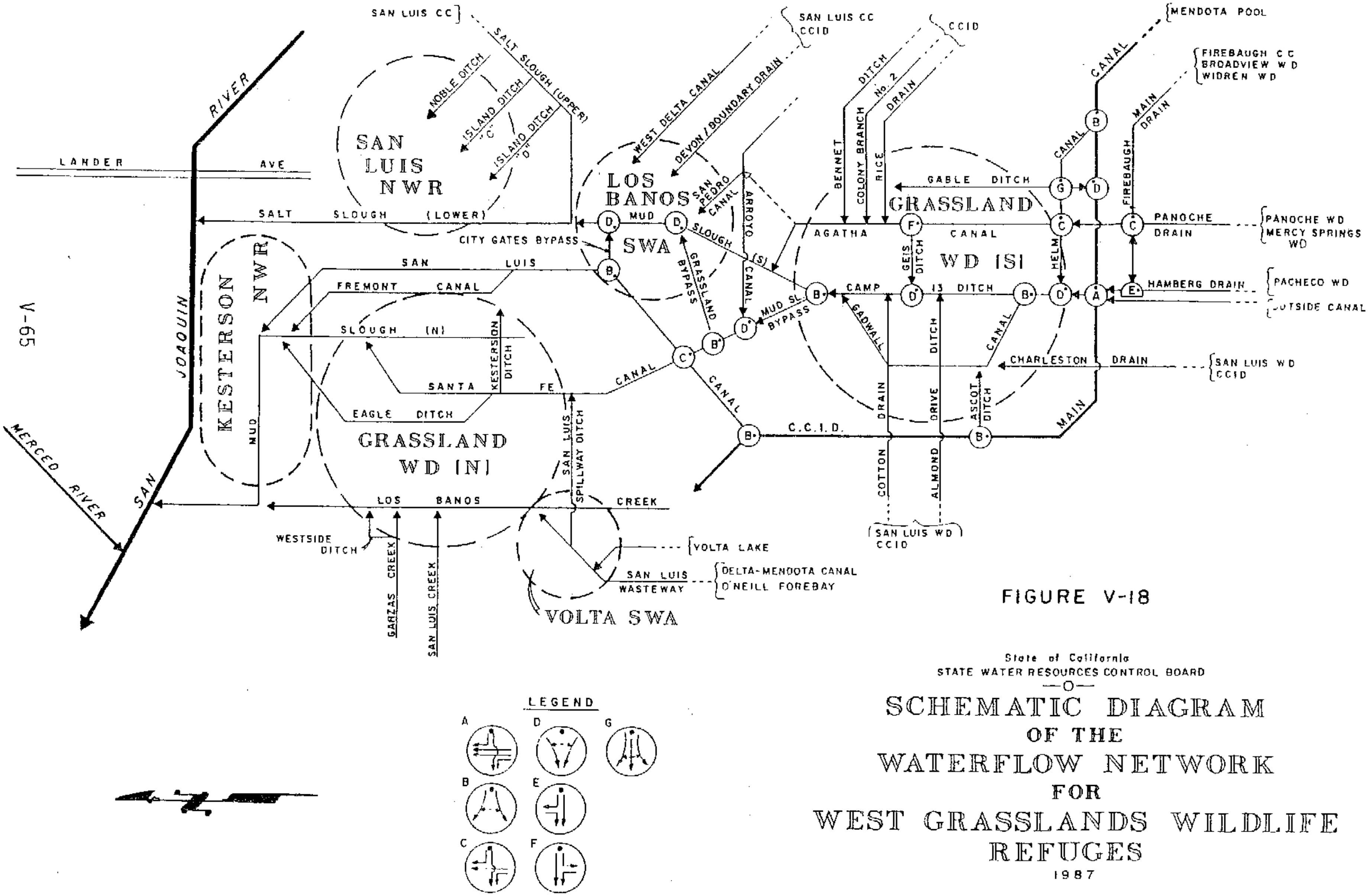


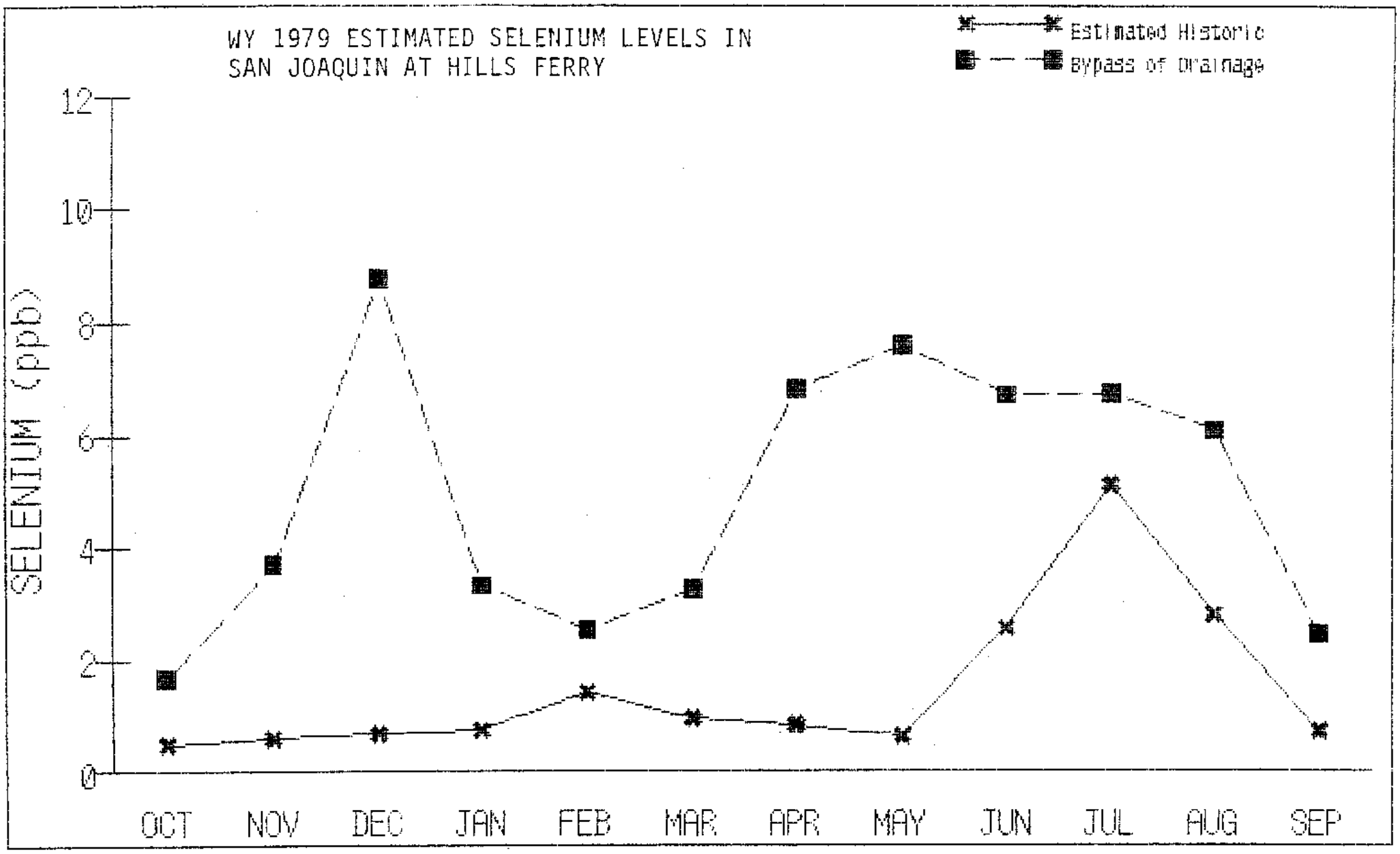
FIGURE V-18

State of California
STATE WATER RESOURCES CONTROL BOARD

SCHEMATIC DIAGRAM OF THE WATERFLOW NETWORK FOR WEST GRASSLANDS WILDLIFE REFUGES

1987

FIGURE V-19



WY 1979 ESTIMATED SELENIUM LEVELS IN
SAN JOAQUIN AT HILLS FERRY
Estimated Historic
Bypass of Drainage
SELENIUM (ppb)
12
10
8
6
4
2
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OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE V-20

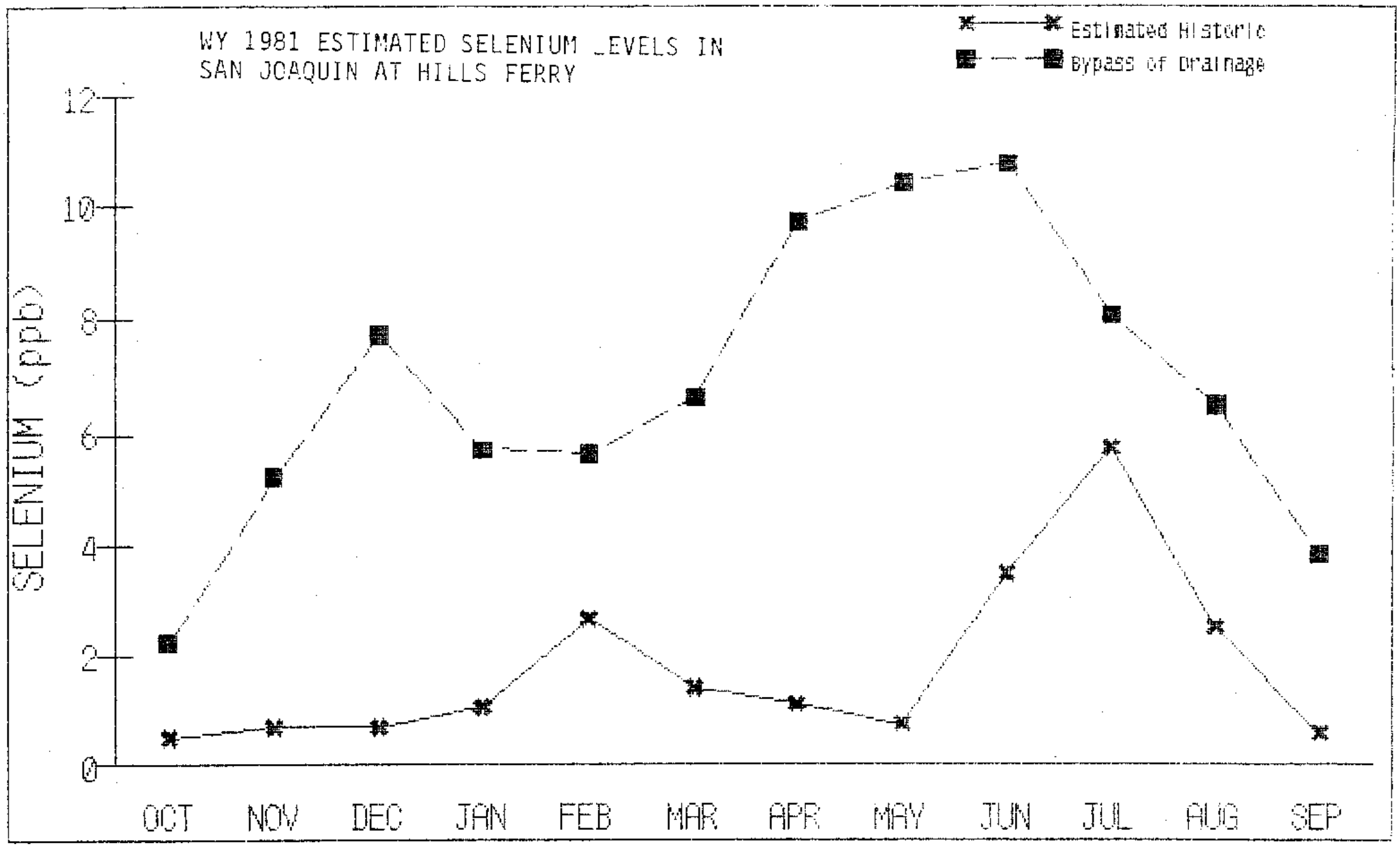
WY 1981 ESTIMATED SELENIUM LEVELS IN
SAN JOAQUIN AT HILLS FERRY
Estimated Historic
Bypass of Drainage
SELENIUM (ppb)
12
10
8
6
4
2
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP

FIGURE V-21

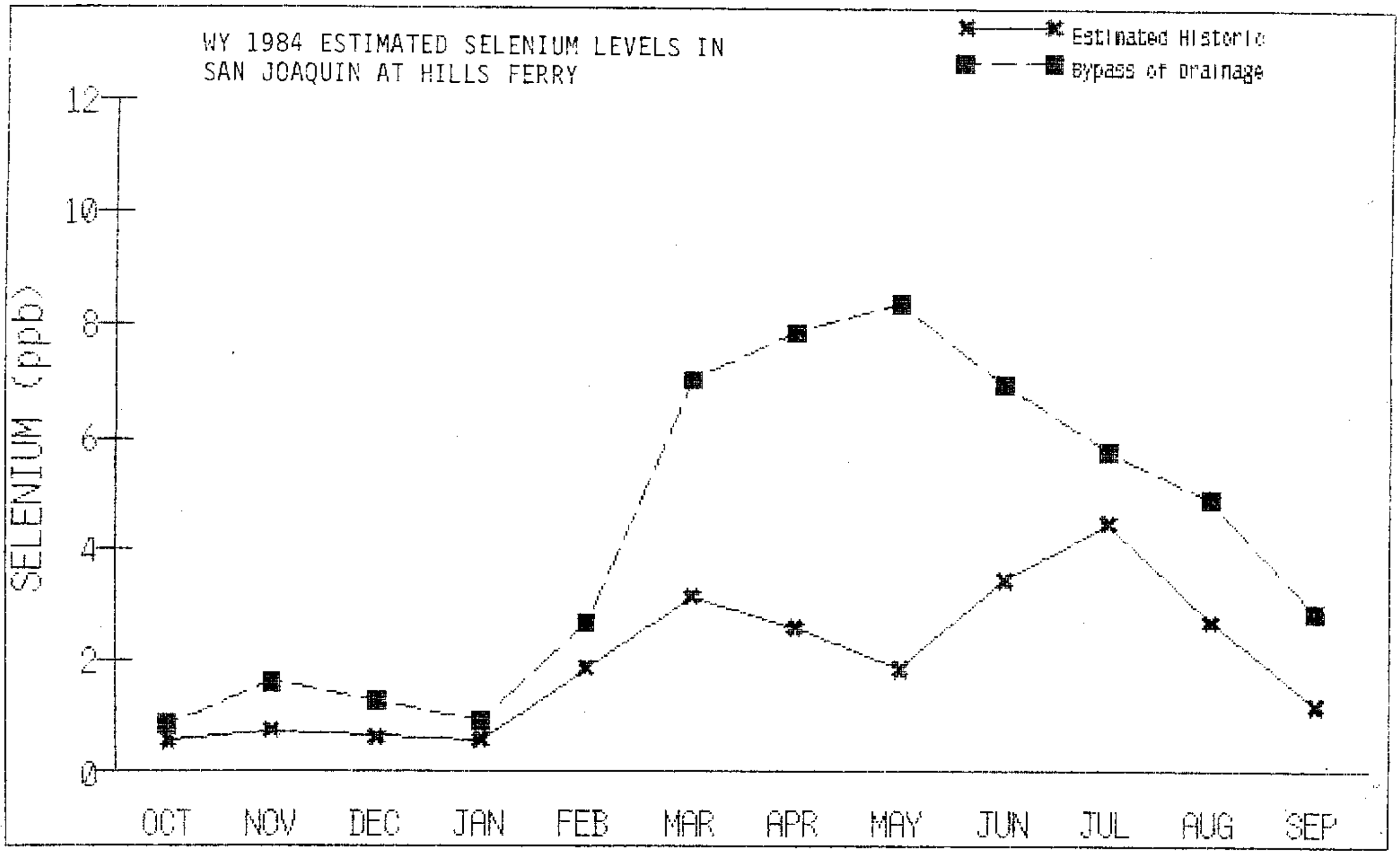
WY 1984 ESTIMATED SELENIUM LEVELS IN
SAN JOAQUIN AT HILLS FERRY
Estimated Historic
Bypass of Drainage
SELENIUM (ppb)
12
10
8
6
4
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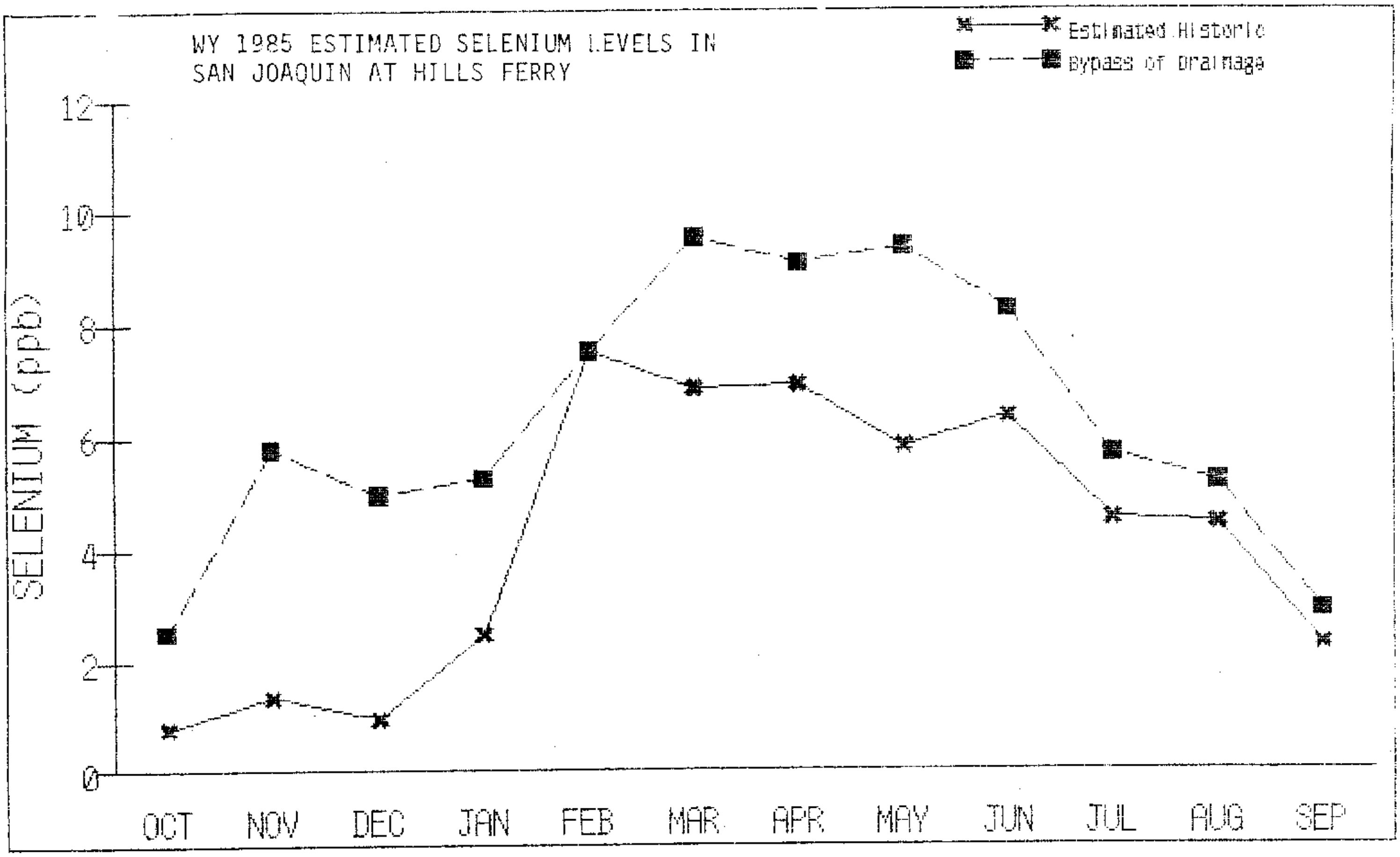
FIGURE V-22



WY 1985 ESTIMATED SELENIUM LEVELS IN
SAN JOAQUIN AT HILLS FERRY
Estimated Historic
Bypass of Drainage
SELENIUM (ppb)
12
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JUL
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SEP

VI. AGRICULTURAL ECONOMY OF THE DRAINAGE STUDY AREA

Introduction

This chapter summarizes data on (1) current cropping patterns, (2) the profitability of present crops and future prospects for changes in cropping patterns, (3) a model of farm profitability for the Drainage Study Area (DSA) and (4) a methodology for assessing the economic impacts of drainage costs in both the short and long-term, and impacts on rents and property taxes. This information provides the basis of economic impact analysis presented in Chapter VII. It appears here to give the reader an understanding of the basis for the assumptions inherent in such an analysis and the work that has gone into it. The discussion is rather technical but much summarized over that presented in Appendix G, Chapter 4. Improvements in this analysis can be made if better critical economic data are collected and evaluated. Until such data are available, the reader should consider these as approximations. The methodology described represents our consultant's best attempt to develop a method to assess the economic impacts of water quality regulation on the farm economy in the DSA.

There are several special features of this economic analysis which distinguish it from more conventional methodologies. First, in assessing the profitability of farming, our consultants focused on cropping rotations rather than individual crops. This is important because one can obtain a somewhat misleading impression by looking at the profitability of individual crops taken separately. Low value crops such as barley and wheat have to be grown in rotation with higher value crops such as cotton to control pests and maintain soil conditions. If this is ignored, the profitability of farming operations is overstated.

Second, instead of focusing only on the average profitability of farming our consultants have attempted to deal with the variability in farming conditions by estimating a probability distribution of profits based on the distribution of soil quality in the region. If one follows the conventional practice and calculates only the average profit, this yields a knife-edge situation. Suppose the calculated profit is $100/acre; then, one is forced to conclude that any cost increase less than $100/acre will have no long-term effect such as forcing any land out of production, while a cost increase of $101 causes the entire region to go out of production. In reality, of course, one knows that even a small cost increase may push some marginal, low quality land out of production, while other, high quality land may be able to sustain even large cost increases. Our consultants have sought to capture this reality in the economic model.

Third, instead of following the conventional practice of focusing exclusively on long-term economic impacts (land out of production) and ignoring short-term financial impacts (bankruptcy and turnover in ownership), the consultants have constructed an explicit short-term model based on, admittedly imperfect, information about current financial conditions. A final point should be noted. Most existing regional economic models focus primarily on changes in cropping patterns. In this particular region, no significant change in cropping patterns are anticipated as a consequence of higher drainage costs. There may be changes in irrigation practices, and some land may go out of production, but, as explained below, the basic cropping patterns are expected to be relatively stable for the foreseeable future.

Cropping Patterns

The data on cropping patterns come from the individual water districts. Cropping patterns for most of the districts in the DSA were reviewed. However, because both the overall area that discharges to Mud and Salt sloughs (MSSDA) and the DSA (Figure V-15) cut across district lines to some degree, it was necessary to extrapolate from an 81,113 acre area for which cropping patterns were available ("Drainage Area" in Appendix G) to the DSA. Similarly, the MSSDA roughly corresponds to the term "Broad Area" in this chapter. Cropping patterns for both areas are summarized in Tables VI-1 and VI-2.

Cotton is the major crop grown in both these areas. Data for 1983 are excluded from Tables VI-1 and VI-2 because of the large decrease in cotton acreage in that year (from 120,000 to 90,000 acres) due to the federal Payment-In-Kind (PIK) program. This program paid growers of major crops, including cotton, to keep land out of production in 1983. The PIK program had no long-term effect because cotton acreage rebounded to almost 120,000 acres the following year. It should be noted that almost all the cotton is grown south of State Highway 152 which runs from Los Banos to Chowchilla.

The Broad Area and the Drainage Area are both primarily cotton-growing areas, with some diversification into crops such as processing tomatoes, sugar beets, alfalfa, grains and melons. Overall, this cropping pattern has been constant for more than a decade.

Profitability of Present Crops and Future Prospects

Using current 1986 commodity prices and extrapolating from the Drainage Area (Appendix G, Table 4.3) to the entire 94,480 acres of the DSA, it is estimated that the gross value of agricultural production in the DSA was $77.7M, or about $822/acre (see Table VI-3). In order to translate this into a measure of average profitability, our consultants needed information on production costs. For this purpose the crop budgets prepared by the Fresno County Cooperative Extension Service were used. They are shown in Appendix G, Table 4.8. These costs are intended to represent good management practices, and therefore they may be slightly on the high side. Unfortunately, however, no other source of cost information is available. The costs in the table exclude all fixed costs of production such as depreciation, interest, rent and taxes. The crop yield estimates also come from the crop budgets, and represent averages in the area. In practice, these will vary with soil quality, farming practices, and weather conditions. Average gross profitability of major crops grown in the DSA are shown in Table VI-4. It will be seen that the three most profitable crops are (in descending order) processing tomatoes, sugar beets and cotton.

The data on relative crop profitability might be mistaken to imply that there could be significant changes in cropping patterns within the DSA in the near future, with shifts away from the less profitable crops and towards the more profitable ones. However, several considerations suggest that the present pattern of agricultural production in the DSA - primarily cotton growing, with some diversification into tomatoes, sugar beets, alfalfa, grains and melons - will continue for the foreseeable future. The reasons for this are discussed in detail in Appendix G, Section 4.3.

California agriculture, has experienced a decline in commodity prices over the past five years. Between 1980 and 1985 net income of California farms declined at an annual rate of 2.1 percent in nominal terms, and 7.6 percent in real terms. Some data on trends in prices received by Fresno County farmers for various crops are presented in Appendix G, Table 4.6. From 1980 to 1985, prices received for cotton, for example, fell by 27.5% in nominal terms and 44.7% in real terms. During the same time there has been a decline in farmland values, which is also discussed in Appendix G.

In most cases prices appear to have stabilized during the past year, and in a few cases they actually rebounded to a modest degree. However, it is unlikely that prices will return to their previous high levels in the foreseeable future. For cotton, by far the most important crop in the DSA, the major influences on prices received by growers is the federal government's price support program. Under the 1985 Food Security Act this is scheduled to decline from its 1986 level of 81 cents/lb. to 72.9 cents/lb. in 1990. The latter is still considerably higher than current world market prices (36.5 cents/lb. in 1986), and would permit cotton to be grown profitably in the area.

A sampling procedure was used to estimate the number and size of landholdings in the DSA. Assessor's maps from Fresno County were compared to maps of tile-drained and adjacent areas and a random sample of map book pages covering these lands was taken. Sampling intensity varied among draining entities, ranging from 25.6% to 43% of the total acreage of the entity. Within the DSA, 29.4% of the total acreage was sampled, including 55.9% of the tile-drained land. The owners of the parcels were identified. In many cases, it was found that owners at a single address hold many parcels. For the purposes of assessing economic impacts, it was assumed that parcels held by owners at the same address form a single landholding. In all districts, holdings were of moderate size, averaging about 500 acres overall. Extrapolating to the entire DSA, there are an estimated total of 158 landholdings in the DSA. Approximately 34 of those holdings would encompass half the total acreage (Table VI-4A).

The size of farm operating units for the Westlands Water District, just south of the DSA, was estimated to be about 930 acres (Assembly Office of Research, 1985). The farm operating units in the San Luis Water District which is generally upslope of the DSA average about 435 acres in size (Moore, 1985). The estimated farm size in the DSA of about 500 acres presented in Table VI-4A is intermediate between these two districts.

A Model of Farm Profitability for the Drainage Study Area

This section summarizes how various factors are incorporated into a model of farm profitability which will be used in Chapter VII to estimate the economic effects of possible regulatory actions. A detailed discussion of the development of the farm profitability model is presented in Appendix G, Section 4.4. The estimates of the gross profitability of various crops are shown in Table VI-4. Although derived in a manner that is conventional for farming economics studies, the estimates should be treated with some caution. In reality, production costs and revenues vary among growers due to differences in soil conditions, cultural practices, and marketing practices. As a result of this variability, there is actually a range of gross profitability associated with each crop. The values in Table VI-4 should be interpreted as approximate averages because they do not capture any of the variability in farming profitability. For example, different soil types will produce different yields for various crops, and this provides the basis for the estimate of the distribution of crop profitability. The farm profitability model uses the existing data on soil type variation to estimate the distribution of land profitability within the DSA.

Table VI-5 shows the amount of each soil type that exists in the water districts in the DSA. These data are normalized to the total 1984 cropped acreage in each district. (In the case of Firebaugh Canal Company, the acreages in the second column are normalized not to the district's total cropped acreage but to the 29,000 acres containing subsurface drainage in

Firebaugh, Widren and CCID.) The total area represented in the second column is 81,133 acres. That is the basic land unit for the analysis of the distribution of farm profitability to be described in the remainder of this section.

Cropping patterns and cropping rotations on these soils were predicted using an optimization program which maximized profit for the soils in each district within the DSA given the current cropping patterns, crop budgets and crop yields on these soils discussed earlier. The methods used are discussed in detail in Appendix G, Section 4.4.1 and 4.4.3. On the basis of this analysis, an overall areawide distribution of farming gross profitability was constructed, which is exhibited in Figure VI-1.

Several points about the distribution should be noted. First, it is not smoothly curved because of the presence of discrete quantities of soil with specific yield characteristics. Thus, the various line segments in the figure correspond to separate blocks of soil assigned to separate rotations. Second, the figure is constructed on the assumption that the only source of variability in profits is soil quality. It omits other factors such as differences in farming ability and production expenses which certainly exist, but about which there is no information. Nevertheless, because of the relatively small size and homogeneity of the area our consultants believe that Figure VI-1 is valid as a first approximation to the true distribution of gross profitability. Third, the computations are based on 1986 prices and revenues and the 1984 cropping pattern, which is the last year for which we have complete cropping data. In view of the relative stability of farming operations in the area, as discussed earlier, it is reasonable to employ the distribution in Figure VI-1 for future projections. Finally, although the analysis was actually based on farming profitability on the 81,113 acres whose soils were mapped, it is reasonable to extrapolate the distribution in Figure VI-1 to the entire 94,480 acres of the DSA. It may not be appropriate, however, to extrapolate to the entire area that discharges to Mud and Salt sloughs, the MSSDA (Figure V-15). Farming conditions in some of the western and northern parts of the MSSDA lying outside the DSA are different from those in the DSA.

In the subsequent analysis the distribution in Figure VI-1 will only be applied to the DSA. For the purposes of the following economic analysis, the following terms will be used:

Gross income = amount received from the sale of crops

Production (or variable) costs = amount necessary to produce the crop, e.g., planting cost, seed, fertilizer, water, pesticides, harvesting costs

Gross profit (or net income) = gross income minus production costs

Fixed costs = costs incurred regardless of production, e.g., equipment depreciation, rent or interest on land and property taxes

Net profit = gross profit minus fixed costs; compensation for human effort and endeavor

The average gross profits in the DSA is about $200/acre. It is estimated that fixed costs average $100/acre. Consequently, the average net profit is about $100/acre. If the estimated fixed cost is correct, between 10 percent and 30 percent of the DSA in agricultural production may be insolvent, i.e., operating at a loss. These calculations are a rough approximation and may overstate the amount of insolvency. There are no accurate data on fixed costs, and the production costs used in the construction of Figure VI-1 may be a little too high since Cooperative Extension crop budgets sometimes lean towards the high side in estimating farming costs. [Cooperative Extension crop budgets assume good management practices (usually more expensive) which may not be adopted by the grower.] About 10 percent of the DSA earns greater than $300/acre gross profit. Imposition of costs to meet water quality standards will increase fixed costs and reduce the net profit in the DSA. Operating at a loss may offer tax advantages to some growers.

As a check on these calculations, it is useful to compare the average net income per acre ($100/acre) with the average gross revenue per acre in the DSA which was estimated in Table VI-3 to be about $822/acre. That implies a cash receipt/production expense ratio of about 1.14 [=822/(822-100)], which is slightly lower than the 1983 Pacific region average of 1.16, reported in Gabriel (1986). Nationally, at best, that ratio has increased somewhat since 1983 (USDA, 1986). Thus, the estimate of average farming profitability appears to be in the right range, and possibly slightly low.

Economic Impacts of Drainage Costs - Methodology

This section briefly summarizes the methodology that will be used later in the report to assess the economic impacts of possible farming cost increases associated with meeting the proposed water quality objectives for the San Joaquin River.

Direct Impacts

Some of the possible economic impacts of drainage-related cost increases are listed in Table VI-6 (a more complete list appears in the next section). The most immediate effects are those in item (1), referred to as the direct economic impacts on the DSA. For growers in the area, higher costs will reduce the profitability of farming, lower land values, and perhaps cause some land to go out of production. In the long-term, some of the land driven out of production may come back into production with new owners. Therefore, a distinction will be made between short-term direct economic impacts - financial distress - and long-term impacts - land going permanently out of production. The remainder of this section will briefly explain how, by building on the economic analysis presented earlier, an analysis of these short and long-term impacts can be performed. The methodology for assessing the other impacts listed in Table VI-6 will be explained in subsequent sections.

o Short-Term Direct Economic Impacts

In the short-term, the crucial determinants for a grower being able to stay in business are whether or not he can meet his current cash-flow needs and whether or not he can qualify for a production loan from his bank or production credit association. The two are closely related. Although they did not always do so in better economic times, most banks are now requiring farmers to show a positive cash flow before granting a production loan. These banks are unwilling to rely exclusively on the value of the crops and the land as security for the loan. The main fixed component in cash flow is interest and debt repayment, or rent for those who farm on leased land. If this sum plus variable production cost exceeds cash revenue from farming operations, one can assume that the grower is losing money and will go out of business unless the losses provide tax advantages and/or are offset by income from other sources.

To assess the short-term impacts of increased drainage costs on the agricultural operations, information is needed on (1) profitability of land due to differences in the soil quality discussed in the previous section, (2) variability of debt burdens due to when land was purchased and the amount borrowed, (3) debt/asset ratios and their likely distribution among growers and (4) and land values. In developing this information, the components of gross profit earned and other factors were evaluated. The gross profit earned from an acre of land may be thought of as having two main components: the returns on the land (and other physical capital associated with it), and the returns on the human capital (skill and ability of the grower). In the previous section information was presented which suggests that land in the DSA earns an average gross profit of about $200/acre and that about half of this, $100/acre, is net profit to the operator, i.e., return on human capital. In the absence of more detailed information, our consultants assumed that this ratio of average gross profit to average net profit is roughly constant over all soil types within the DSA. When there is no return on human capital, i.e., net profit, the farming operation is no longer making money for the operator and it becomes insolvent.

A detailed analysis of the above factors was performed. This procedure is discussed in Appendix G, Section 4.5 to 4.5.2. The method used to estimate short-term economic impacts has some qualifications that must be discussed. It is based on indirect estimates of asset values and debt to asset ratios due to the complete absence for direct information on debt loads. For the same reason, it is calculated on a per acre basis rather than per grower. It neglects contributions to cash flow, both positive and negative, associated with economic activities other than farming in the DSA. On the whole this is likely to bias these predictions in the direction of overestimating financial distress because there is a chance that financial pressure on land within the DSA may be buffered, at least to some degree, by income from farming elsewhere on lands unaffected by drainage problems within the same farming operation. Finally, by the manner in which it was constructed, this model focuses on incremental financial distress associated with the extra costs of meeting San Joaquin River water quality objectives: it abstracts from current financial distress in the area caused by the decline in commodity prices and land values over the last five years. As stated earlier between 10 and 30 percent of the land in the DSA may already be insolvent. However, for the purposes of this report our consultants believe that it is legitimate to concentrate on the additional cost and potential insolvency caused by water quality regulatory actions. Consequently, all discussion, tables, and figures in this report which deal with economic impacts of regulatory costs assume all land is solvent at the time these costs are imposed. This assumption is based on the premise that insolvency is a short-term condition that is rectified by market pressures apart from drainage regulatory costs.

- Long-Term Direct Economic Impacts - Land Taken Out of Production

In the long-term most fixed costs become variable. Under the burden of existing debt, land may be unable to remain solvent with additional drainage-related costs. Should this situation develop, both the grower and his lender may lose some of their capital unless income from other sources offset losses on these lands. However, if land goes out of production, the land may later be sold to a new buyer who could operate with a positive cash flow, despite the additional drainage costs, because of his lower debt burden. That is to say, not all of the land which might become insolvent necessarily goes out of production permanently. This section describes how our consultants predict the fraction of land that goes out of production permanently.

In the long-term, land goes out of production only if its gross profit is negative. Because the DSA is overwhelmingly agricultural with little urban development, nonagricultural demand is not likely to provide an alternative use for the land. Although we have no firm information on how districts might impose drainage-related charges, in this section it is assumed that growers bear all costs of meeting water quality objectives through fixed charges per acre; consequently, cropping patterns will not be affected by the imposition of drainage-related costs. If the land stays in production in the long-term, it is assumed that it will produce the same crops as if these costs had not been imposed. Therefore the allocation of soil types to the crop rotations that were developed in the previous section still apply. Accordingly, the proportion of land remaining in production in the long-term can be predicted.

Three caveats should be noted. First, this analysis is concerned with predicting the long-term incremental impacts of drainage-related costs. As with short-term impacts, this analysis subtracts from the long-term analysis the consequences of the decline in farming profitability over the past five years. Instead it focuses on the increment of land going out of production due specifically to future cost increases. Therefore, with zero cost increase, no land is taken out of production in the long run. Second, the distribution of land staying in production is discrete because there are discrete blocks of different soil types in the DSA. Third, when land does go out of production, as one would expect, it is the land currently making the least profit.

