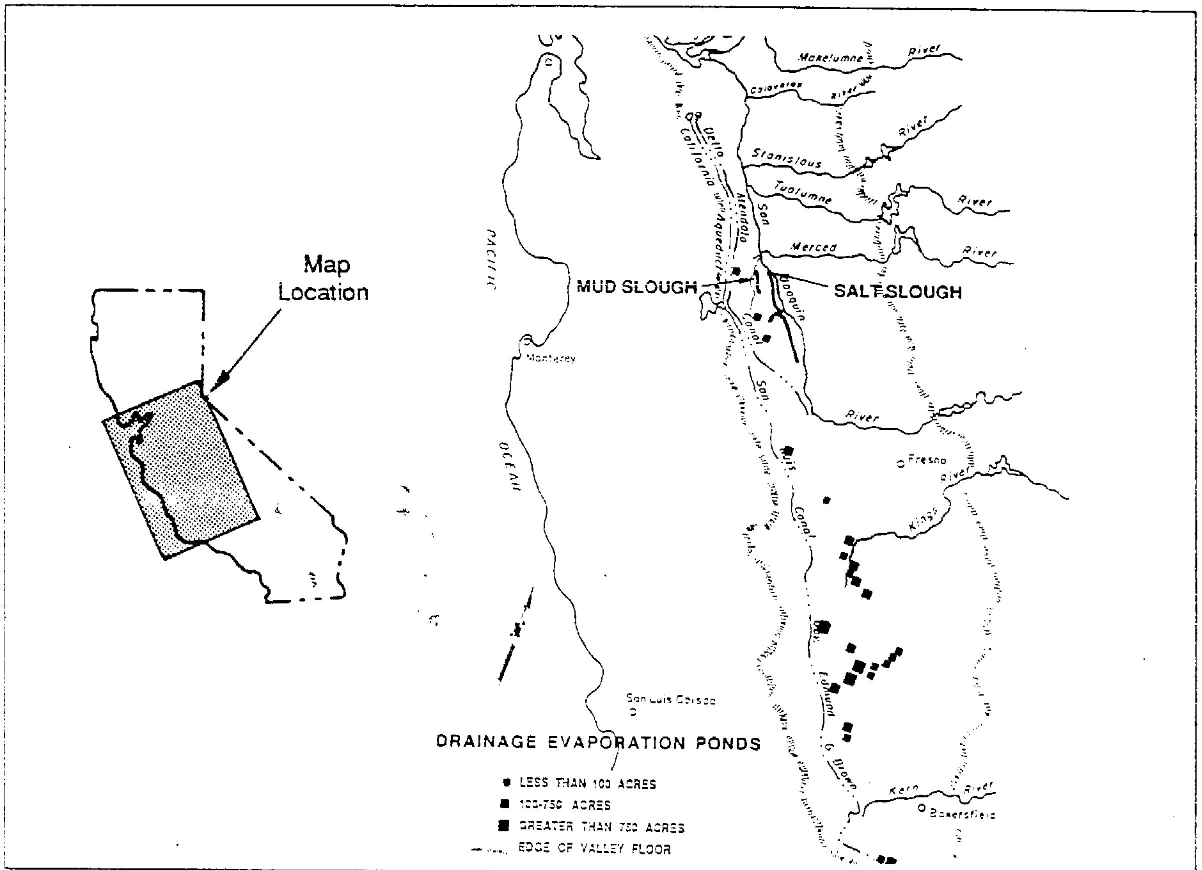

SELENIUM AND AGRICULTURAL DRAINAGE STUDIES IN CALIFORNIA

Progress Report 90-5-WQ

August 1990

WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

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Prepared by:
M. "Manuchehr" Alemi, Ph.D.
Division of Water Quality
State Water Resources Control Board

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We are greatful to the State, federal, and local agency cooperators (see Appendix D) for updating the tables of Appendix A and providing background information to this report. Special thanks is offered to Dennis Westcot of the California Regional Water Quality Control Board, Central Valley Region for preparing Section 1.2 of Chapter 1 and Kenneth Tanji of University of California, Davis for his contribution to Section 3.1 of Chapter 3.

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PROGRESS REPORT
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SELENIUM AND AGRICULTURAL DRAINAGE STUDIES IN CALIFORNIA

EXECUTIVE SUMMARY

On July 1, 1985, the California Legislature approved a State Water Resources Control Board (State Board) study plan entitled, "Selenium and Other Trace Elements in California" (Study Plan). One of the Study Plan's objectives is to conduct investigations that would complement the studies done by other State, federal, university, and local entities. One element of the Study Plan provides for State Board coordination of the other entities involved in activities to help solve the selenium and drainage-related problems in California. This annual progress report is part of the coordination element.

Studies conducted by State and federal agencies, universities, and others on the west side of the San Joaquin Valley (Valley) during the last few years indicate that: (1) the salt loading is increasing at a rate of about 3.3 million tons each year; (2) the water table is rising in about 800,000 acres; and (3) selenium has been found at concentrations greater than 50 ppb in the shallow ground water underlying more than 200,000 acres of irrigated lands. These studies also indicate that the long-term acceptable solution to the salinity, waterlogging, and toxic substances problems can be achieved if the mass (salts and water) balance can be attained and maintained in the Valley and the problems of removal and safe disposal of toxic trace elements are resolved.

State Board Order No. 85-1 directed the California Regional Water Quality Control Board, Central Valley Region (Central Valley Regional Board) to adopt water quality objectives for the San Joaquin River Basin and to implement a program to regulate agricultural drainage water discharges. A Basin Plan Amendment adopted by the Central Valley Regional Board, states that, "The valleywide drain to carry the salts generated by agricultural irrigation out of the valley remains the best technical solution to the water quality problems of the San Joaquin River and Tulare Lake Basin".

In the interim, the Central Valley Regional Board in its Program of Implementation uses the Drainage Operation Plan (DOP) as the control mechanism to reduce the drainage pollutant discharges to meet the water quality objectives. It is expected that implementation of Best Management Practices (BMPs) will help to reduce adverse water quality impacts. The Central Valley Regional Board may use Waste Discharge Requirements to control the toxic trace elements in the drainage waters if the implementation of DOPs and BMPs fails to achieve compliance with the water quality objectives within the specified time frame.

Some specific findings and topics discussed in this report are as follows:

1. The concentration of salts and trace elements (including selenium) in the drainage discharges from the east side of the San Joaquin River Basin and the Sacramento River Basin are generally low.

2. Reconnaissance surveys conducted on several waterfowl and wildlife refuges in the Central Valley indicated that the water supplies to these areas were generally low in trace elements and pesticides. However, the potential for short-term wildlife exposure to pesticides exists in the Sacramento National Wildlife Refuge.

3. The major source of selenium to the San Joaquin River is by way of Salt and Mud Sloughs. During 1985-87, the concentration of selenium in the San Joaquin River upstream of the Merced River occasionally exceeded 10 ppb. The concentration of selenium in Mud and Salt Sloughs frequently exceeded 10 ppb. It is expected that implementation of best management practices in the west side of the Valley would result in significant water quality improvements in the above waterbodies.

4. The concentration of selenium in the upper part (10-20 feet) of the semiconfined aquifer in the west side of the San Joaquin Valley ranges from 10-50 ppb, and in the 20-150 feet layer ranges from 50-1000 ppb, and below 150 feet is less than 10 ppb.

5. Based on samples analyzed as part of the Toxic Substances Monitoring Program, the State Mussel Watch Program, and the Selenium Verification Study, selenium was observed in various media collected from selected sites in the State. Elevated levels of selenium were found in liver tissues from birds collected at certain evaporation ponds in the Tulare Lake Basin, from Suisun, and San Pablo Bays and in mussels collected from the San Pablo Bay. No adverse impacts have been observed in birds from San Francisco Bay. A U.S. Fish and Wildlife Service study including various bird species at a number of evaporation ponds in the San Joaquin Valley indicated an elevated incident of embryonic deformity or low hatchability when selenium in eggs exceeded 20 ppm (dry weight). Selenium levels in the diet exceeding eight ppm (dry weight) affect reproduction of mallard ducks. Selenium seems to be rapidly taken up by birds and rapidly lost once exposure ends. The loss is particularly rapid from the liver.

   Other trace elements such as arsenic, boron, vanadium, molybdenum, and uranium have been observed in water and sediments collected from evaporation ponds. Segregation of drainage water, optimum pond design and management (steep slopes, removing levee vegetation, deepening ponds, and bird hazing), and providing alternative wetlands seem to be the interim solution for the problems associated with the disposal of agricultural drainage water in evaporation ponds in the San Joaquin Valley.

6. An analysis of catfish collected from Salt and Mud Sloughs indicated bioaccumulation of selenium but no adverse effect was observed and no threat to human consumers exists (based on DHS health advisory levels). San Joaquin River biotoxicity studies show that an invertebrate toxicosis problem due to pesticides exists.

7. University of California research indicates that there is a potential for cyclic use (intermittent use) of agricultural drainage water for irrigation of vegetables. Experiments with tomatoes indicated a yield increase when drainage water was used in a cyclic scheme. The increase in tomato yield is attributed to the high nitrate concentrations in the drainage water. Long-term continuous irrigation of cotton with saline water in Tulare Lake Basin resulted in a decrease in cotton lint and seed production. Long-term use of high sodium saline water requires intensive management of soil.

8. Department of Water Resources drainage water reduction studies on the west side of the San Joaquin Valley show promising results. Considering the four irrigation methods studied, subsurface drip irrigation had the highest

water use efficiency (grams of water used per kilogram of cotton lint produced) and resulted in the highest net income to the grower. A tiered-pricing schedule for irrigation water provided an incentive for growers to save water. The volume of subsurface drainage water decreased by approximately seven percent when tiered-pricing was implemented by the Broadview Water District.

9. No economically feasible technique is currently available for treatment and disposal of agricultural drainage waters containing selenium. However, several promising techniques are currently being studied. Microbial volatilization, adsorption onto iron filings, bacterial reduction, agroforestry, and evaporation ponds are among the techniques currently under study. Studies are being conducted to assess the efficiency and costs of large scale use and potential long-term environmental impacts of these treatment and disposal techniques.

10. The San Joaquin Valley Drainage Program is preparing a final report on alternative management plans addressing agricultural drainage problems in the San Joaquin Valley. The draft of that report was distributed for review and comment in June 1990. Focusing on in-valley options, the Drainage Program's Preliminary Planning Alternatives Report presented the following options: (1) source control to reduce drainage, (2) management of shallow ground water, (3) drainage water treatment, (4) drainage water reuse, (5) drainage water disposal in the Valley, (6) fish and wildlife measures, and (7) institutional changes. The Drainage Program is scheduled to complete its mission in September 1990.

11. The dischargers, including irrigation and drainage districts, and State and federal agencies in the western part of the San Joaquin River Basin have developed Drainage Operation Plans which have been reviewed for adequacy by the Central Valley Regional Board. Various methods are proposed by the dischargers to reduce the volume of drainage water and improve its quality, including water conservation, tiered-pricing, improved irrigation practices, treatment methods, and reuse of drainage water.

12. On September 21, 1989 the State Board approved the U.S. Bureau of Reclamation's final cleanup plan for the Kesterson Reservoir. Site management is being implemented. Microbial and plant volatilization techniques for removal of selenium from the contaminated sediments are under study at the site.

<u>Organization of the Report:</u>

The status and findings of the State Board and the Central Valley Regional Board studies are described in Chapter 1.

Chapter 2 of this report describes the status and findings of the San Joaquin Valley Drainage Program and the Kesterson Program.

Chapter 3 of this report discusses the research and coordination activities by the University of California and California State University, Fresno.

In addition to the federal and State agencies mentioned above, other federal and State agencies and local irrigation and drainage districts have continued to expend resources on the subject of trace elements and agricultural drainage problems. Their activities are discussed in Chapter 4.

This report is not meant to cover technical details of all the individual projects by all agencies. Only examples of those activities and a brief description of their findings are given and the readers are provided with tables (Appendix A) identifying the title, purpose, and status of the individual projects by various agencies. Funding levels are presented in Appendix B. Appendix C has the litigation and legislation in 1989-90 related to selenium and agricultural drainage subjects. Appendix D contains the names, addresses, and phone numbers of individuals who provided background information for this report. The references cited in this report are also provided in Appendix D. Thus, details beyond the scope of this report may be obtained from these sources.