Because it is the marginally profitable land which goes out of production, one needs to exercise some care in computing the loss in profits from farming in the DSA. For example, suppose that product costs rise uniformly throughout the area by $15/acre because of drainage-related expenditures. Then, if no land goes out of production, the aggregate profits earned from farming in the area fall by $1,417,200 annually (=$15x94,480). Now suppose that drainage costs rise by $40/acre and 2,119 acres are taken out of production as a result. In that case aggregate profits fall by something less than $3,779,200

(=$40x94,480) because profits fall by $40/acre on the 92,361 acres (=94,480-2,119) remaining in production, but by less than $40/acre on the 2,119 acres that go out of production. For example, if the profitability of farming the latter land is only about $35/acre, the aggregate decline in the profitability of farming is $3,768,605 (=$40x$92,361 + $35x$2,119).

o Impacts on Rents and Property Taxes

If all the land in the DSA was being rented to farm operators, the long-term reduction in aggregate profitability caused by a drainage-related increase in costs would be shared in some manner between landlords and tenants. At one extreme, the entire burden may fall on tenants: rents stay constant, so that the cost increase comes entirely out of the tenants' profits from farming operations. At the other extreme, it may all fall on landlords: rents are reduced by the full amount of the cost increase. In reality, the outcome is likely to be somewhere between these two extremes. Precisely where depends on a number of factors (including whether one focuses on short or long-term adjustments in rents, and institutional arrangements between landlords and tenants in the DSA) about which there is little information.

The only data available in this area is from Moore's (1985) study of leasing practices in the San Luis Water District. He found that landlords in the district tend to pay for most of the fixed costs associated with irrigation water supply, while the variable costs (charges per acre foot of water delivered) are shared between the landlord and tenant in roughly the ratio 1:2. That is to say, rents are reduced by about 33 cents for each dollar increase in variable water service expenses (this is based on a regression of rents in different parts of the district as a function of water services charges and other variables). At the present time it is not known how the water agencies in the DSA intend to finance any expenses they incur in meeting water quality objectives in the San Joaquin River. We do not know to what extent these costs will be passed on in the form of increases in fixed or variable water charges. The experience in San Luis Water District suggests that the landlords will bear almost all the costs if the districts raise their fixed water charges. However, the landlords will bear only one third of the costs if the districts raise their variable water charges.

In the economic impact analysis presented in Chapter VII, our consultants assume, for simplicity, that fixed per-acre charges are used to finance drainage expenditures. For the purpose of predicting impacts on property values (but not for predicting the amount of land driven out of production), they assume that 65 percent of these drainage costs are passed on to landlords in the form of lower rents. That is to say, land rents fall by 65 cents/acre for each $1/acre increase in costs, assuming that the land does not go out of production. This assumption has ramifications for the analysis of indirect effects of drainage-related costs, in terms of reductions in property taxes and consequent impacts on local government revenues, since assessments of land values for property tax purposes are frequently keyed to estimates of the rents that the land would command if it were leased. Thus, any reduction in the profitability of farming a piece of land is translated into a reduction in assessed value by the use of a capitalization factor (Appendix G). For land not under the Williamson Act, the most common capitalization factor is f=0.05. For land under the Act (which applies in Fresno County, but not Merced County) the capitalization factor is presently f=0.0935. Therefore, in the DSA as a whole, the weighted average capitalization factor is 0.079173. Combining this with the estimate that 65 percent of cost increases are translated into rent reductions implies that each $1/acre cost increase generates a $8.21/acre (=0.65/0.079173) reduction in assessed value. Reassessments are currently performed about once every three or four years in the DSA.

- Indirect Economic Impacts

Another model, based partly on the California Department of Water Resources' input-output model, was developed to translate direct economic effects into indirect and induced impacts on the California economy and to calculate the share of these impacts falling specifically on the San Joaquin River Basin. Further, a fiscal model was developed to estimate the indirect and induced impacts on the budgets of the west side cities closest to the DSA, the City of Fresno, and the Merced and Fresno county governments. The results of these analyses are presented in Chapter VII.

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Gabriel, Stephen C. 1986. "A Financial Analysis of the Farm Sector: Distributional Characteristics and Nonfarm Comparisons", in Financing the Agricultural Sector, Dean W. Hughes, et al. Westview Press, Boulder, Colorado.

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USDA/ERS. 1986. Farm Sector Financial Problems: Another Perspective. Agricultural Information Bulletin.

TABLE VI-1

SHARES OF MAJOR CROPS IN THE BROADER STUDY AREA, 1978-1984

Crop	Average Share	Standard Deviation	Coefficient of Variation
Cotton *	29.44	4.16	0.14
Grains *	12.88	2.80	0.22
Cotton + Grains *	42.20	3.49	0.08
Alfalfa	12.36	2.58	0.21
Sugar Beets	5.55	1.13	0.20
Tomatoes	4.00	1.10	0.27
Melons	3.64	0.92	0.25
Rice	3.27	1.01	0.31
Safflower	0.73	0.65	0.89
Tree Crops	3.91	0.30	0.08
Other Vegetables	6.41	1.51	0.24
Total Land	336,718	19,110	0.06

* 1983 excluded.

Source: Based on Appendix G, Table 4.2

TABLE VI-2

SHARES OF MAJOR CROPS IN THE DRAINAGE AREA,

1978-1984

Crop	Average Share	Standard Deviation	Coefficient of Variation
Cotton *	48.00	7.27	0.15
Grains *	13.18	3.97	0.30
Cottons + Grains *	61.00	5.91	0.10
Alfalfa	3.10	1.10	0.36
Sugar Beets	3.17	1.19	0.38
Tomatoes	8.55	3.62	0.42
Melons	3.64	1.50	0.41
Safflower	1.64	1.12	0.68
Other Vegetables	4.74	1.76	0.39
Total Land **	74,051	1,160	0.02

* 1983 excluded
** 1974 and 1983 excluded

Source: Based on Appendix G, Table 4.3

TABLE VI-3 VALUE OF CROP PRODUCTION IN THE DRAINAGE STUDY AREA, 1986

Crop	Acreage	Sales ($1,000)
Alfalfa	4,823	3,696
Barley	1,130	223
Corn	231	114
Cotton	49,402	40,773
Dry Beans	6,532	2,796
Melons	4,824	8,526
Rice	2,563	1,615
Safflower	2,100	907
Sugar Beets	5,534	5,143
Tomatoes (processing)	6,091	8,429
Other Vegetables	1,548	2,322
Wheat	9,702	3,109
Total	94,480	77,654

Average Sales per Acre $822/acre

TABLE VI-4 AVERAGE GROSS PROFITABILITY OF MAJOR CROPS GROWN IN DSA

Crop	Variable Production Costs ($/acre)	Average Yield (tons/acre) 1984	Average Yield (tons/acre) 1985	Crop Price ($/ton) 1984	Crop Price ($/ton) 1985	Gross Profit ($/acre) 1984	Gross Profit ($/acre) 1985
Alfalfa Hay	594	8	8.8	90	77.7	130	90
Barley	236	1.92	1.98	129	108	10	-20
Cotton	526	1,117[1]	1,350[1]	.675[2]	.602[2]	230	290
Melons	2,069	10	10.1	222	175	150	-300
Safflower	286	1.6	1.8	275	240	150	150
Sugar Beets	583	27.24	29.96	33.2	30.9	320	340
Processing Tomatoes	1,263	31.3	31.5	52	51.4	360	360
Wheat	292	2.85	3.08	128	114	70	60

NOTES: [1]Yield in lbs/acre

[2]Price in $/lb

(Sources: Prices and yields from Fresno County Agricultural Commissioners's Report, 1984 and 1985. Variable costs from the most recent available budgets prepared by the Fresno County Cooperative Extension Service.)

TABLE VI-5 SIZE OF LANDHOLDINGS WITHIN THE DRAINAGE STUDY AREA

District Name	Number of Landholdings Sampled	Acres of Tiled Lands Sampled	Minimum Size Landholdings Sampled	Maximum Size Landholdings Sampled	Mean Landholding Size	Median Landholding Size	Acres of Tiled Land in Distric(s)	% of Tiled Area Sampled	Total Acreage in District(s)	% of Total Acreage Sampled	Estimated Number Owners in District(s)	Percent Sample Holdings with 50%/Land	Estimated Number of Holdings with 50%/Land
Panoche DD	18	10813.33	103.30	1862.44	600.74	388.23	22000	49.2	42300	25.6	70	20	14
Firebaugh C.C.; C.C.I.D.; Widren W.D.	21	8861.51	47.04	1292.95	421.97	245.60	13100	67.6	29000	30.6	69	21	14
Broadview I.D.	8	4096.70	157.25	1111.61	512.09	572.02	7410	55.3	9515	43.1	19	31	6
Grand Total	47	23771.54	47.04	1862.44	505.78	338.70	42510	55.9	80815	29.4	158	22	34

TABLE VI - 6 SOIL TYPES AND YIELDS IN THE DSA

District/Soil type	Mapped Acreage (1)	Full Acreage (2)	Percent Distribution (3)	Cotton (4)	Alfalfa (5)	Barley (6)	Wheat (7)	Sugarbeets (8)	Tomato (9)
				Crop Yields (tons/acre)					
PACHECO									
450 Milham sandy loam 0-2%	480	578.8	10.19%	1125	9	1.92	2.88	0	0
479 Cerini clay loam 0-2%	96	115.8	2.04%	1300	0	0	0	0	28
442 Panoche clay loam 0-2%	6.4	7.7	0.14%	1300	9	1.92	2.88	35	0
167 Deldota clay, partially drained	2233.6	2693.4	47.42%	1200	7	0	0	28	25
169 DosAmigos clay, partially drained	12.8	15.4	0.27%	1000	7	0	0	30	0
229 Paver clay loam 0-2%	1177.6	1420	25.00%	1000	0	0	0	0	30
280 Woo clay 0-2%	704	848.9	14.95%	1000	8	0	0	26	25
Subtotal	4710.4	5680	100.00%						
BROADVIEW									
460 Ciervo clay saline-sodic 0-2%	25.6	24.7	0.26%	900	0	1.92	2.88	24	0
442 Panoche clay loam 0-2%	2700.8	2603.9	27.55%	1300	9	1.92	2.88	35	0
445 Excelsior sandy loam 0-2%	838.4	808.5	8.55%	1200	8	2.16	3.24	0	0
436 Panoche loam 0-2%	1049.6	1011.9	10.70%	1300	9	1.92	2.88	35	0
459 Ciervo clay 0-2%	5190.4	5004.2	52.94%	1300	0	0	0	27	28
Subtotal	9804.8	9453	100.00%						
FIREBAUGH									
460 Ciervo clay saline-sodic 0-2%	15827.2	19109.2	65.89%	900	0	1.92	2.88	24	0
479 Cerini clay loam 0-2%	76.8	92.4	0.32%	1300	0	0	0	0	28
442 Panoche clay loam 0-2%	1094.4	1321.3	4.56%	1300	9	1.92	2.88	35	0
445 Excelsior sandy loam 0-2%	409.6	494.5	1.71%	1200	8	2.16	3.24	0	0
459 Ciervo clay 0-2%	6611.2	7982.1	27.52%	1300	0	0	0	27	28
Subtotal	24019.2	29000	100.00%						
PANOCHE									
435 Lethent clay loam, 0-2%	1728	1487.3	4.02%	1000	0	1.68	2.52	23	0
450 Milham sandy loam 0-2%	3059.2	2633	7.12%	1125	9	1.92	2.88	0	0
460 Ciervo clay Saline-sodic 0-2%	1747.2	1503.8	4.06%	900	0	1.92	2.88	24	0
479 Cerini clay loam 0-2%	1241.6	1068.6	2.89%	1300	0	0	0	0	28
474 Westhaven loam 0-2%	281.6	242.4	0.66%	1300	9	1.92	2.88	0	22
442 Panoche clay loam 0-2%	17862.4	15374	41.55%	1300	9	1.92	2.88	35	0
445 Excelsior sandy loam 0-2%	3596.8	3095.7	8.37%	1200	8	2.16	3.24	0	0
447 Excelsior sandy loam, sandy substratum 0-2%	51.2	44.1	0.12%	900	6	1.92	2.88	0	0
436 Panoche loam 0-2%	4454.4	3833.9	10.36%	1300	9	1.92	2.88	35	0
459 Ciervo clay 0-2%	6412.8	5519.4	14.92%	1300	0	0	0	27	28
150 Chateau clay, partially drained	1305.6	1123.7	3.04%	1100	0	1.68	2.52	28	0
167 Deldota clay, partially drained	1190.4	1024.6	2.77%	1200	7	0	0	28	25
229 Paver clay loam 0-2%	57.6	49.6	0.13%	1000	7	0	0	0	30
Subtotal	42988.8	37000	100.00%						
TOTAL	81523.1	81133							

Note: Cotton yield is in lbs/acre

Source: Merced and Fresno Field Offices of SCS.

TABLE VI- 7 SOME ECONOMIC IMPACTS OF DRAINAGE-RELATED COST INCREASES

AFFECTED PARTY	HOW AFFECTED	CONSEQUENCES
1. Agricultural Producers in the DSA	o costs of meeting water quality standards	o short run: financial distress/bankruptcy o long run: land out of production loss of jobs, employee income loss of profits lower land values
2. Consumers of Agricultural Products from the DSA	o reduced supply/higher prices	o loss of consumer's surplus
3. Suppliers of Agricultural Inputs to Producers in the DSA	o reduced demand	o loss of jobs, employee income, profits
4. Processors of Agricultural Products from the DSA	o reduced supply/higher costs	o loss of jobs, employee income, profits
5. Other California Production Sectors	o reduced demand for inter-industry inputs o reduced demand for final goods	o loss of jobs, employee income, profits

TABLE VI-8 LONG RUN REDUCTION IN SALES ($1,000) AND PRODUCTION (ACRES) IN THE DSA AS A FUNCTION OF LAND GOING OUT OF PRODUCTION

Crop	Baseline Production		Reduction in Sales/Acres Associated with Cost Increase ($/acre) of:							
	Sales	Acres	$35 - 45		$45 - 68		$68 - 76		$76 - 91	
			Sales	Acres	Sales	Acres	Sales	Acres	Sales	Acres
Alfalfa	3,695.9	4,823	0	0	0	0	0	0	0	0
Cotton	40,773.1	49,402	601.7	872	947.6	1,429	1,934.3	3,018	2,150.5	3,366
Barley	223.3	1,130	0	0	0	0	126.8	635	126.8	635
Wheat	3,109.0	9,702	0	0	0	0	0	0	0	0
Sugar Beets	5,143.3	5,534	0	0	0	0	0	0	0	0
Tomatoes	8,429.3	6,091	0	0	726.6	556	726.6	556	726.6	556
Rice	1,614.7	2,563	113.4	180	113.4	180	113.4	180	146.2	232
Corn	114.3	231	7.9	16	7.9	16	7.9	16	10.4	21
Melons	8,526.4	4,824	595.6	337	595.6	337	595.6	337	768.9	435
Safflower	907.2	2,100	63.5	147	63.5	147	63.5	147	81.6	189
Dry Beans	2,795.7	6,532	196.0	458	196.0	458	196.0	458	252.5	590
Other Vegetables	2,322.0	1,548	163.5	109	16[illegible]5	109	163.5	109	210.0	140
Total (1)	77,654	94,480	1,741.7	2,119	2,814.2	3,232	3,927.8	5,456	4,473.5	6,164

(1) Totals may not add due to rounding.

Source: Computed from Table 4.16 and Figure 4.9

FIGURE VI-1

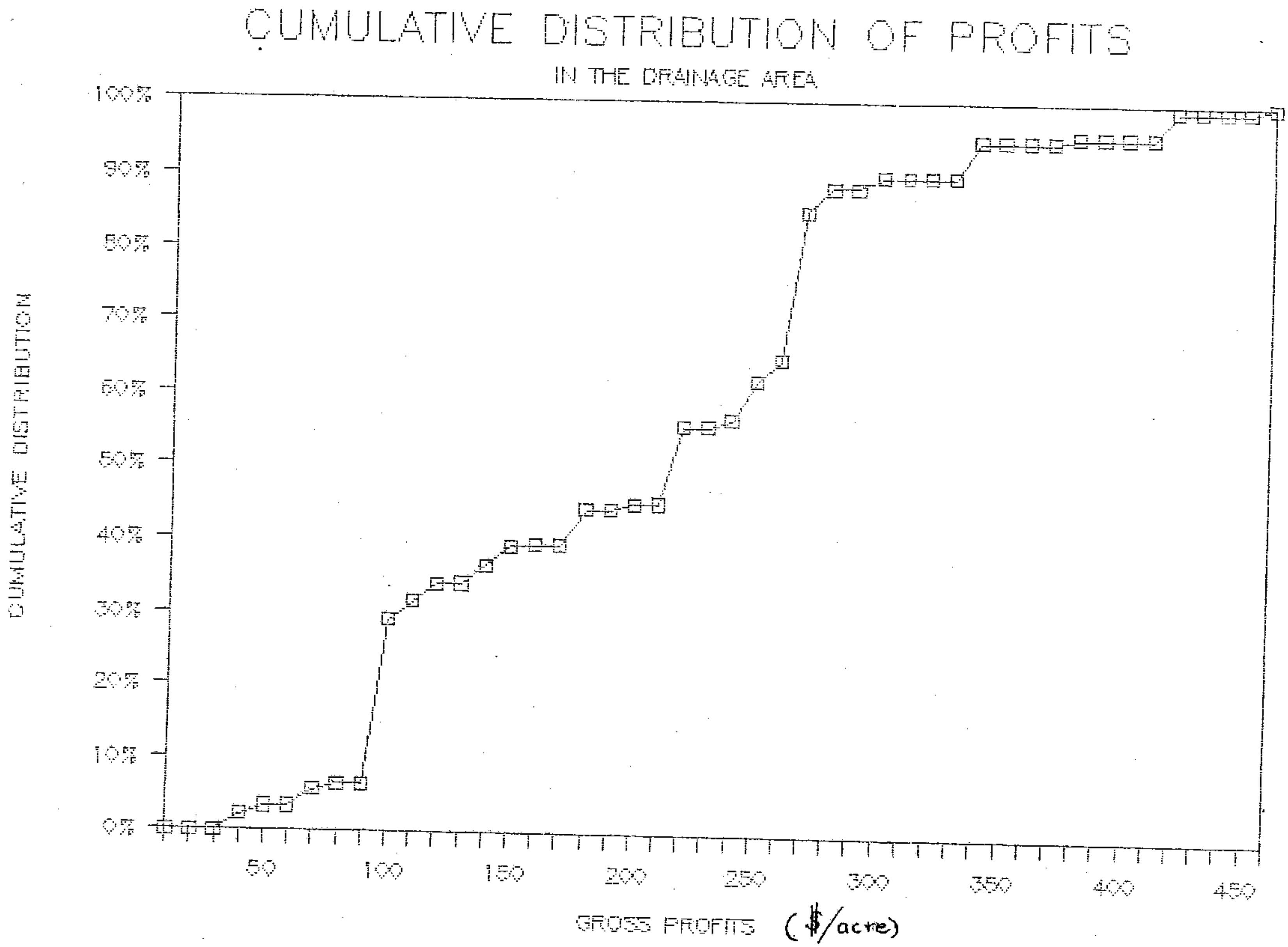

CUMULATIVE DISTRIBUTION OF PROFITS
IN THE DRAINAGE AREA
CUMULATIVE DISTRIBUTION
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
50
100
150
200
250
300
350
400
450
GROSS PROFITS ($/acre)

FIGURE VI-2

% ACREAGE SOLVENT

AFTER AN INCREASE IN COSTS

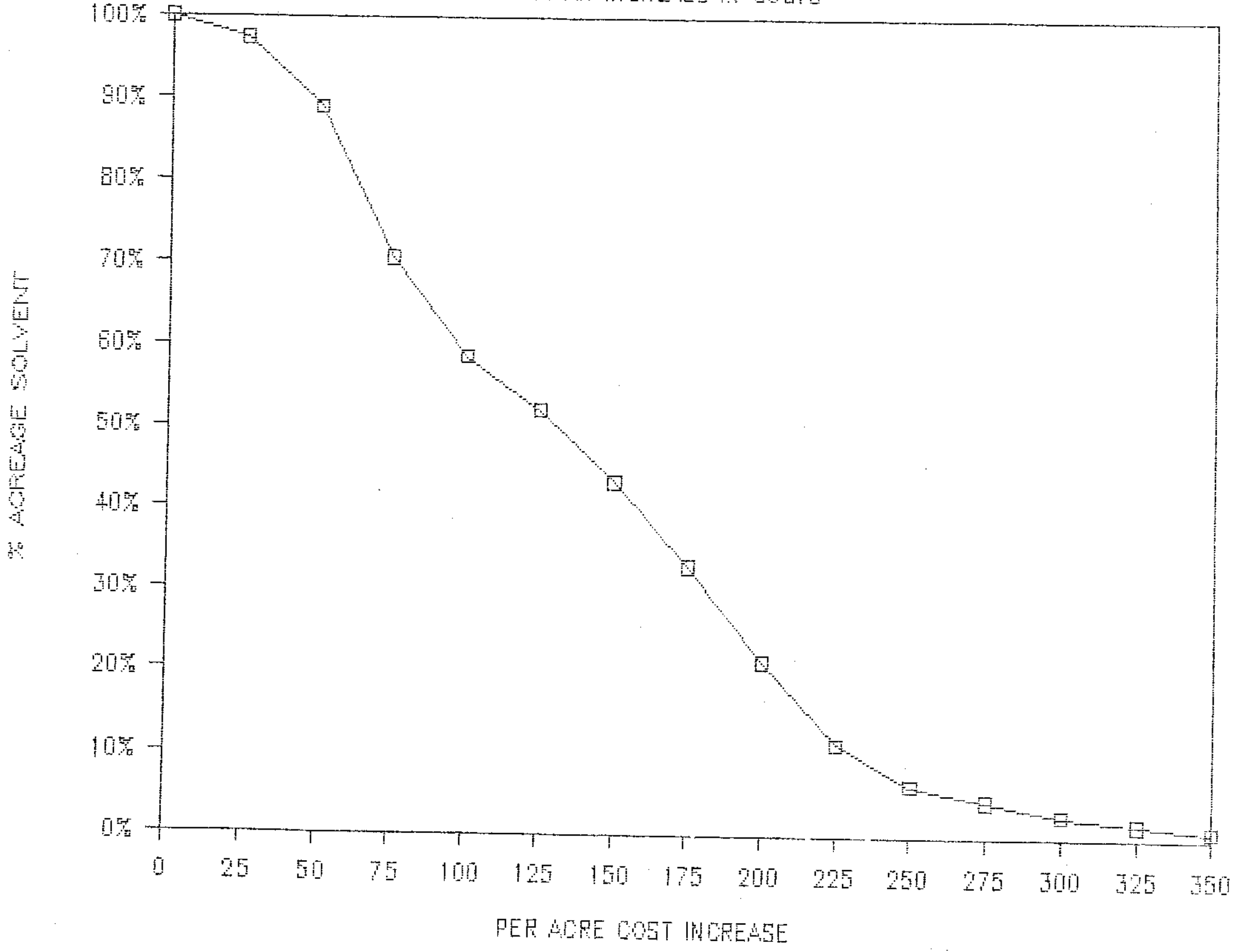
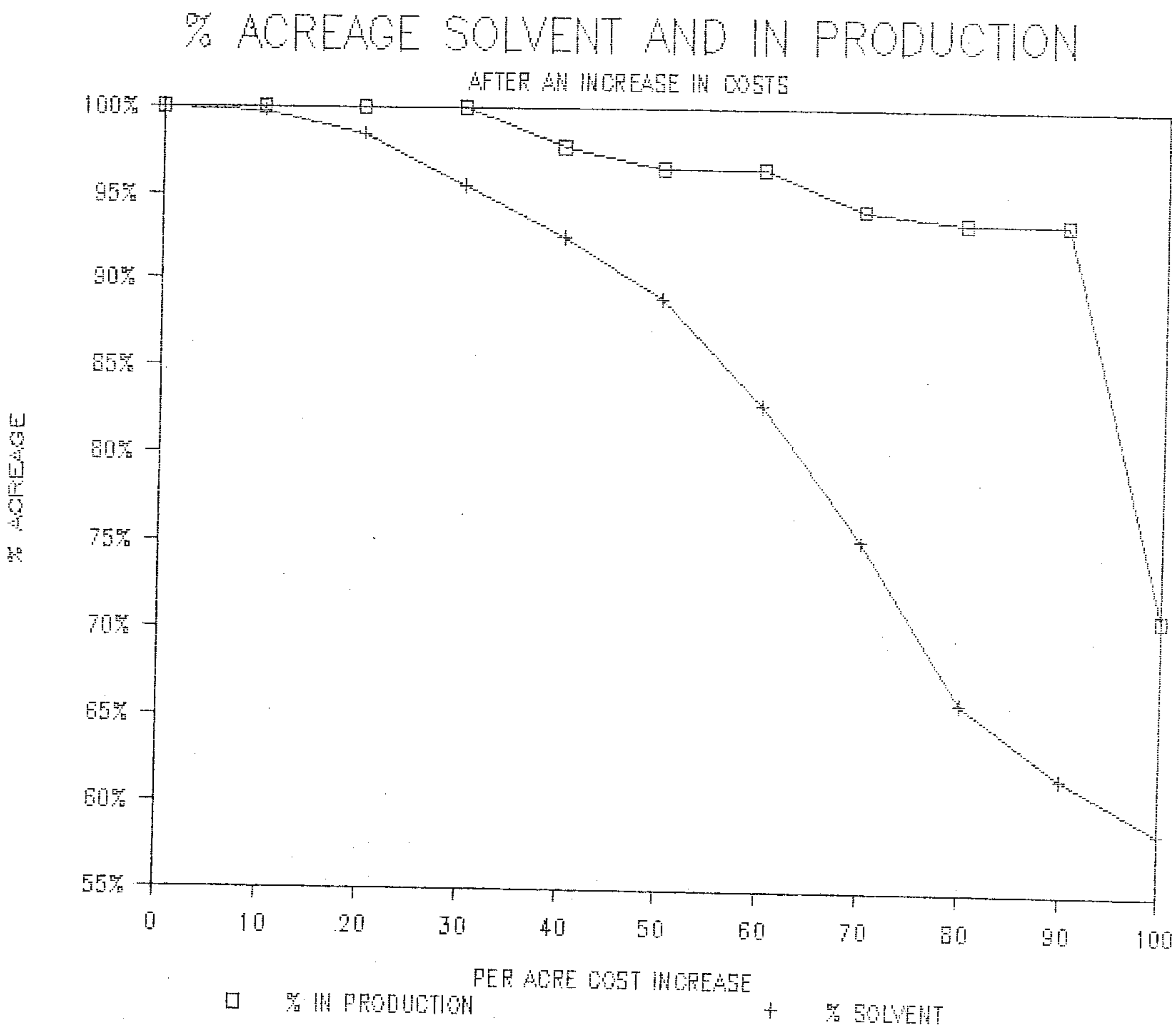


FIGURE VI-3


% ACREAGE SOLVENT AND IN PRODUCTION
AFTER AN INCREASE IN COSTS
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
% ACREAGE
0
10
20
30
40
50
60
70
80
90
100
PER ACRE COST INCREASE
% IN PRODUCTION
% SOLVENT

VII. DRAINAGE FLOW MANAGEMENT ALTERNATIVES AND THEIR ECONOMIC EFFECTS

Chapter IV presents information on the various constituents of concern found in subsurface agricultural drainage in the San Joaquin River Basin. In the Technical Committee's January 1986 Workplan this list was narrowed to four constituents which would receive the central focus. These are selenium, salt, boron and molybdenum. This chapter summarizes (1) information on the technologies available to remove these constituents from agricultural drainage water (see Appendix H for more details), (2) the engineering costs of these treatment alternatives (see Appendix I for more details), (3) the cost of treatment alternatives; drainage flow reduction alternatives; and dilution to achieve various levels of selenium and (4) the economic impact of these alternatives.

Available Treatment Technologies

A detailed assessment of some of the most promising technologies for the removal of selenium, salt (also referred to as total dissolved solids or TDS), boron and molybdenum was performed and is presented in Appendix H. A summary discussion is provided below. Most of these processes are unproven in full-scale treatment operations.

- Selenium Removal

  The agricultural drainage water of the Drainage Study Area (DSA) is a very difficult matrix from which to remove selenium for three reasons. First, selenium is present largely as the highly soluble selenate ion. Second, this ion is present together with a relatively massive background level of the chemically similar sulfate ion. Third, there are significant levels of nitrate present that must first be removed before biologically mediated reductions of selenate can be achieved.

  Methods employing only chemical precipitation, adsorption or ion exchange are not suitable for removal of selenate from the wastewater to the levels set forth in the Workplan of the Technical Committee, i.e., 2, 5, and 10 ppb total selenium. The use of algae ponds for removal of selenate by algal uptake from these wastewaters may be infeasible to achieve these levels. The only chemical equilibria that allow a sufficient distinction between selenate and sulfate so that selenium can be removed appear to be the redox equilibria. Processes involving selenate reduction therefore appear to bear the most promise.

The "Harza" process, which employs beds of iron filings and is being tested by the Panoche Water District, has demonstrated selenium removal, albeit at low waste application rates and with significant column cementation problems. Prior to the considered scale-up of this process, laboratory-scale investigations of the mechanism of this process should be conducted. Alternative reactor configurations may well lead to increases in waste application rates. At this time it is too early to assess the long term selenium removal ability of this process.

Chemical methods for reducing selenate, using reductants known to function at high concentrations and temperatures, should be investigated for their efficacy at the relatively low selenate levels and in the chemical matrix typical of agricultural drainage wastewater. Such methods include the use of sulfide, sulfur dioxide and sulfur.

The microbial reduction of selenate to a variety of reduced selenium forms (e.g., selenite, inorganic selenium compounds, selenide, selenium metal and organic selenium compounds) is claimed by pilot plant experiments at Murietta Farms (also known as the "Binnie" process). The plant employs a series of anaerobic reactors dosed with a degradable carbon source, followed by filtration and boron ion exchange units. Published data on the performance of this pilot plant are not yet available so that independent evaluation is not currently possible. However, based on oral reports it would appear that the entire process configuration can achieve, at best, effluent selenium levels of 2 to 5 ppb selenium. Using anaerobic reactors and filtration only, effluent selenium levels of 10 to 20 ppb are estimated.

At the present time operation of individual selenium removal plants on each farm does not seem feasible. At a minimum, these processes should be under the control of the drainage districts or other entities made responsible for waste discharge, and should be operated by licensed wastewater treatment operators.

- Boron Removal

  The only currently feasible technique for boron removal is the use of a selective ion exchange resin. This technique is already in commercial use in the removal of boron from magnesium chloride brines. Its use for the desired boron removal from San Joaquin Valley agricultural drainage wastewater has been successfully demonstrated on a pilot plant scale. The boron selective resin appears to have some capacity for selenium removal.

- Molybdenum Removal

  Molybdenum removal methods have not been evaluated on the type of wastewater encountered or for the levels of residual required in the San Joaquin River Basin. Molybdenum removal techniques have been developed for molybdenum mining and mineral processing wastewaters. These methods employ either precipitation/adsorption with ferric hydroxide at low pH or selective ion exchange. Further investigation is needed of the levels of molybdenum in agricultural drainage wastewater and of removal methods at these levels to produce the desired residual molybdenum concentrations.

- Salt Removal

  The removal of salts in subsurface agricultural drainage involves impounding this drainage water in evaporation ponds or desalination of this drainage water. Evaporation pond designs have been developed to allow progressive salt concentration, crystallization and storage. A variety of methods, none completely effective, are available to discourage birds from using these ponds. Methods for preventing ground water contamination are being developed. As the name implies, evaporation ponds remove both salt and water from the aquatic system.

  Reverse osmosis with pretreatment, to reduce membrane-fouling constituents, has been pilot tested for a limited period of time using San Joaquin Valley agricultural drainage wastewater. Product water has met or exceeded predicted levels of salt removal. The generation of electricity via solar energy ponds using waste brine from a reverse osmosis facility has been suggested as one method of reducing desalting costs. However, this could be impeded by the high calcium sulfate levels present in the drainage waters of the area. More work needs to be done before the economic and technological feasibility of this method can be determined.

o Conclusions

Our consultant's assumptions about what can be achieved in terms of removal efficiencies are summarized in Table VII-1. Our consultant is reasonably confident about the efficiencies for boron and salt removal because there is significant operating experience with these technologies. The assumptions about selenium removal efficiencies are far more speculative because these technologies are still at the development stage. This uncertainty must be borne in mind when reading the rest of this chapter.

Engineering Cost Analysis for Treatment Alternatives

Appendix I contains detailed cost estimates for selenium, boron and TDS removal with various sizes of treatment facilities. This appendix was prepared under contract by Professor Neethling at UCLA. The cost estimates for these facilities are summarized in Table VII-2. The flowsheets showing capital and other costs are also shown in Appendix G, Figures 5.1 to 5.8. All of the costs were calculated as of March 1986. These estimates should be regarded as preliminary and treated with caution, because many of the processes are still under development. Except for very small scale experimental plants, no historical experience is available with regard to construction costs or operation and maintenance costs for selenium removal.

o General Observations

Several points should be noted. First, selenium removal costs are independent of the selenium concentration in plant inflow, but instead depend on (1) the desired selenium concentration in the treatment plant effluent, and (2) the volume of drainage to be treated in the plant. The effluent concentration depends essentially on the type of treatment process selected. However, for any given process, the effluent concentration is relatively fixed, regardless of inflow concentrations, and depends primarily on the concentration attained when the reactions reach equilibrium. Two possible processes associated with two alternative effluent concentrations have been identified as showing promise. These are (1) biological treatment and filtration, without ion exchange, which results in an effluent selenium concentration as low as 10 ppb, and (2) biological treatment and filtration combined with ion exchange, which results in an effluent selenium concentration as low as 2 ppb. Apart from this, the primary factor influencing selenium removal costs is the volume of drainage to be treated. Larger volumes are significantly more expensive to treat than smaller volumes, regardless of inflow selenium concentrations. For this reason, water management strategies which reduce volume of plant inflow are generally superior to those which reduce the concentration of selenium in plant inflow alone. Within the DSA this reduction could be accomplished by encouraging on-farm regulation of drain flow (e.g., within the sumps) and reduction in overall drainage volume through more efficient irrigation practices.

- Economies of Scale and Safety Factors

The cost estimates for selenium removal do not include economies of scale because there is no operating experience with this new technology. Cost estimates for ion exchange and other facilities do include modest economies of scale. Also, the cost estimates are based on designs to meet peak drain flows from the DSA. In a regional system peak flows from different districts may not coincide; therefore, the plant size may be made smaller if this occurs. On the other hand, the costs identified in this report do not include a margin of safety for possible higher flows than those expected. On the premise that the likelihood of these two latter factors are nearly equal, neither is included in our estimates. Cost estimates also assume that the plant operates at its design capacity 100 percent of the time even though it may only have to operate at this level a few months of the year in order to meet the objectives. This assumption may slightly overestimate O&M costs but also more closely reflects how the plant may actually be operated.

o Capital Costs

All capital costs have been annualized assuming a plant life of 20 years and an interest rate of 4 percent. This reflects the interest subsidy in Proposition 44 (Water Conservation and Water Quality Bond Law of 1986), enacted in June 1986, which authorized two bond funds, each of $75 million to finance water conservation projects and agricultural drainage projects. The loans can cover up to 100 percent of total eligible feasibility study, design and construction costs and are repayable over periods up to 20 years at an interest rate to be set annually at 50 percent of the State's true interest cost. At the present time, the State's true interest cost is about 7.5 percent, so that the interest rate on the loan would be about 3.75 percent. The assumption of 4 percent slightly overestimates the current interest costs.

Without the Proposition 44 program, the districts in the DSA would face a significantly higher interest charge, probably in the range of 9 to 11 percent. The smaller districts might not be able to get such loans at all. Compared to 4 percent, an interest rate of 10 percent over 20 years would raise annual capital costs by about 60 percent. Because of the interest subsidy, capital costs are generally about 45 percent of total annual costs, while operational and maintenance costs are 55 percent. A more detailed breakdown of the share of capital costs for the various treatment technologies and plant sizes is presented in Appendix G, Table 5.3.

o Performance Characteristics and Assumptions

Four groups of treatment process are presented in Table VII-2. They are:

(1) Treat tile drainage only for selenium
(2) Treat tile drainage only for selenium and remove TDS, using evaporation ponds
(3) Treat tile drainage only for selenium and remove TDS, using reverse osmosis and disposal of brine in evaporation ponds
(4) Treat combined tile plus surface drainage for selenium and removeTDS using evaporation ponds.

The assumed performance characteristics of these processes are shown in Table VII-1. Other assumptions are as follows:

(1) Sludge generated in the selenium removal process will be dried and transported to a Class I landfill.
(2) The combined surface and tile water is considered to be turbid, requiring coagulation, flocculation and sedimentation as primary treatment; this is not required when the tile drainwater is treated alone.
(3) Selenium removal is always employed before discharge of drainwater to an evaporation pond in order to limit the need for a Class I (double-lined) evaporation pond. Accordingly, in the evaporation ponds considered here, only a small section (4 percent) is double-lined. Because of uncertainty concerning the cost of a Class I pond (estimates range from $85,000/acre to $200,000/acre), two estimates are used for the costs of the overall evaporation pond facility: $6,100/acre (low) and $15,000/acre (high).

Several implications of these costs should be noted:

(1) At high capacity levels the change in the costs per acre/foot of water treated becomes small.
(2) It costs approximately $61 to $92/af extra to reduce the selenium concentration from 10 to 20 ug/L (using biological treatment and filtration) down to 2 to 5 ug/L (using ion exchange).
(3) The cost of coagulation and suspended solids removal (required when tailwater is part of the inflow to the selenium removal facility) is $27 to $28/af.
(4) The cost of removing salt from drainwater by reverse osmosis is not very sensitive to the cost of constructing the disposal pond. At the lower disposal pond cost, salt removal increases costs by $229 to $321/af. At the higher toxic pond cost, salt removal increases the cost by $257 to $376/af.

Treatment Alternatives for Attaining Various Water Quality Objectives

Upon reviewing public comments on the August draft of this report, the Technical Committee decided to focus its attention on the detailed evaluation of the costs of achieving various selenium objectives. This is not to imply that other constituents such as TDS or trace elements are not a concern. It simply reflects that:

(1) Selenium is an element in drainage water currently posing a threat to public health.

(2) The addition of boron removal also helps to remove selenium, therefore all costs for selenium removal to the 2 to 5 ppb range also include boron removal.

(3) Removal costs for salts are extremely high. At this time they include the construction of ponds which may pose a threat to wildlife and groundwater in this area. Many other methods of disposal including deep well injection are currently being investigated by the Interagency San Joaquin Valley Drainage Program. Implementation of plans to physically remove large quantities of drainage water from the River should await the results of this program.

(4) The effects of high salt concentration in the San Joaquin River appear to be manageable with existing agricultural practices by the users of this water except for the users in the South Delta Water Agency, located downstream of the confluence with the Stanislaus River. These water users recently signed a temporary agreement with the Bureau of Reclamation which guarantees them acceptable water quality and water flows through releases of water from New Melones Reservoir regardless of the flows or quantities in the San Joaquin River over the next few years. Negotiations for a permanent agreement are underway. Therefore, the critical area of concern related to salinity is between the Merced and Stanislaus rivers. Concerns about salts in the River should focus on decreasing salinity concentrations in this critical reach.

The scenarios in this section focus on treatment for selenium removal by biological means such as the Binnie process, with disposal of the sludge in a Class I landfill and discharge of the treated drainage downslope of the DSA. Deep well injection, evaporation ponds, and reverse osmosis are not considered as strategies for meeting selenium objectives due to their high costs and environmental concerns. Strategies involving on-farm water conservation as a means of reducing tile drainage and attaining selenium objectives will be discussed in the following section. Possible options available to the water districts for treating drainage flows in the DSA are discussed in detail in Appendix G, Section 5.3.1. and are listed below:

(1) Construct a new lined drainage conveyance facility to bypass the Grassland Water District and discharge above the Merced River ($11 million) or below the Merced ($15 million) (Summers 1986).
(2) Use of unused portions of the San Luis Drain to carry existing drainage around the Grassland Water District and Mud and Salt sloughs.
(3) Construct a regional treatment plant using biological removal and ion exchange to remove both boron and selenium.
(4) Separate surface and tile drainage (estimated in Summers 1986 to cost approximately $500/acre for the entire 48,000 acres or $24 million).
(5) Reduction in peak drain flow through either a surface regulating reservoir or changes in tile sump pumping to allow interim storage in the soil profile. This can provide a substantial cost savings byreducing the size of the treatment facility.
(6) Collect and treat drainage only from "hot spots".

Due to the lack of data on some of the possible actions and the sheer volume of possible options that could be generated by considering various aspects of the options listed above, our consultants limited their detail cost analysis to the four basic scenarios shown in Table VII-3. These four alternative treatment scenarios were analyzed for the three different year types discussed in Chapter V. Water years 1979 (normal), 1981 (critical), 1984 (normal), and 1985 (dry) are examined. Also the scenarios were each run with and without supplemental water to the Grassland Water District (GWD) and meeting potential water quality objectives of 2, 5, and 10 ppb selenium in the San Joaquin River, or at the downslope border of the DSA. This combination of variables produced a grand total of 100 scenarios that were evaluated.

o Initial Screening of Alternatives

In order to determine how conditions would change under each of these scenarios and the optimum level of treatment required, a DSA-Grassland Hydrologic Model was developed. This model is discussed in detail in Appendix G, Section 5.3.3. In summary, this model (1) removes the effects of drainage flows from the DSA and GWD from the San Joaquin River for each of the four years of study as discussed in Chapter V, (2) adds in the tile and surface drainage flows under different flow patterns and (3) optimizes the selenium treatment plant size and regulating capacity that can most economically meet the specified selenium water quality objectives using the cost data discussed in this chapter.

The model output also includes the monthly pattern of drainage and river flows and the concentrations of selenium, boron and TDS, in those flows. Inputs and assumptions used in this model are presented in Appendix G, Table 5.7.

The analysis of this array of scenarios is presented in Appendix G, Section 5.4. Some basic information can be summarized from this analysis:

(1) Whether or not GWD receives supplementary water has no effect on the amount of selenium treatment required.
(2) Short term relaxation of potential water quality objectives of 2 or 5 ppb in the River has little effect on the needed treatment plant size. A large effect is seen if the objective is 10 ppb and periodically relaxed.
(3) Regulating drainage flows during the year to minimize variability has a substantial effect on reducing the size of the selenium removal plant and therefore overall costs. Such a program could reduce the needed plant size to less than one-half the size needed without such a program. If regulation is accomplished with in-ground storage, no additional costs would be required.
(4) Using the Central Valley Regional Board's data on the monthly distribution of tile drain flows results in no differences when the treatment of combined surface and tile flows are considered. Also, about the same volume of treatment is required when separate tile flows are considered in the cost controlling critical year 1981. In normal water years there is a difference but this does not control the costs of the treatment plant.

Costs from these various alternatives are discussed in Appendix G, Section 5.4.2. They are based on one of the three following alternatives:

(1) Four percent financing for on-farm conservation and district-wide drainage collection and treatment.
(2) Four percent financing for district-wide drainage collection and treatment, but ten percent financing for on-farm conservation.
(3) All treatment system elements at ten percent.

The remainder of this analysis will focus on four percent financing for district-wide drainage collection and treatment. Also, the cost data presented will be for the critical year 1981. This was, in each case, the highest cost of the four years analyzed, assuming no relaxation of water quality objectives in critically dry years.

The costs, presented on a per-acre-foot basis, assumes that the costs of treatment facilities are spread over all lands equally in the DSA (94,480 acres) except where noted. This may not be the way the districts wish to impose such costs. They may elect to assess larger charges to those areas with tile drains and less costs to areas within the district which may contribute drainage flow but which do not have tile drains. Also, no allowance has been made for upslope areas outside the DSA districts (such as San Luis Water District) to help pay for these drainage costs. To the extent that such areas contribute to drainage problems on downslope land, they should contribute to the costs of properly disposing of this drainage. However, these factors are items of negotiations between the various districts involved and cannot be addressed with any degree of certainty at this time.

Our economic analysis of potential treatment and management options provides some interesting conclusions.

1. Changing the cost of financing from four percent to ten percent affects the total cost of the alternatives but does not affect which actions should be taken to minimize these costs.

2. When the objectives need only be met in the San Joaquin River at Hills Ferry (downstream of the Merced River), available flows in the River are used to help decrease treatment costs by diluting the effluent to meet objectives. This allows the construction of a much smaller treatment plant.

3. Review of the operation and maintenance costs for meeting the 10 ppb selenium objective in the San Joaquin River indicates that almost all the cost of this alternative is for physical works (e.g. pipe, canals, treatment facilities) and includes very little actual

treatment for the removal of selenium. Conversely, water quality objectives to be met in the agricultural drains requires the treatment of large quantities of drain flow to meet either the 2, 5, or 10 ppb potential selenium water quality objectives. Therefore, the incremental costs of achieving the various objectives is relatively small.

4. Costs for achieving the water quality objectives in the agricultural drains via a new collection and disposal system (for disposal directly downstream of the Merced River) are generally lower than those to meet objectives via treatment on the border of the DSA. However, this is not true if the conveyance facility from the treatment plant to the San Joaquin River downstream of the Merced River is a closed pipeline. Also, a large outfall directly into the San Joaquin River raises issues regarding (1) concerns with diffuser design to provide maximum mixing in the shortest time and (2) the allowable zone of initial dilution. These issues will have to be explored by the Regional Board as they consider the water quality objectives, the plan of implementation and waste discharge requirements for such a facility.

5. For those alternatives requiring achievement of water quality objectives in the agricultural drains, the best strategy is always to minimize drainage flow variability and then separately collect and treat the tile drainage. Drainage flow reduction is also an important component of reducing overall treatment costs.

Estimated costs for meeting potential selenium water quality objectives of 2, 5 or 10 ppb at three different locations through the treatment of agricultural drainage or water management are shown in Table VII-4. This table shows the least cost option, its capital costs, annual costs and cost per acre. Costs are extremely sensitive to both the potential selenium objective to be attained and the location at which it is to be achieved.

Achieving Selenium Objectives Through Drainage Flow Reduction

Upon reviewing the results of treatment cost analyses we were struck by the relatively large capital costs involved with this approach to achieve selenium objectives. Also, the discussion in Chapter V illustrates that excess deep percolation in the DSA could be reduced if better management of the existing furrow irrigation systems or more efficient irrigation systems were employed. The effect that these reductions in deep percolation would have on subsurface drain flows in the DSA is uncertain. However, available information indicates that an even greater percentage reduction in subsurface drainage flow is likely because there appears to be a net loss of deep percolation of agricultural drainage to deep ground water. If these losses remain constant in the future, proper irrigation and drain flow management could achieve drastic reductions in subsurface drain flows out of the DSA and into the San Joaquin River. A better understanding of the shallow aquifer is needed. The USGS is performing studies which should provide this understanding. However, due to the relatively small quantities of water involved and the inherent uncertainties with any ground water model, perhaps the only real way to know exactly how effective more efficient water use will be on reducing subsurface drainage flow from the DSA is to implement such a program on a large scale and monitor the results. As stated earlier, deep percolation flows can be reduced by 35 percent through better management practices using current irrigation systems. Drainage will be reduced by at least this amount and perhaps more, depending on the relationship between upslope areas and tile flows and the actual amount of deep ground water losses in the area.

- Effects of Reduced Drain Flow on Selenium Load

  The real goal of drainage flow reduction is to decrease the load of constituents of concern being discharged. For example, if reduction in drainage flow simply caused selenium concentrations to increase proportionately, then there would be no net reduction in the load of selenium to the system. Theoretically there should be little, if any, increase in selenium concentrations with decreases in subsurface drainage. As shown in Figure VII-1 the flow lines into the tile drains sweep deeply beneath the tile lines bringing with it the higher concentrations of selenium found deeper in the ground water profile. Decreasing deep percolation will decrease the hydraulic head on this flow system and cause less of this deeper, more selenium-laden water to flow into the tile drains. To test this hypothesis we evaluated monthly or biweekly selenium level and flow data for 13 sumps. Also the estimates as shown in Table V-7 were evaluated. Only two of the 13 sumps evaluated showed a statistically significant correlation between drain flow and selenium levels. Data for the entire DSA also showed no statistically significant relationship. However, the data sets all tended to have a negative slope indicating a possible trend toward increasing selenium concentration with decreasing flow. While this possible trend cannot be shown statistically for the sumps analyzed, it indicates that a desired percentage reduction in selenium load might require either the same or a slightly higher reduction in drainage flows. Available data on selenium and flow from individual sumps should continue to be analyzed to better understand possible relationships between the two.

Reduction in Drainage Flow Alternatives

Two drainage flow reduction alternatives were evaluated. The first deals with the reductions in excess deep percolation and subsurface drainage that can be achieved through better management of the existing predominately furrow irrigation systems in the DSA. The second involves the implementation of available new technology to more uniformly apply water and thus reduce drainage volumes.

o Water Management Alternative

The water management alternative centers on the principles discussed in the water balance section of Chapter V. In this section we develop a rough water balance for the DSA, summing the various sources of water and dividing the water outputs into various categories. One important category is called excess deep percolation. This is the amount of water that percolates to the ground water table in excess of that required for the leaching of crops. It can be related to a factor called the "distribution uniformity" of applied water. No irrigation system can uniformly apply water across a field. In a furrow system, water stands near the head ditch for a long time before enough water to irrigate the driest part of field works its way into the furrow. In this report we are defining distribution uniformity as the water needed to satisfy evapotranspiration requirements divided by the depth of water applied to the field. Our consultants estimate that a well managed furrow irrigation system should be able to achieve 80% uniformity or a deep percolation rate in the DSA of about 0.45 af/acre. We estimate, in Chapter V, that the uniformity in the DSA is a little less than 70% with an average excess deep percolation rate of 0.7 af/acre. By increasing water use efficiency to 80% uniformity, the deep percolation can be reduced by about 35%. As discussed in Chapter V this may equate to an even greater reduction in subsurface drain flows.

Chapter V also discusses the reductions in selenium load needed to achieve a 5 ppb water quality objective in the San Joaquin River at Hills Ferry. Depending on water year type, the reductions range from 12% to 29%. Even assuming some increase in selenium concentration with a reduction in drain flow, it appears that an objective of 5 ppb in the San Joaquin River at Hills Ferry can be achieved through better management of existing systems.

The costs for better water management need to include the costs of both better irrigation management and better drain flow management. The reductions in selenium load discussed earlier are annual averages with significantly greater reductions required in some months than in others. Drainage flows from the DSA would have to be closely managed to ensure that only allowable quantities of drainage are leaving the DSA. This would likely mean centralized control on the pumping of tile flow sumps and using the soil profile as an intermediate storage system. The costs for such a DSA-wide system for the approximately 100 sumps is estimated at about $3.00/acre.

The Central Valley Water Use Study Committee (1987) estimated increased water management costs at about $17/acre. These costs cover the development of water management plans, implementation of these plans and monitoring. Therefore, total increased costs for both drainage flow management and irrigation management is estimated at $20/acre.

Because of better management there would be less use of applied water in the DSA. The reduced deep percolation alone amounts to over 23,000 AF/year. An approximately equal amount could be saved in surface runoff. Total water savings would be approximately 46,000 AF/year. The water districts in the DSA currently charge their operator an average of about $8.35/AF for power to pump this water to turnouts. Therefore, an energy savings of about $380,000/year or about $4/acre would occur to the operations within the DSA. Additional cost savings might be realized if the Bureau of Reclamation modified their existing contract rules and regulations to allow the Districts to pay for only the water they use rather than a contractually established minimum quantity. Such possible changes to the Bureau's contract rules and regulations are being discussed by the San Joaquin Valley Drainage Program and the Bureau staff.

The net per acre cost of achieving the 5 ppb selenium objective at Hills Ferry would be about $16/acre with essentially no capital costs. These costs are shown on Table VII-4.

o Improved Irrigation Methods

The alternative dealing with improved irrigation methods refers to increasing the distribution uniformity of water application from the 80%, achievable with better management, to 90% through the use of new, but available, irrigation techniques.

As discussed in Chapter V, a 90% distribution uniformity of applied water would reduce deep percolation in the DSA from its present 0.7 AF/acre to 0.2 AF/acre. This is a reduction in deep percolation of

71%. As stated earlier, we expect an even greater percentage reduction in subsurface drain flow because of losses to deep ground water in the area.

Chapter V presents the reduction in selenium load needed to achieve 2 ppb selenium in the San Joaquin River at Hills Ferry. Depending on the year type, the reductions range from 40% to 68%. Even assuming an increase in selenium concentration in the tile drainage due to reduced drainage flows, it appears that selenium load reduction is possible with the implementation of improved irrigation techniques to increase the uniformity of water application to 90%.

There are a suite of such technologies now available which could produce uniformities of 90%. They include surge irrigation, gated pipe, sprinkler irrigation, drip irrigation, a technique known as Low Energy Precision Application (LEPA) and a host of others. Upon reviewing these systems it appears that a 90% uniformity of water application is both feasible and cost effective when compared to selenium treatment to achieve selenium levels of 2 ppb in the San Joaquin River at Hills Ferry.

The Technical Committee does not advocate the use of any one of these systems. However, in order to develop an idea of the costs involved, we evaluated the LEPA system, one technique that could have general application in the DSA. Other alternatives may have higher or lower costs than LEPA. We must emphasize that while LEPA has been used successfully in Texas, it would need to be field tested in California before it could be advocated for widespread use. This system provides at least 90% uniformity of water application and, because it is a low pressure system, its energy costs are much less than sprinkler irigation. Also, it is an above ground laterally moving system that has advantages over drip irrigation for some crops (Lyle, 1987).

The capital cost of LEPA is similar to that of laterally movingsprinklers. With the capital cost to purchase pumps to pressurize the system, the costs are estimated at $350/acre or $33 million, if implemented over the entire DSA. Amortized at 4% over ten years the annual cost would be $4.06 million or $43/acre in the DSA. (At an interest rate of 10% the capital costs would increase to $57/acre/year).

Operation and maintenance costs are principally related to the energy to pressurize the system. With such a system, average applied water would be reduced to 2.2 AF/acre. To apply 2.2 AF/acre, the fuel costs are about $13/acre. There are some labor savings with LEPA over furrow irrigation. Also, the water management and drainage management programs would need to be performed. The net operation and maintenance cost is estimated to be about $10/acre. Therefore, total operation and maintenance costs are estimated at $23/acre.

Less water would be used under this more efficient system; a savings of about 0.8 AF/acre over that currently used is a conservative estimate. For the entire DSA this is about 75,000 AF/year. The energy cost savings to the farm operators, at an average district energy cost of $8.35/AF, is about $6.70 per acre.

The costs of this alternative are shown in Table VII-4. The total per acre cost is $59/acre.

We must emphasize again that the use of the LEPA system to evaluate costs does not suggest its use throughout the DSA. A combination of different methods will likely be used. It simply provides us with a basis to evaluate costs of reasonable alternatives that may be selected by the entities in the DSA to address water quality problems related to the discharge of subsurface drainage into the San Joaquin River system. Obviously, growers in the DSA should evaluate the costs of achieving 90% application uniformity with the irrigation techniques best suited for the soils, topography, crops grown, and water and energy costs applicable to them.

Benefits of Drainage Flow Reduction Over Treatment

A review of the cost data presented in Table VII-4 shows that drainage flow reduction is the least expensive alternative evaluated. Drainage flow reduction also provides some other significant advantages over treatment to remove selenium.

- Reduction of Other Constituents in Subsurface Drainage

  As presented in Chapter IV, the State and Regional Boards are concerned not only with selenium, but boron, salt and a host of trace elements found in subsurface drainage. Treatment schemes reviewed by the Technical Committee focus on the removal of selenium and boron. Thus, removal of other elements is only incidental, and no removal of salt is effected. Because water quality objectives will be recommended for salt and boron, reduction in the load of these constituents may be needed to achieve these objectives. It is possible that in the future the other elements may also be of concern. The reduction in drainage volumes reduces the load of all drainage related constituents and may prevent the need for additional actions by the Regional Board in the DSA to control these elements.

- Reduced Drainage Volume Will Decrease Treatment Costs if Treatment is Required in the Future.

  As stated earlier, the costs of selenium treatment are related to the volume of the waste to be treated with a reduced volume, the costs of possible treatment in the future will be less.

- Agricultural Production Benefits Can be Achieved by the More Efficient Use of Water

  Studies have shown that yields will increase and production costs will be less for an irrigation system like LEPA due to more efficient application of fertilizers and pesticides. These benefits have not been quantified in our report but they areimportant factors that must be weighed in the decision-making process.

- More Efficient Water Use in the DSA Makes This Scarce Resource Available for Other Uses

  The water savings related to achieving 5 ppb selenium is estimated at about 46,000 AF/year. Water savings to achieve the 2 ppb selenium objective is about 75,000 AF/year. This water could be put to other beneficial uses in either the waterfowl areas of the San Joaquin River Basin or other areas of the State.

- Drainage Flow Reduction Technologies are Proven and Readily Available

  Research into more efficient use of water has been a high priority in the arid west and southwest regions of the nation. Many techniques have been shown to work in California. Others still need to be field tested. The techniques to employ better water management to achieve 80% uniformity are available and implementable today. To implement technologies to achieve 90% uniformity will take a few years. Implementation of treatment technologies on a large scale is several years away.

- Implementing Drainage Flow Reduction Requires a Smaller Capital Outlay.

  The treatment technologies all require a large capital expenditure. It seems unwise to spend large amounts of capital for selenium treatment until more data on drainage flow volumes in the DSA becomes available. At least a phased program of implementation should be considered to allow the collection of this data. The drainage flow reduction alternative lends itself nicely to such a phased approach.

Achieving Selenium Objectives Through Dilution

Achieving selenium water quality objectives in the San Joaquin River through dilution was discussed at length by the Technical Committee. Tables V-10, V-11, V-12, and V-15, column 14 show the volume of water needed per month to achieve an objective of 5 ppb selenium in the San Joaquin River at Hills Ferry, assuming that all the agricultural drainage in the DSA is bypassed by the Grassland Water District.

During normal years approximately 130,000 AF would be needed to augment the flows in the San Joaquin River. Approximately 200,000 AF would be needed in dry and critical years. Much of this water would be needed in the months of April, May, June and July of normal years and almost every month in dry and critical years. One method of providing this large volume of water to the San Joaquin River system would be for some entity to pay the Department of Water Resources (DWR) or the Bureau of Reclamation (Bureau) to pump this water from the Delta and to discharge it into the San Joaquin River at the Newman Wasteway or an area further upstream.

The cost of providing this water can be broken down into two components. They are (1) the canal costs associated with transporting this water and (2) the energy and water charges for this water. At times DWR has canal capacity to carry this volume of water while the Bureau does not. However, the Bureau at times has the water and energy sufficient to satisfy this demand. An arrangement involving these two agencies would be necessary to provide these dilution flows. However, competing demands for the water for other consumptive uses in other areas of the State and competition for the canal capacity may make such an arrangement difficult to attain. In addition, changes to the water right permits of the Bureau would be needed to allow the use of the DWR pumping plant as a point of diversion on a long term basis.

To assess the costs which may be associated with providing dilution flows, we looked at the canal usage costs currently being charged by DWR and the energy and water costs which would likely be charged by the Bureau. DWR currently charges the Bureau about $10.50/AF for canal useage from the

Delta Pumping Plant and the California Aqueduct to an area near the Newman Wasteway (Kennedy, 1987). Present energy and water costs from the Bureau are about $5.60/AF. Therefore, the present day costs to dilute existing selenium loads to 5 ppb during normal and dry years would be about $2.5 million per year and $3.2 million per year, respectively. The actual price would likely change depending on negotiations with the Bureau and the DWR to supply this water and future water price increases. Changes to existing physical facilities which might be needed to accommodate these flows into the San Joaquin River system have not been determined at this time, but would also need to be financed.

Use of additional water to dilute selenium to acceptable levels in the San Joaquin River has four major disadvantges:

(1) Agreements with the DWR and the Bureau to provide dilution flows may be difficult to obtain due to 1) the large volume of water involved, 2) application of reclamation law and 3) the present pumping limitations to help protect fishery resources in the Delta during May, June and July.

(2) The adverse environmental effects on Delta fisheries of pumping this additional amount of water would need to be assessed.

(3) The annual cost of this option is almost double the drainage flow reduction alternative to achieve the same level of protection, and the cost of this dilution alternative will increase as water and energy prices increase in the future.

(4) For water quality objectives of less than 5 ppb selenium, the amount of water and the associated costs would increase dramatically.

For these reasons, the Technical Committee did not consider further the option of providing dilution flows to achieve selenium water quality objectives. Also, because water in California is a scarce resource, the Technical Committee believes that dedicating water supplies (or canal capacity) to dilute man-induced pollutants should be considered only after all reasonable source control and treatment methods have been exhausted.

Economic Effects

Chapter VI presents the Agricultural Economy of the Drainage Study Area and describes the methodology that is used to estimate economic effects of possible regulatory actions to control agricultural drainage that may be taken by the Central Valley Regional Board. These possible actions and their costs were discussed in the previous section of this chapter. This section on economic effects will briefly summarize both short- and long-term effects of attaining possible water quality objectives for selenium at various locations in the San Joaquin River Basin. These effects are described in terms of both the direct effects on the economy and their ripple effects through the economy, better known as indirect and induced impacts. A detailed discussion on how these effects are estimated is presented in Appendix G, Chapter 6. The types of short- and long-term effects that are discussed are:

Short-term effects:

- positive impact to the construction industry of constructing physical works to attain water quality objectives in terms of total construction expenditures, jobs generated and personal income generated.

- percent of agricultural land in the DSA that becomes insolvent due to added costs of attaining the water quality objectives.

Long-term effects:

- acreage of land that can no longer generate net profits and goes out of production.

- losses associated with lands going out of production in terms of:
  - reduced crop production
  - reduced employment income
  - loss of jobs
  - decrease in profits
  - decrease in assessed valuation of agricultural land

- losses associated with land remaining in production in terms of:
  - net income loss to the economy
  - decrease in assessed valuation of agricultural land
- decrease in personal income
- loss of employment
- decrease in population
- impact on housing
- decrease in student population
- decrease in residential property assessed valuation
- decrease in commercial property assessed valuation
- decrease in retail sales

In Appendix G, these long term statewide effects are evaluated to estimate the amount of these economic effects that will be experienced in the San Joaquin River Basin as a whole, Fresno County, Merced County, westside cities and the City of Fresno.

o Short-Term Economic Effects

- Positive Impacts of Construction

Table VII-5 shows the initial direct and indirect positive economic impacts of meeting potential water quality objectives for selenium at various locations in the San Joaquin River Basin. These positive economic effects are related to the construction expenditures to build the conveyance and treatment facilities needed to attain these objectives. These positive economic effects are short-lived and last only during the construction period of about one to three years. Once the facilities are completed and in operation, they must be paid for through the per acre charges shown on Table VII-4. Paying for the facilities results in negative economic impacts that will be discussed in subsequent sections.

The values shown in Table VII-5 are based on the total capital expenditures for the actions shown in Table VII-4 for each of the five alternative locations and methods of attaining the selenium water quality objectives. The factors used to estimate the direct effects of jobs generated and personal income generated in the community, i.e., profit plus employment income, are taken from DWR Bulletin 210 (1980) and are shown on Table VII-5. The factors have been modified slightly from Bulletin 120 to reflect inflation since the time these data were collected in 1976 to the present (1986). In addition to these direct effects there are also indirect and induced impacts. Indirect impacts in this case result from construction sector purchases of goods and services manufactured by other sectors of the economy, e.g., fuel, transportation, etc. These purchases generate income and employment in these nonconstruction sectors of the economy. The increased economic activity in these nonconstruction sectors increases their own inter-industry purchases which creates increases in sales, income and employment throughout the economy. Induced impacts are those resulting from increases in household income which stimulates increased purchases of more goods and services in numerous sectors of the economy. The industries which produce these goods and services experience higher sales and higher profits leading to higher employee income and increased purchases of products from other producing sectors. These other sectors experience an increase in sales, income and inter-industry purchases. The ultimate total increase in sales, income and employment throughout the California economy is known as the direct, plus indirect, plus induced impacts. The values shown in Table VII-5 assume that this construction activity is a new activity and not simply a diversion of construction activity from other areas which would have occurred anyway.

The values shown in Table VII-5 represent statewide impacts. The regional distribution of personal income originating from construction activity within the San Joaquin Basin are discussed in Appendix G, Section 6.2 and DWR Bulletin 210 (1980). They show that about 60 percent of all the personal income in the State generated directly and indirectly by construction activity within the San Joaquin Valley stays within the Valley. About 20 percent goes to the Los Angeles area and about 12 percent to the San Francisco Bay area. The distribution of the employment benefits are likely similar.

Table VII-5 shows that construction costs to achieve the objectives through treatment range from $20.6 to $68 million. The construction expenditures to achieve the objectives through drainage flow reduction are $0 to $33 million. For treatment alternatives the estimates of total short-term jobs generated for the capital intensive alternatives range from about 135 to 445. For the drainage flow reduction alternative the short-term jobs generated range from 0 to 216. Personal income generated in the California economy would be about $29 to $97 million for the treatment alternatives and $0 to $47 million for the drainage flow reduction alternative.

- Negative Short-Term Economic Effects

Short-term economic effects are defined as the amount of land which does not generate sufficient income to pay for the cost of farming under its current debt load. These lands become insolvent, leading to default on the existing debt. These data are derived from an economic model discussed in Chapter VI. The results of this model are shown in Figure VI-2. The model has numerous limitations. There is no direct information on the curent debt burdens of farm operations and land owners in the DSA. Therefore, our consultants were forced to use some rather crude and aggregate data. Because of this lack of data, our consultants estimated the percentages of acres rather than the number of farm operations in distress. As discussed in Chapter VI, this calculation does not include the contribution to cash flow from activities other than farming in the DSA, e.g., farming elsewhere in the San Joaquin Valley or out of state, nonfarm income and debt, etc. This lack of data probably leads to an over-estimate of financial distress because it is likely that financial pressure on land in the DSA can be buffered by income from other sources. It must also be emphasized that these estimates are of incremental financial distress caused by increases in drainage-related costs. This separates the added financial burden of additional drainage-related costs from the current financial distress associated with the recent decline in commodity prices and land values over the past five to six years. As discussed in Chapter VI, between ten and thirty percent of the land in the DSA is currently believed to be insolvent.

Table VII-6 shows the cost per acre and the number of acres and percent of land that would become insolvent with implementation of the potential water quality objectives at various locations. It is important to note that these estimates assume that all lands within the DSA are solvent at the time drainage costs are imposed. That is to say that the ten to thirty percent of the land currently estimated to be insolvent has changed owners and is free of existing debt at the time drainage costs are levied. This table shows that for the treatment alternatives, between 3 percent and 35 percent of the 94,480 acres of agricultural land in the DSA could become insolvent. For the drainage flow reduction alternative 2 percent to 17 percent of the land in the DSA would become insolvent. If this occurred, there would be not only a social and financial impact on the borrowers, but also an impact on the lenders arising from the loss of capital and interest income. This land could remain in production once land values have been adjusted to the reduction in farming profitability caused by the imposition of drainage charges and all current debt is either paid off or wiped out. Therefore, insolvency is a short term situation. The next section discusses the long term impacts of lands that no longer stay in production due to increased drainage management costs and the long term effects on the lands that stay in production.

- Long-Term Negative Economic Effects

  - Direct Effects

Estimates of the direct effects on the 94,480 acre DSA of increased drainage related costs are divided into two categories. These are shown on Table VII-7 as (1) the effects from land going out of production and (2) the effects on land remaining in production. These effects are based on the farm profitability model discussed in Chapter VI which is summarized in Figure VI-3 and Table VI-7. This model generates estimates of the distribution of gross profitability from farming on the basis of the variability in soil quality. Because soil quality within the DSA is a discrete distribution, the model predicts a step function for gross profitability. The most marginal land, about 2,119 acres, is estimated to be earning a gross annual profit of only about $35/acre. The next most marginal block of land is 1,113 acres with a gross profit of $45/acre and so on. In Chapter VI information is presented which shows that the average gross profit for the 94,480 acres in the DSA as a whole is about $196/acre.

The calculations of farm profitability are keyed to current commodity prices and cropping patterns. Forecasting commodity prices is notoriously difficult but, as explained in Appendix G, Section 4.3.8, the post-1980 decline in prices appears to be over and prices have stabilized during the past year. Our consultants do not anticipate any further decline nor any return to the high prices of six or seven years ago. If subsidies provided for cotton in the existing Farm Bill should decrease, this could have a significant impact on the DSA, where over 60 percent of the land is planted to cotton and rotation-related crops. But assessing that impact is not easy. Other cotton producing regions of the county - the Mississippi Delta, for example, have lower yields and grow cotton less profitably than the DSA even after the imposition of drainage charges. Also, the long staple cotton grown in California still commands a premium in the marketplace. If the cotton subsidy were eliminated nationwide, some of these other regions would be pushed out of cotton production before the DSA, to the latter's advantage. At this time, however, it is too early to predict whether there will be any change in the Farm Bill, or what form it would take. In the absence of a change, the historical stability of cropping patterns in the area leads our consultants to believe that it is reasonable to employ current cropping patterns for predicting future farming profitability. The amount of land that will be forced out of production due to higher drainage-related costs for each alternative water quality objective is shown in Table VII-6 alongside the acreages that may become insolvent.

When land goes out of production there is a direct impact in terms of reduced agricultural production, fewer farm jobs, and less employment income. In addition to the loss of employment income, there is a loss of profit. Together these two items constitute the direct reduction in personal income on land going out of production. On the land staying in production there is, by definition, no reduction in agricultural production or farm employment, but there is a loss of profit. For example, a drainage charge of $36/acre reduces the profitability of all land in production by $36/acre. That constitutes the direct reduction in personal income on such land. However, part of this income reduction results in a transfer to another section of the economy. While some of the money growers pay for drainage management is used to pay off the debt incurred in constructing conveyance, treatment facilities and water conservation equipment, the rest would go to pay for the operation and maintenance cost of the treatment system or water conservation measures, which is largely labor costs. To the extent that the operation of a selenium removal facility generates jobs and income, both directly and indirectly, drainage expenditures transfer income generated from the farming sector to the wastewater treatment sector, and are not a net loss to the California economy. To adjust for this, only the capital component of the annual drainage costs are used to estimate the net reduction in personal income from the land remaining in production. Finally, on both the land going out of production and the land remaining in production there are direct losses of assessed property value which are calculated from equation 4.22 in Appendix G.

As an example of how these economic impacts are calculated, a review follows of those associated with the 2 ppb selenium potential objective under Alternative 1 in Table VII-6, involving a drainage cost of $74/acre. It is estimated that 2,119 acres in the DSA earn $35 to $45/acre, 1,113 acres earn a profit of between $45 and $68/acre, 2,224 acres earn a profit between $68 and $76/acre, and 708 acres earn a profit of $76 to $91/acre. To assure that the Technical Committee does not underestimate the economic effects of drainage costs, two assumptions were used:

- that all land within each profit range mentioned above only earns the minimum profit within that range.

- that even land believed to be earning $76 to $91/acre will go out of production when drainage charges reach $74/acre.

Thus the total annual profit lost when this acreage goes out of production would be $329,290. This acreage produces about $4,473,500 in gross revenues (the breakdown by crop is shown in the last two columns of Table VI-7) or about $726/acre. This is 12 percent less than the average sales revenue per acre for the 94,480 acres as a whole. That is because this is poorer quality land and, by assumption, it is this land which would go out of production first. Multiplying the reduction in acreage by the crop-specific coefficients in the first two columns of Table 4.19 in Appendix G yields an estimated reduction in the employment of 87 Full Time Equivalent (FTE) jobs, which translates into about 117 workers (after an allowance is made for part-time seasonal field labor) and an estimated reduction in annual employee income of $964,000. From Table VII-4 the estimated capital component of the $74/acre drainage charge is $50/acre; therefore, the net income loss on the 88,316 acres remaining in production is $4,415,800/yr. The assessed valuation of the 6,164 acres going out of production was based on its gross annual profit of $329,290, capitalized at 7.9173 percent. It is assumed that the land is now used for non-irrigated pasture and has an annual rental value of $10/acre, or $61,640. Using the same capitalization factor, the reduction in the assessed value of this land is $3,380,572 [= ($329,290 - $61,640)/0.079173]. Finally, as discussed in Chapter VI our consultants assumed that the annual rental value of the 88,316 acres remaining in production is reduced by $48.10/acre (= 0.65 x $74 per acre). Capitalized at 7.9173 percent this implies a reduction in assessed value of $53,654,650 [= 88,316 x $48.10 ÷ 0.079173].

The other selenium objectives in Table VII-7 are analyzed in a similar manner. Note that, because relatively little land goes out of production in the long run, the net reduction in personal income on the land remaining in production is more significant than the corresponding income loss associated with the land going out of production. The effect on lands staying in production is generally three or four times larger than the effects on lands going out of production.

The most striking direct effect of increased drainage costs is the decrease in assessed valuation of agricultural land on the lands staying in production. This decrease for the treatment alternatives ranges from 14 percent to 50 percent for the drainage flow reduction alternative. The reduction in assessed valuation is about 10 percent for the 5 ppb objective and 37 percent for the 2 ppb objective.

- Statewide Direct Plus Indirect and Induced Negative Economic Effects

The computation of the statewide indirect and induced impacts associated with the direct impacts in Table VII-7 are discussed in detail in Appendix G, Chapter 6 and Appendix J. These impacts are presented in Table VII-8 with the statewide baseline of the economic benefit provided by farming in the DSA. This allows calculation of the percent loss in economic benefits of farming in the DSA due to implementation of one of the alternatives presented. Depending on the water quality objective for the treatment alternatives, the state reduction in annual personal income ranges from about $1.8 million (3.5 percent of all the income generated directly and indirectly by farming operations on the 94,480 acres) to $8.5 million (16.7 percent of the baseline total (1984-85)). The reduction in personal income for the drainage flow reduction alternative is zero for the 5 ppb objective because there are no capital costs involved with this alternative and $6.6 million or 13 percent of the baseline for the 2 ppb objective. The statewide long-term impact on employment for the treatment alternatives ranges from 47 jobs (expressed as actual employees rather than FTE jobs) to 474 jobs. The statewide long-term impact on employment for the drainage flow reduction alternative is 320 jobs for the 2 ppb objective and zero for the 5 ppb objective.

It must be emphasized that these calculations are subject to the same qualification as the initial impact analysis in Table VII-5, namely that there are no offsetting changes in other parts of the California economy which mitigate these impacts, i.e. the workers idled by the changes in the DSA remain unemployed rather than being employed in other sectors of the economy. These calculations are also subject to the qualification, mentioned in connection with the short-term impacts in Table VII-6. They are the <u>incremental</u> impacts caused by DSA drainage-related costs - they abstract from impacts on personal income, employment and property values associated with other events which may affect farmers in the area.