TECHNICAL SUMMARY

There are approximately 10.5 million acres (MA) of irrigated land in California. The total volume of water used to irrigate the lands in 1983 was estimated to be 35.6 million acre feet (MAF)(1). The Central Valley of California includes two smaller valleys, the Sacramento Valley (2.1 MA irrigated land) in the north and the San Joaquin Valley (5.6 MA of irrigated lands) in the south (Figure 1).

The San Joaquin Valley extends from the Sacramento/San Joaquin Delta in the north to the Tehachapi Mountains in the south. The San Joaquin Valley is divided into two basins: the San Joaquin River Basin which is drained by San Joaquin River, and the Tulare Lake Basin which is a closed basin with no natural surface drainage water outlet. In very wet years it drains to the San Joaquin River through Fresno Slough.

The drainage water from the western part of the San Joaquin Valley is disposed of by discharge to the San Joaquin River or evaporation ponds. Drainage water from the Grasslands area has been discharged to the San Joaquin River through Salt and Mud Sloughs a few miles south of the confluence of the Merced River to the San Joaquin River. The drainage water from Tulare Basin (portions of Westland Water District lands) has been conveyed through San Luis Drain to Kesterson National Wildlife Refuge ponds (during 1970-1985), has been discharged to privately owned evaporation ponds, or has more recently been recycled.

On the average there are 2,235,000 acres of irrigable land in the western part of the San Joaquin Valley (2). The total irrigation water applied in 1988 was 6.3 MAF. Soils of the most part of the west side of the Valley are formed through natural erosion of marine sediments in the Coast Ranges. The soils have low permeability and high salinity. Ten percent of the Valley soils have selenium concentrations greater than the national median of 0.3 milligrams/kilograms (mg/Kg). The Valley median is 0.13 mg/Kg and concentrations as high as 4.5 mg/Kg occur in alluvial-fan material derived from erosion and weathering of the coast range rocks. Trace elements and salts are leached from soils into the ground water as a result of intensive irrigation of the west side soils. The net accumulation of salt in the west side is 3.3 million tons per year. The water table has risen and the concentration of selenium and other trace elements and salts has increased in the shallow ground water. The salt buildup and high water tables adversely affect the productivity of California's billion dollar agricultural industry.

The San Joaquin Valley Drainage Program (2) estimates that there are 847,000 acres of land with shallow ground water within five feet from the ground surface. Estimated problem water (subsurface agricultural drainage water with elevated levels of selenium) for the year 2000 is 307,500 acre feet (AF) from approximately 436,000 acres of land on the west side of the San Joaquin Valley.

[1] Superscript number in parenthesis denotes reference cited, see Appendix D.

There are approximately 220,000 acres of land in the San Joaquin Valley where the concentration of selenium in shallow ground water exceeds 50 microgram/liter (or parts per billion (ppb)). Approximately 50,000 acres of this area have selenium concentrations greater than 200 ppb. Potentially, adverse environmental impacts can occur if shallow ground water containing selenium is drained and discharged to the rivers or ponds.

Following the discovery by U.S. Fish and Wildlife Services (USFWS) researchers [3] of wildlife contamination at Kesterson Reservior in 1983, State and federal agencies initiated studies on selenium and agricultural drainage in California. The State Board's Study Plan (approved by the Legislature in 1985) objective was to complement the studies done by other State, federal, and local entities. One element of the Study Plan is coordination among all the entities involved in the activities to help solve the selenium and drainage related problems. This annual progress report is part of the coordination element to apprise all parties involved of the state wide efforts directed towards solution of selenium and agricultural drainage-related problems.

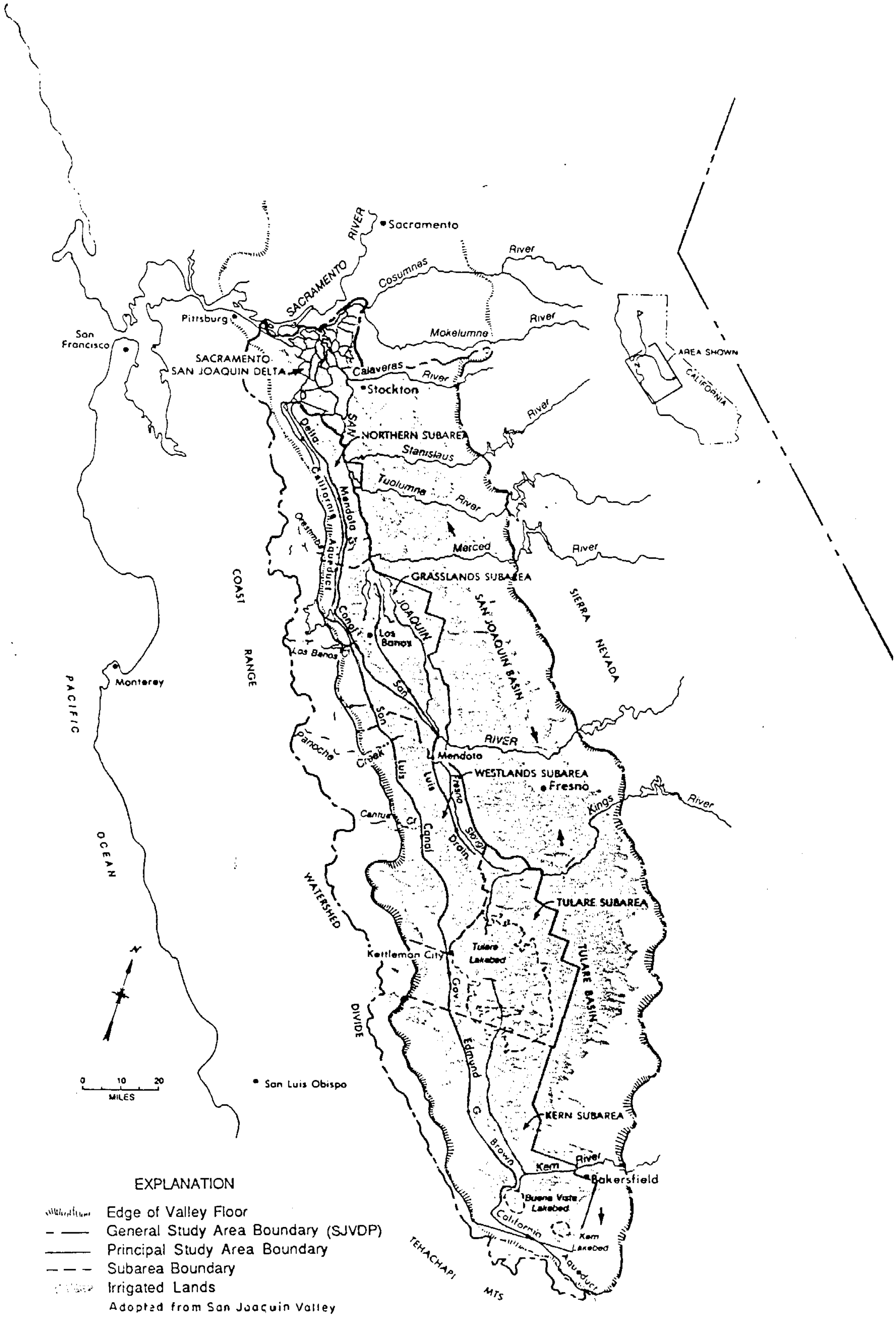

Figure I. Irrigated lands in San Joaquin River and Tulare Lake basins

Chapter 1

California State Water Resources Control Board Study Plan

1.1 - California State Water Resources Control Board (State Board)

The Budget Act of FY 1985-86 contained funds to begin the process of regulating subsurface agricultural drainage water. General Fund appropriation for FY 1985-86 was $2,270,000 (including 9.3 Personnel Years and funds for selenium studies). The concept of the Subsurface Agricultural Drainage Program was contained in the Budget Change Proposal (BCP) for FY 1986-87 and was approved by the State Board and incorporated into the Governor's Budget. The Subsurface Agricultural Drainage Program objective is to develop and implement a regulatory program for all areas of California.

The multi-element Study Plan called for problem identification, problem verification, and regulatory efforts to protect the beneficial uses of water from potentially toxic trace elements found in subsurface agricultural drainage waters in California. The elements of the Study Plan are:

1. General Overview Studies
2. Verification Studies
3. Evaluation of Corrective Actions
4. Development of Objectives
5. Guidelines for Treatment and Disposal
6. Laboratory Quality Control/Quality Assurance
7. Regulatory Actions
8. Coordination/Management

So far, the following have been accomplished: (1) monitoring efforts have identified sources of trace elements; (2) fish and wildlife verification impacts have been noted; (3) appropriate water quality objectives and criteria for certain constituents have been developed; (4) computer models as an evaluation tool have been developed; (5) laboratory quality control/quality assurance has been established, and (6) extensive coordination activities accomplished. The State Board adopted water quality objectives for the San Joaquin River Basin (the Basin Plan Amendment) in September 1989.

Having accomplished the objectives of certain elements of the Study Plan, the Subsurface Agricultural Drainage Program as planned in the 1986-1987 BCP is currently directed to: (1) investigate specific agricultural drainage problems that merit further study including trace elements and constituents such as nitrate and pesticides, (2) identify best management practices to reduce the drainage volume and improve its quality, and (3) continue studies and monitoring for a successful regulation of subsurface agricultural drainage.

Activities of the State Board and the Central Valley Regional Board are presented in Sections 1.1 and 1.2 and a summary of the State Board projects are provided in Table A1 of Appendix A.

1.1.1 - Selenium and other Trace Elements in California
1.1.1.1 - General Overview Studies (Element 1)
1.1.1.1.1. - Toxic Substances Monitoring Program (TSMP)

The Toxic Substances Monitoring Program involves collecting fish samples from throughout the State where samples are analyzed for toxic substances. Since 1985, samples have also been analyzed for selenium.

Selenium levels exceeding DHS advisory level of 2.0 parts per million (ppm) (wet weight) were observed in fish samples collected from selected sites in 1985, 1986, and 1987. In 1988, a total of 63 fish samples were analyzed for selenium. Selenium was detected in all but four samples. The selenium level exceeded 2.0 ppm (median international standard) at only one station (Rose Drain, Region 7). Concentrations between 1-2 ppm were found at Alamo River (Region 7) and San Diego Creek (Region 8). (See inside of back cover for a map of the Regional Boards). More information on TSMP can be found in the Annual TSMP Report [4].

1.1.1.1.2 - State Mussel Watch Program (SMWP)

SMWP is a bioaccumulation monitoring program that started in 1977 to detect certain chemical pollutants suspected to be present in ambient waters. The goal of SMWP was to provide a means to assess coastal marine water quality. SMWP also serves to help Regional Boards locate and characterize specific areas of contamination, and to provide monitoring information for permitted dischargers. Transplanted and resident mussels and transplanted clams are sampled at approximately 130 sites each year in bays, harbors, estuaries, and on the open coast. Seven permanent resident mussel or clam sites are utilized for reference and for transplantation. Substances analyzed for include 13 trace elements and approximately 70 synthetic organic compounds. The results are made available through annual reports.

The SMWP data may prompt the Regional Boards, DHS, or the Department of Food and Agriculture (DFA) to conduct more intensive sampling of a waterbody. It has also assisted DHS in assessing the potential threat to humans from sport or commercial shellfishing.

During 1988-89, samples from 15 sites were analyzed for selenium in mussel or clam tissues. The highest tissue concentration from 1988-89, and in fact the highest ever reported by SMWP, was 3.1 ppm (wet weight) in mussels from a site at the Union Oil Company outfall in eastern San Pablo Bay (1987-88 finding from same site was 1.9 ppm (wet weight)). This is well above the 0.5 ppm (wet weight) found in source mussels from Bodega Bay. Selenium is known to be a component of some petroleum-based products. The next highest value found in 1988-89 was 0.98 ppm selenium (wet weight) at Treasure Island in San Francisco Bay.

The median of international standards used by the State Mussel Watch Program to help judge the severity of a tissue burden in shellfish is 0.3 ppm (wet weight). During 1988-89, all 15 SMWP samples equaled or exceeded this value, including tissues from animals collected at Bodega Head (mussels) and Lake San Antonio (freshwater clams). Over twelve years (1977-89) and approximately 80 samples taken for selenium, about 70 samples equaled or exceeded 0.3 ppm (wet weight) selenium in bivalve tissues. Bodega Head values ranged from 0.32 to 0.52 ppm selenium (wet weight) [5,6].