Regional Distribution of Economic Impacts

The statewide economic impacts of the alternative selenium water quality objectives are discussed in the previous section. These include direct, indirect and induced impacts (ripple effects) throughout the State's economy associated with the loss of part of the economic benefits generated by farming in the DSA. The total statewide economic benefits generated by farming in the DSA are shown as the baseline (see Table VII-8). Both the economic benefits of farming in the DSA and the loss of some of these benefits can be split into those experienced within the San Joaquin River Basin and those experienced outside the Basin. (For this economic analysis, the River Basin referred to in this section includes the actual San Joaquin River Basin plus all of Fresno County.) Table VII-9 shows how the categories of impacts in Table VII-8 are divided between areas within and outside the San Joaquin River Basin. Simply multiplying these factors times the values in Table VII-8 provides an estimate of the extent of the statewide impacts that are expected to be felt within the San Joaquin River Basin. These values are presented in Table 6.15 in Appendix G.

These Basin-wide impacts are further divided into more local impacts. Most of the impact will be experienced on the local level. Our consultants have evaluated these economic impacts in the form of reductions in annual revenues to four local entities. They are: (1) the west side cities of Mendota, Firebaugh, Los Banos, and Dos Palos, (2) the City of Fresno, (3) Fresno County and (4) Merced County. Table VII-10 shows the reductions in revenues to these entities. It also shows, as baseline, the total benefit in terms of revenues that these entities receive from irrigated agriculture in the DSA. Also shown is the total tax generated revenue for 1984-85 for these entities. This total tax generated revenue includes all local taxes and the return of other taxes (like sales tax) to local governments but excludes other sources of income that are in the form of user charges, service fees and state or federal grants. These other (excluded) sources of income can be substantial (especially state and federal grants), but will not be affected by the economic effects discussed above. Income from user charges and service fees might be reduced because of losses in population. However, this is offset by no longer needing to supply the service so there is probably no net impact. Removing the non-tax related items from the total revenues allows for a fairer comparison of the economic impacts of the alternative selenium water quality objectives on these entities' budgets.

Comparing the baseline values of the economic benefits to the local entities from farming in the DSA with their total tax generated budget provides an idea of the economic importance of farming in the DSA. This is shown in the bottom line in Table VII-10. As one would expect, the west side cities of Mendota, Firebaugh, Los Banos and Dos Palos receive the most economic benefit from farming in the DSA. About 12% of their tax revenues are generated by farming in the DSA. Fresno and Merced Counties benefit to a lesser degree at 3.5% and 2.5%, respectively. The least affected is the City of Fresno at 0.9%. The losses in tax generated revenues to the local entities discussed above by implementation of any of the selenium alternatives presented in Table VII-10 are extremely small. Losses in total tax generated revenues for the west side cities are less than 1% and much less than 1% for the other entities.

References

Central Valley Water Use Study Committee. 1987. Irrigation Water Use in the Central Valley of California.

Kennedy, D. N. 1987. Letter to D. G. Houston, Regional Director, Mid-Pacific Region, U.S. Bureau of Reclamation.

Lyle, W. 1987. Personal Communication. Texas Agricultural Experiment Station, Lubbock, Texas.

Neethling, J. B., Y-C. Chung, R. Ten Bosch. 1986. Cost of Alternative Techologies for Removing Selenium, Boron, Molybdenum and Salinity from Agricultural Drainage. Appendix I - Regulation of Agricultural Drainage to the San Joaquin River, August 1987.

TABLE VII-1 **ATTAINABLE LEVELS OF REMOVAL EFFICIENCY**

Selenium Removal

- A biological process with filtration may reduce selenium concentrations to 10-20 ppb. We will employ 10 ppb as an optimistic estimate.

- If ion exchange is added to the biological process, the effluent concentration is reduced further, perhaps in the range of 2-5 ppb. We will employ 2 ppb as an optimistic estimate.

- Reverse osmosis can reduce selenium to 10-20 ppb.

Boron Removal

- Ion exchange will reduce boron to less than 1 ppm.

- Reverse osmosis will reduce boron to 5-90 ppb.

Molybdenum Removal

- It does not appear likely that either of these two processes will effect significant removal of molybdenum.

TDS Removal

- Reverse osmosis will reduce TDS to below 750 ppm.

TABLE VII-2 DRAINAGE TREATMENT COSTS ($/AF/yr)

Treatment System	Treatment Plant Capacity AF/MO (mgd)				
	93.3 (1)	933 (10)	2,800 (30)	4,667 (50)	7,467 (80)
Treat Tile Drainage Only					
Se removal with Ion Exchange	237	169	154	151	--
Se removal without Ion Exchange	145	105	93	90	--
Se removal, evaporation pond, no effluent: low estimate	277	234	217	215	--
high estimate	461	416	401	396	--
Ion Exchange, Reverse Osmosis, 85 percent of effluent available for use, 15 percent of effluent treated for SE removal and disposed in evaporation ponds: low estimate	476	375	329	319	--
high estimate	521	400	357	347	--
Treat Combined Tile plus Surface Drainage (Add Coagulation to Remove Suspended Solids)					
Se removal without Ion Exchange	--	133	120	--	102
Se removal, evaporation pond (low estimate)	--	261	240	--	222

Note: Capital costs discounted at 4 percent over 20 years.

Source: Neethling et al. (1986)

TABLE VII-3 SUMMARY OF SCENARIOS

Scenarios	Dual Collection System	Treat Combined Tile Plus Surface Drainage	Detention/Equalization of Drain Flows Prior to Treatment	On-Farm Conservation
Treat Combined Drain Flow				
Without Storage		x		
With Storage		x	x	
Separate, Treat Tile Drain Only				
Without Storage	x			
With Storage	x		x	

Note: x = included in scenario

LOCATION OF STANDARD

(A) Standard is met in the San Joaquin River, downstream of the Merced River
  (i) without delivery of supplementary CVP water to Grassland WD
  (ii) with delivery of supplementary CVP water to Grassland WD

(B) Standard is met as drainage exits the DSA, upstream of Grassland WD

Minimum Annual Costs and Best Treatment Strategies for Meeting Selenium Objectives at Various Locations

Table VII-4

2 ppb Selenium Objective

	Actions	Costs[1]: total capital $M	Costs[1]: annual costs $M	Costs[1]: annual per acre $/acre
(1) Objectives met in San Joaquin River and Mud and Salt sloughs	-separate tile drain -regu. of tile flow -Se treatment -open canal to SJR below Merced R.	$64.4	cap 4.74 O&M 2.29 total $7.03	$74
(2) Objectives met in San Joaquin River, Mud and Salt sloughs & Ag. drains via new collection and disposal system	-separate tile drain -regu. of tile flow -Se treat. -open canal to SJR below Merced R.	$64.4	cap 4.74 O&M 2.29 total $7.03	$74
(3) same as #2	same as above except[3] -closed pipe to SJR below Merced R.	$60.0	cap 4.42 O&M 3.35 total $7.77	2/
(4) Objectives met in San Joaquin River, Mud and Salt sloughs & Ag. drains via higher treat. in DSA[4]	-separate tile drain -regu. of tile flow -Se treatment	$60.0	cap 4.42 O&M 3.35 total $7.77	$82
(5) Objectives met in San Joaquin River at Hills Ferry and Downstream via drainage flow reduction	-increase in distribution uniformity to 90% -no treatment	$33.0	cap 4.06 O&M 2.17 energy savings -0.63 total $5.60	$43[5] $23 -$6.70 $59

5 ppb Selenium Objective

	Actions	Costs[1]: total capital $M	Costs[1]: annual costs $M	Costs[1]: annual per acre $/acre
(1)	-separate tile drain -regu. of tile flow -Se treatment -open canal to SJR below Merced R.	$52.4	cap 3.85 O&M 1.18 total $5.03	$53
(2)	-separate tile drain -regu. of tile flow -Se treat. -open canal to SJR below Merced R.	$52.4	cap 3.85 O&M 1.18 total $5.03	$53
(3)	same as above except -closed pipe to SJR below Merced R.	$68.1	cap 5.01 O&M 1.18 total $6.19	$66
(4)	-separate tile drain -regu. of tile flow -Se treatment	$57.0	cap 4.19 O&M 3.08 total $7.27	$77
(5)	-better water management in DSA -no treatment	-0-	cap -0- O&M 1.89 energy savings -0.38 total $1.51	-0- $20[5] -$4 $16

10 ppb Selenium Objective

	Actions	Costs[1]: total capital $M	Costs[1]: annual costs $M	Costs[1]: annual per acre $/acre
(1)	-regu. of tile flow -Se treatment -open canal to SJR below Merced R.	$20.6	cap $1.52 O&M $0.45 total $1.97	$21
(2)	-separate tile drain -regu. of tile drai. -Se treat. -open canal to SJR below Merced R.	$44.0	cap $3.23 O&M $0.40 total $3.63	$38
(3)	same as above except -closed pipe to SJR below Merced R.	$59.7	cap 4.39 O&M 0.40 total $4.79	$51
(4)	-separate tile drain -regu. of tile flow -Se treatment	$52.8	cap $3.89 O&M $2.68 total $6.57	$70
(5)				

1 Annual costs based upon 4% for 20 years, cap factor 0.0736, total annual costs divided by the 94,480 acres in the Drainage Study Area (DSA)
2 Least cost alternative is actually meeting objectives via treatment rather than a new disposal system to below the Merced River
3 Additional cost of closed pipe to the San Joaquin River below the Merced River is estimated to be $15.76 million in increased capital costs
4 This alternative does not rely on San Joaquin River dilution to achieve water quality objectives

TABLE VII-5

INITIAL DIRECT AND INDIRECT POSITIVE ECONOMIC IMPACTS OF MEETING SELENIUM OBJECTIVES

Water Quality Objectives	Total Construction Expenditures ($M)	Direct Impact: Jobs Generated	Direct Impact: Personal Income Generated ($M)	Direct Plus Indirect and Induced Impacts: Jobs Generated	Direct Plus Indirect and Induced Impacts: Personal Income Generated ($M)
1. Selenium objectives met in San Joaquin River and Mud and Salt slough via treatment					
2 ppb	64.4	421	26.4	2,089	91.4
5 ppb	52.4	343	21.5	1,700	74.3
10 ppb	20.6	135	8.4	668	29.2
2. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural via treatment, new collection and disposal system - open canal to San Joaquin River					
2 ppb	64.4	421	26.4	2,089	91.6
5 ppb	52.4	343	21.5	1,700	74.3
10 ppb	44.0	288	18.0	1,427	62.4
3. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via treatment, new collection and disposal system - closed pipe to San Joaquin River					
2 ppb	1/	1/	1/	1/	1/
5 ppb	68.1	445	27.9	2,209	96.6
10 ppb	59.7	390	24.5	1.937	84.7
4. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via higher treatment in DSA					
2 ppb	60.0	392	24.6	1,946	85.1
5 ppb	57.0	373	23.4	1,849	80.9
10 ppb	53.0	347	21.7	1,719	75.2
5. Selenium objectives met in San Joaquin River @ Hills Ferry and downstream via drainage flow reduction					
2 ppb	33.0	216	14.0	1,071	46.8
5 ppb	-0-	-0-	-0-	-0-	-0-

1/ least cost alternative to achieve the 2 ppb selenium objective is through higher treatment in DSA as shown in alternative #4 below. Construction costs and economic impacts are shown under the #4 alternative

Note: Column 2 = 6.54 x Column 1
Column 3 = 0.41 x Column 1
Column 4 = 32.44 x Column 1
Column 5 = 1.4187 x Column 1

TABLE VII-6

ECONOMIC IMPACT OF MEETING SELENIUM OBJECTIVES

Water Quality Objectives	Annual Drainage Costs $/Acre	Short-Term Impact Land Insolvent %	Short-Term Impact Land Insolvent Acres	Long-Term Impact Land Out of Production %	Long-Term Impact Land Out of Production Acres
Baseline	0	100	94,480	100	94,480
1. Objectives met in San Joaquin River and Mud and Salt sloughs					
2 ppb	74	28	26,455	7	6,164
5 ppb	36	6	5,670	3	3,232
10 ppb	21	3	2,834	-0-	-0-
2. Objectives met in San Joaquin River, Mud & Salt sloughs and agricultural drains via new collection and disposal system - open canal to San Joaquin River					
2 ppb	74	28	26,455	7	6,164
5 ppb	53	12	11,340	3	3,232
10 ppb	38	6	5,670	2	2,119
3. Objectives met in San Joaquin River, Mud & Salt sloughs and agricultural drains via new collection and disposal system - closed pipe to San Joaquin River					
2 ppb	82	35	33,070	7	6,164
5 ppb	66	21	19,840	6	5,456
10 ppb	51	11	10,393	3	3,232
4. Objectives met in San Joaquin River, Mud & Salt sloughs and agricultural drains via higher treatment in DSA					
2 ppb	$82	35	33,070	7	6,164
5 ppb	77	30	28,345	7	6,164
10 ppb	70	24	22,675	6	5,456
5. Objectives met in San Joaquin River @ Hills Ferry and downstream via drainage flow reduction					
2 ppb	59	17	16,062	3	3,232
5 ppb	16	2	1,890	-0-	-0-

DSA = Drainage Study Area (see Figure V-15)

TABLE VII-7

LONG-TERM DIRECT NEGATIVE ECONOMIC IMPACTS OF ALTERNATIVE SELENIUM OBJECTIVES

	LAND GOING OUT OF PRODUCTION						LAND REMAINING IN PRODUCTION	
Water Quality Objectives	Acres	Crop Production ($1,000/yr)	Employment Income ($1,000/yr)	Jobs	Profit ($1,000/yr)	Assessed Valuation ($1,000)	Net Income Loss [a] ($1,000/yr)	Assessed Valuation ($1,000)
Baseline	94,480	77,654	13,024	1,605	9,448	119,334	9,448	119,334
1. Selenium objectives met in San Joaquin River and Mud and Salt slough via treatment								
2 ppb	6,164[b]	4,474	964	117	829	3,381	4,416	53,655
5 ppb	3,232	2,814	677	78	124	1,161	3,741	39,704
10 ppb	-0-	-0-	-0-	-0-	-0-	-0-	1,512	16,289
2. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via treatment, new collection and disposal system - open canal to San Joaquin River								
2 ppb	6,164[b]	4,474	964	117	329	3,381	4,416	53,655
5 ppb	3,232	2,814	677	78	124	1,161	3,741	39,704
10 ppb	2,119	1,742	367	44	74	669	3,140	28,814
3. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via treatment, new collection and disposal system - closed pipe to San Joaquin River								
2 ppb	6,164	4,474	964	117	329	3,381	4,151	59,455
5 ppb	5,456[c]	3,928	848	103	275	2,790	4,718	48,238
10 ppb	3,232	2,814	677	78	124	1,161	4,289	38,206
4. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via higher treatment in DSA								
2 ppb	6,164	4,474	964	117	329	3,381	4,151	59,455
5 ppb	6,164	4,474	964	117	329	3,381	3,886	55,830
10 ppb	5,456	3,928	848	103	275	2,790	3,650	51,161
5. Selenium objectives met in San Joaquin River @ Hills Ferry and downstream via drainage flow reduction								
2 ppb	3,232	2,814	677	78	124	1,161	3,924	44,199
5 ppb	-0-	-0-	-0-	-0-	-0-	-0-	-0-	12,411

a Reduction in profits minus annual O&M expenditures for meeting selenium objectives
b Evaluated for cost increase of $76/acre/yr. instead of $74/acre/yr.
c Evaluated for cost increase of $68/acre/yr. instead of $66/acre/yr.

TABLE VII-8

STATEWIDE

LONG-TERM DIRECT PLUS INDIRECT AND INDUCED NEGATIVE ECONOMIC IMPACTS OF MEETING SELENIUM OBJECTIVES

Water Quality Objectives	Personal Income ($1,000/yr)	Employment	Population	Dwelling Units	Student Population	Residential Prop. Assessed Value ($1,000)	Commercial Prop. Assessed Value ($1,000)	Taxable Retail Sales ($1,000/yr)
Baseline	50,845	4,872	10,105	3,813	1,907	261,286	217,366	7,818
1. Selenium objectives met in San Joaquin River and Mud and Salt slough via treatment								
2 ppb	8,490	474	1,005	379	190	2,269	67,757	1,122
5 ppb	6,428	314	666	251	126	1,506	47,948	847
10 ppb	1,784	47	107	40	20	202	17,709	232
2. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via treatment, new collection and disposal system - open canal to San Joaquin River								
2 ppb	8,490	474	1,005	379	190	2,269	67,757	1,122
5 ppb	6,428	314	666	251	126	1,506	47,948	847
10 ppb	4,827	214	460	174	87	1,007	34,612	651
3. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via treatment, new collection and disposal system - closed pipe to San Joaquin River								
2 ppb	8,178	466	986	372	186	2,234	73,308	1,082
5 ppb	8,445	444	946	357	178	2,113	61,275	1,115
10 ppb	7,075	331	705	266	133	1,579	46,965	931
4. Selenium objectives met in San Joaquin River, Mud & Salt slough and agricultural drains via higher treatment in DSA								
2 ppb	8,178	466	986	372	186	2,234	73,308	1,082
5 ppb	7,865	457	968	365	183	2,199	69,434	1,041
10 ppb	7,185	411	870	328	164	1,970	63,195	951
5. Selenium objectives met in San Joaquin River @ Hills Ferry and downstream via drainage flow reduction								
2 ppb	6,644	320	679	256	128	1,530	52,615	875
5 ppb	-0-	-0-	-0-	-0-	--0-	-0-	12,411	-0-

Table VII -9

ESTIMATED REGIONAL INCIDENCE OF DIRECT, INDIRECT AND INDUCED IMPACTS INSIDE AND OUTSIDE THE SAN JOAQUIN RIVER BASIN

Type of Impact	% of Impact: Outside San Joaquin River Basin 1/	% of Impact: Within San Joaquin River Basin 1/
FTE Jobs		
Direct impact associated with land going out of production	0	100
Indirect and induced impacts associated with land going out of production	33	67
Indirect and induced impacts associated with net income loss on land remaining in production	37	63
Population (1)		
Direct impact associated with land going out of production	0	100
Indirect and induced impacts associated with land going out of production	33	67
Indirect and induced impacts associated with net income loss on land remaining in production	37	63
Taxable Retail Sales		
Direct impact associated with land going out of production	0	100
Indirect and induced impacts associated with land going out of production	33	67
Direct, Indirect and induced impacts associated with net income loss on land remaining in production	37	63
Personal Income		
Direct impact associated with loss of employee income on land going out of production	0	100
Indirect and induced impacts associated with loss of employee income on land going out of production	33	67
Direct, indirect and induced impacts associated with loss of profit on land going out of production	48	52
Direct, indirect and induced impacts associated with net income loss on land remaining in production	48	52
Assessed Value of Commercial Property		
Direct impact associated with land going out of production	0	100
Indirect and induced impacts associated with land going out of production	33	67
Direct impact associated with land remaining in production	0	100
Indirect and induced impacts associated with net income loss on land remaining in production	37	63

Note: (1) Dwelling units, residential property assessed value, and student population are proportional to population.

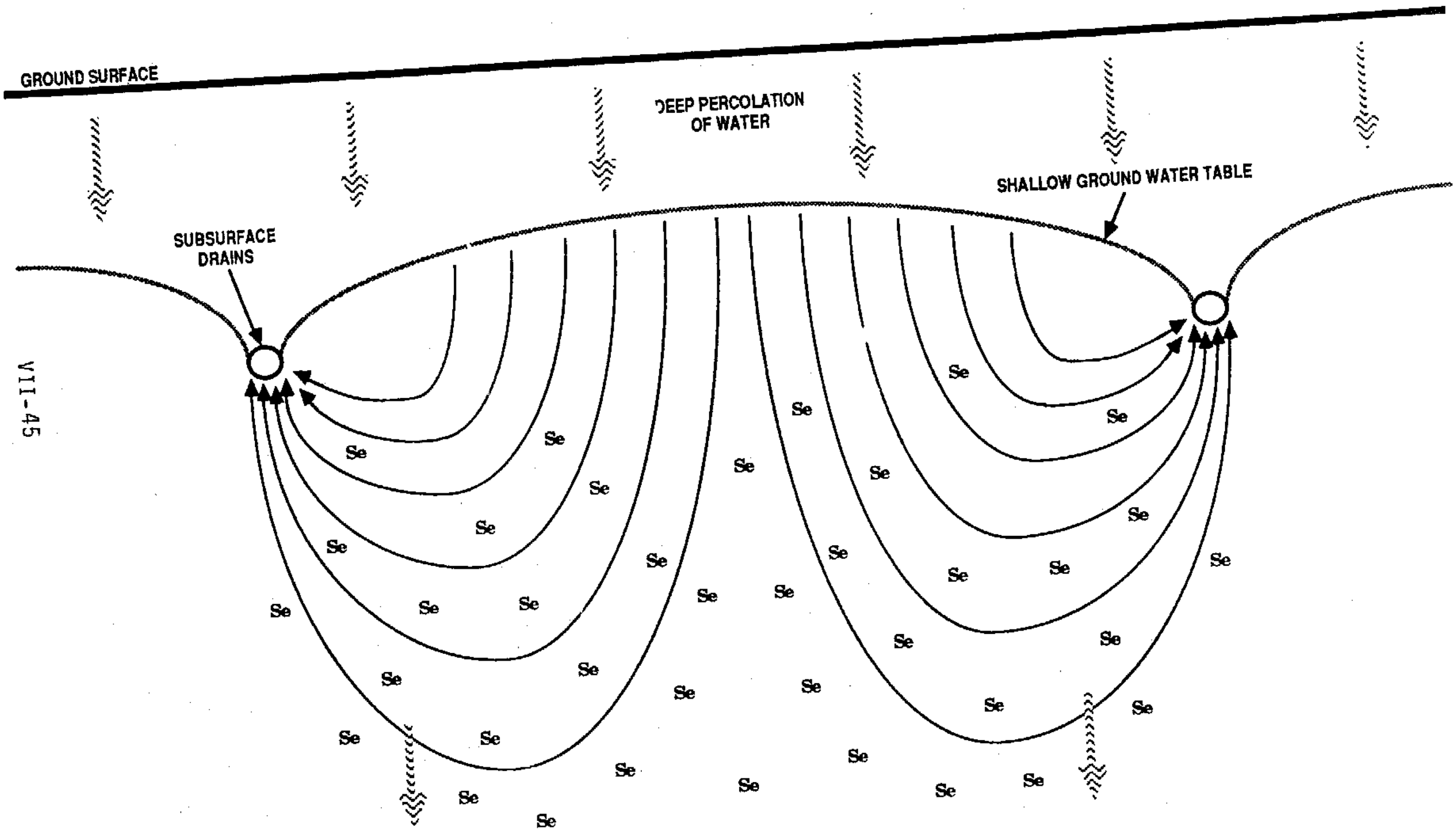
1/ Includes the San Joaquin River Basin plus all of Fresno County.

Table VII-10

REDUCTION IN ANNUAL REVENUES FOR VARIOUS JURISDICTIONS WITHIN THE SAN JOAQUIN RIVER BASIN AS A RESULT OF THE DIRECT PLUS INDIRECT AND INDUCED IMPACTS OF ALTERNATIVE SELENIUM WATER QUALITY OBJECTIVES

Water Quality Objectives	Westside Cities ($1,000/yr)	City of Fresno ($1,000/yr)	Fresno County ($1,000/yr)	Merced County ($1,000/yr)	Total ($1,000/yr)
Baseline	543	726	3,384	556	5,209
1. Selenium objectives met in San Joaquin River, Mud and Salt slough via treatment.					
2 ppb	32	54	584	125	795
5 ppb	21	37	411	89	558
10 ppb	2	7	144	33	186
2. Selenium objectives met in San Joaquin River, Mud and Salt slough and agricultural drains via treatment, new collection and disposal system--open canal to San Joaquin River.					
2 ppb	32	54	584	125	795
5 ppb	21	37	411	89	558
10 ppb	14	26	294	64	398
3. Selenium objectives met in San Joaquin River, Mud and Salt slough and agricultural drains via treatment, new collections and disposal system--closed pipe to San Joaquin River.					
2 ppb	32	53	629	136	850
5 ppb	30	52	528	113	723
10 ppb	22	39	403	86	550
4. Selenium objectives met in San Joaquin River, Mud and Salt slough and agricultural drains via higher treatment in DSA.					
2 ppb	32	53	629	136	850
5 ppb	31	52	597	129	809
10 ppb	28	47	543	117	735
5. Selenium objectives met in San Joaquin River, at Hills Ferry and downstream via drainage flow reduction.					
2 ppb	22	38	449	97	606
5 ppb	0	0	101	24	125
TOTAL TAX GENERATED REVENUES 1984-1985 (This excluses user changes, service fees and State and Federal Grants)	4,535	71,120	95,560	25,011	196,226
PERCENT OF TAX REVENUES GENERATED BY FARMING IN DSA	12%	1.0%	3.5%	2.2%	2.6%

FIGURE VII-1
GENERALIZED LINES OF WATER FLOW INTO SUBSURFACE DRAINS



VIII. WATER QUALITY OBJECTIVES

In this chapter, the Technical Committee recommends water quality objectives for eleven constituents of concern. This information should be considered by the Central Valley Regional Board (Regional Board) when the Water Quality Control Plan for the San Joaquin River Basin (Basin Plan) is revised. The recommended interim and long-term objectives and the proposed compliance dates are shown in Table VIII-1 for four constituents (salts, selenium, boron and molybdenum). The Regional Board should collect more information regarding reasonable compliance dates for the long-term objectives through the Basin Planning process. The development of these objectives is discussed in detail in later sections of this chapter.

In addition to salts, selenium, boron and molybdenum, there are seven priority constituents of concern in subsurface agricultural drainage. The Committee anticipates that any methods used to reduce volumes of subsurface agricultural drainage to meet the water quality objectives for selenium and salts should also reduce loadings and decrease concentrations of the other constituents in the water courses of the San Joaquin River Basin. The Technical Committee recommends that the Regional Board consider adopting water quality objectives for the other seven elements which do not exceed the Instantaneous Maximum Criteria developed in Chapter IV (see Table IV-7).

The Technical Committee has assembled and evaluated much information to develop water quality objectives as part of a plan for the regulation of subsurface agricultural drainage in the San Joaquin River Basin. Beneficial uses were reviewed and updated (see Appendix B and Chapter III). The effects of subsurface agricultural drainage on water quality were determined (see Appendices A and C, and Chapter V). Environmental characteristics of the Basin were described (see Appendices A and B and Chapter II). Water quality criteria to protect beneficial uses are discussed for 11 priority constituents of subsurface agricultural drainage (see Appendix D and Chapter IV). Economic conditions were evaluated (see Appendix G and Chapter VI). Methods to control subsurface agricultural effluent were presented and the costs determined (see

Appendices H and I, and Chapter VII). An implementation program to regulate subsurface agricultural drainage and achieve the recommended objectives is presented in Chapter IX.

The development of reasonable water quality objectives is a complex process. It involves balancing many competing needs and interests. Water quality concerns in the San Joaquin River Basin have been the subject of intense interest and controversy for many years. The Technical Committee realizes that the objectives proposed in this chapter will require some measure of sacrifice and compromise on the part of each of the special interests concerned with water quality issues in the Basin. However, in the long-term, the Committee believes that achieving the recommended water quality objectives will benefit and protect not only the beneficial uses of the San Joaquin River Basin but resources of statewide and international importance (see Chapters II and III and Appendices A and B).

During the process of developing reasonable water quality objectives, the following factors were given serious consideration:

- impacts to beneficial uses from subsurface drainage constituents
- historical water quality conditions and the hydrogeology of the area
- water quality conditions needed to reasonably protect beneficial uses
- current agricultural operations and practices
- agricultural practices that could be achieved, at reasonable cost, which would significantly improve water quality in the next several years
- current or proposed studies that will provide site-specific information on the biological effects of subsurface drainage constituents
- existing or developing agricultural or treatment technologies that would enable achievement of long-term water quality objectives.

The Technical Committee developed numeric water quality objectives for selenium, salt, boron and molybdenum that are believed to reasonably protect beneficial uses and that could be achieved by dischargers of subsurface agricultural drainage in the Drainage Study Area (DSA) at moderate initial cost. A staged approach to compliance with these objectives over the next several years is recommended.

The first phase of implementation is based on the fact that existing irrigation and drainage systems in the DSA can be managed more efficiently. The Committee concluded that best management practices could immediately increase the infiltrated water use efficienty (see Chapter V) from the less than 70 percent presently achieved to 80 percent. This should result in a decrease in the deep percolation rate of applied water to ground water from about 0.75 af/acre to 0.45 af/acre. In their July 1987 draft report the University of California Committee of Consultants on Drainage Water concluded that such a reduction is probably achievable with better management of existing systems. It is expected that this reduction in deep percolation will result in a reduction in the head (pressure) on the subsurface water table with a concomitant decrease in drain flows of about 40% (see Chapter V). It is expected that the loads of selenium and other constituents entering the San Joaquin River will also be decreased by about this same amount. This is discussed further in the selenium water quality objective section and in Chapter IX.

Treatment of subsurface drainage effluent was evaluated and determined to be one of the most costly alternatives for achieving the recommended objectives. The technology has not been proven for large-scale selenium removal and is not effective for removal of many of the other constituents of concern. Therefore, the Committee, at this time, believes that treatment of drainage should be undertaken only if other methods recommended in this report or developed elsewhere fail to effect compliance with the selenium objectives. The Committee believes that to reduce drainage flows and the load of pollutants released to the San Joaquin River by implementing improved irrigation efficiency and water management is reasonable, economically feasible, and achievable. Further, reduction of effluent volume would reduce possible future treatment costs, if that proves necessary.

Statutory and Policy Considerations

Water quality objectives represent the establishment of state policy through risk management procedures. A variety of state and federal laws, regulations, and policies affect the process of water quality control in California. These are discussed in detail in Appendix F. This section summarizes the requirements pertinent to setting water quality objectives.

The California Water Code (CWC §13050(h)) defines water quality objectives as, "the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area." The determination of what conditions will provide reasonable protection of beneficial uses involves a complex evaluation and balancing of a variety of factors including (CWC §13241):

- o Past, present, and probable future beneficial uses of water.
- o Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.
- o Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area.
- o Economic considerations.
- o The need for developing housing within the region.

The Division of the California Water Code known as the Porter-Cologne Water Quality Control Act defines the responsibilities of the State and Regional Boards (CWC Sections 13000 et seq.). The Regional Board has primary responsibility for development of the Basin Plan and waste discharge requirements. The Basin Plan contains the existing and designated beneficial uses and the water quality objectives to protect these uses. Waste discharge requirements represent the implementation procedures necessary to control and monitor pollutants to achieve these objectives. The State Board exercises an oversight role and final approval of Basin Plans.

The Federal Water Pollution Control Act Amendments of 1977, also known as the Clean Water Act, require the states to develop water quality standards. The identification and adoption of beneficial uses and water quality objectives to protect those uses in the Basin Plan constitute water quality standards under Section 303 of the Clean Water Act (state water quality objectives, the beneficial uses they protect and their program of implementation are equivalent of federal water quality standards). These standards are subject to approval by the federal Environmental Protection Agency (EPA).

The EPA has adopted regulations in 40 Code of Federal Regulations (CFR) Part 131 as to how such standards should be formulated. Existing uses are beneficial uses actually attained in the water body on or after November 28, 1975. Designated uses include actual or potential beneficial uses. The states must identify waters adversely affected by toxic pollutants and protect the designated uses. When there are multiple designated uses the most sensitive use must be supported (40 CFR 131.3(b)). Standards must also ensure the attainment and maintenance of downstream water quality. Waste transport or assimilation may not be a designated use.

State water quality standards must also contain an antidegradation policy consistent with that in the EPA regulations. The EPA antidegradation policy requires that 1) all existing instream water uses be maintained and protected, 2) if limited water quality degradation is allowed to accommodate important economic or social development in the area existing uses must still be fully protected and 3) high quality waters constituting an outstanding national resource such as waters of National and State parks and wildlife refuges, and waters of exceptional recreational and ecological significance must be maintained and protected. (40 CFR § 131.12)

The State Board adopted Resolution 68-16 to meet the federal antidegradation mandate. This resolution requires that existing high water quality must be maintained if it is better than water quality required in existing policies. Exceptions are allowed if it is demonstrated that a change will 1) be consistent with maximum benefit to the people of the State, 2) not unreasonably affect present and anticipated beneficial uses and 3) not result in lesser water quality than that prescribed in existing policies. In State Board Order WQ 86-17 it was concluded that where the federal policy applies, a change in water quality must be consistent with the three-part federal policy.

The California Water Code also requires that, "prior to implementation of any agricultural water quality control program, an estimate of the total cost of such a program, together with an identification of potential sources of financing, shall be indicated in any regional water quality control plan" (CWC § 13141). This report only addresses an estimate of total costs for selenium control and potential financing sources. However, the program of implementation discussed in Chapter IX would simultaneously diminish concentrations of most of the other constituents of concern in addition to selenium.

<u>Selenium Water Quality Objectives</u> - General Discussion

The San Joaquin River Basin contains fish and wildlife resources of national and statewide ecological significance. The sloughs, channels, wetlands, and riparian areas of the grasslands and downstream areas of the San Joaquin River provide habitat for fish and wildlife resources in two national wildlife refuges, two state wildlife areas, as well as on significant amounts of private lands such as the Grassland Water District (GWD). These areas provide a major wintering ground for a significant proportion of migratory waterfowl using the Pacific Flyway. Sightings of rare, threatened and endangered species have been documented. Human consumption of fish and wildlife from these areas also occurs; however, public health concerns arising from selenium contamination of fish and wildlife have led to the posting of public health warnings in these areas.

Selenium water quality data collected in the San Joaquin River prior to the latter part of water year 1984 are of questionable reliability. Estimated selenium values were developed using information on selenium loading from tile drains in the DSA as prepared by Summers Engineering (1986). Chapter V discusses estimated historic selenium levels in the San Joaquin River at Hills Ferry for the water years 1979 (normal), 1981 (critical), 1984 (normal) and 1985 (dry). Prior to 1985 about half of the GWD's water supply to maintain wetland habitat contained subsurface agricultural drainage water. Use of drain water in marsh habitat appears to have substantially lowered the selenium loads reaching the River through biological and/or physio-chemical removal of selenium in the wetlands. Prior to 1985, selenium in the San Joaquin River at Hills Ferry rarely exceeded 2 ppb. The bypass of drainage water around the wetlands by GWD in early 1985 resulted in a substantial increase of selenium levels to 5 ppb or more in the San Joaquin River downstream of GWD (see Chapter V).

Mud and Salt sloughs have long bee used to convey subsurface agricultural drainage to the River but no measurements of selenium concentrations in these tributaries were collected prior to May 1984. Figures VIII-1 and VIII-2 show the estimated monthly selenium concentrations in these sloughs for water years 1979 (normal) and 1981 (critical) compared with the estimated levels in the River at Hills Ferry developed in Chapter V. The slough concentrations are estimated by assuming their total load to equal the DSA and GWD discharge load (see Chapter V, Tables V-10, V-11, V-12, and V-15) and dividing this load between the sloughs based on their load ratios calculated from data for water years 1984 and 1985. In the summer months Mud Slough often did not have enough flow to receive its percentage of the total load. In these months the Mud Slough selenium concentration was assumed to be the flow-weighted average DSA and GWD discharge concentration. Thus, in Figures VIII-1 and VIII-2 the estimated Mud Slough selenium concentrations range from 1 to 24 ppb and the estimated Salt Slough selenium concentrations range from 0.5 to 12 ppb.

Chapter IV discusses selenium water quality criteria to protect beneficial uses in the San Joaquin River Basin. The most sensitive beneficial uses are those for fish, wildlife and recreation (public health). Selenium exhibits both direct toxic effects to fish from exposure to elevated levels in the water column and bioaccumulation through the food web to harmful tissue levels in fish and wildlife. Elevated levels of selenium in animal tissues can affect the health of fish, wildlife and also humans who eat them on a regular basis.

Selenium criteria differ depending on the type of effect being evaluated. There are criteria to protect against the effects of bioaccumulation as well as a criterion to prevent direct toxicity. The criteria are summarized in this section (see also Table IV-4) to make it clear how the Committee arrived at the recommended objectives. The criterion for bioaccumulation in flowing water was based on site-specific studies. The criteria for bioaccumulation in impounded water was based primarily on non-site-specific studies. The site-specific data on bioaccumulation indicate that selenium may accumulate to lower levels in the flowing waters of the San Joaquin River Basin than in impounded water habitats in other areas of the nation. Several site-specific studies are in progress and more are proposed to evaluate direct toxicity and bioaccumulation in the aquatic ecosystem, and potential effects of human consumption of wild food organisms containing selenium. Completion of site-specific bioaccumulation studies of impounded water biota is expected by 1988 or 1989. As shown in Chapter III, impounded water habitats in the San Joaquin River Basin exist in the grasslands area and a few areas within Reach 4 of the San Joaquin River (downstream of Hills Ferry).

Based on the available nonsite-specific data, the bioaccumulation criterion for impounded waters is 1.0 ppb for the protection of: (1) fish which may accumulate high tissue levels through the food chain, and (2) human consumers of these fish. A selenium criterion of 1 ppb in water should not allow fish tissue levels of selenium to rise above 1 ppm wet weight. The Department of Health Services developed a recommended residue level in fish and duck meat of 1 ppm wet weight. The 1 ppb criterion protects against bioaccumulation of selenium to levels in fish that might adversely effect the fish as well as the health of human consumers of these fish. However, health advisories are not issued until tissue levels of selenium exceed 2 ppm wet weight.

The site-specific flowing water bioaccumulation criterion to protect human health from the consumption of contaminated fish is 10 ppb. The flowing water bioaccumulation criterion to protect fish themselves from the toxic effects of selenium bioaccumulation is 11 ppb (see Chapter IV).