1.1.1.1.3 - Selenium in California

The Dry Lands Research Institute of the University of California, Riverside has prepared a two-volume report for the State Board to compile the existing knowledge on selenium and its effects on the environment.

The first volume [7] discusses basic physical, chemical, and biological properties of selenium, its sources, uses and technological and management options to solve selenium problems in California.

Three basic options for dealing with selenium problems in California, treatment, disposal, and source control; the need for research to identify the amounts and forms of selenium in soils, water, vegetation, and aquatic systems; and the relationship to human activity and the human health impacts are discussed in Volume 1 of Selenium in California.

Selenium in California Volume 2 - Critical Issues, discusses the role of selenium in agriculture, human health, wetland and aquatic ecosystems, and selenium deficiency and toxicity in livestock and wildlife. The report also discusses treatment and disposal of selenium-tainted drainage water and proposes a systems approach to deal with environmental problems of selenium. This volume is completed and release is expected in late 1990.

1.1.1.2 - Verification Studies (Element 2)

1.1.1.2.1 - Selenium Verification Study (SVS)

The SVS was begun in December 1985 as one element of the State Board Study Plan. The purpose of the SVS is to provide an intensive assessment of selenium and trace elements in biota from previously identified areas of potential concern.

The SVS is conducted by the California Department of Fish and Game (DFG) under an interagency agreement with the State Board. Two laboratories within the DFG are involved in this study. Sample collection and interpretation of the results are performed by the biologists at the Bay-Delta Project in Stockton. Sample preparation and analyses are performed by the Analytical Chemistry Unit of the Fish and Wildlife Water Pollution Control Laboratory (WPCL) in Rancho Cordova.

SVS, 1985 - 1986 [8]:

The areas investigated in 1985-86 were: the San Francisco Bay-Estuary (Figure 2), including the Suisun Marsh; subsurface agricultural drainage evaporation ponds in Kern County; Salton Sea, including several surface water systems tributary to the Salton Sea and tributaries to the Colorado River in Imperial and Riverside counties; and the San Joaquin River and selected tributaries in western Merced County. Collection of bird, fish, aquatic invertebrates, and water samples was initiated in 1986. In September of 1986, results led to the issuance of a health advisory for limited consumption of certain diving ducks from Suisun Bay. Some of the findings are:

1. HUMBOLDT BAY
2. SACRAMENTO RIVER, CLARKSBURG
3. SAN PABLO BAY
4. SUISUN BAY
5. ANTIOCH
6. SAN JOAQUIN RIVER, MAZE BLVD.
7. SAN JOAQUIN RIVER, MERCED RIVER
8. SAN JOAQUIN RIVER, LANDER AVENUE
9. SALT SLOUGH
10. MUD SLOUGH
11. CAMP 13 DITCH
12. MEYERS RANCH EVAP. PONDS
13. PRYSE EVAP. PONDS
14. WESTLAKE 3 EVAP. PONDS
15. WESTFARMERS EVAP. PONDS

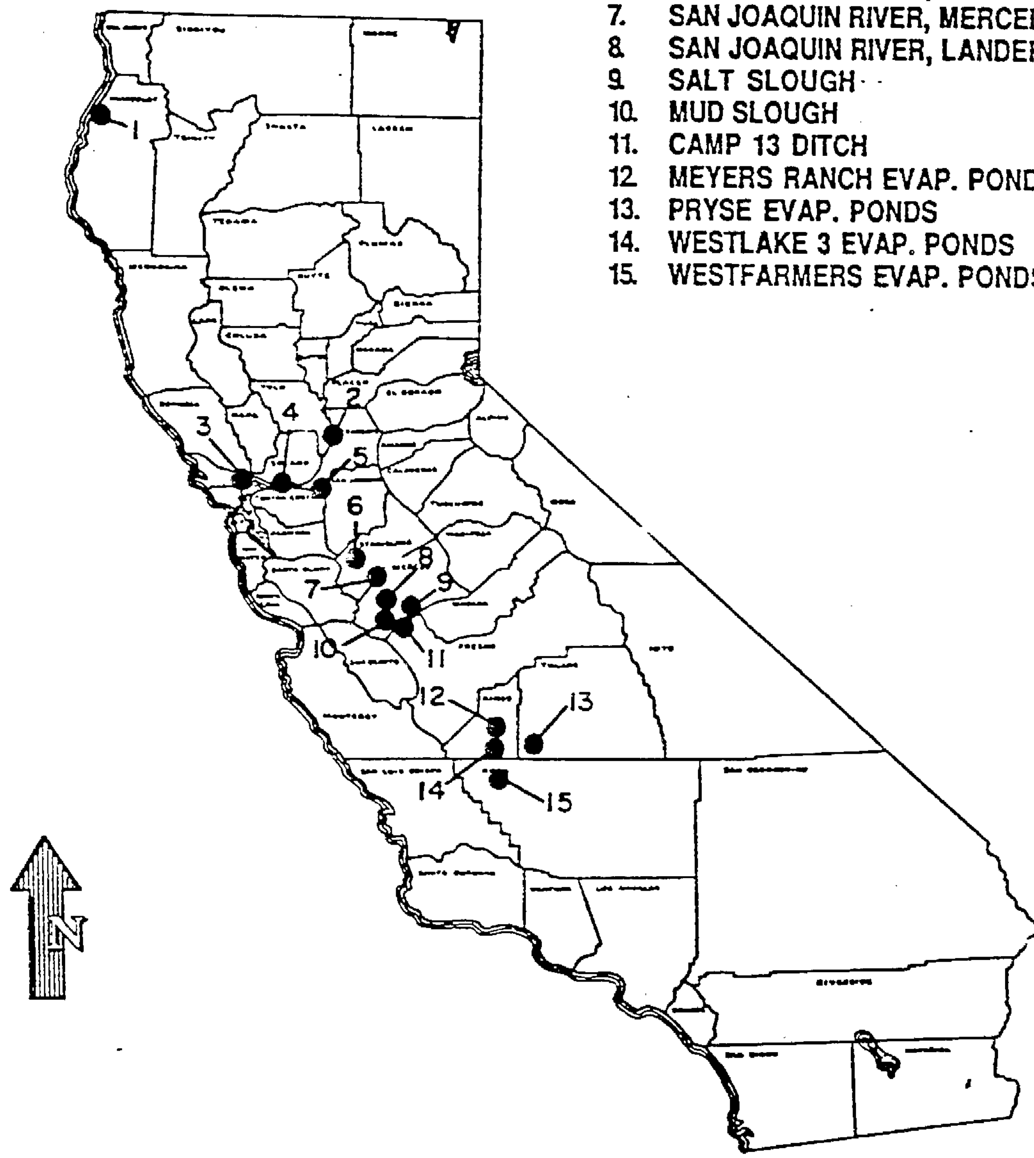

Figure 2

SELENIUM VERIFICATION STUDY: STATEWIDE DISTRIBUTION OF SAMPLING SITES - 1987-1988

1. Findings suggested that there was either input from sources near Suisun Bay or enhanced bioavailability of selenium due to localized physical, chemical, or biological processes. Findings from this location also suggested that selenium may be more available for uptake near the sediment-water interface.

2. Selenium concentration in shorebirds in the San Francisco Bay Estuary were about those measured at the control sites. Elevated levels of selenium were measured in all fishes sampled in the Salton Sea. American wigeon from the Salton Sea had higher selenium levels in muscle tissue than reported in the literature for other dabbling ducks but less than one third average levels in ducks (no wigeon) at Kesterson National Wildlife Refuge (NWR) in 1983 and 1984. Comparative data for wigeon were lacking.

3. Selenium levels in black-necked stilts from the Salton Sea were significantly higher than in stilts from Grizzly Island and Gray Lodge Wildlife areas and the Sacramento NWR but less than in stilts from Kesterson NWR where stilt reproduction was heavily impacted by selenium.

4. Bird livers collected from agricultural drainage evaporation ponds in Kern County indicated elevated selenium values ranging from 5.5 to 17 ppm (wet weight). The mean (x=8 ppm) concentration of selenium in livers of black-necked stilts from this evaporation pond complex was similar to levels in stilts from Kesterson NWR, where severe reproductive effects were associated with selenium. Aquatic invertebrate in ponds accumulated selenium to the concentration levels ranging from 1.6 to 3.6 ppm (wet weight). The invertebrate accumulated selenium at about 50 to 300 times selenium levels in water.

5. Selenium levels in catfish from San Joaquin River and its tributaries and Salt and Mud sloughs are far below documented toxic levels in these species, however, concentrations in the range measured (0.32 to 0.75 ppm, (wet weight), in muscle tissue) in catfish from Camp 13 Ditch and Mud Slough are indicative of selenium enriched environments. The significance of these levels to catfish has not been determined.

SVS, 1986-1987 (9)

The 1987 SVS focused on a better understanding of the occurrence and effect of selenium in the San Francisco Bay, the Sacramento-San Joaquin River Delta and the lower River. The findings during 1986-87 sampling are:

1. Once again waterfowl from the San Francisco Bay area had higher selenium content than background locations, and it was shown that waterfowl increased their selenium content after their arrival at San Francisco Bay. The 1987 concentrations were similar to 1986 concentrations in birds from Suisun Bay, but average selenium concentrations in muscle tissue in waterfowl from San Pablo and South San Francisco Bay increased from 1.0 to 6.0 ppm (wet weight) between years.

2. Based on wet weight tissue concentrations, diving ducks in Suisun Bay accumulated selenium up to 0.5 to 2.8 ppm (12,000 to 30,000 times the concentration of total selenium dissolved in Bay water). Filter-feeding clams, food for diving ducks, contained 4,000 to 5,000 times the waterborne level. The bioaccumulation of selenium in mussels and oysters transplanted

to sites in San Francisco Bay indicate selenium enrichment in areas near oil refineries in Suisun and San Pablo Bays, and near municipal outfalls in South San Francisco Bay. The concentration of selenium in bivalves from Suisun, San Pablo, and South San Francisco bays were about 1.0, 2.0, and 0.7 ppm, respectively. The concentration of selenium in water was about 0.2 - 0.5 parts per billion (ppb).

3. Based on wet weight tissue concentrations, striped bass from the Bay-Delta Estuary contained more selenium in 1987 (0.43 ppm) than in 1986 (0.34 ppm) and more than an inland population at Success Lake (0.18 ppm). Striped bass from Lake Havasu (Colorado River) contained significantly more selenium than those from the Bay-Delta Estuary.

4. Catfish collected in the San Joaquin River again reflected exposure to selenium enrichment, especially in the tributary sloughs, and it did not change between years. Catfish in the western Delta did not have more selenium than those from upstream sites, hence apparently were not influenced by selenium from downstream sources in the Suisun Bay area.

SVS, 1987-1988 [10]

The range of selenium concentrations in various media measured during 1987-1988 are tabulated in Table 1.

1. During 1988, consistent with previous findings, birds wintering on Suisun and San Pablo bays had higher selenium concentrations than those from control sites. Selenium levels in surf scoter tissues increased up to two fold during the winter months when these migratory birds were using Suisun and San Pablo bays. This increase was most pronounced for Suisun Bay scoters. The wet weight geometric mean selenium levels increased from 3.6 to 8.9 ppm in muscle tissue compared with 2.9 to 6.9 ppm in scoters from San Pablo Bay.

   Histopathological examination of tissues of waterfowl from Suisun and San Pablo bays in 1986, 1987, and 1988 studies revealed no abnormal conditions attributable to selenium even though those birds with the highest levels of selenium in their tissues were chosen for examination.

2. Diving ducks in Suisun Bay accumulated selenium, on a dry weight basis, up to 1,200,000 times the concentration of total selenium dissolved in bay water. Filter-feeding clams commonly eaten by these ducks contained, on a dry weight basis, 3,000 to 30,000 times the waterborne selenium level.

   The selenium concentration in water from eastern San Pablo Bay (ranging from 0.05 to 0.19 ppb) suggested the influence of nonoceanic and non-agricultural sources of selenium. Selenium in Suisun Bay strongly suggested a local input of selinide and elemental selenium. This study's findings tend to support earlier conclusions [8] that selenium for agricultural drainage in the San Joaquin River does not significantly affect bioaccumulation in the lower estuary.

3. Striped bass from the Sacramento-San Joaquin Estuary contained lower selenium levels in spring 1988 than in spring 1987, but higher than in spring 1986. Although bass from the Bay-Delta Estuary have higher selenium levels than an inland population from Success Lake, levels measured in all

TABLE 1. RANGE OF SELENIUM CONCENTRATIONS MEASURED IN WATER, SUSPENDED SOLIDS, PLANKTONS, SEDIMENTS, INVERTEBRATES, BENTHIC BIVALVES, LIVER TISSUE IN FISH AND BIRDS
SVS - 1987-1988

Location	Water ppb.	Susp. Solids ppm., DW*	Planktons ppm., DW	Sediments, ppm., DW	Invertebrates ppm., WW**	Benthic Valves ppm., DW	Cat Fish, ppm., WW	Surfscoter ppm., WW
Camp 13 Ditch	62 - 104	1.6 - 2.4	0.5 - 2.10	0.7 - 1.4	N.A.	N.A.	0.66 -1.4	N.A.
Mud Slough	1 - 20	1.2 - 2.7	0.19 - 0.92	0.31 - 1.3	N.A.	N.A.	0.31 - 0.67	N.A.
Salt Slough	3 - 19	1.2 - 2.10	0.17 - 0.91	0.31 - 1.4	N.A	N.A.	0.28 - 0.37	N.A.
San Joaquin River (Lander Avenue)	0.5 - 5	0.98 - 1.2	0.13 - 0.16	0.04 - 0.7	N.A.	N.A.	0.18 - 0.22	N.A.
San Pablo Bay	0.05 - 0.19	0.29 - 0.65	< 0.26	0.20 - 0.30	0.16 - 0.67	0.5 - 2.3	0.5 - 3.3+	16 - 51
Suisun Bay	0.09 - 0.21	0.35 - 0.53	< 0.2	< 0.06	0.46 - 0.87	3.4 - 4.6	N.A.	18 - 84
Homboldt Bay***	0.05 - 0.06	0.27 - 0.37	< 0.20	< 0.25	0.26 - 0.37	2.0	N.A.	1.2 - 16.
Evaporation Ponds	0.3 - 460	0.49 - 24.0	0.16 - 27	0.15 - 1.9	0.36 - 8	N.A.	N.A.	1.7 -31.0++

* DW - Dry Weight Basis
** WW - Wet Weight Basis
*** Control Site
\+ White Sturgeon
\++ Ruddy Duck

three years (mean of 0.40 ppm (wet weight)) are at or below the median level measured for fish tissue nationwide. There is no direct evidence that selenium has had an impact on striped bass in the estuary and current concentrations in fish tissues are below the level of concern (2 ppm, wet weight) established by DHS.

White sturgeon selenium concentrations were lower in spring 1988 (mean of 1.48 ppm, (wet weight)) than in either preceding year, indicating no trend for selenium in white sturgeon.

4. White catfish and channel catfish from Camp 13, Mud Slough, and Salt Slough had higher selenium levels (1.40 ppm (wet weight)) than catfish from two sites downstream in the San Joaquin River (0.20 ppm). The concentration of selenium in samples of filtered water, suspended particulates, plankton, and sediment (taken concurrently with the fish) generally followed the same decreasing trend. Selenium levels in catfish are substantially elevated in the tributary sloughs and Camp 13 Ditch but have still not reached levels known to be of concern for the health of fish populations. Selenium concentrations in catfish muscle tissue are below the level of concern for human consumption established by DHS.

5. Selenium levels in ruddy duck from San Joaquin Valley Evaporation Ponds averaged from 1.7 to 31.0 ppm (wet weight) in liver and from 0.5 to 10.0 ppm (wet weight) in muscle tissue. Bioaccumulation of selenium was greatest at the lowest trophic level, but the degree of bioaccumulation between each trophic level was less than 10 times for each level above suspended particulates.

   The concentration of selenium in evaporation pond waters (Table 1) ranged from 0.3 to 460.0 ppb. The concentration of selenium in water samples from Camp 13 ditch ranged from 62.0 to 104.0 ppb. The concentration of selenium in water from Mud Slough, Salt Slough, Suisun Bay, San Pablo Bay, San Joaquin River (Lander Avenue), and Humboldt Bay ranged from a minimum of 1 to a maximum of 21 ppb. The concentration of selenium in suspended solids, planktons, sediments, invertebrates, benthic valves, and fish followed spacial trend similar to that of selenium in water at the above locations. However, the concentration of selenium in bird liver tissue were highest in Suisun Bay (without apparent adverse effect on Birds) and lowest in evaporation ponds where embryonic deformities have been reported (see Section 2.1.1, 2.1.3., and 3.1). It is worth mentioning that sampling sites represent different biogeochemical environments, and inhabit different species and age populations.

SVS, 1988-1989

The Selenium Verification Study during 1988-89 has been focused on evaporation ponds, the San Joaquin River, and the Bay-Delta Estuary.

Data from the 1988-1989 Selenium Verification Study has not yet been completely analyzed. The information presented here is preliminary but the results will be included in the 1989-90 report where both year's data will be evaluated. The final report should be completed in fall 1990. The means and standard deviations on a wet weight basis are presented here.

1. Surf scoters collected from the San Francisco Estuary had patterns and levels of selenium accumulation similar to those seen in previous years. The highest levels were seen in birds from Suisun Bay (liver: 50.7± 31.4 ppm), followed by San Pablo Bay (44.0± 12.00 ppm), while the lowest levels were in birds from South San Francisco Bay (17.7± 5.6 ppm). The levels seen in birds from the first two locations were similar to 1988 values while the levels of selenium measured in birds from South San Francisco Bay appear to be higher than levels measured in 1986.

2. Striped bass continue to have low levels of selenium in their muscle tissue (Antioch: 0.49± 0.03 ppm; Clarksburg: 0.46± 0.4 ppm), but sturgeon muscle levels may be increasing (Suisun Bay: 4.1± 3.1 ppm). Three Corbicula samples from Suisun Bay (0.48± 0.05 ppm), had levels in their flesh less than were seen in 1987-88 and the one composite Potamocorbula sample collected had a value of 0.41 ppm (whole body sample), similar to that seen in 1988. Diet analyses in 1988 indicate that Potamocorbula is the food item most frequently consumed by sturgeon. The 1989-90 study plan includes more extensive sampling of the selenium levels in sturgeon and their prey species.

3. Surveys in the lower San Joaquin River and its tributaries indicated that selenium levels in catfish muscle were highest in Agatha Canal (1.4± 0.32 ppm) and Camp 13 Ditch (0.54± 0.37 ppm), which are agricultural drainage canals and tributaries to the San Joaquin River. Levels in Mud Slough (0.26± 0.22 ppm) and Salt Slough (0.36± 0.08 ppm) were much lower than in the agricultural drainage canals and levels decreased as samples were taken downstream of these two tributaries in the main stem San Joaquin River (at Dos Reis Launch Ramp: 0.19± 0.02 ppm). Levels in Old River (0.19± 0.03 ppm) and Middle River (0.24± 0.06 ppm) were similar to those in the main stem San Joaquin River.

   Selenium levels measured in the flesh of various centrarchids were approximately twice as high as those of catfish, though in all but two cases, (red ear sunfish from Old River 1.1± 0.22 ppm and bluegill sunfish from Salt Slough 1.3± 0.20 ppm) the levels were below one ppm. Selenium levels in centrarchid flesh decreased downstream in the San Joaquin River, but as was the case for catfish, levels in the San Joaquin River at Lander Avenue were lower than at any of the stations downstream of the influence of agricultural drainage from Mud and Salt Sloughs.

   Whole body selenium levels of various small forage fish from Mud and Salt Slough exceeded 1.0 ppm (1.2± 0.19 ppm and 1.1± 0.17 ppm at each location, respectively) which equals levels in excess of five ppm on a dry weight basis.

4. Selenium levels in the livers of ruddy ducks, northern shovelers, and black-necked stilts were highest at Westfarmers evaporation ponds, intermediate at Westlake Farms and Tulare Lake Drainage District (TLDD) south ponds and lowest at TLDD north ponds. The trends in the selenium levels of waterfowl parallel the trends in the selenium levels of aquatic invertebrates collected from the same locations. Selenium levels in waterfowl from TLDD north ponds appear to be similar to levels in birds collected from Kern NWR while those from other locations were much higher.

SVS, 1989-1990

Based on the study findings to date, the purposes of the 1989-90 Selenium Verification Study are as follows:

1. Determining the trend of selenium levels in striped bass from Sacramento San Joaquin Delta Estuary and white sturgeon in San Pablo and Suisun Bays.

2. Determining the selenium levels in the white sturgeon diet from the San Pablo and Suisun Bay.

3. Determining the trends of selenium levels in diving ducks in the South San Francisco Bay, San Pablo Bay, and Suisun Bay.

4. Determining selenium levels in biota (fish and bivalve) of the Suisun bay, the Delta, the Sacramento River, and the San Joaquin River and Salt and Mud sloughs during minimum and maximum selenium input to the San Joaquin River.

5. Testing the potential for using the clam Corbicula species as a selenium intergrator for monitoring purposes.

6. Determining intra-cell selenium levels of invertebrates utilized in the diets of waterfowl and shorebirds, to determine whether intra-cell variability in selenium contaminations may affect differences in shorebird contaminations and hatchability, and whether current invertebrate monitoring programs are adequate.

The 1989-90 sampling began in November 1989. The 1988-89 findings will be incorporated into the 1989-90 final report which is anticipated to be complete in September 1990.

1.1.1.2.2 - Analysis of Trace Elements

The California Veterinary Diagnostic Laboratory System, University of California, Davis was selected in 1988 to establish a referee laboratory. Two hundred eighty selected samples of bird and fish livers, invertebrates, and water from 1986-88 SVS sampling were sent to the laboratory for analysis of twenty trace elements. The methods were developed with regard to minimum detection limits in biological tissue matrices. The method of Zeeman Corrected Graphite Furnace Atomic Absorption was used for chromium, lead, silver, and low levels of cadmium. Inductively Coupled Argon Plasma Spectroscopy (ICP) was used for the analysis of aluminum, boron, barium, cadmium, copper, iron, lithium, magnesium, manganese, molybdenum, nickel, vanadium, and zinc. Selenium and arsenic were analyzed by hydride generation and mercury was analyzed by cold vapor ICP.

The laboratory prepared a report [11]. The report includes a brief discussion of chemistry of the trace elements, project quality assurance/quality control, methods of analysis, and tabulated results.

1.1.1.2.3 - Wildlife Toxicological Assessment of Trace Elements in the Geochemical Environment

Under a separate contract, the California Veterinary Diagnostic Laboratory with the State Board is preparing a report on the statistical and analytical interpretation of interrelationships among the twenty trace elements. The preliminary findings are:

1. The statistical analysis of trace elements concentrations in the aquatic bird liver collected from the San Francisco Bay-Delta Region and San Joaquin Valley evaporation ponds indicated significant correlations among Cd-Mn-Se-Hg-As, Cd-Mn-Se-Hg, Cd-Mn-Se, Cu-Ag, and Mn-Zn.

2. The Mn-Se pair-wise correlation is of particular environmental significance. The concentration of selenium in bird liver from the estuary was linearly related to total sedimentary manganese (Figure 3-see also SVS, 1985-1986). The concentration of selenium in bird liver collected from evaporation ponds was also positively related to water soluble manganese. Manganese either affects bioaccumulation of selenium or elevated dissolved manganese is an indicator of oxidation state of aquatic systems which affects selenium bioavailability.

3. The concentration of bird liver selenium in Suisun, San Pablo, Central, and South San Francisco bays were 134, 126, 81, 7, and 47.5 (mg/kg dry weight), respectively. These values are higher than the toxic level of poultry liver selenium of 14.82 ppm (dry weight) cited in the report. However, no apparent adverse effects have been observed in the birds sampled.

   Final report is being reviewed and release is expected in late 1990.

1.1.1.3 - Evaluation of Corrective Actions (Element 3)

1.1.1.3.1 - San Joaquin River Model

The State and Regional Boards conduct studies to generate information needed for establishing and implementing water quality objectives for the San Joaquin Basin. San Joaquin River Model [12] is an input/output model that was developed to evaluate the potential of drainage reduction as a method for meeting water quality objectives established for San Joaquin River. Various scenarios of drainage reduction and its effectiveness for meeting water quality objectives for total dissolved solids, boron, and selenium in the San Joaquin River has been evaluated [13, 14, 15, and 16].