The EPA freshwater aquatic life criterion for selenite is 26 ppb. However, the Adverse Effect Level (AEL) presented in this report for total selenium in water has been calculated to be 26 ppb total selenium. Based on the toxicity literature, at 26 ppb selenium some chronic effects to sensitive aquatic species would be expected. Chronic toxicity has been observed in aquatic life at concentrations of selenium in water as low as 10 ppb for a green alga and 28 ppb for rainbow trout (see Chapter IV, Table IV-5 and Appendix D).

A criterion to protect all aquatic life from chronic effects, other than those due to bioaccumulation, was also developed by DWQ. The criterion developed from nonsite-specific data to fully protect aquatic life from chronic effects was calculated to be 2.6 ppb. This criterion is the estimated lowest AEL of 26 ppb divided by 10 (see Chapter IV for an explanation of the methodology). Use of this method provides a large safety factor which may or may not be needed to protect aquatic resources in the San Joaquin River Basin. It is used because a no effect level based on site-specific tests of sensitive species is not available. The Technical Committee believes that additional site-specific data are needed before a criterion or objective is developed to protect aquatic resources from direct selenium toxicity.

Based on available nonsite-specific data, the Technical Committee believes that long-term selenium objective of 2 ppb for waters of the San Joaquin River Basin which are impounded for wetland habitat (fish and wildlife and recreational beneficial uses) may prove to be appropriate for the following reasons:

1. The U. S. Fish and Wildlife Service has indicated that water with 2 ppb selenium would be acceptable for water supplies to waterfowl management areas.

2. The available nonsite-specific data indicated that a maximum monthly concentration of 2 ppb in water would not cause potentially dangerous levels of selenium in meat of fish and waterfowl.

3. Estimated historical water quality (see Figures VIII-1 and VIII-2) indicate that selenium concentrations in the San Joaquin River at Hills Ferry were 2 ppb or less in most months of 1979 and 1981. According to federal regulations, beneficial uses existing as of November 28, 1975 must be protected. The Committee believes attainment of 2 ppb selenium would reasonably protect the beneficial uses existing at that time.

However, as pointed out above, the 2 ppb potential long-term selenium objective to protect impounded water uses is based on nonsite-specific data. Site-specific data to be collected over the next few years should be used to refine this number. The objective may be lower or higher based upon these data but the Technical Committee feels confident that it will likely remain below 5 ppb.

Water quality objectives for selenium for specific areas are discussed below. For areas not specifically mentioned the "tributary rule" applies.

San Joaquin River at Hills Ferry and Downstream

The implementation of water management practices to achieve 2 ppb at Hills Ferry and areas downstream would take more time and be more costly than achieving the interim objective of 5 ppb. The Technical Committee recommends a staged approach to achieving this or other appropriately protective concentrations to modify present water management practices, assess the success of these changes in reducing selenium loads, and evaluate site-specific bioaccumulation and toxicity studies. The Committee recommends adoption of an interim selenium water quality objective of 5 ppb in the San Joaquin River at Hills Ferry. This objective provides reasonable interim protection to beneficial uses based on the balancing of (1) the need for site-specific data on the selenium levels which will protect impounded water uses, (2) the limited impounded water uses downstream of Hills Ferry and (3) the economic effects of more restrictive objectives. If site-specific data clearly show that a lower selenium level is needed to reasonably protect these uses, it should be considered by the Regional Board during their 1991 triennial review. As discussed previously, this objective appears achievable within three irrigation seasons (from the time they are adopted) with better water management practices. Such a program would reduce not only selenium loads to the River but other constituents of concern such as salts, boron, and certain metals as well.

Due to the nonsite-specific nature of the data used to develop the 2 ppb potential selenium objective for impounded water uses and the need to develop an interim objective to initiate progress toward reducing pollutant loads to the San Joaquin River system, the Technical Committee does not recommend adoption of a long-term selenium objective for impounded water uses at this time. Adoption of a long-term selenium objective for impounded water uses should wait until the results of site-specific data are analyzed.

Based on results of the calibrated SJRIO-1 model for water year 1985, attainment of the proposed 5 ppb selenium objective at Hills Ferry will not generally allow for the maintenance of the historical selenium concentration (<1 ppb) at Vernalis during dry water years (see Figure VIII-3). However, attainment of 2 ppb selenium in the River at Hills Ferry would permit the maintenance of the less than 1 ppb concentration at Vernalis in all months during dry years (see Figure VIII-4). This is depicted in Figures VIII-3 and VIII-4 wherein the selenium load from Mud and Salt sloughs was reduced as necessary to meet 5 or 2 ppb at Hills Ferry. The calibrated SJRIO-1 model was then run to determine the corresponding downstream concentrations.

Grasslands Area Waterfowl Areas

A 5 ppb interim selenium objective such as that recommended for the San Joaquin River may not protect fish and wildlife beneficial uses of the impounded water habitats in the Grassland Water District, San Luis National Wildlife Refuge (NWR), and Los Banos State Wildlife Area (SWA). Low selenium levels are needed in this area to expedite leaching of high selenium concentrations in the marsh environments which have accumulated through the past use of selenium-laden drainage as a partial water supply to this area. A separate objective of 2 ppb selenium in the water supply drains and canals which supply the San Luis NWR, the GWD and other state or federal waterfowl areas, which historically diverted subsurface agricultural drainage for waterfowl habitat is recommended. Protection of waterfowl can also be achieved if the waterfowl habitat areas are provided a substitute water supply containing 2 ppb or less selenium in a volume equal to either (1) the historical quantity of water diverted for waterfowl habitat or (2) the actual quantity of water in the canals available after the implementation of best water management practices, whichever is less (see Chapter IX, Nature of Actions - substitute water supply for waterfowl areas). The recommended 2 ppb selenium objective is achievable through either the bypass of subsurface drainage around the grasslands waterfowl areas or the provision of a substitute supply.

Mud and Salt Sloughs

Based on site-specific bioaccumulation data, the Technical Committee recommends adoption of a 10 ppb long-term selenium objective for Mud and Salt sloughs (see Table VIII-1), unless a lower objective based on site-specific data proves applicable. A 10 ppb objective would protect instream fishery resources and human consumers of these fish from adverse effects due to bioaccumulation in flowing water. A specific objective for the waterfowl areas (i.e., 2 ppb) is intended to protect the offstream wildlife uses in this area. According to our estimated historic selenium condition for water years 1979 and 1981 (see Figures VIII-1 and 2), the sloughs were less than 10 ppb except during June and July. Due to changes in water management practices in 1983 and 1985, selenium levels in Mud and Salt sloughs are now typically greater than 10 ppb and reach 30 ppb in some months. Attaining the 10 ppb objective in the sloughs combined flow will substantially improve existing quality but may not improve selenium levels to those estimated to have occurred during the late 1970's (Figures VIII-5 and 6). However, attainment of the objective will assure protection of existing beneficial uses from the bioaccumulation of selenium and eliminate periodic episodes of selenium concentrations between 20 and 30 ppb.

If commingling of flows is accomplished upstream of the sloughs, concentrations of 10 to 15 ppb selenium in Mud and Salt sloughs will allow attainment of the interim 5 ppb objective at Hills Ferry.

The water quality criterion developed for the direct effects of selenium (2.6 ppb) is not recommended as a proposed water quality objective by the Technical Committee at this time. The technique used to develop this criterion has been used with success in the State Board's Ocean Plan. However, this technique assumes that the national background (or 1/10 of the adverse effect level, whichever is greater) is an adequate estimate of the no effect level for the constituent of concern. While this may be a valid assumption in the relatively stable background levels found in ocean waters, it may not be appropriate for inland waters. As documented in Chapter IV, the water quality of the San Joaquin River Basin contains levels of nearly all the elements of concern which are higher than natural background levels. The organisms that regularly inhabit this River Basin may have adapted to these higher levels without adverse effects. Also the difference between the adverse effect and no effect levels for selenium may be closer than the 100-fold estimate inherent in the water quality criteria development methodology. For example, if site-specific data showed that the no effect level was 1.0 ppb instead of the hypothesized 0.26 ppb, the water quality criteria would be about 5 ppb. Due to (1) the sensitivity of the criteria to the estimated no effect level, (2) the inexactness to which this level is known for selenium and (3) the economic effects of applying the Ocean Plan methodology to inland waters, the Technical Committee recommends that site-specific studies be performed before this methodology is used for inland waters.

During the 1991 triennial review of the Basin Plan, the Regional Board should assess the data from water quality monitoring and studies of direct toxicity and bioaccumulation to determine whether the 5 ppb interim objective is still appropriate. At that time the Regional Board should determine whether best management practices (BMP) have been successful in meeting the interim objective and how the long-term objective should be achieved. Revision of the interim and development of long-term objectives may be warranted by new information available by 1991.

Selenium Waste Load Allocation

The drainage flows and load reductions achievable with a program of efficient water management are discussed in Chapter V. In order to achieve 5 ppb or 2 ppb selenium in the San Joaquin River at Hills Ferry, selenium loadings from all drainage entities in the DSA should not exceed those shown on Table VIII-1. Rather than adopting waste load allocations at this time, the Technical Committee recommends that the Regional Board consider use of BMP's to achieve the interim objectives.

Salinity Water Quality Objectives

Agriculture is the most sensitive beneficial use in regard to salinity. Therefore, the agricultural salinity criterion is controlling. Chapter IV discusses the salinity water quality criteria to protect agricultural crops. The criterion of 0.7 mmhos/cm EC (about 415 to 430 mg/l TDS) provides full protection of all crops on all soils with adequate drainage in the San Joaquin River Basin and the Southern Delta. Salinity levels of 0.8 mmhos/cm EC (about 470 to 495 mg/l TDS) or more may have detrimental effects on certain sensitive crops. In the past, blending high salinity water with lower salinity water or growing more salt tolerant crops has been the practice in the San Joaquin River Basin.

Historical salinity conditions in terms of TDS along the San Joaquin River from Hills Ferry to Vernalis for the water years 1979 (normal), 1981 (critical), 1984 (normal) and 1985 (dry) are shown in Figures VIII-7 to VIII-10. These figures show that salinity levels at Hills Ferry, even in normal years, exceeded the 0.7 mmhos/cm EC criterion (about 430 mg/l TDS for this location) for most months. Salinity levels in dry and critical years at this upstream location were above 500 mg/l TDS for most of the year. Salinity often reached or exceeded 1,000 mg/l TDS (1.7 mmhos/cm EC). At Vernalis, salinity levels are usually at or below 0.7 mmhos/cm EC (415 mg/l TDS for this location). This is due in part to dilution from the

Tuolumne River and surface runoff from agricultural areas. Also, the water right permit for New Melones Reservoir on the Stanislaus River requires the release of water to maintain the Vernalis salinity level at, or below, 500 mg/l TDS. The areas with the greatest salinity concerns are those in the upper reaches of the River which receive highly saline subsurface drainage and tailwater from the DSA.

The 1975 Basin Plan recognized these water quality concerns and declared the San Joaquin River from about Lander Avenue to below Vernalis a water quality limited segment due to excessive salinity. The Regional Board has taken actions in the past to improve salinity conditions along the San Joaquin River. The most notable was the capping of the abandoned gas wells along the Tuolumne River in the 1970's. The abandoned wells were discharging high concentrations of salts to the River. However, additional actions are needed in order to improve San Joaquin River salinity levels to provide reasonable protection for agricultural beneficial uses in the area immediately downstream of the Merced River (Hills Ferry).

The Regional Board staff has evaluated the soil types and crops that are grown using diversions from the San Joaquin River in the areas immediately downstream of Hills Ferry. They have determined that a water quality objective of 1.0 mmho/cm EC (about 620 mg/l TDS) would provide reasonable protection to these crops on the soils in this area. This is much lower than the historical quality in this area and will likely have to be implemented over time.

As discussed in Chapter V, the majority of the salt load entering the San Joaquin River above its confluence with the Merced River comes from the DSA and other sources to Salt and Mud sloughs. From 50 percent to 80 percent of the salt loading to the San Joaquin River during March through September is discharged from Salt and Mud sloughs (depending on the water year type).

An aggressive program of water management in the DSA to control selenium discharges could decrease the load of salts discharged to the San Joaquin River from the DSA. Figure VIII-11 depicts expected salinity conditions in the San Joaquin River for a water year equivalent to water year 1985 under the following conditions: (1) drainage flow reduction measures to achieve selenium water quality objectives of 5 ppb or 2 ppb and (2) no drainage flow reduction measures are taken; therefore, all drainage is bypassed by GWD and the alternative water supply is discharged. The percentage reductions necessary to meet selenium objectives of 5 or 2 ppb are applied to TDS loads from the DSA as well. All these changes are added to or subtracted from the calibrated SJRIO loads and flows at Hills Ferry.

Unlike selenium, much of the salt load carried to the River by Mud and Salt sloughs is not from subsurface drainage within the DSA. In fact, other sources such as tailwater from outside the DSA, ground water seepage, and natural runoff, appear to contribute over half the salt load to Mud and Salt sloughs. For a selenium objective of 5 ppb at Hills Ferry, the recommended salinity objective of 1.0 mmhos EC (620 ppm TDS) would likely be met only during September through December, according to the estimated salinities for a dry water year like water year 1985 shown in Figure VIII-11. For a selenium objective of 2 ppb, the recommended salinity objective is expected to be met from June through December. Thus, during dry and critical water years, it may be difficult to achieve the salinity objective. Additional measures may be needed. During months of higher river salinity, special techniques such as blending of irrigation supplies might continue to be required of those diverting irrigation supplies for several miles downstream of Hills Ferry. Based upon current water use practices and the types of crops grown in the area, no adverse effects on agriculture are anticipated if this blended water is used for irrigation. This objective will provide an improvement in water quality over that experienced by these water users in the recent past.

In Salt Slough and areas of the San Joaquin River downstream to Hills Ferry there are only a few agricultural diversions. These diversions are for the irrigation of pasture which is very salt tolerant. Historical maximum salinity concentrations in Salt Slough are typically as high as or higher than 3.0 mmhos/cm EC. An objective of 3.0 mmhos/cm EC supports the existing uses in Salt Slough and areas downstream to Hills Ferry consistent with the historic water quality and present agricultural practices. Therefore, an objective of 3.0 mmhos/cm EC is recommended as the water quality objective for this limited area.

The recommended water quality objectives for salinity in the upper reaches of the San Joaquin River Basin are summarized in Table VIII-1.

Boron Water Quality Objectives

Chapter IV discusses the water quality criteria for boron to protect both agricultural crops and fish and wildlife. These criteria are 500 ppb and 760 ppb, respectively. The controlling criterion is the agricultural criterion of 500 ppb. Boron is extremely high (sometimes over 5,000 ppb) in the subsurface drainage flows produced in the DSA. Boron concentrations in the River are diluted by surface return flows and runoff from east side tributaries. The recommended water quality objectives are shown in Table VIII-1.

The recommended long-term water quality objective for boron is a maximum mean monthly value of 700 ppb boron in the San Joaquin River at Hills Ferry. This is based on protection of the most boron sensitive crop grown in the area which is apricots. No crop loss in this area is expected at 700 ppb boron.

The activities to reduce selenium and salinity loading to the San Joaquin River will also help to reduce boron loads. Using the same methodology as for salinity, the estimated boron concentrations for water year 1985 associated with drainage flow reduction measures to meet selenium objectives of 5 or 2 ppb are shown in Figure VIII-12. As with selenium, most of the boron load in Mud and Salt sloughs comes from the DSA. However, boron levels at Hills Ferry are very high at present, and even the reductions in boron associated with meeting a selenium objective of 2 ppb might not allow the River to meet a 700 ppb boron objective during four months of a dry year like 1985.

A boron objective of 2,000 ppb is recommended for Salt and Mud Sloughs. In Salt Slough and areas downstream to Hills Ferry, an objective of 2,000 ppb boron (see Table VIII-1) should apply to protect the three known agricultural diverters growing boron tolerant crops. This objective reflects historical water quality conditions. As mentioned previously, methods to meet the selenium objectives should result in a reduction of boron loads.

The fish and wildlife criterion of 760 ppb boron is exceeded by the recommended objective of 2,000 ppb in Salt and Mud sloughs. However, the toxicity data suggest that while cold water species (trout) are adversely affected by boron concentrations below 2,000 ppb, warm water species (catfish) may tolerate much higher levels (22,000 ppb) (see Appendix D). Although cold water migration is a designated use in the segment of the San Joaquin River to which the sloughs are tributary, migration of cold water species is restricted to below the mouth of the sloughs except during years when autumn river flows are extremely high (see Appendix B). The resident fishery in Mud and Salt sloughs is composed of warm water species. It is not anticipated that warm water beneficial uses will be adversely affected by an objective of 2,000 ppb.

Molybdenum Water Quality Objectives

The recommended water quality objectives for molybdenum are shown in Table VIII-1. The agricultural water supply criterion of 10 ppb molybdenum should apply as the water quality objective in Salt Slough and areas downstream to protect agricultural uses of water in these reaches. Actions taken to reduce subsurface drainage and loads of selenium are expected to reduce molybdenum loads as well. The fish and wildlife criterion is 44 ppb, the agricultural objective of 10 ppb would fully protect these beneficial uses.

Other Constituents of Concern

In Chapter IV, the Technical Committee identified and developed water quality criteria for eleven constituents in subsurface agricultural drainage. In the preceding sections of this chapter, the Technical Committee developed water quality objectives for salt, selenium, molybdenum and boron. As mentioned previously, the Water Quality Act of 1987 requires adoption of numeric water quality criteria (a term equivalent to

California's water quality objectives) for specific priority pollutants listed by EPA when the Basin Plan is revised by the Regional Board. Consequently, numeric objectives are needed for mercury, cadmium, chromium, copper, nickel and zinc. If the Regional Board does not adopt its own objectives, the EPA criteria become effective. Water quality objectives for cadmium, chromium, copper, manganese, mercury, nickel, or zinc are recommended in this report. A mercury criterion (or criteria) is being developed by the State Board's priority chemical program and is expected to be finalized by June 1987. It would be premature for the Technical Committee to recommend a water quality objective for mercury at this time. Revision of the Basin Plan is expected in January 1988. Therefore, the Regional Board will be able to use this criterion as they consider revisions to the Basin Plan.

The maximum, minimum, and median concentrations of cadmium, chromium, copper, managnese, nickel, and zinc at monitoring stations in the River Basin are shown in Figures VIII-13 through VIII-18. Also indicated on these figures are EPA criteria and/or the estimated lowest adverse effect level (AEL or instantaneous maximum criterion) determined for each constituent. (These are also listed in Table IV-7.)

Toxic effects (as measured by the AEL) have been observed in the laboratory below EPA's criteria for cadmium, tri- and hexavalent chromium, copper, nickel and zinc (see Chapter IV and Appendix D, Chapter 2). As shown in Figures VIII-15, VIII-17 and VIII-18, median concentrations of copper, nickel and zinc exceed the AEL at some or all stations. The EPA criteria for copper and zinc under low hardness conditions are exceeded at times as is the federal public health drinking water criteria for nickel. (Although designated as a potential beneficial use, the reaches of the San Joaquin River evaluated in this study are not used directly for municipal drinking water supplies.) Median cadmium levels at all stations were below the detection limit of 1 ppb. The AEL and EPA criteria under low hardness conditions are also less than 1 ppb (see Figure VIII-13); therefore it could not be determined if the criteria were exceeded. Both the EPA chromium criteria and the lowest AEL differentiate between the tri- and hexavalent forms of chromium. The water quality data shown in Figure VIII-14 are for total chromium only; therefore, it cannot be determined if existing water quality exceeds these levels.

Instantaneous Maximum Criteria and Compliance with Objectives

The Committee recommends that the Regional Board consider adopting water quality objectives for the remaining constituents of concern which do not exceed the instantaneous maximum criteria shown in Tables VIII-3 and IV-7 unless appropriate site-specific tests with sensitive local species demonstrate a no effect level which is higher. These recommended values are substantially lower than EPA's national criteria for these constituents. While these instantaneous maximum values may not fully protect all species all the time, they can provide reasonable protection until site-specific data are obtained. The Committee also recommends that additional studies be conducted to determine the site-specific maximum allowable toxicant concentration (MATC) for each constituent. (The MATC is the logarithmic mean of the lowest adverse effect level and the no effect level).

The Technical Committee recommends that random weekly water quality samples be collected for selenium, salinity, boron and molybdenum at the locations shown in Table VIII-1. The monthly average concentration (based on weekly samples) for each constituent should not exceed the recommended objective. At no time should any sample exceed the instantaneous maximum for that constituent (Table VIII-3). More precise monitoring locations should be specified by the Regional Board so that well-mixed representative samples are collected. Additionally, a degree of unscheduled sampling is recommended to detect any intentional or pulsed releases of subsurface drainage in violation of the objectives.

TABLE VIII-1

RECOMMENDED
WATER QUALITY OBJECTIVES
FOR THE
SAN JOAQUIN RIVER BASIN

LOCATION	CONSTITUENT	MAXIMUM MEAN MONTHLY LEVEL	INSTANTANEOUS MAXIMUM	COMPLIANCE DATE
Interim Objectives				
San Joaquin River at Hills Ferry and downstream	Selenium	5 ppb	26 ppb	October 1991
Grassland WD, San Luis NWR and Los Banos SWA	Selenium	2 ppb (can be provided via a substitute supply[1/])		October 1989
Long-term Objectives				
San Joaquin River at Hills Ferry and downstream	Selenium	To be determined based on site-specific data		To be determined
	EC	1.0 mmho/cm		
	Boron	700 ppb	5,800 ppb	
	Molybdenum	10 ppb	440 ppb	
Salt & Mud sloughs & San Joaquin River Lander Ave. to Hills Ferry	Selenium	10 ppb	26 ppb	To be determined
Salt Slough and San Joaquin River Lander Ave. to Hills Ferry	EC	3.0 mmhos/cm		To be determined
	Boron	2,000 ppb	5,800 ppb	
	Molybdenum	10 ppb	440 ppb	
Grassland WD, San Luis NWR and Los Banos SWA	Selenium	To be determined based on site-specific data (can be provided via a substitute supply[1/])		To be determined

[1/] If a substitute supply of 2 ppb or better is provided, the quantity of this supply should be in a volume equal to the lesser of either (1) the quantity of water historically (mid-1970's) diverted by these waterfowl areas or (2) the actual flow in the canals available to these areas.

TABLE VIII-2

EFFLUENT LIMITATIONS[1]
MAXIMUM MONTHLY LOAD OF SELENIUM
DISCHARGED BY ALL ENTITIES
IN THE DSA

	To Achieve Interim Objective of 5 ppb at Hills Ferry		To Achieve Long-Term Objective of 2 ppb at Hills Ferry	
	Dry & Crit.[2] Water Years --	Normal[2] & Above Water Years	Dry & Crit.[2] Water Years --	Normal[2] & Above Water Years
	Selenium (lbs.)	Selenium (lbs.)	Selenium (lbs.)	Selenium (lbs.)
Oct	300	350	250	350
Nov	600	750	150	550
Dec	800	850	200	600
Jan	600	750	150	600
Feb	400	700	0	400
Mar	700	1200	100	450
Apr	600	800	100	200
May	500	800	150	200
Jun	400	600	100	200
Jul	350	450	100	100
Aug	400	500	100	150
Sep	300	300	100	200

1 Compiled from Tables V-10, V-11, V-12 & V-15

2 Water year definitions are those as shown in Figure II-5. Water year type is determined via the median year projected runoff from DWR Bulletin 120 beginning in February. The May Bulletin 120 establishes the year type for that water year. For the purpose of compliance with these limitations the previous year's water year classification shall apply to the months October through January.

TABLE VIII-3

INSTANTANEOUS MAXIMUM OBJECTIVES[1/]
FOR CONSTITUENTS OF CONCERN

Constituent	Instantaneous Maximum in ppb
Selenium in Flowing Water	26.
Boron	5800.
Molybdenum	440.
Manganese	1600.
Cadmium	0.2
Chromium	
Trivalent	116.
Hexavalent	4.5
Copper	1.4
Nickel	6.7
Zinc	37.

1/ This is the same as the lowest adverse effect level

FIGURE VIII-1 WY 1979 Estimated Historical Selenium Conditions

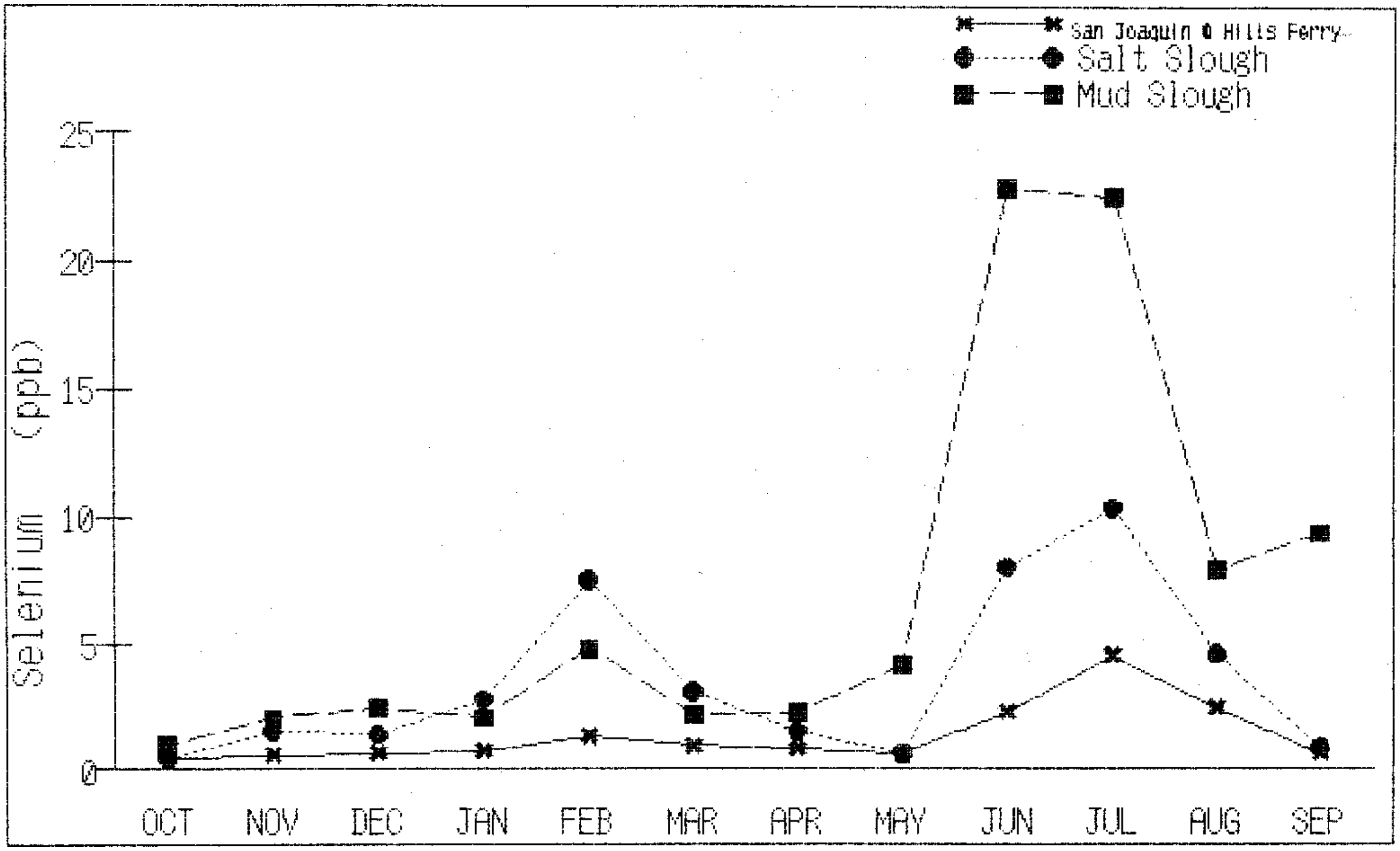


FIGURE VIII-2 WY 1981 Estimated Historical Selenium Conditions

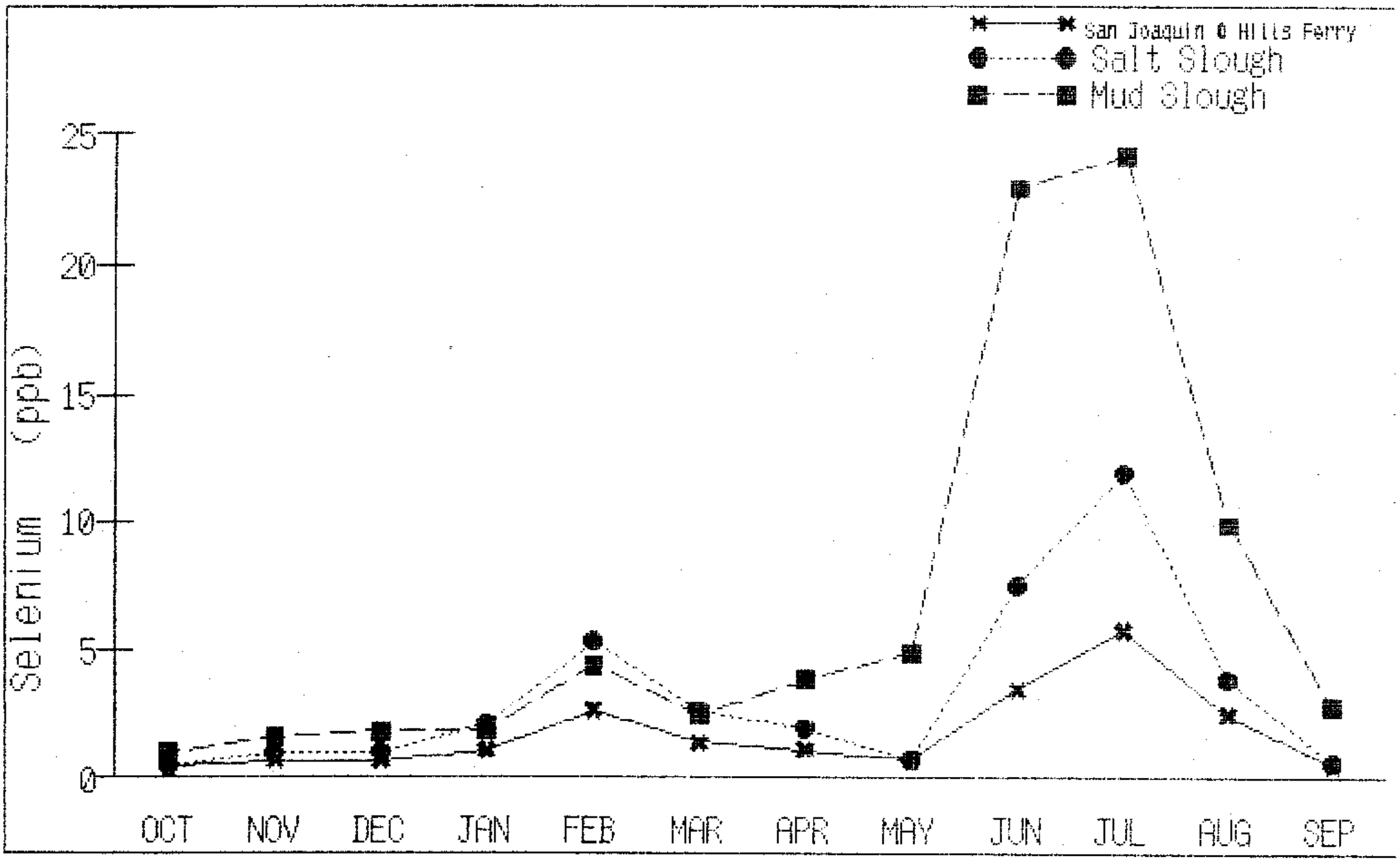


FIGURE VIII-3 San Joaquin River Selenium (W.Y. 1985)

Drainage Reduction, Standard = 5 ppb

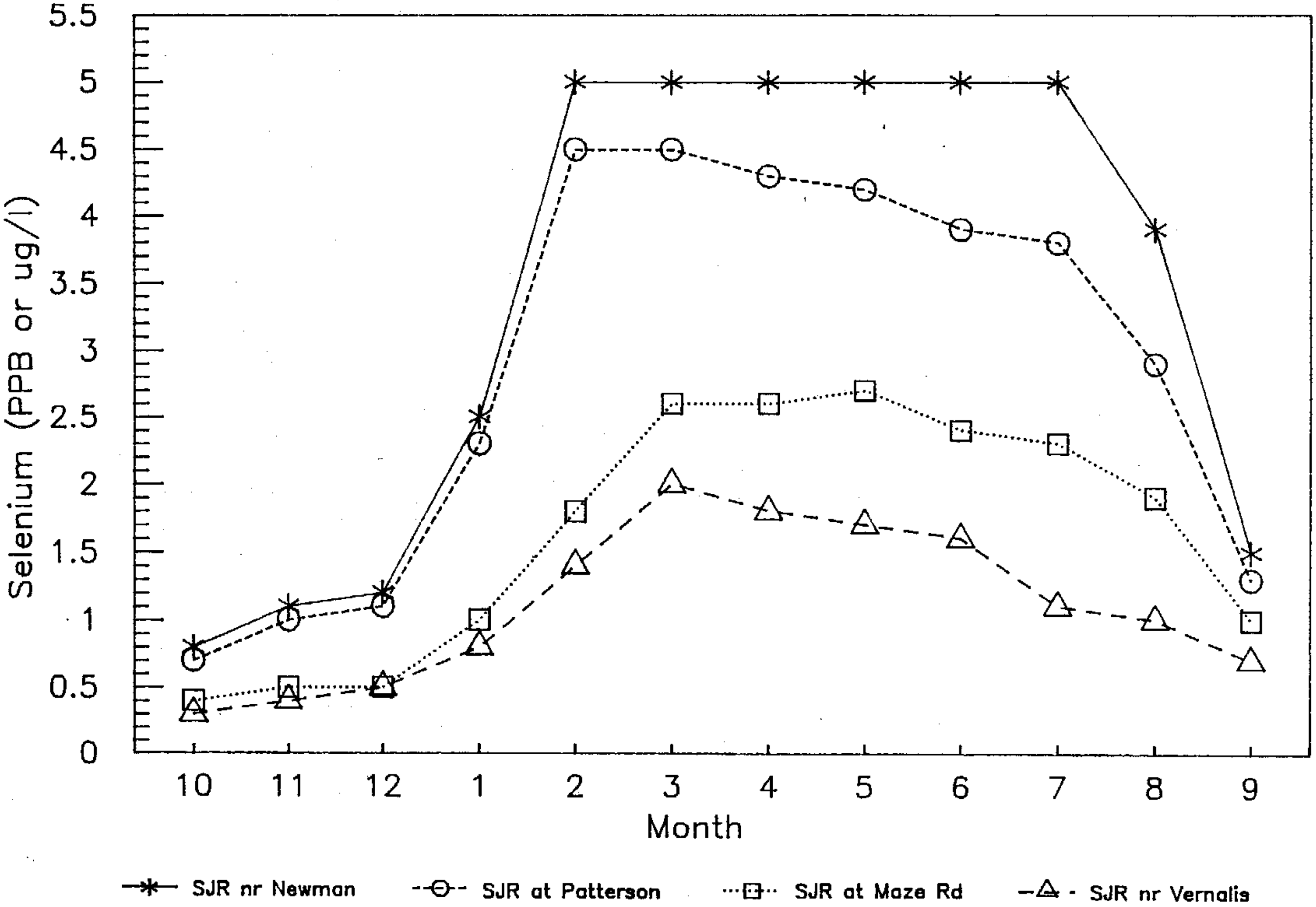


FIGURE VIII-4 San Joaquin River Selenium (W.Y. 1985)