The San Joaquin River Model has been modified [17] to accept stochastic input data. The model utilizes the parameters of frequency distributions of hydrologic variables. The model output is probability distributions of water quality parameters. The stochastic model can be used to determine the probability of meeting certain water quality objectives at a specific point on the river. The advantage of the stochastic model is that a wide range of conditions can be evaluated compared with a worst case scenario in a deterministic approach.

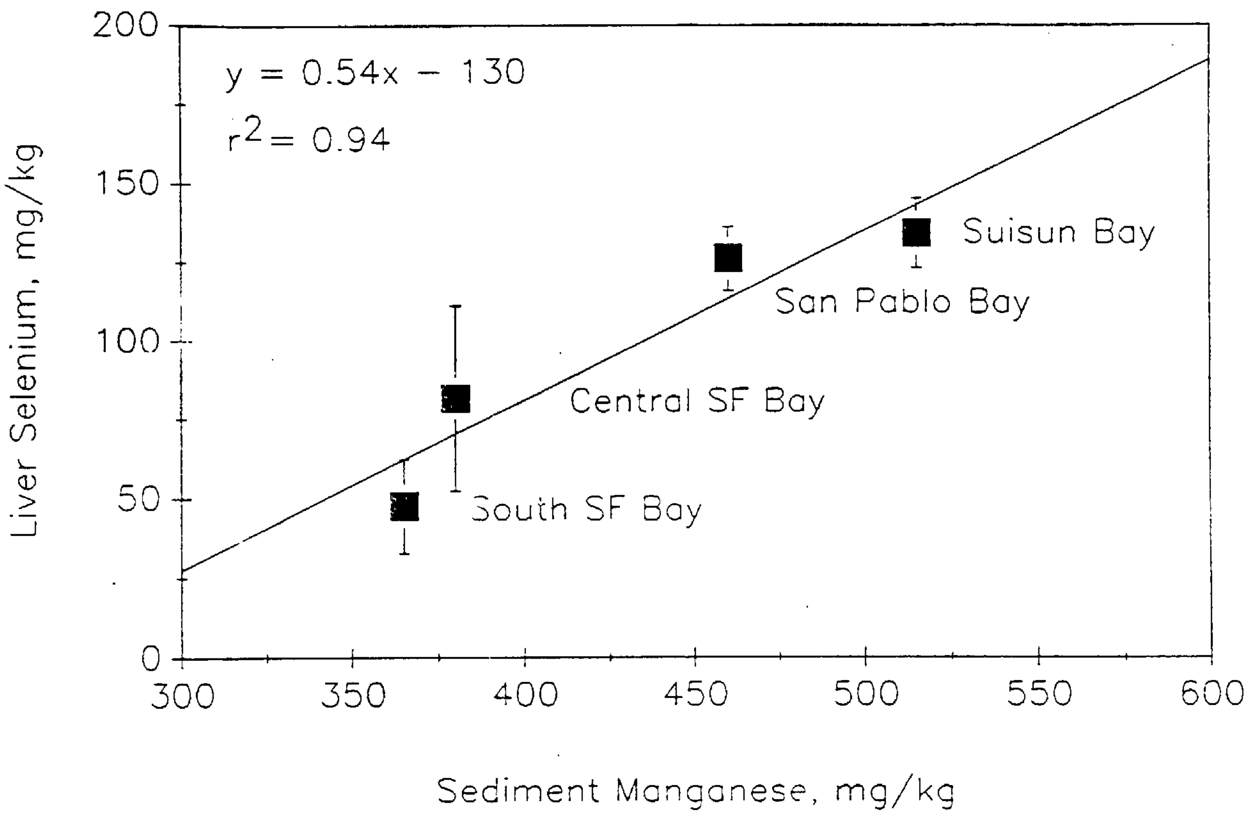

Figure 3: The best linear fit of mean selenium concentration in Surf Scoter liver, dry weight basis, as a function of total sediment manganese in the south to north regions of the San Francisco Bay estuary. Suisun Bay (n = 500, San Pablo Bay (n = 22), Central San Francisco Bay (n = 7), South San Francisco Bay (n = 8). Error bars show the standard deviation of the mean. T-test comparison at p = 0.005 reveals that Surf Scoter liver Se concentrations are significantly different for all regions except Suisun and San Pablo Bay which are not statistically different. Source: Wildlife toxicological assessment in the Geochemicoil Environment-Draft final report).

During 1989-90 the stochastic model was upgraded to include a physics-based approach to pollutant transport. The model will be used to predict water quality in the San Joaquin River for various hydrologic and drainage management scenarios including salt load reduction schemes.

For the activities of the Central Valley Regional Board on evaluation of corrective actions see Section 1.2.1.3.

1.1.1.4. - Development of Objectives (Element 4)

The objective of this element of the Study Plan was to develop water quality objectives or guidelines to protect beneficial uses of water. Water quality objectives for Se, molybdenum, and boron for the San Joaquin River and Salt and Mud sloughs as a part of Basin Plan Amendment was proposed by the Central Valley Regional Board and approved by the State Board on September 21, 1989. Recommended guidelines for a safe level of selenium and molybdenum in livestock drinking water (an important beneficial use in the valley) has been established (see Section 1.2.1.4). Development of water quality criteria for uranium in evaporation ponds has also been studied (see Section 1.2.1.5).

1.1.1.5 - Regulations for Treatment and Disposal (Element 5)

The Regional Water Quality Control Boards and the State Board regulate evaporation ponds under the Porter-Cologne Water Quality Act of 1969 and the Toxic Pits Cleanup Act of 1984. The Regional Boards establish waste discharge requirements that pond operators must meet to protect the quality of waters of the State. Under the Toxic Pits Cleanup Act, wastewaters that pose serious health threat to the quality of drinking water may be discharged to ponds that are double-lined and equipped with a leachate collection system and groundwater monitoring systems. The Regional Board can exempt evaporation ponds from this requirement until January 1, 1992 (AB 3843) if waste discharge requirements are issued for the pond and measures to prevent adverse wildlife impacts have been implemented.

The State Board provides funding for construction of treatment and disposal facilities per the terms of the Water Conservation and Water Quality Bond Law of 1986 (see Section 1.1.2). The State Board also provides funding for preparation of guidelines for hydrological assessment reports required from pond operators (see Section 1.1.3).

Currently, evaporation ponds are the only means of disposing of subsurface agricultural drainage water collected from tile drained areas in the Tulare Basin. In the San Joaquin River Basin, the drainage water is either discharged to the river or evaporation ponds. The Regional Board (Region 5) regulatory activities on evaporation ponds are discussed in Section 1.2.1.5. Regional Board activities in the implementation of Basin Plan Amendments are discussed in Section 1.2.1.7. For additional information on treatment and disposal methods, see Section 2.1.3, 2.1.5, 3.1, 3.3, 4.2.2, and 4.3.

1.1.1.6. Laboratory Quality Control/Quality Assurance Program (Element 6)

This activity is part of any State and Regional Board studies. For example, a study is currently underway to develop analytical techniques for analyzing certain trace elements in highly concentrated drainage water such as evaporation pond waters (see Section 1.2.1.5.6).

1.1.1.7 - Regulatory Activities (Element 7)

The State Board approved the Central Valley Regional Board Basin Plan Amendment and established water quality objectives for Se, boron, and molybdenum (see Section 1.2.1.7 for more details).

1.1.1.8. Coordination (Element 8)

The purpose of this element of the Study Plan is to inform all interested parties of the status of activities of all entities involved in the area of selenium, other trace elements, and agricultural drainage. Progress reports were released on December 1985 [18], March and October 1986 [19, 20], December 1987 [21], and March 1989 [22].

In preparing the 1989-90 report, State, federal, university, and local agencies coordinators and/or researchers were asked to update the status of their projects (Appendix A) and provide input to this report (see acknowledgements).

1.1.2 - Water Conservation and Water Quality Bond Law of 1986

In 1985, the California Legislature enacted Assembly Bill (AB) 1982, the Water Conservation and Water Quality Bond Law of 1986. The sum of $75 million of the fund provided by the bill for agricultural drainage was deposited in the Agricultural Drainage Water Account to aid in the construction of drainage water management units for the treatment, storage, or disposal of agricultural drainage water. Some specific types of facilities eligible for funding include surface impoundments, such as evaporation ponds, conveyance facilities, treatment works and injection wells. The maximum loan amount is $20 million for a period of up to 20 years and the interest rate is one half of the interest rate of State General Obligations Bonds (approximately 3.5%). A maximum of 3 percent of the total amount of bonds may be used for financing feasibility studies of projects potentially eligible for funding. No single potential project can receive more than $100,000 for feasibility studies.

The State Board administers the Agricultural Drainage Water Management Loan Program. Applications are reviewed and a priority list is prepared for State Board approval. All eligible projects from the priority list must be approved by the State Board before Legislative approval can be obtained.

To date, twenty-five applications have been received by the State Board. The projects can be broadly categorized into five groups: (1) disposal facilities; (2) selenium removal projects; (3) ground water cleanup projects; (4) drainage management projects; and (5) feasibility studies. Seven projects were approved by the State Board and the Legislature (AB 2875, 1988) for a total of $6,173,000. Eight projects have either received State Board approval or are in the planning stage and ten projects are listed as inactive and not likely to proceed in 1989-90.

Of the total funding available for loan in the Agricultural Drainage Water Account, $23,994,000 has been approved by the State Board and $47,256,000 is uncommitted. However, the remaining 1988 priority list projects absorbs $15,200,000 and loan requests received in 1989 are for the amount of $35,508,000. More details can be found in an annual report by the Agricultural Drainage Water Management Loan Program to the Legislature in August 1989 [23].

Under a contract with the State Board (Division of Clean Water Program), the University of California, Davis has prepared a report [24] on the status of agricultural drainage problems in California. This report addresses the pollution problems affecting irrigated agriculture, aquatic life, and human health. The report discusses trace elements, and man-made chemicals such as fertilizers and pesticides and proposes solutions to salinity, trace elements, nitrates, and pesticides. The elevated total dissolved solids in shallow ground water, rising water, and lack of adequate safe drainage disposal are recognized as primary factors affecting agriculture in the westside of the San Joaquin Valley. Environmental and wildlife concerns over the trace elements are also discussed in this report. The potential health hazard from use of ground water for drinking purposes occurs in the Central Valley due to the presence of nitrates and pesticides in wells. The report cites ground water contamination due to nitrate and pesticides in several areas of the Central Valley.

Some of the solutions proposed to solve agricultural drainage related problems include source control, drainage reduction, land retirement, physical, chemical, and biological treatments of drainage water, dilution, reuse of saline water, and disposal of drainage water in salt sink or ocean.

The obstacles to improved water management are described to be: relatively low water costs, growers tradition in farming and water management, lack of skills and information, farm constraints, institutional constraints, and difficulty in determining nonpoint source (NPS) pollutions.

1.1.3 - Water Quality Planning Program

The State Board Water Quality Planning Program has funded several studies involving selenium and other trace elements. These studies are as follows:

1. The University of California, Davis, under contract with the Central Valley Regional Board, prepared a report [25] on evaporation ponds as a means of disposing of agricultural waste water. The report is the result of a study on five evaporation ponds in the San Joaquin Valley. The work was funded by 205(j)(5) funds by the State Board. For details see 1.2.1.5.1.

2. To field test the effectiveness of microbial volatilization of selenium from soil, one project is presently in progress at the Peck Ranch near Mendota. The project is being funded by State Board contracts with the University of California Riverside and the Fresno Foundation at the California State University, Fresno, using $219,000 in Section 205(j)(2) grant money from the U.S. Environmental Protection Agency (EPA) and $73,000 in local match. The two contracts started on January 4, 1988, and expire in 1990.

   The field work consists of testing several soil amendments and monitoring the emission rates of dimethyl selenide and dimethyl diselenide gases. The soil amendments are disked into the ground to a depth of six inches, and the soil is kept moist by a sprinkler system. Soil cores are analyzed periodically to monitor the selenium content of the individual subplots.

   A second study (Part II) which is a continuation of the above study with new contracts to the same universities and funded with $58,500 from another Section 205(j)(2) grant and $19,500 in local match, started in January and extend through May 1990. The work to be performed will include a final analysis of the data collected during the first study, a report on the institutional and financial considerations, a management and implementation plan, and a final report. For more information on microbial volatilization of selenium, see Sections 2.2 and 3.1.