Drainage Reduction, Standard = 2 ppb

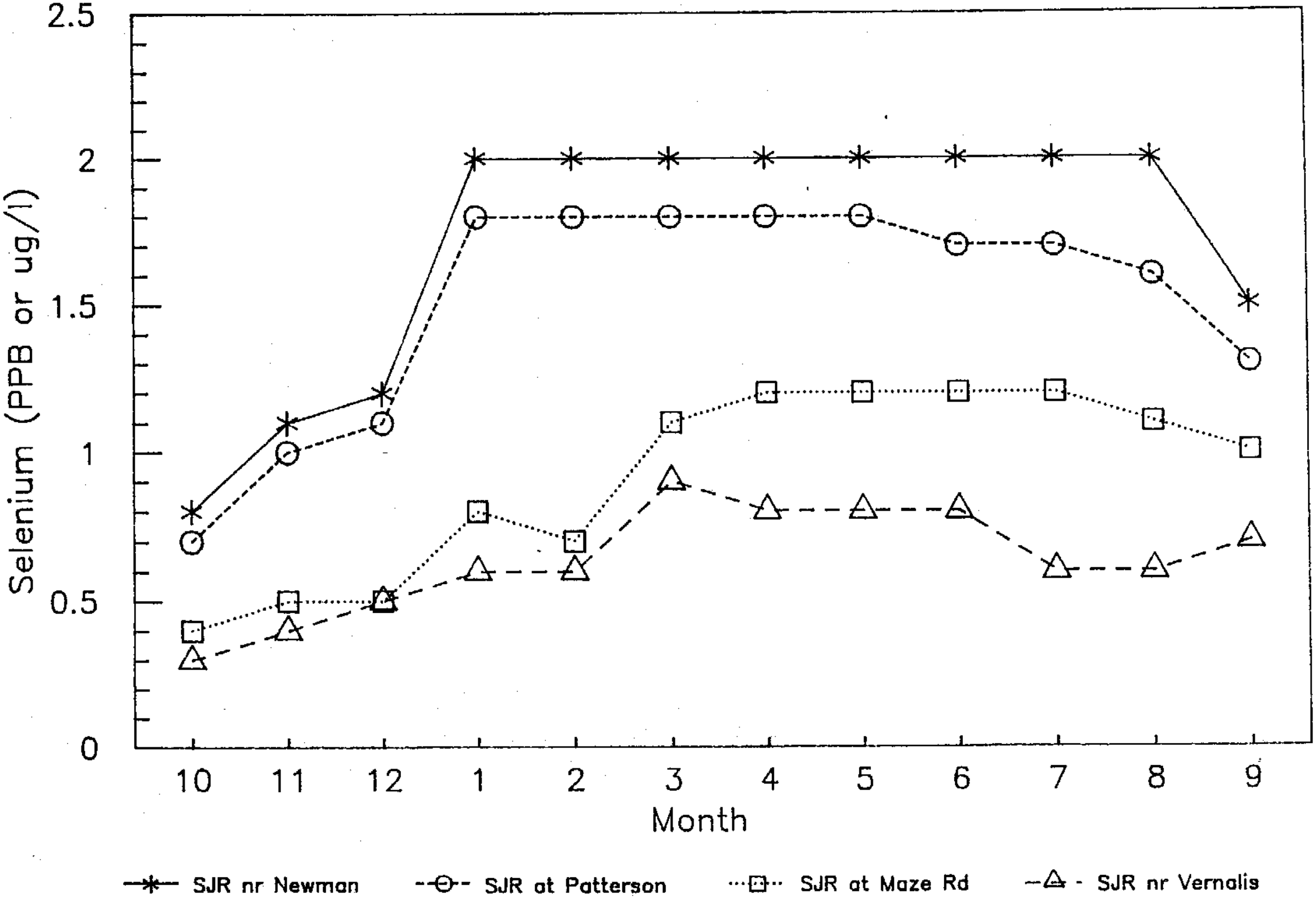


FIGURE VIII-5

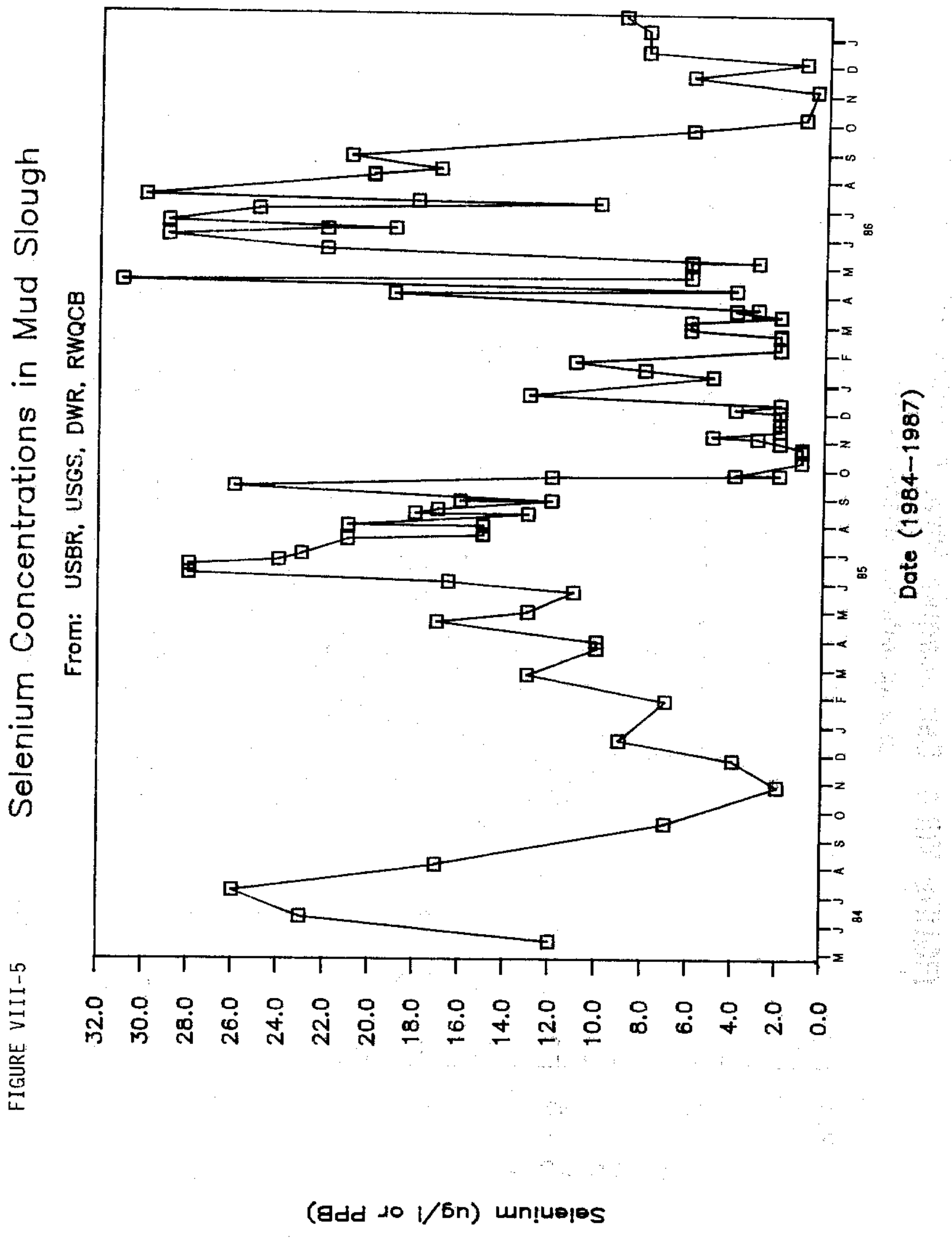


FIGURE VIII-6

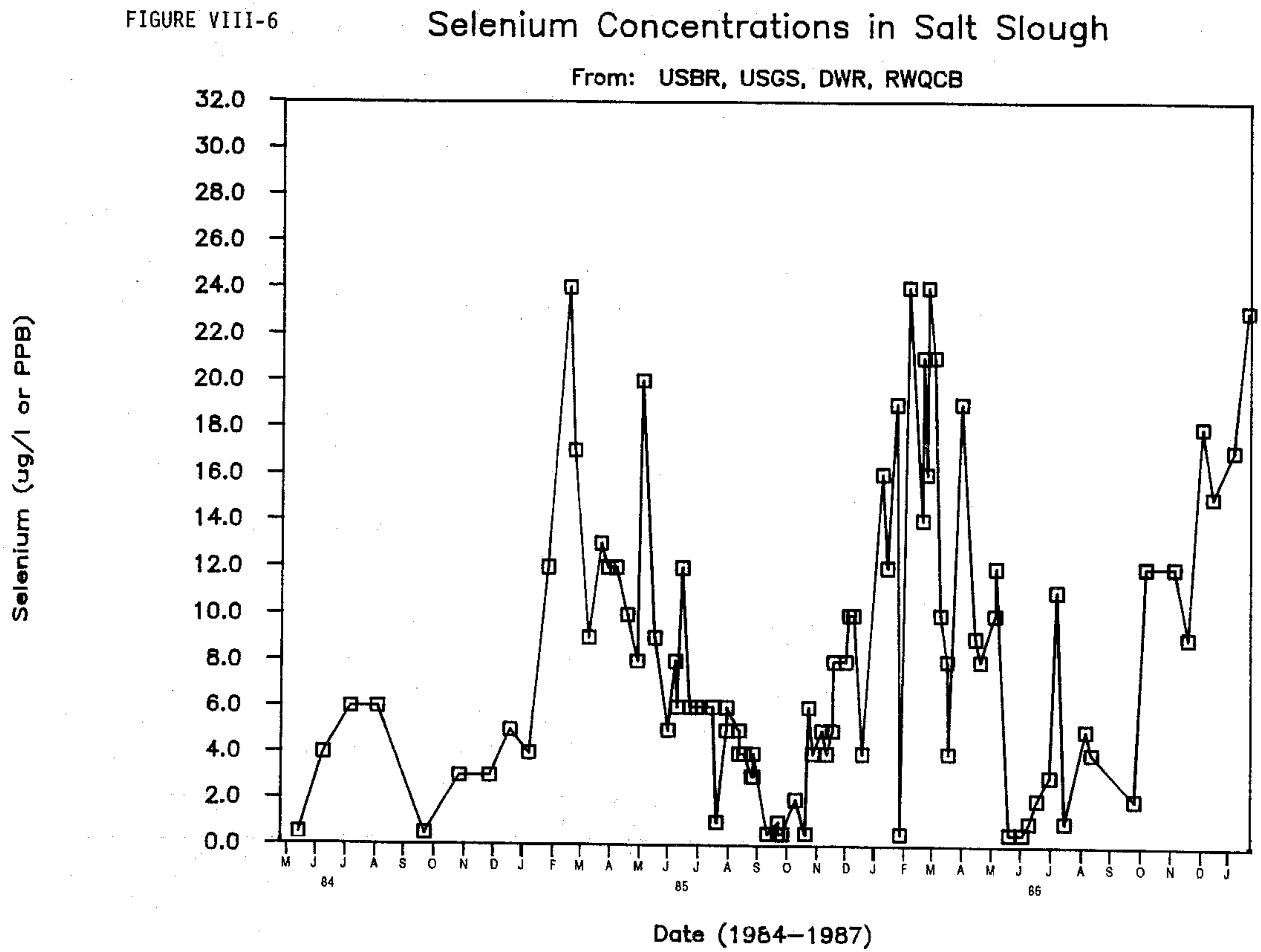


FIGURE VIII-7 WY 1979 (Normal)
San Joaquin River - Hills Ferry to Vernalis

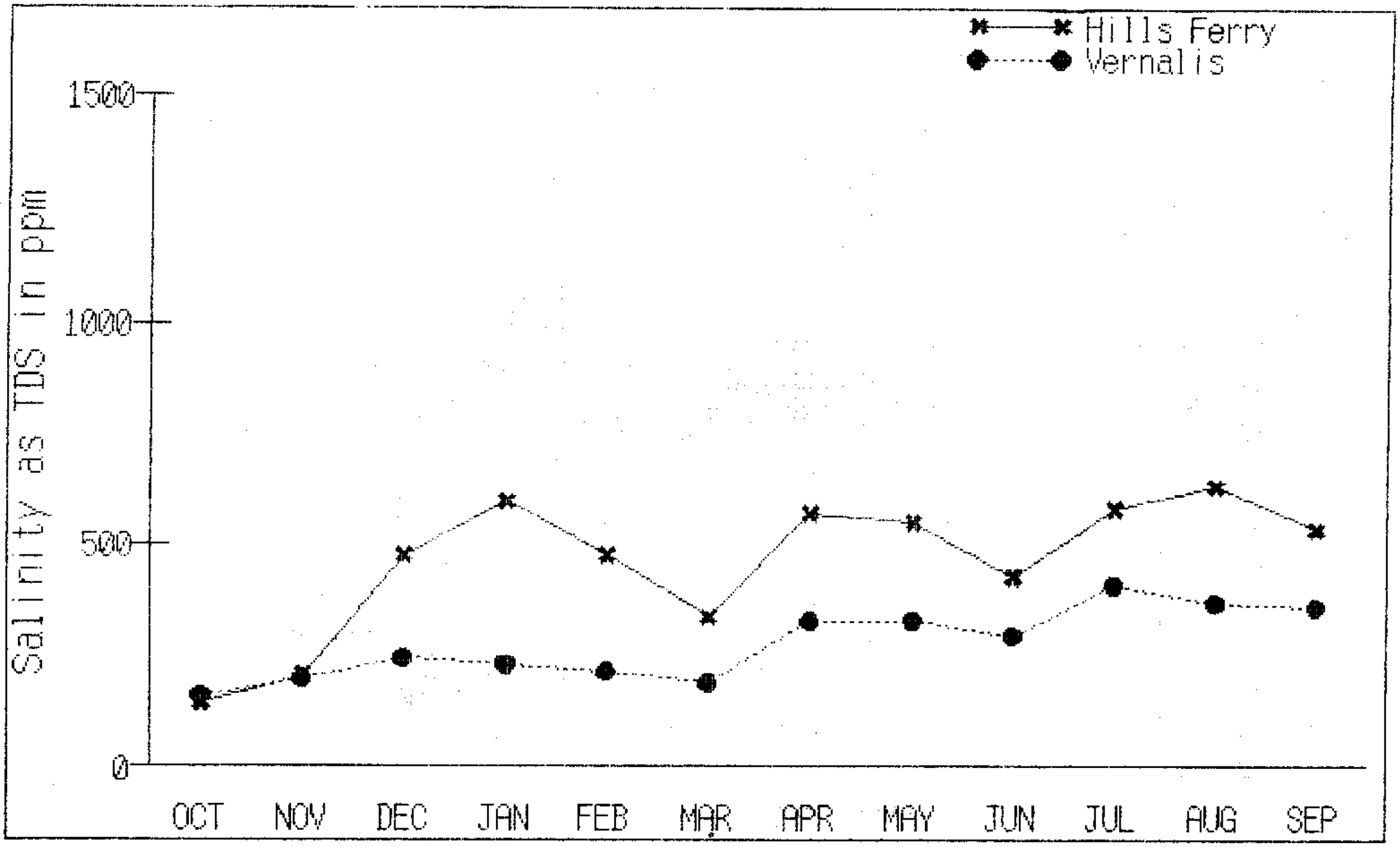


FIGURE VIII-8 WY 1981 (Critical)
San Joaquin River - Hills Ferry to Vernalis

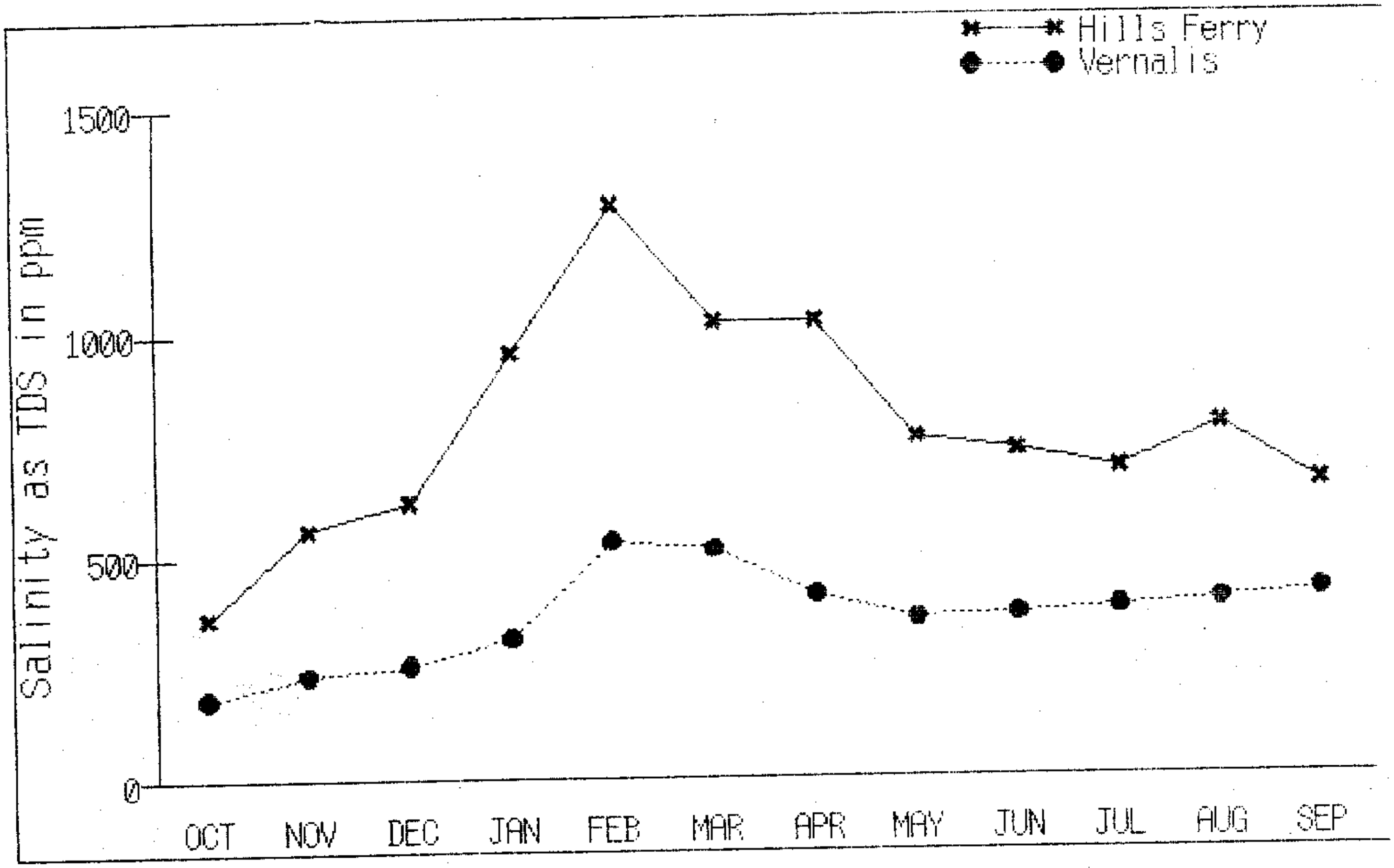


FIGURE VIII-9 WY 1984 (Normal)
San Joaquin River - Hills Ferry to Vernalis

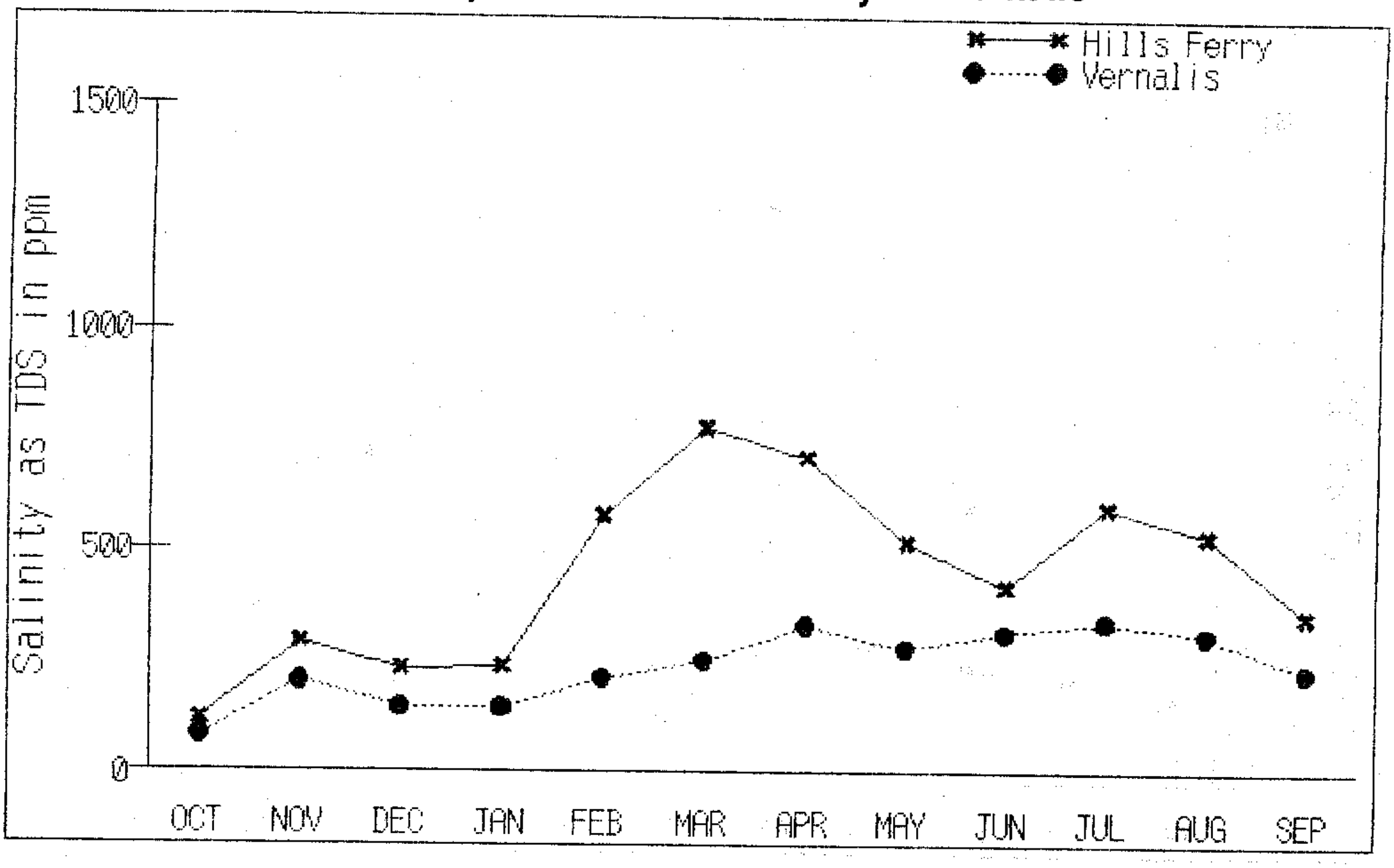


FIGURE VIII-10 WY 1985 (Dry)
San Joaquin River - Hills Ferry to Vernalis

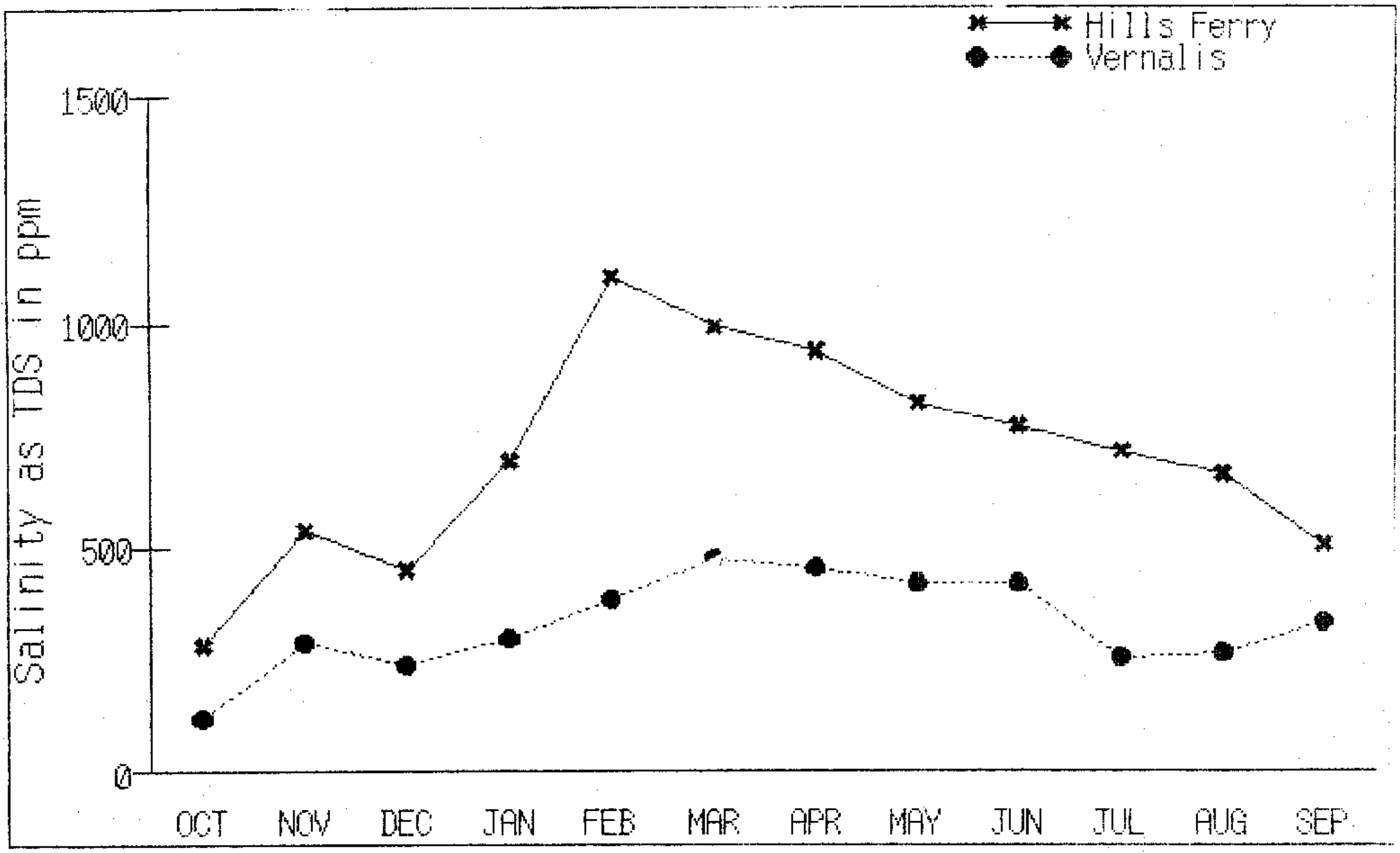


FIGURE VIII-11 WY 1985 Estimated Salinity in San Joaquin River at Hills Ferry

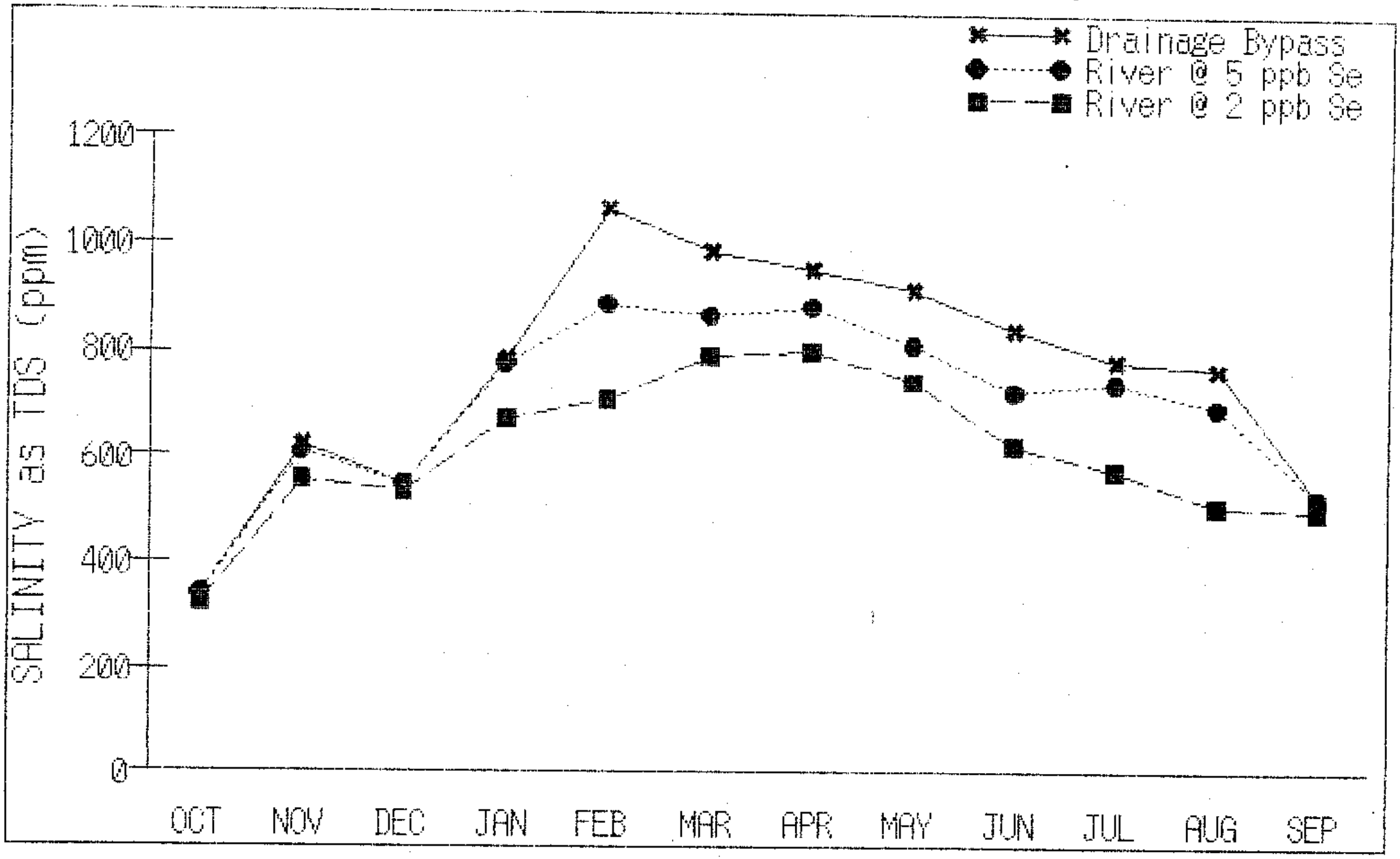


FIGURE VIII-12 WY 1985 Estimated Boron in San Joaquin River at Hills Ferry

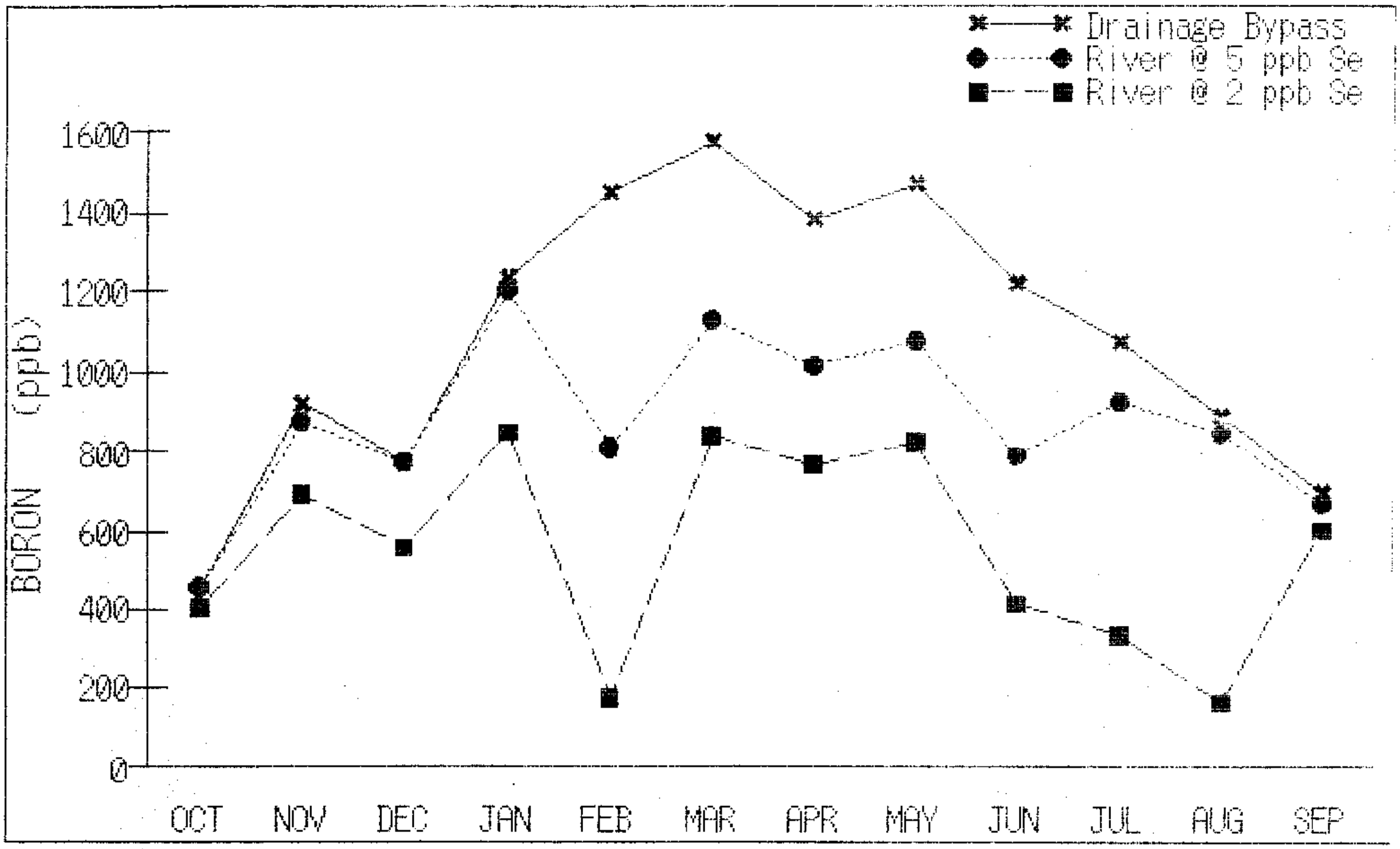


FIGURE VIII-13 Selected San Joaquin River Basin Cadmium Concentrations

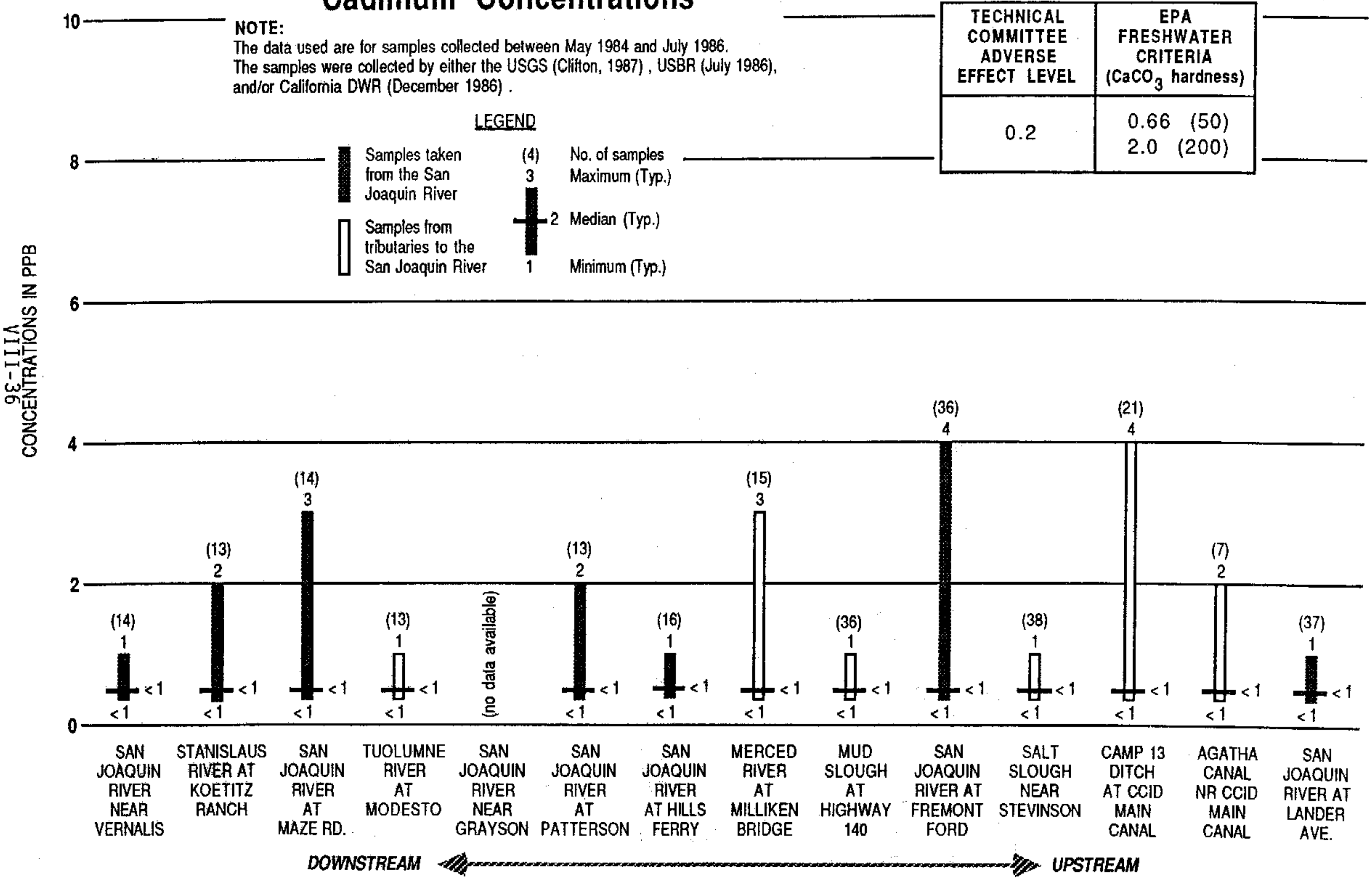


FIGURE VIII-14 Selected San Joaquin River Basin Total Chromium Concentrations

NOTE:
The data used are for samples collected between May 1984 and July 1986. The samples were collected by the USGS (Clifton, 1987), USBR (July 1986), and/or California DWR (December 1986).

TECHNICAL COMMITTEE ADVERSE EFFECT LEVEL	EPA FRESHWATER CRITERIA ($CaCO_3$ hardness)
tri-116	120 (50) 370(200)
hex-4.5	11

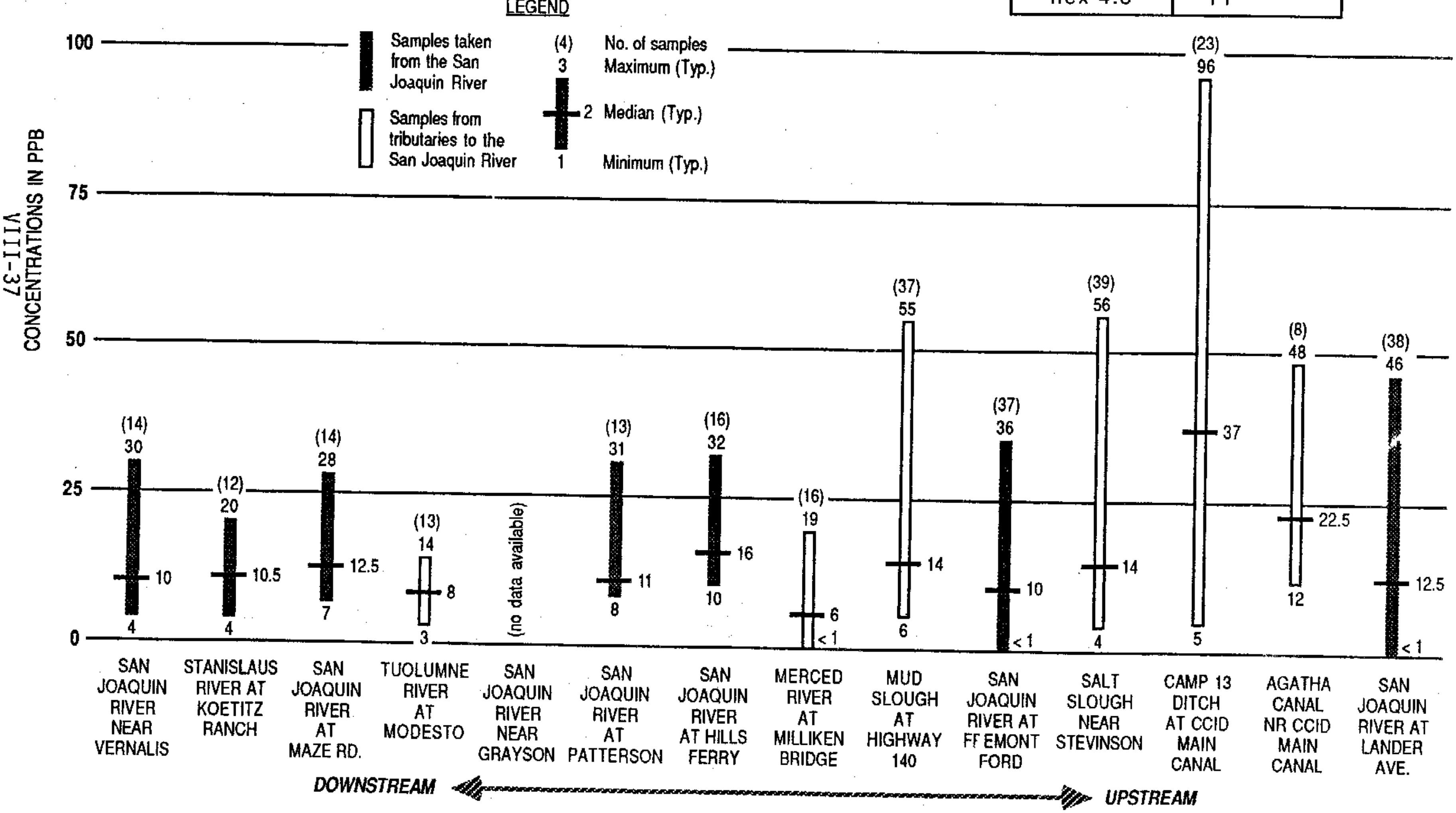
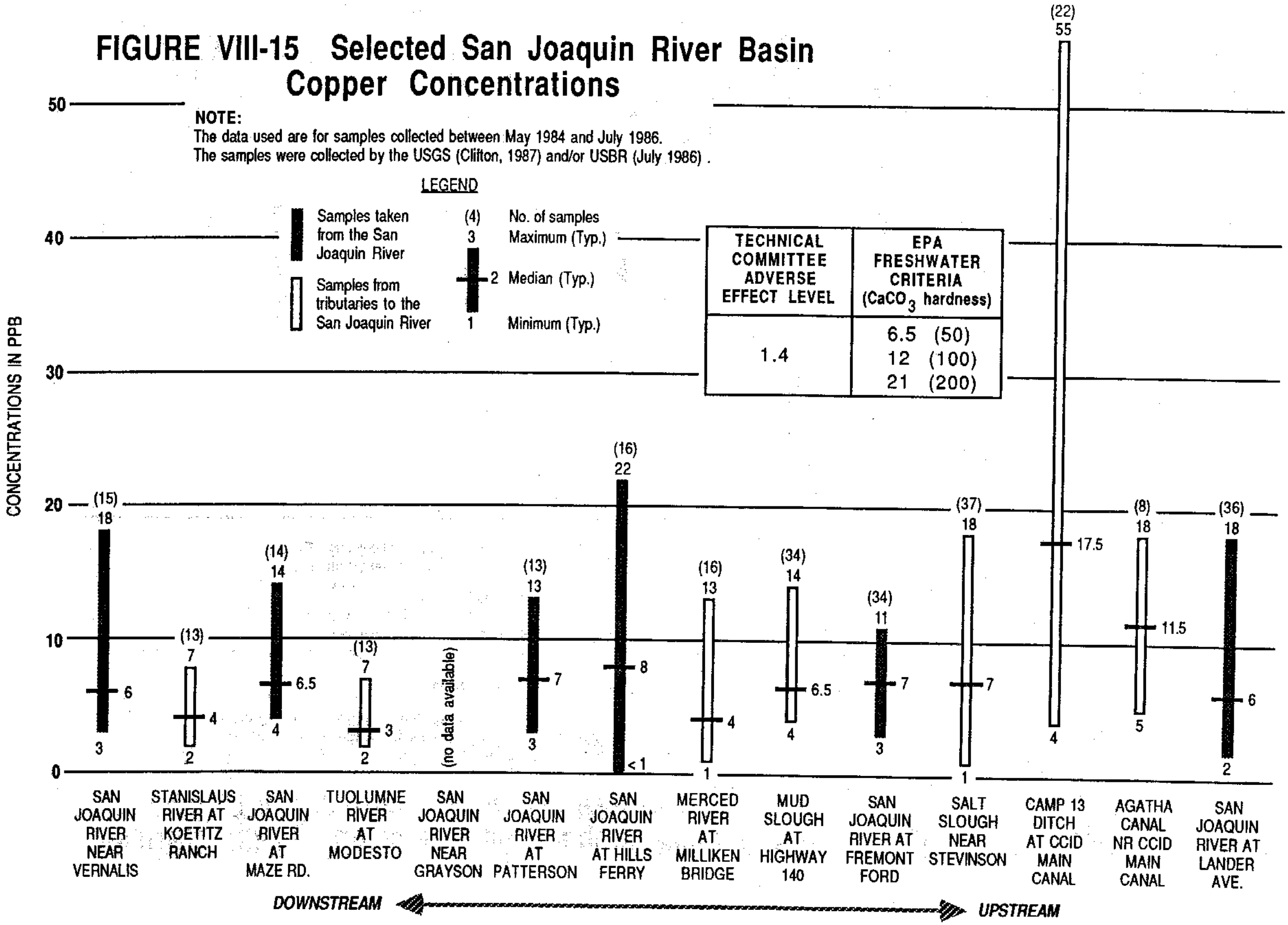


FIGURE VIII-15 Selected San Joaquin River Basin Copper Concentrations

NOTE:
The data used are for samples collected between May 1984 and July 1986.
The samples were collected by the USGS (Clifton, 1987) and/or USBR (July 1986).



TECHNICAL COMMITTEE ADVERSE EFFECT LEVEL	EPA FRESHWATER CRITERIA ($CaCO_3$ hardness)
1.4	6.5 (50) 12 (100) 21 (200)

FIGURE VIII-16 Selected San Joaquin River Basin Manganese Concentrations

NOTE:
The data used are for samples collected between May 1984 and July 1986.
The samples were collected by the USGS (Clifton, 1987) and/or USBR (July 1986) .

TECHNICAL COMMITTEE ADVERSE EFFECT LEVEL	EPA FRESHWATER CRITERIA
1600	-

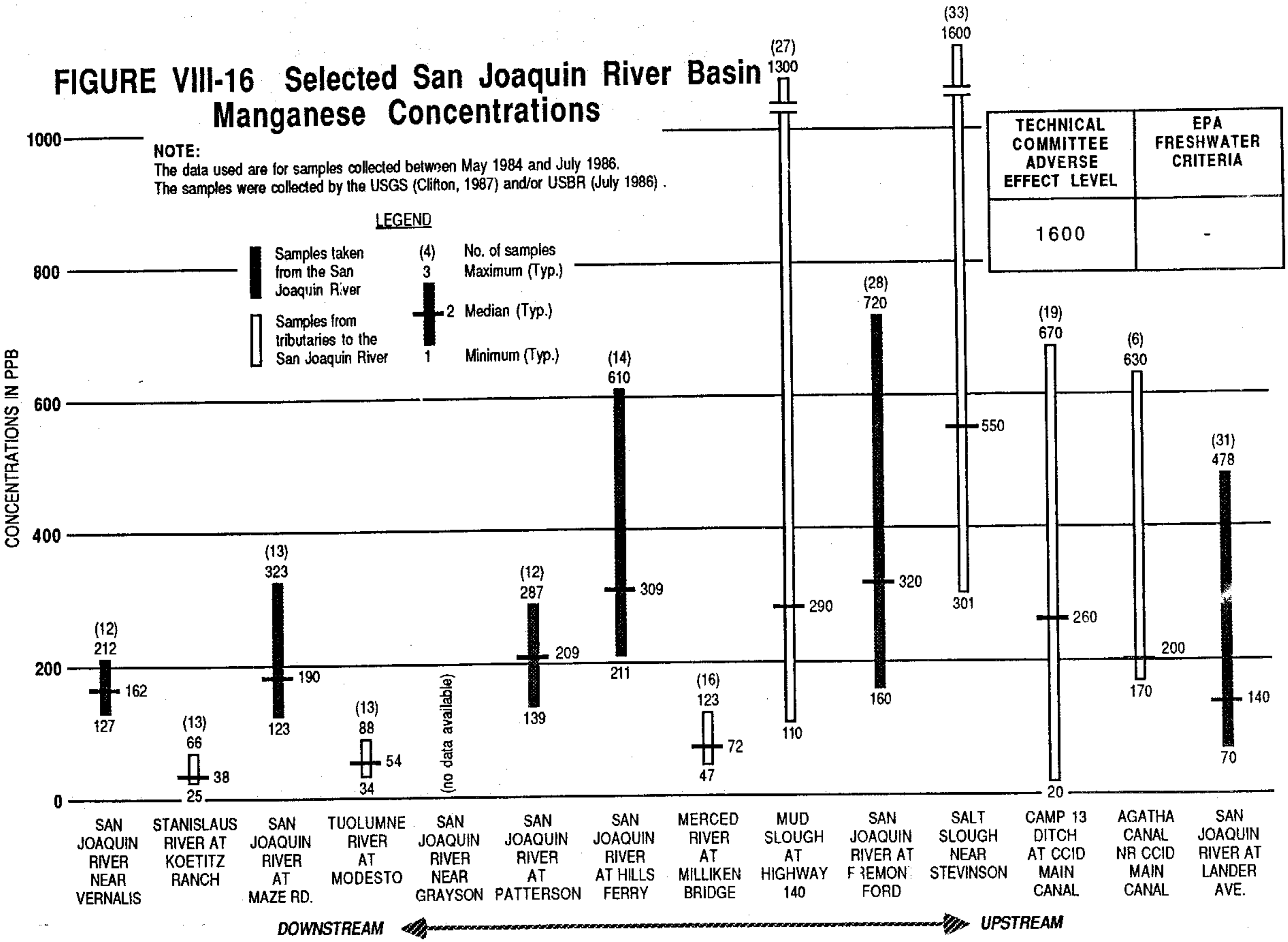


FIGURE VIII- 17 Selected San Joaquin River Basin Nickel Concentrations

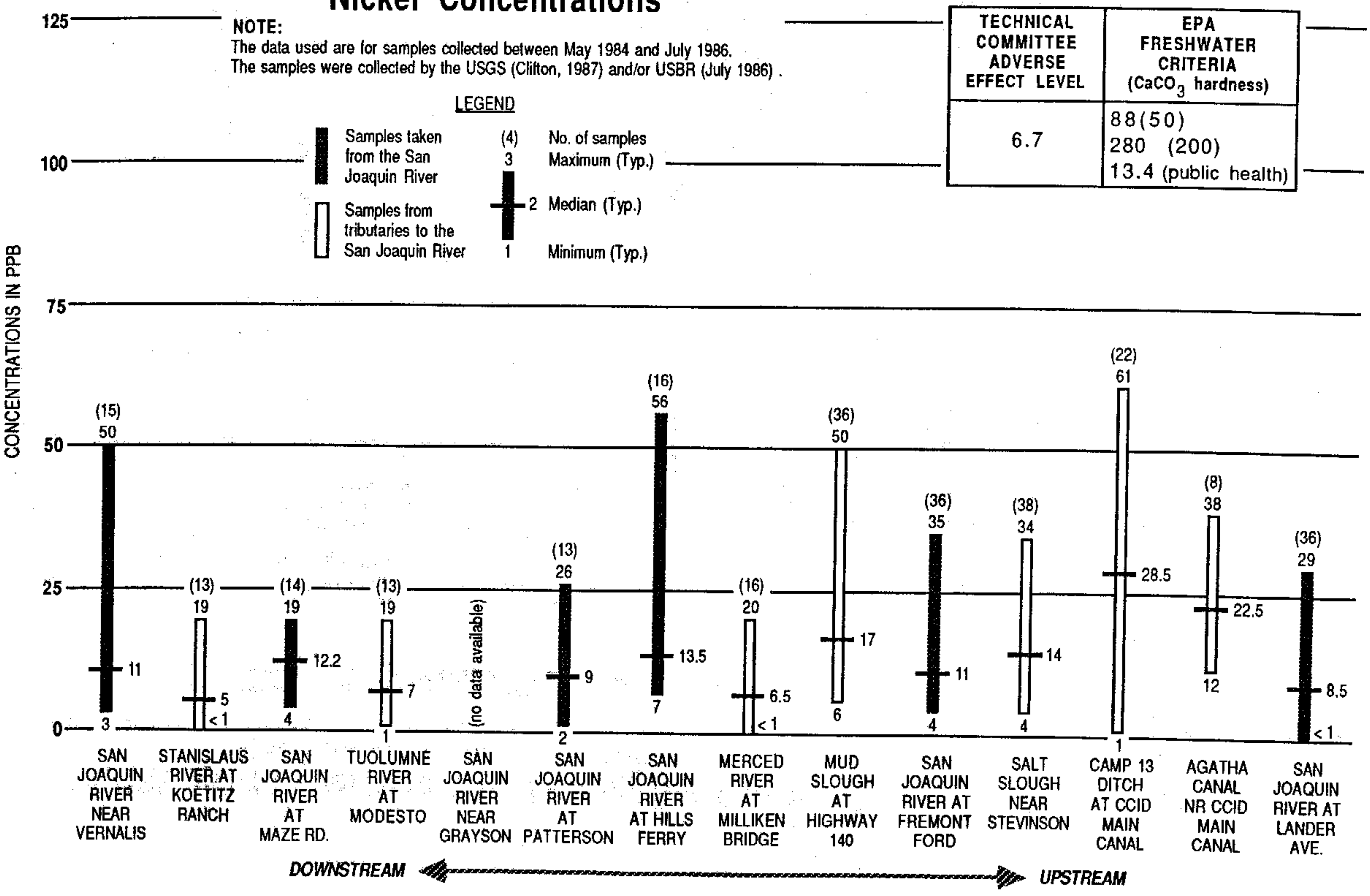
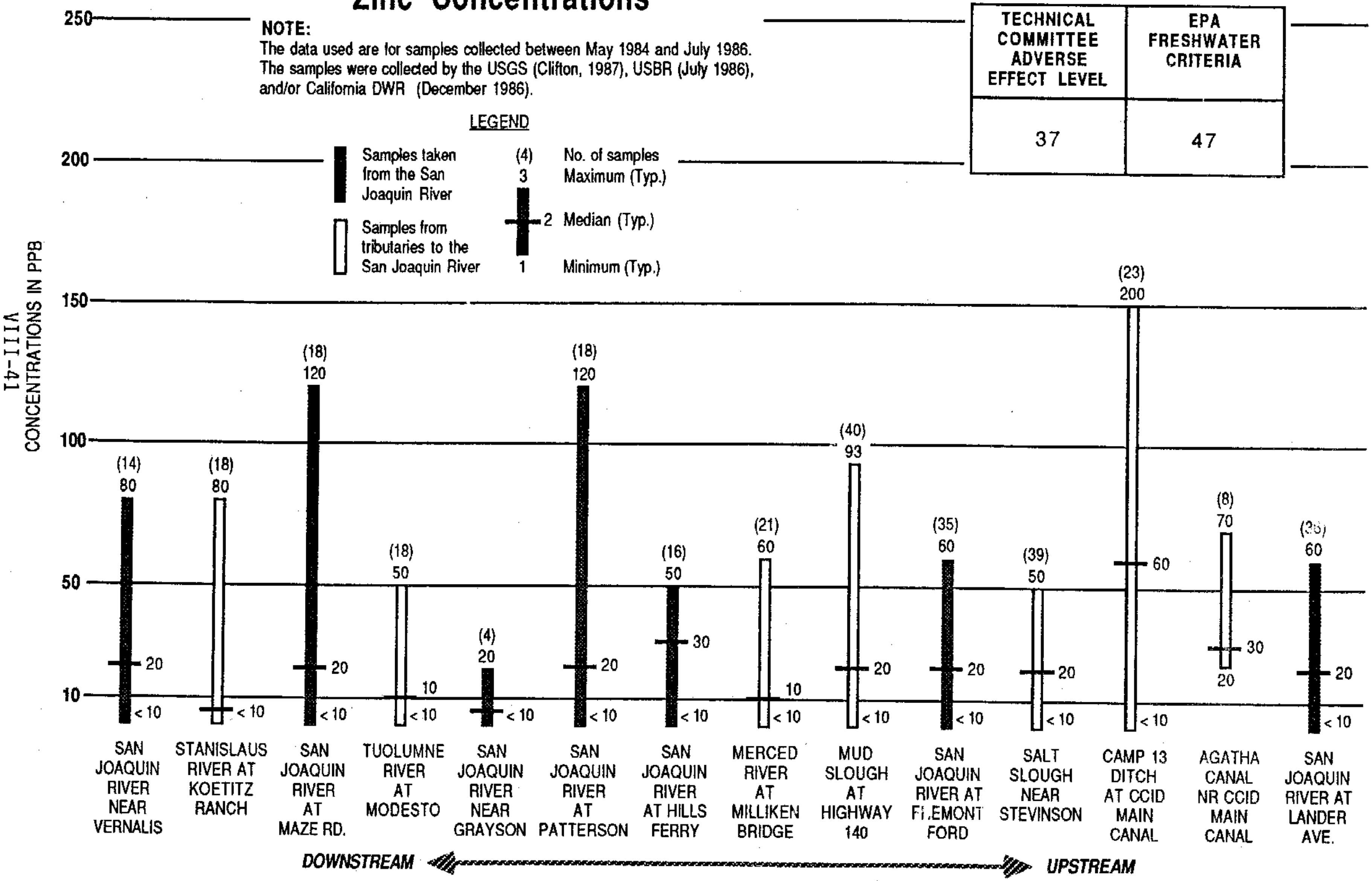


FIGURE VIII-18 Selected San Joaquin River Basin Zinc Concentrations



IX. PROGRAM OF IMPLEMENTATION

When the Central Valley Regional Board considers amendments to its San Joaquin River Basin Plan, it will include a Program of Implementation to achieve the water quality objectives contained in the Basin Plan. As set forth in the California Water Code § 13141 and 13242, a Program of Implementation in a Basin Plan contains the following:

1. A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private.

2. A time schedule for the actions to be taken.

3. A description of surveillance to be undertaken to determine compliance with objectives.

4. Potential sources of financing.

Chapter VIII discusses recommended water quality objectives that the Regional Board should consider. Achievement of these objectives will take some time and implementation should be phased in over time. The reasons for a phased implementation of the objectives include: (1) the need to collect and analyze site-specific data on the biological effects of selenium in the waters of the San Joaquin River Basin, (2) the costs involved to achieve the objectives, (3) the magnitude of the changes in irrigation practices that are needed, (4) the need to conduct large scale field trials of more efficient irrigation methods and (5) the need to verify the effectiveness of drainage flow reduction on reducing the load of pollutants discharged in subsurface agricultural drainage.

The Program of Implementation in the 1975 Basin Plan for the San Joaquin River Basin included a discussion of the need to construct a drain to convey agricultural drainage out of the San Joaquin Basin. Once the drain was in operation, water quality objectives in the San Joaquin River would be adopted and effluent limits imposed to achieve these objectives. In 1975, the Regional Board anticipated that an agricultural drain was only a few years away. Such a drain was not finished and alternative proposals from the San Joaquin Valley Drainage Program for the disposal of agricultural drainage are not expected until late 1990. Therefore, constituents of concern in this drainage including salts (TDS), selenium, boron and molybdenum, will need to be addressed, at least in the near-term, with in-basin solutions.

The following sections briefly discuss the nature of the actions, time schedule and monitoring program that should be considered by the Regional Board in its Basin Plan revisions. The last action in this section refers to one that should be considered by the State Board to assist in implementing the water quality objectives.

Nature of Actions

- Waste Discharge Requirements

  In order to achieve water quality objectives, the Regional Board can establish waste discharge requirements on specific dischargers. A detailed review of the Regional Board's authority to establish such requirements on subsurface agricultural drainage is discussed in detail in Appendix F, Section III.D.1. This analysis concludes that the Regional Board clearly has the jurisdiction to regulate subsurface agricultural drainage. Therefore, in order to implement the water quality objectives set forth in the revised Basin Plan, the Regional Board could adopt waste discharge requirements. Because the State's definition of a point source specifically excludes irrigated agriculture, the Regional Board cannot adopt an NPDES permit for these discharges under Section 402 of the Federal Clean Water Act (Appendix F, III.D.3). The Regional Board may wish to define Best Management Practices and require their use to implement water quality objectives in lieu of adopting waste discharge requirements.

- Responsible Party

  If the Regional Board decides that it is necessary to implement waste discharge requirements, the parties responsible for discharges would need to be determined. The party responsible for the discharge of agricultural drainage waters is the individual farming operation (who presently has legal control over the property) or the company or drainage district that has legal control over the discharges in question. This is discussed in Appendix F, Section III.D.7.

- Joint Discharge Requirements

  Appendix F, Section III.D.4 addresses the issue of placing discharge requirements jointly on all parties contributing drainage to drains which discharge to waters of the State. Because of the numerous farming operations in the Drainage Study Area which discharge directly to waters of the State and the potential contribution of drainage from upslope areas, the Regional Board may wish to place joint requirements on all these individuals to ease the administrative burden of determining compliance. If necessary, enforcement actions would be complicated because each responsible party would be separately liable for non-compliance.

- Regional Drainage District

  Over the last 30 to 40 years, there has been much public discussion about the formation of a San Joaquin Valley-wide Drainage District or several regional drainage districts. Such districts would help their member farming operations develop and implement environmentally acceptable solutions to their drainage problems. Such a district could also take a lead role in assisting farm operators as they seek to comply with waste discharge requirements needed to protect beneficial uses of the State's waters. A regional drainage district could accept waste discharge requirements on behalf of its members and could assist in developing the apportionment of the costs associated with attaining these requirements among its members.

  A regionally developed drainage reduction program developed by a large drainage district would provide greater flexibility in achieving water quality objectives and would provide more efficient management of the regional shallow water table than individual programs developed by each farming operation. Such a regional program would also be less costly than the sum of the individual programs. The Regional Board would also be spared the expense and administrative burden of developing individual waste discharge requirements to ensure that the water objectives were maintained. The agricultural drainage problem in the DSA and areas up-gradient, is a regional problem and is addressed most effectively at the regional level.

- Mixing Zone Policy

Currently the drainage canals in the DSA upstream of Central California Irrigation District's (CCID) main drain serve as mixing areas for both surface and subsurface drainage from the DSA. Provided the Regional Board is able to adopt and enforce waste discharge requirements jointly on the various responsible parties in the DSA, they should consider appropriate portions of these agricultural drains as mixing zones, consistent with regulations adopted under the Federal Clean Water Act.

- Upslope Dischargers

The contribution of subsurface drainage from areas upgradient of the farm land with subsurface drains is briefly discussed in Chapter V. Day and Nelson (1986) analyzed drainage data from Broadview Water District to assess the contribution of upgradient areas to tile drained areas downgradient. They concluded that upgradient irrigation practices do not significantly affect the peak subsurface flows from on-farm drainage systems within the District. This analysis did not include the contribution of upgradient areas to 'base flows' or regional high water tables. Review of this information by our consultants found some features in the data that may possibly be consistent with influence from upgradient irrigators. Also, the discussion in Chapter II on the Regional shallow ground water table shows that the overall flow lines are downgradient to the tile drained lands. In addition, our water balance for the DSA (presented in Chapter V) discusses how nondrained lands and seepage losses from water supply canals can contribute to subsurface drainage discharged from the drained lands. To the extent that upgradient practices and canal seepage losses contribute subsurface drainage to downgradient tile drained areas, the upgradient areas and canal opeators have a responsibility to assist in attaining water quality objectives. A regional drainage district could help ensure an equitable distribution of costs between upgradient and downgradient areas in achieving these objectives. In the absence of such a district, the Regional Board could hold these upgradient areas jointly responsible with the downgradient areas for complying with waste discharge requirements (see Appendix F, Section III.D.2).

- Substitute Water Supply for Waterfowl Areas

As set forth in Chapter V, about half of the historic water supply for the Grassland Water District (GWD) consisted of agricultural drainage water until 1985. Historically the GWD would use this water for both seasonal wetlands and irrigated pasture. Also, the San Luis National Wildlife Refuge (NWR) and the Los Banos State Waterfowl Area (SWA) historically diverted some of their water supply from sources affected by agricultural drainage. In 1985 the GWD and the other waterfowl areas bypassed much of this water directly to the San Joaquin River because of concerns raised by high selenium levels in subsurface drainage. This left the GWD and the other waterfowl areas short of water. These entities have attempted to obtain other water supplies with limited success. The present selenium levels in its historic agricultural drainage water supply preclude the future use of this supply until the selenium levels are reduced. As stated earlier, the canals and ditches which served as a water supply to the GWD and the other waterfowl areas are waters of the State and subject to water quality protection.

The drainage districts upslope of GWD claim a "drainage right" across this area. Appendix F, Section III.D.6 addresses these drainage rights. It states:

> "The existence of a drainage contract, easement or other right to drain does not give the holder of the drainage right a vested right to continue to discharge waste into waters of the state nor to

> pollute waters of the state. See Water Code § 13263 (g). All persons discharging waste which could affect the quality of waters of the state are subject to the regulatory authority of the Regional Boards. See Water Code § 13260 and 13263. The Regional Boards are authorized to either prohibit the discharge or regulate it under waste discharge requirements. § 13243 and 13263."

The water supply to the waterfowl areas did not become heavily contaminated with selenium until the increased installation of tile drains began in the 1960's and 1970's. This subsurface drainage has adversely affected an existing offstream beneficial use of this water when impounded for waterfowl habitat. The recommended selenium objectives for the waterfowl areas in the GWD and the state and federal waterfowl areas can be achieved in one of at least three ways. The objectives could be achieved by (1) removing selenium from the agricultural drainage via treatment, (2) providing a substitute water supply to these areas or (3) routing agricultural drainage around these sensitive areas entirely. As shown in Table VII-4, it is cheaper to bypass agricultural drainage around this area than it is to remove the selenium via treatment. Various parties have an interest in providing water supplies to the grasslands area. Therefore, the costs may be shared by these parties. This makes the task of estimating the costs to any one party extremely difficult to calculate.

To attain any of the possible selenium objectives with the water conservation practices recommended in the report, a substitute water supply to these areas could be provided at little additional cost. The Technical Committee believed that the substitute supply alternative would be selected as the alternative of choice. However, the agricultural district representatives pointed out during the comments at the public workshop that they are actively pursuing mechanisms to bypass their drainage around the grasslands area.

Although this is likely more costly than providing a substitute supply to mitigate for their adverse effects on water quality, other considerations are involved.

Bypassing both surface and subsurface agricultural drainage around the grasslands area would achieve the selenium water quality objectives but not provide sufficient water supplies to maintain important wetland resources. Thus, strict achievement of the objectives could result in a permanent loss of a significant water supply to this area. Therefore, the real issue is obtaining a water supply of appropriate quality that maintains and enhances these important wetland resources. Many parties have interests in securing such a water supply for this area. The agricultural entities with tile drains and areas upgradient have an interest because of their need to mitigate for the water quality degradation they have caused. The operators of the Central Valley Project and State Water Project have an interest because seepage losses from their canals contribute to the shallow water table and can increase the volume of subsurface agricultural drainage in areas downgradient. The Grassland Water District has an interest because even their historic water supplies of about 116,000 AF are not sufficient to satisfy the water demand for this area, which they believe to be about 150,000 AF/year. Both the State Department of Fish and Game and the U.S. Fish and Wildlife Service have an interest because their waterfowl areas are also involved and because of their interest in preserving and enhancing wetland resources in this area.

The water districts in the DSA can either take actions to reduce the selenium concentrations in this water supply to acceptable levels, i.e., 2 ppb selenium (see Chapter VIII) or they can provide the waterfowl areas with a substitute water supply of 2 ppb (or less) selenium. The amount of water provided should be no less than the quantity of drainage water historically diverted by the district for wetland habitat use (approximately 66,000 AF, see Chapter V). However, if the districts opt to provide a substitute supply and the flow quantities in the canals decrease due to water conservation or other actions of the water districts, the districts would only be required to provide the substitute supply equal to the lesser of either (1) the historically diverted quantity or (2) the existing quantity in the canals.

o Prohibitions

The Regional Board should consider the following prohibitions:

(1) No water with a selenium concentration greater than 5 ppb should be discharged directly into the Delta-Mendota Canal if such discharges substantially affect the load of selenium in the Delta-Mendota Canal.

(2) No new subsurface drainage system should be constructed which discharges to surface waters in the Basin unless the long term water quality objectives for salinity, boron, molybdenum and selenium are being met downstream of its discharge location and will continue to be met after the discharge commences.

o Drainage Flow Reduction

It was pointed out in Chapter VII that the best means to provide protection to the beneficial uses in the San Joaquin River and Mud and Salt sloughs is through better irrigation management practices to reduce subsurface drainage flows and loads of pollutants. Also, for economic reasons, drainage flow reduction would be part of any scheme which includes treatment. Drainage flow reduction will reduce the loads of constituents such as selenium if the concentration in subsurface drainage water does not increase greatly as the volume of drainage flow decreases. The water quality objectives discussed in Chapter VIII for selenium appear to be achievable with the implementation of a diligent drainage flow reduction program.

o Best Management Practices/Source Control Program

The Regional Board should consider the adoption of best management practices in the Basin Plan to assist in achieving the water quality objectives recommended in Chapter VIII. As stated previously, better water management practices and improved irrigation techiques can be used to reduce subsurface drainage volumes and the loads of elements like selenium, boron and salts that are discharged from subsurface agricultural drains into the San Joaquin River system. Available information indicates that best management practices provide the foundation for a pollutant source control program for drainage problem areas. The Regional Board can include best management practices into waste discharge requirements in order to aid in the enforceability of such practices.

The interim objective of 5 ppb appears achievable by increasing the infiltrated water use efficiency from its present less than 70 percent in the DSA to 80 percent. Infiltrated water use efficiency relates to the loss of water through deep percolation past the root zone to the ground water table. Increased efficiency would result in less water being lost to the ground water table which will lead to reduced flows into the subsurface drains.

A draft report from the U.C. Committee of Consultants on Drainage Water Reduction titled "Opportunities for Drainage Reduction" was distributed on July 1, 1987. This report confirms that reduction of subsurface drainage flows consistent with an 80 percent infiltrated water use efficiency is probably achievable. This would require best management practices using the predominantly furrow irrigation systems in the DSA.

As a means to achieve the interim selenium objective, the Regional Board should consider adopting an infiltrated water use efficiency of 80 percent as a measure of best management practices for the areas which may contribute to the tile drained lands in the DSA. These lands include upgradient areas in the San Luis Water District which might contribute drainage flows to this area now or in the future (See Figure II-3).

The goal of such practices would be to reduce subsurface tile drainage from existing tile drained areas in the DSA to 0.45 AF/acre.

The type of activities in these best management practices should include (1) better managed preirrigation, (2) better managed initial irrigation through better water scheduling, (3) use of the high ground water table in the summer as a source of water for some crops and, if necessary, (4) increased uniformity of water application through installation of more efficient irrigation equipment.

The Regional Board should require the water and drainage entities to develop plans and provide periodic written reports on the progress being made toward achieving the efficiency goals. The July 1987 draft report on "Agricultural Drainage On-farm Management Alternatives" prepared by the Agricultural Water Management Subcommittee of the San Joaquin Valley Drainage Program discusses time frames to implement various management practices to increase water use efficiency. After review of the public comments and this report, the Technical Committee believes that an additional year will be needed by the farming community in the DSA and areas upgradient to implement best management practices. This will provide three irrigation seasons (until October 1991) to implement these practices. The Regional Board should review this proposed time schedule during its Basin planning process along with the idea of establishing interim dates for the percent of acreage in compliance with these goals.

The Regional Board should consider incremental steps in drainage flow reduction from the existing 0.7 af/acre, in order to achieve the drainage flow reduction goal by October 1991 (e.g., 0.55 af/acre 1989, 0.5 af/acre 1990, 0.45 af/acre 1991). If incremental steps are not attained, the Regional Board should consider appropriate enforcement actions. The purpose of drain flow reduction is to decrease the loads of constituents of concern.

The information presented in Chapter V and VII indicate that a 2 ppb selenium concentration could be achieved if the infiltrated water use efficiency was increased to 90 percent. The U.C. Committee of Consultants' report states that this level of efficiency is achievable only through the implementation of improved irrigation systems in the DSA. The costs of such systems are evaluated in Chapter VII and are generally less than the treatment costs to attain this objective.

After assessing the effectiveness of the 80 percent efficiency best management practices, the Regional Board may need to revise this goal to 90 percent efficiency in order to achieve an appropriate long-term objective. In addition, improved water management practices and irrigation techniques provide yield benefits and decreases in production costs related to pesticide and fertilizer applications. It also requires less use of water which is then available for use in waterfowl habitat areas in the San Joaquin River Basin or other purposes statewide. These benefits have not been quantified but they are important considerations.

o Implementation Through the State Board's Water Right Authority

One method to achieve better agricultural water use practices that the State Board should consider is through its water right authority under the Water Code and its general responsibility to prevent the waste, unreasonable use, or unreasonable method of use of water.

As discussed in Chapter II, the area with tile drains and the areas upgradient contribute to subsurface drainage through the deep percolation of applied irrigation water. This deep percolation can be reduced substantially through better on-farm management practices. Less efficient irrigation practices could contribute to violation of the recommended water quality objectives and may be considered an unreasonable use of water for a drainage problem area. Therefore, the State Board should consider using its waste, unreasonable use and unreasonable method of use authority to regulate such practices in drainage problem areas.

The Bureau of Reclamation has petitioned the State Board to modify its places of use and points of diversion for many of its Central Valley Project water right permits. The Bureau delivers water to the DSA and areas upgradient through these water right permits. The possible adverse environmental impacts of approval of the petitions to modify the Bureau's place of use include: (1) the expansion of existing drainage problems through the delivery of water to new lands and (2) the increase in existing problem areas through the delivery of additional water supplies which could take place in the San Joaquin Valley if the point of diversion petitions are approved. The State Board should consider adding a term to the Bureau's water right permits in the San Joaquin Valley to require areas in the DSA and areas upgradient to minimize deep percolation by increasing their infiltrated water use efficiency to an appropriate level developed during the course of public hearings.

Deep percolation beyond this "best management" water use efficiency could be considered an unreasonable use or method of use of water. If excess deep percolation beyond a specific rate were found unreasonable, a permit term could be imposed to regulate it. The Bureau could report annually to the Board on the calculated deep percolation rates based on lands irrigated, crop types, effective rainfall and amounts of applied water. Alternatively the water application rates could be set based on the most recent five years of data on these parameters and the close monitoring of the water application rates. Water users who did not minimize percolation could be required to explain why. The prescribed deep percolation rate could be modified on a case-by-case basis where appropriate. However, the land of water users who refused to comply could be removed as places of use from the Bureau's permits until they developed a specific plan and time schedule for compliance. Removal of a place of use from the Bureau's water right permits would prohibit delivery of Bureau water to this area.

The Bureau would likely have to modify many of its existing contracting rules and regulations to implement such a water right permit term. The net result of such modifications could be changes in pricing structures, water deliveries and monitoring and reporting requirements by the water districts in the DSA and areas upgradient.

An appropriate water right permit term could be developed as part of the water right hearing of the Bureau's place of use petitions scheduled to begin in 1988. If adequate progress toward compliance with the Regional Board's waste discharge requirements or best management practices was being made at that time, the State Board should consider reserving jurisdiction to allow later adoption of such a term at any time when appropriate progress was not being made.

An issue arises with regard to the pre-1914 water rights of some of the entities in the DSA who are now served through exchange contracts with the Bureau. If enforcement action was taken against the Bureau's permits in these areas and Bureau water deliveries terminated, the entities might seek water deliveries from their prior water source, the San Joaquin River. The same issue exists with regard to the pumping of ground water to make up lost water supplies. This would not likely take place because the proscription against waste and unreasonable use is a constitutional requirement, which applies to all water users. If individuals used water supplies other than those provided by the Bureau of Reclamation to continue wasteful water practices, the Board should consider a waste and unreasonable use hearing, so that such requirements would apply to not only the use of Bureau water but all other sources of water as well.

Time Schedule

The Technical Committee was not specifically requested to develop a time schedule. However, one was proposed principally to outline the sequence of events that should take place in the staged approach to implement these objectives. Table IX-1 lists some of the events that should take place in implementing both interim and long-term objectives for the San Joaquin River Basin.