3. Determination of Hydrological Assessment Report (HAR) Requirements for Agricultural Evaporation Ponds

   The Toxic Pits Cleanup Act (TPCA) requires that a person discharging liquid hazardous wastes to a surface impoundment prepare a HAR. The objective of this study is to evaluate the existing HAR requirement, and modify them for application to evaporation ponds so that the TPCA can be amended accordingly. A management plan will be prepared for individual land owners. The project is being funded by a State Board contract with the University of California, Davis using $95,250 in Section 205(j)(2) grant money from EPA and $31,750 in local match. This study started on June 1, 1989.

1.1.4 - Nonpoint Source Pollution Control Program

In 1987, the U.S. Congress incorporated Section 319 into the Clean Water Act to initiate a new National NPS action program. The amendments to the Clean Water Act require states to assess their waters and to develop NPS management programs to control and reduce specific nonpoint sources of pollution and authorizes federal loan and grant funds to help states and local government, individuals, and farmers to manage NPS of pollution. The states are required to prepare an assessment and NPS management plan. The State Board adopted California's NPS assessment and management plan in November 1988 [27, 28].

On November 9, 1989, the president signed an appropriations bill that included $40 million for Clean Water Act Section 319 grants to states to implement NPS management programs. Congress directed EPA to seek state grant applications and to award NPS grants no later than March 1, 1990. All Section 319 grants require a 40 percent match. The State Board NPS Program submitted 14 projects for a total of $1.9 million. Eleven projects and its administrative costs were approved for a total of $1.67 million.

In order to meet the goals of NPS control program the State Board expanded its existing NPS Unit into a NPS Section. The NPS Section includes an NPS Agricultural Unit, and an NPS Unit. The NPS Section strategy is to raise public awareness, identify practical solutions to control NPS pollution, develop a regulatory program to deal with nonpoint sources of pollution and administer the funding for NPS program implementation.

The State Board encourages a cooperative strategy for NPS control which consists of encouraging dischargers and management agencies to implement Best Management Practices (BMPs) through education, training, financial assistance, and demonstration projects. However, if progress toward implementation of BMPs is not made or BMPs fail to control the NPS of pollution, the State Board will consider taking regulatory steps such as issuance of waste discharge requirements.

The State Board role consists of development of policy, program direction, overall coordination with Regional Boards and management agencies, selection and administration of projects for loans and grants, development of BMPs, demonstration projects, and development of outreach programs.

The State Board's Subsurface Agricultural Drainage Program (the Study Plan established in 1985) was transferred from the Division of Water Rights to the Division of Water Quality - Agricultural NPS Unit. The Agricultural Drainage Program resources are 14.0 personnel years (Board-wide) and approximately $700,000 annual funds which was approved by the California Legislature on July 1, 1985.

1.2.0 - California Regional Water Quality Control Board, Central Valley Regional Board (Region 5)

1.2.1 - Selenium and Other Trace Elements in California

1.2.1.1 - General Overview Studies

1.2.1.1.1 - Municipal and Industrial Discharge Survey for Selenium

The California Legislature, through the Governor's 1985-86 budget, provided funding for an intensive look at municipal and industrial discharges for selenium. Due to the importance of selenium in the Central Valley, selenium samples were taken from 109 discharge points. The majority were taken from discharges that eventually find their way into the Sacramento San Joaquin Rivers and Delta, or from those located in close proximity to the existing agricultural drainage problem area.

A final report on this investigation was prepared by the Central Valley Regional Board in 1988 [29]. The report describes the selenium levels at each site and will be used to evaluate regulatory and monitoring programs. Specific findings are:

1. Only two discharges showed elevated selenium levels, one municipal and one industrial site.

2. Because selenium has occurred in only a few isolated instances in this survey, the report recommends that Central Valley Regional Board staff continue their emphasis on selenium problems related to agricultural tile drainage discharges.

1.2.1.1.2 - Survey of Tile Drainage Discharges into the San Joaquin River

Central Valley Regional Board staff completed three water quality surveys of tile drainage systems that are discharging into the San Joaquin River. The survey of over 300 sites in seven distinct zones in the basin was conducted because of concern for elevated levels of trace elements being found in tile drainage.

A report on this survey has been prepared by the Regional Board [30]. The report describes the ranges of salinity and 13 trace elements that were included in the survey. The results of the report will be used to establish regulatory priorities and discharger monitoring programs, including factors in the development of basin plan amendments. Specific findings are:

1. Only six of the 13 trace elements occurred with frequency; arsenic, boron, chromium, molybdenum, nickel, and selenium.

2. Arsenic and molybdenum were associated with Sierra Nevada deposits in the Valley.

3. Chromium, nickel, and selenium were associated strongly with deposits in the Panoche Fan area, with selenium concentrations elsewhere in the basin very low.

4. Boron was associated with all tile drainage flows from drained areas west of the San Joaquin River.

   Additional work is now underway to document the ranges of three additional trace elements that have been documented in the San Joaquin River sloughs. Uranium and vanadium have both been recorded in elevated levels in the San Joaquin River. The most likely source is the drainage discharges. Elevated chromium concentrations were found in the previous survey and downstream in the San Joaquin River. Recent spot checks of tile drainage discharges show that a high percentage of the chromium in the tile drains is in the Cr^{+6} form, a form known to cause fishery impacts.

   A survey of the 300+ sites in the seven distinct zones in the basin will be conducted in the spring of 1990. In addition to testing for these three trace elements a follow up survey for three of the six trace elements detected in the last survey will be conducted. Those are boron, selenium, and molybdenum. A report on this survey will be prepared and distributed in late 1990. Follow-up work will concentrate on river monitoring, beneficial use impact assessments, and development of needed basin plan amendments.

1.2.1.2 - Verification Studies (Site Specific Studies)

Several site-specific studies were conducted in response to concerns that agricultural drainage, including the trace elements it contains, may be impacting beneficial uses. Most of the studies were directed at the occurrence of selenium; however, other trace elements commonly found in drainage water were also considered. For general location of certain study areas see Figure 1. summary of these investigations is described below.

1.2.1.2.1 - Area Wide Tile and Surface Drainage Surveys in San Joaquin River Basin

Several zones east and downstream of the Grassland Basin within the San Joaquin River Basin have tile drains that either showed elevated levels of trace elements (see previous discussion on tile drain survey) or discharges had the potential to impact beneficial uses. An intensified effort to assess the trace element levels was conducted in seven zones.

1. East Side Discharges

   Periodic monitoring for salts and trace elements by Regional Board staff in addition to monitoring by local irrigation districts was conducted on the

31 major drains entering the San Joaquin River from the east side. The Regional Board began sampling these discharges in January 1986 to compile a database for salts and trace elements. The database will be used in the development and evaluation of an agricultural drainage reduction program in the San Joaquin River Basin. This was supplemented by monitoring programs by the irrigation districts. A report on the monitoring of the east side discharges was prepared (31). The report shows that:

a. EC, boron, and selenium were typically low in all three zones studied.

b. The southern zone had higher maximum values of boron and selenium than the northern and central zones. Only the southern zone is served by water from the Delta-Mendota Canal, in addition to water from the east side streams.

C. Concentrations of copper, chromium, lead, nickel, mercury, molybdenum, and zinc were typically at or below their detection limits.

No further Central Valley Regional Board monitoring is anticipated.

2. Stanislaus County Discharges

Surface and tile drain flows from 44 drains in the western portion of Stanislaus County represent a significant quantity of the flow in the San Joaquin River upstream of Vernalis. Periodic monitoring for salts, trace elements, and sediment content by Regional Board staff in addition to monitoring by local irrigation districts begun in April 1985 on the major drains entering the River. The database will be used in the development and evaluation of an agricultural drainage reduction program in the San Joaquin River Basin. A report on the monitoring of these discharges was prepared by the Regional Board (32). The report shows that:

a. Concentrations of salinity, boron, molybdenum, and selenium in the tile drains were significantly lower than in the Panoche Fan area.

b. Because many of the drains discharging to the river contain significant amounts of surface runoff, the quality of water is influenced most by the source of the supply water.

c. Similar trends were noted for boron, chloride, sulfate, and total recoverable selenium.

D. Total recoverable selenium concentrations were lowest in Water Year (WY) 1986, a wet year, and higher in WY 1987, a critical year (dry). The highest selenium concentrations were recorded in WY 1988, a second consecutive critical year, especially in areas utilizing only San Joaquin River water.

e. The areas discharging the greatest pollutant load to the River are those areas obtaining water from the River only.

f. The source of the supply water is more important than the source of the drain water in the amount of pollutants discharged from the western portion of Stanislaus County.

g. The discharge of pollutants from western Stanislaus County is merely a recycling of agricultural pollutants which have been discharged to the San Joaquin River further upstream.

The sediment data has already been used by the West Stanislaus Resource Conservation District in assessing where the major sediment discharges are originating from. A full report on the magnitude of the sediment discharges was submitted to the Regional Board in March 1989. A follow up program through the NPS Program is now being initiated.

No further Central Valley Regional Board monitoring is anticipated.

3. San Joaquin County Discharges

Surface and tile drain discharges from the western portion of San Joaquin County have the potential to have a significant impact on San Joaquin River water quality downstream of Vernalis. Periodic monitoring of the 38 principal tile drainage discharges for salts and trace elements has been conducted by Regional Board staff. The study area was divided into three zones as determined by local water distribution and management influences. A report on the quality of these discharges has been prepared by the Central Valley Regional Board [33]. The report shows that:

a. Concentrations of salinity, boron, molybdenum, and selenium in the tile drains were significantly lower than in the Panoche Farm area.

b. Median selenium concentrations ranged from 1.6 to 4.6 microg/L for the three zones.

c. The median boron concentration is approximately equal to that reported for the Contra Costa County area but is greater than that reported for the western Stanislaus County area.

d. Boron continues to be elevated in this area even though subsurface drains have been in operation for over 20 years.

No further monitoring by Central Valley Regional Board staff is anticipated.

4. Contra Costa County Discharges

Fourteen major tile drains in the eastern portion of Contra Costa County discharge directly into the Delta and have the potential to impact water quality, especially in some of the channels and sloughs in the Western Delta that are not subject to continuous circulation. Periodic monitoring of these 14 principal discharges for salts and trace elements has been conducted by Regional Board staff. Sampling of these discharges was initiated in December 1985 to compile a database for salts and trace elements. The database will be used in the development and evaluation of the need for an agricultural drainage reduction program. A report on the quality of these discharges has been prepared by the Regional Board [34]. The report shows that:

a. The median salinity (EC) and median boron concentrations were low in this study area in comparison to that observed in drainage discharges from the Panoche Fan area. Median EC and boron concentrations in the study area were 1,720 micromhos/cm and 2.8 mg/L, respectively, compared to 6,100 micromhos/cm and 7.9 mg/L, respectively, in the Panoche Fan area.

b. Although trace element concentrations from the monitored sites were typically low, occasional high concentrations were observed in the Main Drain at Veale Tract. This drain collects high ground water and surface runoff. In addition, past use of soil amendments in the area may have affected the water quality.

c. Although the median boron concentration was not particularly high, boron concentrations in a few of the discharges was quite high, a maximum of 16 mg/L boron being observed. Boron has been known as a cropping problem in this area and, even though subsurface drains have been in operation in this area for over 20 years, boron concentrations continue to be high in some portions of the study area.

No further monitoring by Central Valley Regional Board staff is anticipated.

5. South Delta Islands Discharges

Discharges from 49 surface and tile drains enter the South Delta waters directly from the islands or from lands immediately adjacent to Delta. The discharges from the surface drains often carry blended tile drain water or significant ground water seepage. These discharges have the potential to have a significant impact on Delta water quality, especially at times of poor channel circulation. Periodic monitoring of these 49 principal drains has been conducted by Central Valley Regional Board staff. A report on the quality of these discharges was prepared by the Central Valley Regional Board [35]. The report shows that:

a. The drainage water discharges are better quality than those discharged further upstream. For example, those originating from the South Delta lowlands had a median salinity concentration of only 770 mg/L.

b. The majority of the samples collected from the drainage discharges in the South Delta lowlands were of a quality that they could be used directly for crop irrigation without any harmful effects.

c. The trace element concentrations in the samples collected in this survey were low.

d. The median selenium concentration for all the samples collected was 0.7 microg/L with over 85 percent of the samples collected showing concentrations below 2.0 microg/L, a concentration guideline used by the USFWS for wetland protection.

Further sampling for trace elements measured in this study, including selenium, in agricultural drainage water discharges is not needed in the lowland area of the South Delta. Measured concentrations do not pose a threat to beneficial uses.

6. Central and Northern Delta Islands

   Central Valley Regional Board has been working cooperatively with the Delta Health Effects Monitoring Program of the DWR to assess the levels of selenium entering Delta waters from agricultural discharges. Results of this program are being published in the DWR Health Effects Monitoring Reports and various DWR submittals to the Delta Hearing Process. It is not envisioned that a separate report will be prepared by the Central Valley Regional Board, however, the data collected to date was published in the report on the South Delta Lowlands (see #5 above). Further monitoring by the Central Valley Regional Board is not anticipated as all samples checked showed very low selenium concentrations and elevated levels of other trace elements is not suspected.

7. Kings River Survey

   Numerous tile drains discharge directly into the Kings River. Central Valley Regional Board staff began a preliminary survey of these discharges in October 1988 to determine if trace elements may be impacting beneficial uses. A progress report has been prepared and is being reviewed. A full report on this activity will be prepared in late 1990 or early 1991.

1.2.1.2.2 - Waterfowl and Wildlife Refuges in the Central Valley

Concern was expressed that surface and subsurface tile drainage waters from irrigated agriculture may be impacting wildlife refuges in a manner similar to the impacts seen at Kesterson Reservoir and the Grassland area of western Merced County. Limited data is available on the quality of water entering these areas; therefore, in cooperation with USFWS staff and DFG Refuge Managers, reconnaissance surveys were conducted at several refuges to determine if further evaluation is needed. Emphasis in this program was given to State wildlife refuges although federal areas receiving significant return flows were also considered.

1. Modoc National Wildlife Refuge (NWR) and the Ash Creek Wildlife Management Area

   Staff conducted a reconnaissance survey of the quality of the water supplies entering the Modoc NWR and the Ash Creek Wildlife Management Area. The purpose was to determine if trace elements or pesticides were present that posed a threat to fish and wildlife. A report on this investigation has been prepared by the Central Valley Regional Board [36]. The report describes the water quality found at the refuge and its potential impacts. Specific findings are:

   a. Samples did not contain pesticides at detectable concentrations.

   b. Trace element concentrations were similar to background concentrations found in the Pit River surface water system.

   c. Agricultural return flows do not appear to have impacted water quality at the site including selenium concentrations as these were found to be very low.

2. Merced NWR

Staff conducted a reconnaissance survey of the quality of the water supply to the Merced NWR to determine if problems may be occurring at this site due to agricultural return flows. A report on the Merced investigation has been prepared by the Central Valley Regional Board [37]. The report describes the present water quality used at the refuge and its potential impacts. Specific findings are:

a. The current water supply is of acceptable water quality for both the wildlife habitat and irrigation beneficial uses at the refuge.

b. Agricultural return flows including subsurface drainage discharges do not appear to have impacted water quality at the site, including selenium concentrations as these were found to be very low.

3. Sacramento NWR

Central Valley Regional Board staff conducted a reconnaissance survey for salts, pesticides, and trace elements in the water entering the Sacramento NWR. Emphasis was given to the irrigation season including the rice growing season as this represents a significant inflow period. A follow-up program has been started by the USFWS to survey additional pesticides and other potential contaminants not included in the Central Valley Regional Board survey. The data collected by the Central Valley Regional Board will be incorporated into a USFWS study. A report has been prepared by the Central Valley Regional Board [38]. The report shows that:

a. Mineral and trace element concentrations from agricultural return flows do not appear to be limiting factors in the beneficial use of water for wildlife habitat at this site.

b. Selenium levels ranged from 0.1 - 1.2 microg/L with a median selenium concentration of 0.4 microg/L, which is well below the EPA's 5 microg/L criterion for the protection of freshwater aquatic life, and the 2 microg/L guideline utilized by the USFWS in the management of the federal refuges.

c. Agricultural drainage entering the refuge was monitored for thirty-three pesticides that represent the agrichemical use on crops grown upstream of the refuge during this survey. Three thiocarbamide compounds were detected in the water samples. The results of this reconnaissance level pesticide monitoring signal the potential short term intermittent exposure of wildlife to herbicides from agricultural return flows draining into the refuge.

4. Gray Lodge Wildlife Management Area

Central Valley Regional Board staff conducted a reconnaissance survey for salts, pesticides, and trace elements in the three water supplies utilized by the Gray Lodge State Wildlife Management Area. A report on this reconnaissance level survey has been prepared by the Central Valley Regional Board [39]. The study showed that:

a. Mineral and trace element concentrations, including selenium, do not appear to be limiting factors in the beneficial use of water for wildlife habitat at this site.

b. Selenium levels ranged from <0.2 to 0.8 microg/L with a median selenium value of 0.3 microg/L, which is well below the 5 microg/L EPA criterion for protection of freshwater aquatic life and the 2 microg/L guideline utilized by USFWS in management of federal refuges.

c. Rice herbicide concentrations in agricultural drainage entering the management area were well below the guidelines established by DFG for protection of fish and aquatic invertebrates, although the potential affects of these levels on waterfowl are unknown.

5. Mendota Wildlife Management Area (WMA)

Central Valley Regional Board staff conducted a reconnaissance survey for salts and trace elements in the water supply utilized by the Mendota WMA that comes from NPS agricultural return flows. Preliminary findings show that periods of strongly elevated trace elements are entering the Mendota WMA from irrigated lands to the west. Central Valley Regional Board staff are attempting to determine the source of these metals. Further monitoring will be conducted in the 1990 irrigation season with a report scheduled for preparation in late 1990.

1.2.1.3 - Evaluation of Corrective Actions

1.2.1.3.1 - Stream Quality Evaluations

Several stream water quality surveys were conducted to determine natural background quality, loads that may be entering main stem water supplies or analyses of water quality in relation to beneficial use impacts. Emphasis in this program has been on selenium although periodic monitoring has also been conducted for other trace elements. The data developed in these programs are being utilized in development of water quality objectives, setting baseline conditions for NPS reduction programs and as a database for modeling of the San Joaquin River system.

1. Sacramento River Basin Survey

Concern was expressed that historical data showed selenium concentrations in the Sacramento River and its tributaries often exceeded the present drinking water standard of 10 microg/L. If true, these levels would exceed those presently found in the San Joaquin River. Staff has conducted a water quality survey to verify the historical data and locate potential sources of selenium loading, especially those coming from NPSs. A report on this investigation has been prepared by the Central Valley Regional Board [40]. The report describes the present selenium concentrations in the Sacramento Valley waterways including the main agricultural drains. Specific findings are:

a. Stream monitoring in the Sacramento River Basin does not support historically recorded high selenium concentrations.

b. Only 11 samples of the 366 collected exceeded 1 microg/L with a maximum for the 11 being 1.6 microg/L, far below the present drinking water standard of 10 microg/L.

c. Selenium concentrations recorded in this study do not show that existing or potential beneficial uses are being adversely affected.

2. San Joaquin River Survey, Water Years (WYs) 85, 86, and 87

As part of the San Joaquin River agricultural drainage water investigations, Central Valley Regional Board staff conducted a water quality monitoring program between May 1985 and March 1988 to evaluate the effects of subsurface agricultural drainage on the water quality of a 60-mile section of the San Joaquin River. This work was initiated as a result of concern expressed for elevated levels of selenium and other trace elements in the River. A report on this water quality survey has been prepared by the Central Valley Regional Board [41]. The report describes the water quality in the San Joaquin River in WYs 85, 86 and 87 and will be utilized to evaluate proposed water quality standards and future agricultural drainage reduction programs in the San Joaquin River Basin. Specific findings are:

a. The highest concentrations of selenium, boron, and salt occurred just downstream of the Mud and Salt Slough confluences with the San Joaquin River.

b. River selenium, salt, and boron concentrations decreased downstream as each of the three east side rivers diluted the San Joaquin River.

c. Concentrations appear to be related to climatic and stream flow conditions in the river basin with concentrations highest in drier years.

d. Concentrations show seasonal variations with the highest concentrations occurring during the nonirrigation season (October to March).

3. San Joaquin River Survey, WYs 88 and 89

As part of the San Joaquin River agricultural drainage water investigations, Central Valley Regional Board staff conducted a water quality monitoring program between October 1987 and September 1989 to evaluate the effects of subsurface agricultural drainage on the water quality of a 60-mile section of the San Joaquin River. This work is a continuation of the work conducted on the River in WYs 1985, 1986, and 1987 to evaluate the elevated levels of selenium and other trace elements in the River. A report on the water quality survey in WY 1988 has been prepared by the Central Valley Regional Board [42]. The report describes the water quality in the San Joaquin River, compares it with previous WYs and will be utilized to evaluate proposed water quality standards and future agricultural drainage reduction programs in the San Joaquin River Basin. Specific findings are :

a. The highest concentrations of selenium, boron and salt continue to occur just downstream of the Mud and Salt Slough confluences with the San Joaquin River.

b. The decreasing trend of river selenium, salt, and boron concentrations continue downstream as each of the three east side rivers diluted the San Joaquin River.

c. Chloride, boron, sulfate, EC, selenium, and molybdenum values in the River appear to be directly related to climatic and stream flow conditions in the River basin. During the critical 1987 and 1988 WYs, constituent concentrations were routinely higher than were during the wet 1986 WY.

d. During WY 1988 these same constituents also show seasonal variations in concentrations with the highest levels occurring during the non irrigation season (October to March).

4. San Joaquin River Survey, WY 90

Because of the continuing discharges into the River and the extended low flow conditions in the River caused by the fourth year of drought, monitoring at selected River stations will continue through the WY. Emphasis will be on the evaluation of the effectiveness and achievability of the critical dry year water quality objectives adopted into the basin plan for the San Joaquin River. A report on the monitoring will be prepared in late 1990 or early 1991.

5. Willow Slough Survey

Monitoring in Willow Slough in Yolo County has shown strongly elevated levels of selenium upstream of the City of Davis Wastewater Treatment Plant. Periodic monitoring by Central Valley Regional Board staff shows that the source of selenium appears to be NPSs including return flows from irrigated agriculture. A more intensive survey of agricultural sources was conducted in the 1989 irrigation season. Follow-up monitoring will be conducted in the 1990 irrigation season with a full report planned for late 1990.

6. Westside Creek Survey

Periodic monitoring by Central Valley Regional Board staff has been conducted on several of the creeks which originate in the Coast Range and discharge into the San Joaquin River and Delta. Monitoring concentrated on boron and selenium levels of these intermittent creeks and whether continuous monitoring would be needed to assess significant loads of these two trace elements to the River and Delta. Monitoring will only continue at the time of initial outflows from these creeks following the long dry period of 1987-1990. Additional periodic monitoring is not expected. Because of the extended drought in the Coastal Range, a preliminary report on the monitoring results is being prepared and should be available in late 1990.

7. Stream Background Survey

A one-time monitoring effort was conducted by Central Valley Regional Board staff to determine the range of natural background concentrations of selected trace elements in natural streams. This monitoring effort was conducted to: (1) represent streams above significant discharges or land use that may alter stream quality; (2) represent streams at their highest flow periods (February-April); and (3) periods when no surface runoff is occurring by having at least a ten-day nonrain period prior to sampling. The main effort of this program is selenium concentrations; however, selected samples were checked for other trace elements. Low level detection was used on all samples. The data developed in this program assisted the Regional Board in understanding the relative distribution of selenium and this was used as background information in developing water quality objectives for the San Joaquin River and identifying additional areas where further source monitoring is needed. No further sampling is anticipated. A draft report on this one-time monitoring effort has been prepared and is receiving peer-review. A final report on this stream survey is expected to be completed in mid 1990.