A great deal of public comment was received regarding the time schedule to implement the water quality objectives. However, except for the interim objectives, we have not been able to resolve the diverse comments received. We believe that the Regional Board needs to gather more input on this issue during the Basin Planning Process hearings. The Regional Board should request the University Committee of Consultants on Agricultural Drainage to examine this issue also. This information could be included in that Committee's December 1987 draft report on the costs of better water management practices and would be extremely helpful to the Regional Board in establishing an overall schedule of implementation.

Monitoring Program

- Biological Studies

  If the State Water Resources Control Board has appropriate funds it should conduct research and monitoring related to selenium and its effects in the environment. Over the next three years these studies should include:

  (1) Site specific studies of the chronic effects of selenium in the San Joaquin River Basin using EPA's three species tests.

  (2) Collection of water quality and fish, plant and insect tissue data for the San Joaquin River and its tributaries to verify the extent of bioaccumulation of selenium in both flowing and impounded water environments.

- Water Management Studies by the Permittees or the Regional Drainage District (if one is formed)

  The entities which either receive the waste discharge requirements (permittees) or are required to implement Best Management Practices should be required to collect detailed information to assist the Regional Board in its triennial review of its Basin Plan. The Regional Board should review the adequacy of this information as it is developed. The information collected should include:

  (1) The discharge location of each subsurface drain provided on appropriate maps to the Regional Board along with the area that they drain.

  (2) Flow and quality data. All subsurface drain discharges should be metered and reported to the Regional Board, along

with water quality measurements for electrical conductivity, selenium and boron and other trace elements, as may be required by the Regional Board.

(3) Water application rates, surface and subsurface flows for each farm operation within the DSA and areas upgradient.

(4) Water use efficiencies and distribution uniformity should be reported annually to the Central Valley Regional Board for each farm operation within the DSA and areas upgradient.

(5) Development of a detailed drainage flow reduction plan to attain the interim and long-term water quality objectives.

(6) Engineering studies and detailed costs of separation of tile drain flows from surface flows in the DSA.

(7) Participation in the San Joaquin Valley Drainage Program studies on alternative solutions to attain the long term selenium, boron and TDS objectives for the San Joaquin River Basin.

Potential Alternative Sources of Funding

The Technical Committee has looked into potential alternative sources of financing to implement the water quality objectives. They include: (1) private financing by the individual sources of agricultural drainage; (2) bonded indebtedness or loans from governmental institutions; (3) a surcharge on water deliveries to lands contributing to drainage problems; (4) an ad valorem tax on lands contributing to drainage problems; (5) taxes and fees levied by a district created for the purpose of drainage management; (6) State or federal grants or low-interest loan programs; and (7) single-purpose appropriations from federal or State legislative bodies. All of these options appear to be viable at this time; however, costs associated with these options could vary widely, and it is anticipated that all options may not be available to existing draining entities in the DSA.

The analysis of the costs and economic effects associated with achieving the recommended water quality objectives analyzed in Chapter VII were based on financing by the farming community in the DSA at an interest rate of four percent. The State funds for such low interest loans, made available under the Water Conservation and Water Quality Bond Law of 1986, are nearly exhausted at this time. Failure to continue to provide low interest loans would add to the total cost of meeting water quality objectives and the economic impacts to the growers in the DSA (see Chapter VII).

The low interest loans given under the Water Conservation and Water Quality Bond Law of 1986 are made to public agencies, not to private individuals. Since drainage flow reduction will take place on-farm, its costs will be those typically paid for by the individual operators, not the water district. Private parties could benefit from funding only if a public agency sponsored the project and has financial capability to repay the loan. If on-farm improvements are funded, a district would likely retain ownership of the improvements through the loan repayment period.

New fees or taxes adequate to fund necessary drainage management activities in the DSA may be needed. A fee and tax structure that encourages water conservation and highly efficient use of irrigation water would appear to be preferrable to one which does not.

Under the Agricultural Water Management Planning Act of 1986 the following water districts in the DSA and areas upgradient can receive up to $25,000 each from the California Department of Water Resources to prepare a water conservation plan:

Central California Irrigation District
Firebaugh Canal Company
Panoche Water District
San Luis Canal Company
San Luis Water District
Westlands Water District

TABLE IX-1
PROPOSED TIME SCHEDULE
TO IMPLEMENT
WATER QUALITY OBJECTIVES

(1)	Regional Board adopts revised monitoring requirements for collection of drainage discharge data by water districts in the DSA.	*
(2)	Regional Board adoption of Revised Basin Plan including Best Management Practices.	February 20, 1988 (per SWRCB Order WQ 85-1)
(3)	Formation of Regional Drainage District (recommended action)	*
(4)	Required monitoring and engineering programs initiated by water agencies	*
(5)	Substitute supply to GWD, San Luis NWR and the Los Banos SWA	*
(6)	Drainage flow reduction program developed by water agencies and drainage districts	*
(7)	Implementation of drainage flow reduction program begins	*
(8)	Regional Board completes triennial review and establishes the long-term selenium objective	*
(9)	Interim selenium objectives of 5 ppb become effective	October 1991
(10)	Water agencies and drainage districts submit detailed plan of action to achieve long term selenium objective	*
(11)	Long-term objectives become effective	*

* Dates not specified; to be determined by Regional Board

GLOSSARY

Glossary

Acid soluble basis - The quantity of a constituent, element or radical, contained in a sample that passes through a 0.45 micron membrane filter after the sample is acidified to a pH = 1.5 to 2.0 with nitric acid.

Acre-foot (AF) - The quantity of water required to cover one acre to a depth of one foot: equal to 325,851 gallons or 43,560 cubic feet.

Acute toxicity - A measure of the toxicity of a toxic material which reflects death after short-term exposure to a relatively high concentration.

Adsorption - A type of adhesion by which molecules accumulate in the immediate vicinity of the surface of a solid or liquid in contact with another medium. Physical adsorption involves a non-specific weak attraction between molecules. Chemical adsorption involves much stronger attraction.

Adverse effect level - The logarithmic mean of the three lowest accepted toxicity data points representing three relevant (North American freshwater) test organisms exposed to it.

Agricultural supply - see Water, uses of.

Agricultural tile drainage - The effluent from a system of drainage pipes installed under a field to relieve high ground water problems.

Alkaline - Of, containing or relating to a carbonate or hydroxide of an alkali mmetal (including lithium, sodium, potassium). May also refer to solutions having a pH greater than seven (7).

Alluvial fan - A stream deposit whose surface forms a segment of a cone that radiates downslope from the point where the stream channel emerges from a mountainous area.

Alluvial fan zone - The region underlain by sedimentary material from the convergent west side alluvial fans. The terrain is moderately sloping and the soils are mostly low salinity.

Ambient - The prevailing condition in the vicinity, usually relating to some physical measurement such as temperature. Sometimes used as a synonym for background.

Anadromous - Pertaining to fish that spend part of their life cycle in the ocean and return to freshwater streams to spawn.

Annualization factor - A constant used to calculate the annual payment of capital costs of a project as they would be distributed each year over the life of a project, given the interest rates and useful life of the facility.

Annual flow - The quantity of water passing a particular point during the water year.

Appropriate, Appropriator, Appropriative - see Water rights.

Aquatic wetland - A zone permanently or frequently inundated, (generally to a depth of six feet or less) with saturated soil and water dependent vegetation; typically bounded on its terrestrial border by a riparian wetland.

Aquifer - A geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

Arithmetic mean - The sum of a series of values divided by the number of such values.

Arsenic - A highly poisonous metallic element. Arsenic and its compounds are used in insecticides, weed killers and industrial processes.

Association - A collection of animals, plants, or both, into a physical proximity or grouping, without necessarily requiring or implying interactions between units of the group; in contrast to "community," which does.

Basin Plan - A plan for the protection of water quality prepared by a Regional Water Quality Control Board in response to the federal Clean Water Act.

Basin rim zone - An area underlain by a mixture of sedimentary material from the convergent west side alluvial fans and marsh and lacustrine deposits. The terrain is more level than the alluvial fan zone but because the basin rim is an evaporative discharge area, soils are moderately to highly saline.

Basin trough zone - The region underlain by marsh and lacustrine deposits. The terrain is very level and the soils have low salinity.

Beneficial uses - the uses of the waters of the state to be protected against quality degradation including, but not necessarily limited to, municipal, agricultural and industrial supply; power generation; recreation; esthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves.

Beneficial use designation - See water, uses of.

Bioaccumulation - The increased concentration of a chemical in the tissue of organisms obtained via water and diet.

Bioconcentration - The positive difference in concentration of a chemical between water and that in an organism living in that body of water due to direct uptake of the chemical from the water.

Biomagnification - The net accumulation and increase of a substance in an organism as a result of consuming organisms from lower trophic levels, e.g., the consumption of algae by fish or water plants by ducks.

Boron - A metalloid element usually found in nature combined with sodium or calcium as a salt. Boron is non-essential to animals and toxic to plants at excessive concentrations.

Cadmium - A soft, bluish-white metallic element known to cause cancer in animals, though not a confirmed human carcinogen. It is also a toxicant for a variety of species.

Capillary action - The upward movement of water through the tiny spaces between soil particles due to adhesion of the water to the soil particles. Wicking action.

Capital cost - The initial cost of the physical facilities in a construction project, as separted from operation and maintenance of the completed project.

Capitalization factor - A component of the capitalized value of land which is approximately equal to the interest rate, and can be used to convert land rents to land prices.

Chemical precipitation - The act or process of separating a substance from a solution in a solid state as a result of some chemical or physical change.

Chloride - The ionic form of the gaseous element chlorine, usually found as a metallic salt with potassium or sodium.

Chromium - A lustrous, hard, steel-gray metallic element which is a known human carcinogen. It occurs in two environmentally significant valence states Cr +3 (trivalent) and Cr +6 (hexavalent), with different toxic properties.

Chronic toxicity - The degree to which a material is harmful or poisonous by virtue of long or continuous exposure.

Class I, II rates - Rates set by the Bureau of Reclamation for water delivered by the Central Valley Project. Class I water is paid for at a contacted rate even if actual delivery is less. Class II water, when available, (after all Class I contact are fulfilled) is priced at a lower rate. In some cases users entitled by contact to Class II water must pay for it even though they are unable to use it.

Cleanup and Abatement Order - An order pursuant to Water Code Section 13304 to a discharger who violates requirements, order or prohibitions of the State Board or Regional Water Quality Control Board directing the responsible party to correct a nuisance.

Clean Water Act - see Federal Water Pollution Control Act Amendments.

Coagulation - Transformation from a solution to a solid mass.

Cold freshwater habitat - see Water, uses of.

Column cementation - The clumping and hardening of materials in a treatment process. This results in less surface area in the treatment column for the waste to contact and thus lower treatment efficiency.

Community - An association of living organisms having mutual relationships among themselves and to their environment and thus functioning, at least to some degree, as an ecological unit.

Concentration - The quantity of a given material in a given volume of water, e.g. total dissolved solids in milligrams per liter (TDS mg/l).

Confined aquifers - Aquifers between impermeable layers. Because of the presence of an upper impermeable layer, the water is not open to atmospheric pressure; therefore water that occurs within the pores of the aquifer is at greater than atmospheric pressure.

Conjunctive use - A resource utilization or management plan in which surface and ground water supplies are used in a manner to maximize use from both sources without degration to either.

Contamination - An impairment of the quality of the waters of the state by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease.

Consumers' surplus - The difference between the price actually paid for a good or commodity and the greater price consumers would have been willing to pay.

Copper - A ductile, malleable reddish-brown metallic element, toxic to aquatic organisms from algae and plants to fish.

Critical - see Critical water year under Water year class

Crop budget - The sum of costs associated with the production of a crop.

Crop root zone - That top layer of the soil occupied by the roots of crops.

Deep percolation - The downward percolation of water past the lower limit of the root zone of plants.

Deep pumping - Use of ground water from a deep aquifer - 200' to 1,000' to provide irrigation. Used, despite high energy costs, when surface water is unavailable or shallow ground water is of poorer quality.

Department of Fish and Game - The state agency responsible for resident fish, wildlife and plant resources.

Depletion - Decrease in stream flow resulting from losses to the banks or ground water.

Designated use of water - see Water, uses of.

Domestic use of water - see Water, uses of.

Drainage Study Area - The area in western Merced and Fresno counties contributing subsurface agricultural drainage to the Grassland Water District.

Dry water year - see Dry year under Water year class.

Duck club - A parcel of land operated so as to provide a hunting opportunity for waterfowl hunters. Land management may include flooding during hunting season, maintenance of wetland habitat during spring, summer, or throughout the year, and cultivation of crops which provide foods preferred by ducks or geese.

Economies of scale - Savings in cost per unit produced, processed or treated stemming from increases in size of plant and output. Economies of scale result from the fact that certain plant costs are fixed so that increasing production (or, for example, volume of waste treated) by 50% may only increase the processing cost by 30%.

Ecosystem - The complex interactions with the environmentof biological communities functioning as an ecological unit in nature.

Effective precipitation - The portion of the annual precipitation which is actually used by crops. It is approximately the sum of rainfall absorbed by the soil during the growing season, plus soil moisture stored in the rooting zone of the crop from rainfall prior to the growing season.

Effluent limitation - Limitations placed on specific constituents contained in waste discharges.

Electrical conductivity (EC) - Measured in micromhos/cm. The ability of a particular parcel of water to conduct electricity. The EC of a water sample is an indirect measure of the total dissolved solids (TDS) and salinity levels of a water sample.

Elemental - The native, uncompounded, un-ionized form of an element.

Eminent domain - The right of a government to appropriate private property for public use, usually with compensation to the owner.

Environment - The complex of climatic, edaphic, and biotic factors that act upon an organism or an ecological community and ultimately determine its form and survival.

Ephemeral stream - A watercourse which flows only briefly during and shortly after a period of precipitation.

Esthetic enjoyment - see Non-contact water recreation under Water, uses of.

Evapotranspiration - The quantity of water transpired (given off) and evaporated from plant tissues and surrounding soil surfaces.

Exchange contractors - Parties to a water contract whose original water rights to the San Joaquin River were exchanged for water rights to be provided by Central Valley Project water delivered from the Delta-Mendota Canal.

Existing use - see Water, uses of.

Federal Water Pollution Control Act Amendments of 1972 - Commonly referred to as the Clean Water Act, it is the principal Federal legislation for the attainment and protection of water quality in the United States.

Fish migration - see Water, uses of.
Fish spawning - see Water, uses of.

Five-year running average - A technique of reducing the irregularity in a series of data points in which the sum of the actual values of a variable from the previous four years is added to that of a given year, divided by five and plotted in place of the value for the year.

Fixed costs of production - Those costs which a producer or farm operator must pay regardless of whether or not a crop is produced. Examples are taxes, depreciation, interest and rent.

Food chain - The pyramidal relationship of producers (plants) and consumers (animals) by which solar energy is converted through photosynthesis to plant tissue which is consumed by animals which are in turn consumed. At each step up the food chain consumers are usually larger but fewer in number.

Food web - The sum of interacting food chains in an ecological community.

Flocculation - The formation of small, loosely held masses or aggregates of fine particles suspended in or precipitated from a solution.

Flood-up - The practice of filling ponds with water to attract waterfowl to duck clubs, usually done shortly prior to start of autumn hunting season.

Freshwater replenishment - see Water, uses of.

Friant Dam - A dam on the San Joaquin River near Fresno; part of the U.S. Bureau of Reclamation Central Valley Project.

Geometric mean (same as logarithmic or log mean) - The antilogarithm of the mean of a group of logarithms of a measured variable. Used to transform logarithmic distributed numbers for statistical purposes.

Grab sample - A single sample taken at an instant in time to represent the conditions at that instant.

Grasslands - A region of the San Joaquin Valley near Los Banos named for its historic value as pastureage and the perennial grass plant community which grew in the flood plain of the San Joaquin River and Tulare Lake overflows.

Grasslands Water District - A local water supply and drainage agency which serves agricultural uses and duck clubs in the area around Los Banos.

Gross profitability - An approximation of the advantageous gain or return of growing a crop, reached by multiplying average yield times price per ton and subtracting an estimate of variable production costs.

Ground water - Water that occurs beneath the land surface and completely fills all pore spaces of the alluvium or rock formation in which it is situated.

Ground water recharge (GWR) - Natural or artificial recharge for future extraction for beneficial uses and to maintain salt balance or halt salt water intrusion into freshwater aquifers.

Habitat - The ecological and/or physical place determined by the needs and presence of a specific plant or animal population, which provides the environmental conditions for that population's survival.

Hardness - A measure of the quantity of the dissolved substances in hard water.

Hard water - Water containing dissolved substances which interfere with the lathering action of soap, such as salts.

Health advisory - A warning by the California Department of Health Services which identifies a threat to one's health which would arise if one partook of a food item which was contaminated with a naturally occurring substance.

Hydropower generation - see Water, uses of.

Indirect economic effects - The incremental increase in economic activity which results when sales income and employment are increased in the sectors of the economy which serve the sector employed in a project.

Induced economic effects - The incremental increase in economic activity which results from direct plus indirect increases in personal income following initiation of a project.

Industrial process supply - see Water, uses of.

Industrial service supply - see Water, uses of.

Industrial use - see Water, uses of.

Input/output economic model - A double-entry bookkeeping system of social accounting. It describes in detail the purchases and sales between the major elements of an economy; the transactions that link an economy together. The linkages are calculated and used to show effects in the economy resulting from changes in physical conditions, such as elimination of agricultural tile drainage discharge options.

Insolvent - Net returns to an owner or a parcel of land are negative. Occurs if losses exceed profits over a period of time. In an agricultural situation with fluctuating markets, a loss in one or more years may be offset by profits in others. When losses consistently exceed profits for an ownership or on a parcel, it is insolvent.

Instantaneous maximum criteria - The maximum level of a constituent in a grab sample which would cause an observable adverse effect if exceeded.

Instantaneous maximum objective - The maximum level of a constituent in a grab sample which should be permitted to avoid an unreasonably adverse effect.

Ion - An electrically charged atom or group of atoms, the electrical charge of which results when a neutral atom or group of atoms loses or gains one or more electrons during chemical reactions, by the action of certain forms of radiant energy, etc.: the loss of electrons results in a positively charged ion (cation), the gain of electrons results in a negatively charged ion (anion).

Ion exchange - A treatment method for water and wastewater in which waste ions in the liquid effluent are inter-changed with ions on a solid medium exposed to the liquid.

Ionized - To have been changed into an ion; dissociated into ions, as a salt dissolved in water, and thus having a negative or positive electric charge.

Iron - A silvery-white metallic element, found abundantly in combined forms and a significant nutritional requirement for vertebrates.

Irrigation efficiency - The degree to which applied irrigation water is used to meet crop needs and soil protection needs without escape through surface runoff or deep percolation.

Kesterson National Wildlife Refuge - A waterfowl management area adjacent to Kesterson Reservoir which was originally planned to utilize San Luis Drain water. When first established, Kesterson NWR used a mixture of fresh CVP water and tailwater to develop wetland habitat. As San Luis drainwater, including an increasing proportion of tile drain waters was phased in, deformities and reproductive abnormalities began to affect the birds nesting there.

Kesterson Reservoir - A water storage facility adapted as an interim evaporation basin for the Central Valley Project San Luis Drain.

Lacustrine - Of or pertaining to a lake.

Leaching - The flushing of salts from the soil by the downward percolation of water.

Lead - A soft, malleable, ductile, bluish white dense metallic element, with a variety of toxic salts.

Lethal endpoint - The endpoint of a test is the death of the test organism. This does not address other adverse effects which may occur short of death.

Limnetic - Of or pertaining to the deeper open waters of a lake.

Load - Quantity of material measured in units of mass (in contrast with concentration) as the quantity parameter, e.g. pounds of salt.

Log mean - see Geometric mean.

Lowest observed adverse effect level - The lowest concentration of a toxicant in a bioassay test in which an adverse effect was seen on the test organism.

Marginal land - Land for which returns to the operator do not repay his efforts to manage it.

Maximum allowable residue level - The level of a substance which is allowable in edible tissue by the Food and Drug Administration.

M.A.R.L. - see above.

Maximum allowable toxicant concentration - The maximum level of a toxicant in water considered safe by the Environmental Protection Agency.

M.A.T.C. - see above.

Median - A measure of central tendency in a series of values; being the value for which half of the observations are larger and half smaller.

Mendota Pool - A small storage reservoir impounded by a diversion dam on the San Joaquin River about 30 miles west of Fresno into which the Delta-Mendota Canal discharges water from the Tracy Pumping Plant.

Mercury - A silvery metal, liquid at ordinary temperatures, which is toxic itself or in most compounds.

Millerton Lake - A reservoir on the San Joaquin River near Fresno, created by Friant Dam, part of the Central Valley Project.

Millimho/cm - A unit of measure for electrical conductivity equal to a decisieman/meter or 1000 micromhos/cm.

Molybdenum - A metallic element chemically similar to chromium that is a trace element in plant and animal metabolism. Excessive concentrations are harmful to plant growth.

Mosquitofish - A small topminnow (genus Gambusia) which feeds on invertebrates.

Municipal and domestic supply - see Water, uses of.

Municipal use - see Water, uses of.

Navigation - see Water, uses of.

Navigation and commerce use - see Water, uses of

Nitrate - An ion composed of one atom of nitrogen bound to three atoms of oxygen. In high concentrations, can bind to hemoglobin to cause methemoglobinemia. Also refers to salts of the nitrate ion with ionic substances, usually metals. An important plant nutrient.

Non-contact water recreation - see Water, uses of.

Non-point source - Any source of discharge to a surface water body that is not from a point source (see below).

NPDES permit - (National Pollutant Discharge Elimination System permit) - A waste discharge permit developed under §402 of the federal Clean Water Act and its regulations.

No observed adverse effect level - The highest concentration of a toxicant in a bioassay test for which no adverse effect was found on the test organism.

Normal water year - See Normal water year under Water year class.

Normalized - A transformation of data which allows it to be treated in accordance with the assumptions required by a statistical method. For example, logarithmic data may be transformed by taking logarithmic of the raw numbers and then treating the logariths as the variable of interest instead of the raw numbers.

Objective - see Water quality objective.

Operational spill - The pumping and discharging of irrigation water to surface waters without having been applied to the field.

Percolation - The downward movement of water through the soil or alluvium to the ground water table.

Percolation rate - The rate at which water passes through the soil under the influence of capillary action and gravity.

Pesticide - Any agent used to kill insects, weeds, etc.

pH - The negative logarithm to the base ten of the hydrogen ion concentration in a solution. A measure of the relative acidity and alkalinity of a material. A pH greater than 7 is alkaline (or basic) and a pH less than 7 is acidic.

Phosphate - An ion composed of one atom of phosphorus bound to 4 atoms of oxygen. An important plant nutrient.

Phytotoxic - Causing injury to plants by virtue of toxic activity.

Point source - Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollution - An alteration of the quality of the waters of the state by waste to a degree which unreasonably affects such waters for beneficial uses, or facilities which serve such beneficial uses. "Pollution" may include "contamination".

Population - A group of individuals of the same species inhabiting a specific zone or system.

Porter-Cologne Water Quality Control Act - The primary State Legislation dealing with water quality protection in California. The Porter-Cologne Act is codified as Chapter 7 of the Water Code, beginning with Section 13000. The Act establishes a comprehensive statutory program for water quality control and is administered by the nine Regional Water Quality Control Boards.

Potassium - A soft, silvery white, light, highly reactive metallic element found in a variety of salts and used extensively in plant fertilizers.

Power generation use - See Water, uses of.

Preservation and enhancement of aquatic resources - see Water, uses of.

Preservation of rare and endangered species - see Water, uses of.

ppb - parts per billion, a measure of concentration essentially equal to micrograms/liter.

ppm - parts per million, a measure of concentration essentially equal to milligrams/liter.

Public trust - An obligation on the state as sovereign to hold public resources, including navigable waterways and the land under them for the benefit of the people. Its purpose is to protect certain values and uses of these resources for the people.

Pre-1914 appropriative rights - Water rights obtained by appropriation prior to the date at which a state law was passed which established a standard procedure. See also Water rights.

Radical - A group of two or more atoms that act as a single atom and goes through a reaction unchanged, or is replaced by a single atom or another radical: it is normally incapable of separate existence.

Recreation use - See Water, uses of.

Reduced sediments - Sediments in which dissolved oxygen is not typically present, i.e. anaerobic strata.

Redox equilibria - The state of a chemical reaction in which the oxidation and reduction reactions occur at equal rates so that the concentration of the reactants does not change with time.

Reducing conditions - See reduction.

Reduction - The act or process of changing an element from a higher to a lower positive valence, involving the gain of electrons.

Regulating reservoir - A facility for retaining water downstream of a fluctuating release reservoir which is able to store the fluctuating flow and release it at a steady rate.

Relaxation (of a condition or standard) - A level less restrictive than the ordinary condition, which will be allowed under special circumstances.

Residue - Toxic material found when a sample has been analyzed; usually refers to a toxicant in a food or tissue sample, expressed as a proportion of the original weight.

Reverse osmosis - A process for removing dissolved material from water by forcing it, under pressure, through a semi-permeable membrane.

Riuparian - Pertaining to the banks and other terrestrial environs adjacent toj freshwater bodies, watercourses, and surface-emergent aquifers (e.g. springs, seeps, oases), whose waters provide soil moisture significantly in excess of that otherwise available through local precipitation. Vegetation typical of this environment is dependent on the availability of excess water.

Riparian water right - The right to use water on land bordering a stream. See also Water rights.

Riparian wetland - A zone which may be periodically inundated by water, characterized by moist soil and associated vegetation; typically bounded on one border by a drier upland and on the other by a freshwater body.

Running average - see five-year runing average.

Saline water habitat - see Water, uses of.

Salinity - The salt content of a water sample. Salinity is measured by determining the amount of total dissolved solids in, or the electrical conductivity of, a sample of water.

San Luis Drain - A wastewater drainage facility begun by the USBR to provide drain service to areas irrigated by the Central Valley Project.

Scale-up - A process in which experimental techniques are applied in gradually larger operations until a full size plant is built. During scale-up, the efficiency of experimental methods and costs of larger plants can be assessed.

Schedule one water - Water supplied by the Central Valley Project to purchasers.

Schedule two water - Water supplied to users by the CVP in exchange for water held by those users under prior rights.

Seepage - Water escaping from a channel or impoundment by percolation.

Sedimentation - The process by which suspended or precipitated particles settle to the bottom of the fluid.

Selenite - Ionized selenium at a valence state of +6 (see Valence below).

Selenite - Ionized selenium at a valence state of +4 (see Valence below).

Selenium - A non-metallic element chemically resembling sulfur. Essential for animals at trace concentrations, selenium is toxic to animals in deficient or excessive dietary exposure.

Sludge - Solid matter or sediment such as that precipitated by the treatment of sewage.

Subsurface drains - Perforated pipes installed about eight feet below the soil surface to intercept and convey soil moisture away from the crop root zone by gravity.

Subsidy - That part of the costs of a program or enterprise which is offset by a party or parties who may receive no direct benefit. Examples of subsidies are crop price supports and reduced rates for senior citizens.

Sulfate - A chemical compound containing the bivalent group SO_4.

Sulfide - A compound of bivalent sulfur with an electropositive element or group - especially a binary compound of sulfur with a metal.

Sump - A basin, pool or ponding site into which unwanted or contaminated material can be placed until removed for disposal.

Synergistic - Properly synergetic - of or pertaining to the action of two or more substances to achieve an effect of which neither alone is capable.

Tailwater - Irrigation water which flows over an irrigated field without infiltrating the soil. Synonymous with irrigation return flow.

Tile drains - System of clay pipes installed beneath irrigated lands and depending on gravity flow to artificially remove water saturating the soil of the crop root zone. Used synonomously with subsurface drain.

Tissue burden - The quality or concentration of an element or compound measured in animal or plant tissue usually resulting from the organism's exposure to the constituent in the environment.

Total dissolved solids (TDS) - A measure of the salinity equal to the amount of material remaining after evaporating a water sample at 103 to 105 degrees Celsius (formerly centigrade) for one hour.

Trace element - Those elements generally present in natural water samples at concentrations of less than one ppm.

Trophic level - One of the strata of a hierarchical food web. Trophic refers to how an organism feeds and the flux of energy. There are generally more organisms at the lower levels and it takes more energy to support the consumers in each successive trophic level.

Turbid - Having sediment stirred up or suspended; muddy.

Unconfined aquifers - Aquifers where water i pore spaces at the top of the aquifer is at atmospheric pressure. The top of the aquifer is defined by the water table.

Unimpaired runoff (also unimpaired rimflow) - The sum of the gaged flows, adjusted for upstream storage, at four stations on the major tributaries: (1) San Joaquin River at Friant Dam, (2) Merced river at Exchequer Dam, (3) Tuolumne River at Don Pedro Dam, (4) Stanislaus River at New Melones Dam.

Upland - The ground above a floodplain. That zone sufficiently above and/or away from the freshwater bodies, watercourses, and surface-emergent aquifers as to be entirely or largely dependent upon precipitation for its water supplies.

Use attainability analysis - A structured scientific assessment of the factors affecting the attainment of a particular use, which may include physical, chemical, biological and economic factors (Section 131.3 (g) of federal Clean Water Act).

U. S. Fish and Wildlife Servide - The federal agency with responsibility for fish or wildlife - particularly migratory species, commercially harvested species, and federally listed threatened and endangered species.

Vadose zone - Unsaturated or aerated soil zone above the water table.

Valence - The capacityof an element or radical to combine with another to form molecules, as measured by the number of atoms with which one radical or one atom of the element will combine or replace (e.g., oxygen has a valence of two, i.e., one atom of oxygen combines with two hydrogen atoms to form the water molecule).

Vernalis - A location along the San Joaquin River downstream from the confluence with the Stanislaus River.

Volta Wildlife Management Area - A public wildlife area managed by California Department of Fish and Game, and supplied with Delta-Mendota Canal water via the Volta wasteway.

Waiver of waste discharge requirements - Section 13260 of the Water Code provides that a waste discharger must report to the Regional Water Quality Control Board on the nature of any proposed discharge; Section 13263 provides the Regional Board shall prescribe requirements as to its nature. Section 13269 allows the Regional Board to waive its requirements if doing so could not be against the public interest.

Warm freshwater habitat - see Water, uses of.

Waste application rate - The rate at which waste is applied to the treatment mechanism.

Waste discharge permit - The Federal Water Pollution Control Act uses the term "permit" in the same sense as the Porter Cologne Act uses "requirements" (Water Code Section 13374); see Waiver of waste discharge requirements.

Waste load allocation - The quantity of waste that an individual may discharge into a surface water body without affecting its beneficial uses, considering another allowable waste discharge to wate body or portion thereof.

Wasteway - A channel used to carry off water which spills as a result of unbalanced supply toand withdrawal from a canal.

Water application rate - The rate at which water is applied to a crop.

Water contact recreation - see Water, uses of.

Water quality criteria - Scientifically derived constituent concentrations or levels which are thought to protect specific beneficial uses in a water body. Water quality criteria do not include the consideration of all the other factors necessary to develop water quality objectives or standards.

Waterfowl - Waterfowl are migratory birds associated with wetlands, open water, or sometimes upland areas. They include ducks, geese, and shorebirds.

Water quality limited segment - Any segment of a river where applicable water quality objectives are not met after the application of federal minimum treatment levels to municipal and industrial effluent discharges to the water body.

Water quality model - A system of postulates, data, and inferences presented as a mathematical description of the quantitative changes in various water quality parameters.

Water quality objectives - The measureable limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area and time frame. Factors to be considered in establishing water quality objectives shall include, but not be limited to all of the following:

(a) past, present, and probable future beneficial uses of water,
(b) environmental characteristics of the hydrographic unit under consideration, icluding the quality of water available thereto,
(c) water quality condietions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area,
(d) economic considerations,
(e) The need for developing housing within the region.

Water quality standard - A term used in connection with the federal Clean Water Act which is roughly equivalent to water quality objective, except that a water quality standard also includes a plan of implementation to achieve the standard.

Water rights - Water rights, which are a form of property rights, give their holder theright to use public waters. During the history of the state, a variety of procedures have been in effect by which a person could acquire a water right. A summary of the methods follows:

Appropriative rights initiated prior to December 19, 1914 - prior to the 1914 statutes which established the present system for appropriating water (taking water and putting it to a use removed from property adjoining the water source) two methods of appropriation existed. Prior to 1872, appropriative rights could be acquired simply by taking water and utting it to beneficial use. In 1872, Sections 1410 through 1422 of the California Civil Code enacted a permissive procedure by which priority of rights could be established as of the date of posting of notice of intention to appropriate water, subject to a show of diligence in carrying out construction of diversion works and actual use of water. Appropriators who did not follow the permissive procedure had priority from the date of actually putting the water to use. Because in an appropriative water rights system, first in priority means first served by available water, considerable advantage attaches to an earlier date of appropriation.

Appropriative rights initiated after December 19, 1914 - an appropriation of water must now comply with provisions of Part Two, Division Two of the Water Code. The right to use water appropriated under earlier procedures as well as under the current procedure maybe lost by abandonment or non-use.

Riparian rights - an owner of land adjoining a water source has, under common law, the right to use a share of the water available from the source. Only those parcels of land adjoining the source may be served by it under a riparian right, unless a nonadjoining parcel was at one time part of a riparian parcel and the riparian right was transfereed when the parcel was sold. No priority is established for riparian rights, and all riparian users must share the available supply. Riparian owners have priority of use over all appropriators.

Prescriptive rights are obtained when water is taken and put to use for five years even though other rightholders' interests are damaged, if the injured parties take no action in their own defense. Water Code Section 1225 and Water Resources Control Board policies have made obtaining secure prescriptive rights essentially impossible since 1914.

Water table - The area in unconfined subsurface material where hydrostatic pressure equals atmospheric pressure. Generally the boundary between the saturated and unsaturated subsurface soil zones.

Water, uses of -

Agricultural supply (AGR) - Includes crops, orchard and pasture irrigation, stock watering, support of vegetation for range grazing and all uses in support of farming and ranching operations.

Cold freshwater habitat (COLD) - Provides a cold water habitat to sustain aquatic resources associated with a cold water environment.

Designated use - A use to which water is being put at the present time, as distinguished from a potential use, to which it may be put in the future.

Fish migration (MIGR) - Provides a migration route and temporary aquatic environment for anadromous or other fish species.

Fish spawning (SPWN) - Provides a high quality aquatic habitat especially suitable for fish spawning.

Freshwater replenishment (FRSH) - Provides a source of freshwater for replenishment of inland lakes and streams of varying salinities.

Hydroelectric power generation (POW) - Used for hydroelectric generation.

Industrial process supply (PROC) - Includes process water supply and all uses related to the manufacturing of products.

Industrial service supply (IND) - Includes uses that do not depend primarily on water quality such as mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.

Municipal and domestic supply (MUN) - Includes usual uses in community or military water systems and domestic uses from individual water systems.

Navigation (NAV) - Includes commercial and naval shipping.

Non-contact water recreation (REC-2) - Recreational uses that involve the presence of water but do not require contact with water, such as picnicking, sunbathing, hiking, beachcombing, camping, pleasure boating, tidepool and marine life study, hunting and aesthetic enjoyment in conjunction withthe above activities as well as sightseeing.

Preservation of rare and endangered species (RARE) - Provides an aquatic habitat necessary, at least i part, for the survival of certain species established as being rare and endangered species.

Saline water habitat (SAL) - Provides an inland saline water habitat for aquatic life resources. Soda Lake in the Central Coastal Basin is a saline habitat typical of desert lakes in inland sinks.

Warm freshwater habitat (WARM) - Provides a warm water habitat to sustain aquatic resources associated with a warm water environment.

Water contact recreation (REC-1) - Includes all recreational uses involving actual body contact with water, such as swinning, wading, water skiing, skin diving, surfing, sport fishing, uses in therapeutic spas, and other uses where ingestion of water is reasonably possible.

Water year - A designated period that includes the annual flood season. In this report the water year is October 1 through September 30 and assumes the year designation in which most of the months fall.

Water year class - Because of the great difference in precipitation received in California from year to year, the river flows and irrigation requirements both vary. To characterize the different precipitation patterns the terms wet, normal, dry and critical (or critically dry) are defined by 1975 Basin 5C Water Quality Control Plan.

Critical - A year is classed as critical when estimated unimpaired runoff to the San Joaquin River and key tributaries in DWR Bulletin 120 is less than 3.37 million acre-feet; except if the previous year was critical, in which case, critical is less than 4.13 million acre-feet.

Dry - A dry water year is defined when estimated unimpaired runoff to the San Joaquin River and key tributaries in DWR BVulletin 120 is between 3.37 and 4.13 million acre-feet, except in years following a critical year, when dry is between 4.13 and 5.32 million acre-feet.

Normal - A water year is classified as normal when the estimated unimpaired runoff at the above points is between 4.13 and 7.38 million acre-feet, except in years following a critical year, when normal is between 5.32 and 7.38 million acre-feet.

Wet - A water year is classed as wet when the estimated unimpaired runoff exceeds 7.38 million acre-feet as published in California Department of Water Resources Bulletin 120 for the sum of the following locations: San Joaquin River at Friant Dam, Merced River at Exchequer Dam, Tuolumne River at Don Pedro Dam, and Stanislaus River at New Melones Dam.

Weighted average - An average calculated using multipliers for the raw numbers to reflect the relative importance of each quantity's contribution to the average.

Wetland - A zone periodically or continuously submerged or having high soil moisture, which has aquatic and/or riparian vegetation components and is maintained by water supplies significantly in excess of those otherwise available through local precipitation.

Wildlife habitat (WILD) - Provides a water supply and vegetative habitat for the maintenance of wildlife.

Zinc - A brilliant bluish white metal which is brittle at room temperature but malleable with heating. Compounds of zinc are used as fungicides and wood preservatives.

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