1.2.1.4 - Development of Objectives

1.2.1.4.1 - Beneficial Use Assessments (Surface Waters)

As part of the process of amending the San Joaquin River Basin Plan (5C), a review of selected beneficial uses of surface and ground waters was made. Efforts were concentrated on those waters affected by the discharge of agricultural subsurface drainage water. Six surface water surveys were made of water diversions and their type of use and a survey was made of the type of tributaries that are entering the Mud and Salt Slough system. Each of the surveys was used as a basis for review of the Basin Plan which was amended on December 8, 1988. No additional surveys are planned. Summaries of completed surveys are presented here:

1. Water Use on the Main San Joaquin River (Mendota to Mossdale)

   A field and aerial survey was made of water diversion points along the 150 mile reach of the San Joaquin River from the Mendota Pool near Mendota to the Mossdale Bridge near Tracy. In addition to the segments of the main channel that were surveyed, special surveys were conducted on Bear Creek, the West Stanislaus Irrigation District Main Intake Channel, and the Grayson Slough Channel which was formerly the main branch of the San Joaquin River. All of these special surveys were conducted as significant inflow and outflow points occur on these channels and the main channels are not monitored as they enter the San Joaquin River. The survey included locating all sites, determining active or inactive use and the type of use being made of diverted water. The majority of sites were being put to agricultural beneficial use; therefore, a survey was made of the acreage being irrigated, the type of crop being grown and the likely seasons of use. This information has formed the basis for the San Joaquin River input-output model developed by the State Board. A final report on this survey has been prepared [43]. The report has been prepared in three volumes--the main text, Appendix A, and Appendix B. The main text summarizes information from both the discharge points to the San Joaquin River as well as the diversions from the River. Appendix A provides detailed descriptions of each diversion point. Appendix B contains the beneficial use survey conducted along the River between Lander Avenue and Airport Way. Due to the importance of maintaining beneficial use of the water being diverted, a special use survey was conducted of the 48 water diversion points occurring in between Lander Avenue and Airport Way. These 48 points supply all or a portion of the irrigation supply for over 60,000 irrigated acres which produce a variety of field, vegetable, orchard, and pasture crops. All of the diversion points were putting the water to agricultural beneficial use with almost all using the water for irrigation. This reach of the River is most directly affected by discharges of agricultural subsurface drainage water. A detailed discussion of the results of this survey are given in Appendix B. The report shows that:

a. The 150-mile reach of the San Joaquin River has 89 points of water diversion for beneficial use.

b. The greatest density occurs in the lower reaches of the River.

c. The density of diversion points increases downstream from the Hills Ferry Bridge as each east side tributary contributes flow to the River. The density per mile doubles in moving from the Hills Ferry Bridge to the Mossdale Bridge

Results from this survey, in particular information from Appendix B, has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

2. Water Use on the Tuolumne River Downstream of Highway 99

A field and aerial survey was made of water diversion points along 16 miles of the Tuolumne River from the Highway 99 Bridge to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.1.1). A final report on this survey has been prepared by the Central Valley Regional Board [44]. The report shows that:

a. Flow in the Tuolumne River within the study area was found to be highly regulated and strongly influenced by discharges or diversions into the River.

b. The 16-mile section of the Tuolumne River surveyed in this study has 18 diversion points from the River.

c. The greatest density of diversion points occurs on the northern bank of the River with all water diverted for the beneficial use of irrigated agriculture.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

3. Water Use on the Merced River Downstream of Cressey Bridge

A field and aerial survey was made of water diversion points along a 28 mile reach of the Merced River from the Cressey Bridge to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.1.1). A final report on this survey has been prepared by the Central Valley Regional Board [45]. The report describes:

a. The 28-mile section of the Merced River as having 49 water diversion points for beneficial use of irrigated agriculture. These are scattered throughout the entire 28-mile River section.

b. The sites are equally divided between the north and south bank of the River; however, in the upper River section (Highway 99 to the Cressey Bridge) a high number of diversion sites occur along the northern bank. In the lowest River section (mouth to the Stevinson Bridge), the opposite is true, a higher number of sites occurring along the southern bank.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

4. Water Use on the Stanislaus River Downstream of Highway 99

A field and aerial survey was made of water diversion points along a 16-mile reach of the Stanislaus River from the Highway 99 Bridge to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.1.1). A final report on this survey has been prepared by the Central Valley Regional Board [46]. The report shows that:

a. The 16-mile section has 16 points of water diversion for beneficial use.

b. The greatest density of diversion points occurs in the lower section of the River (mile 0-8). The majority of diversions from the River occur within miles 4-7 and 9-11.

c. The number of diversion points are equally divided between the northern and southern banks of the River.

d. Beneficial use of the diverted water is irrigated agriculture.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

5. Water Use on Mud Slough (north)

A field and aerial survey was made of water diversion points and their beneficial use along Mud Slough (north) from its origin to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.1.1). Mud Slough (north) has only two diversions. Both diversions are by gun clubs and the water is now used for pasture irrigation and on some field crops. Prior to 1985, the water was used to maintain seasonal wetlands. Because of the limited water use, the report on this activity was included in the report on discharge points into Mud Slough (see Section 1.2.1.4.3.6). A report was prepared by the Central Valley Regional Board [47].

Results from this survey have been used as part of the basis for review of the San Joaquin Basin Plan (5C).

6. Water Use on Salt Slough

A field and aerial survey was made of water diversion points and their beneficial use along Salt Slough from its origin to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.1.1). Salt Slough currently has nine diversions. Of the nine diversions, six are used for irrigation of pasture and stock watering and one is used for irrigation of field crops. The remaining two diversions are used by the San Luis NWR for flooding duck ponds. Because of the limited water use, the report on this activity was included in the report on discharge points into Salt Slough (see Section 1.2.1.4.3.7). The results from this survey [48] have been used as part of the basis for review of the San Joaquin Basin Plan (5C).

7. Tributaries to Mud Slough (north)

As part of the process for amending the San Joaquin Basin Plan (5C), beneficial uses of surface waters within the Basin had to be determined. Mud Slough (north) is a major tributary to the San Joaquin River. In addition, the slough serves as a conveyance for subsurface agricultural drainage from its tributaries to the San Joaquin River. A detailed field and aerial appraisal of the slough tributaries was conducted to determine their location, actual use and operation and how these might influence water quality in Mud Slough (north). The information developed in this program was utilized in establishing beneficial uses for Mud Slough (north) during the San Joaquin River Basin Plan Amendment process. A final report on the tributary survey was prepared by the Central Valley Regional Board [49]. The report shows that:

a. The slough has four major tributaries: Santa Fe Canal, Los Banos Creek, Fremont Canal, and Kesterson Ditch. Each of these tributaries has several tributaries, some of which carry agricultural drainage water.

b. Of the four main tributaries, only Los Banos Creek is not a man-made earth-lined canal along its entire length.

c. The tributaries of Mud Slough (north) are a complex network that is used for different purposes (sometimes incompatible) throughout the year.

d. The water quality of all these tributaries is highly influenced by management decisions which result from the manipulation of the water system in the Grassland Water District. Because the slough's major tributaries are maintained as man-made or man-altered agricultural drainage channels, they do not provide the same beneficial uses as Mud Slough (north).

8. Tributaries to Salt Slough

Salt Slough is a major tributary to the San Joaquin River. In addition, the slough serves as a conveyance for subsurface agricultural drainage from its tributaries to the San Joaquin River. A detailed field and aerial appraisal of the slough tributaries was conducted to determine their location, actual use and operation and how these might influence water quality in Salt Slough.

The information developed in this program was utilized in establishing beneficial uses for Salt Slough during the San Joaquin River Basin Plan Amendment process. A final report on the tributary survey prepared by the Central Valley Regional Board [50] shows that:

a. The slough has three major tributaries; Salt Slough Ditch, West Delta Drain, and Mud Slough (south).

b. Each of these tributaries has several tributaries, some of which carry agricultural drainage water. The water quality of all these flows is highly influenced by management decisions which result in manipulation of the water system in the Grassland Water District.

c. Because of this operation and the large fluctuations in water quality, the beneficial uses of the tributaries to Salt Slough stand alone and cannot be considered to be the same as the beneficial uses of the slough itself.

1.2.1.4.2 - Beneficial Use Assessments (Ground Waters)

The discharge of agricultural drainage water, including that into evaporation basins and other areas, has raised concern that localized ground water impacts may be occurring that are affecting designated beneficial uses. Ground water surveys in three areas have been conducted: the south Grassland area, the Patterson-Westley area, and the Kesterson Reservoir area. The work on these are summarized below. Further ground water work in the vicinity of the evaporation basins will continue as part of the regulatory process for these facilities.

1. South Grassland Area

Agricultural subsurface drainage water from the Panoche Fan area of Fresno and Merced Counties has been discharged into and through the south Grassland area for several years. With the finding of elevated trace elements, especially selenium, in this drainage water, concern has been raised that impacts to ground water beneficial use, especially drinking water, may be occurring. A staff ground water survey was conducted which included locating all existing and abandoned wells in the South Grassland area, field surveys of all existing and potential uses, water quality background sampling and comparison of this data to historical data to determine if major changes have occurred. The report [51] shows that:

a. The beneficial uses of the local ground water include domestic, irrigation, stock watering, dairy industrial, and recreational use. The 44 wells sampled in this study included domestic and irrigation wells.

b. Ground water quality in the area which received agricultural drainage water had high levels of salinity, boron, chloride, and molybdenum. The high levels may be due, in part, to the application of agricultural drainage water, but are strongly influenced by the natural features of the area.

c. Natural features of the area which affect ground water quality are an arid climate, a shallow water table, and fine-textured and poorly-drained, alkaline soils.

d. High levels of molybdenum are related to the presence of Sierra-Nevada deposits in the subsurface.

e. Ground water quality upgradient of the study area is better in terms of salinity, boron, chloride, and molybdenum but selenium and chromium levels are higher.

f. Ground water quality downgradient is similar to that observed within the study area.

2. Patterson-Westley Ground Water Investigation

The finding by a USGS reconnaissance study of high selenium levels in drinking water wells in the Patterson-Westley area of Stanislaus County raised a concern that tile drainage or other agricultural practices may result in high levels being discharged to surface water. Staff conducted a more intensive ground water survey in the area to verify the levels and potential sources. The report [52] describes the water quality found in the Patterson-Westley area and its potential origins. Specific findings are:

a. Water samples collected from 34 wells confirms the location and concentrations identified in the 1985 USGS study.

b. Concentrations of selenium exceeding the 10 microg/L EPA drinking water standard occurred both within and outside the present subsurface drainage problem areas.

c. The selenium in the Patterson-Westley ground water appears to be the natural background level and the Moreno and Panoche Formations in the Coast Ranges directly to the west of the study area are likely sources of selenium.

d. There is no evidence that present irrigation practices are contributing to the selenium levels in the Patterson-Westley ground water.

3. Kesterson Area Ground Water Survey

In March 1987, the State Board directed the Central Valley Regional Board (State Board Order No. WQ 87-3) to reconsider the beneficial use designations for ground water in the vicinity of Kesterson Reservoir in Merced County. Specifically, the Order asks the Central Valley Regional Board to "consider establishing beneficial uses which distinguish between the upper and lower ground water aquifers". The basis for the request was preliminary evidence submitted by USBR that indicated the upper aquifer was of marginal quality which did not support current beneficial use designations, and that the vast majority of ground water users were taking water only from the better quality lower aquifer. A report [53] has been prepared by the Central Valley Regional Board and transmitted to the State Board to meet the requirements of State Board Order No. WQ 87-3. The report findings are:

a. The ground water aquifer in the Kesterson Reservoir Area is similar to the remainder of the ground water basin designated in the Basin Plan and should not be considered separately for beneficial use designations.

b. The beneficial use designations in the Basin Plan are all existing beneficial uses within the study area and should not be modified.

c. The designated beneficial uses of the ground water are active uses in both the upper and lower aquifers in the study area; therefore, the Central Valley Regional Board should not consider setting separate beneficial use designations for each aquifer.

d. The beneficial use for waterfowl and aquatic habitat is an existing beneficial use in the study area and throughout the Basin Plan designated ground water basin. The Central Valley Regional Board should consider adding this beneficial use during the Basin Planning update process but should recognize that, as with other designated uses, existing water quality does not always meet criteria established for this use.

e. The quality of water being extracted for beneficial use from the upper aquifer was found to be of equal or better quality than that used from the lower aquifer; therefore, the Central Valley Regional Board should not consider removing beneficial use designations because of water quality. The Central Valley Regional Board may want to consider noting in the Basin Plan that quality occasionally does not meet the established safe levels but this has not limited beneficial use.

f. Because existing water quality periodically approaches or exceeds established safe levels in the study area, the Central Valley Regional Board should maintain a strong regulatory program for ground water protection in the area to prevent degradation which would limit beneficial uses.

g. Approximately 30 percent of the wells located in the study area were abandoned wells. The Central Valley Regional Board should request the Merced County Health Department to increase its efforts to assess whether these wells should be properly abandoned and sealed in accordance with their present well ordinance.

1.2.1.4.3 - Discharge Assessment

Several site-specific assessments were conducted to determine the location and extent of agricultural surface and subsurface drainage water discharges. Initial efforts for the assessment of agricultural surface discharges has concentrated on those locations which carry a blend of surface and subsurface drainage water. Emphasis in this program is on selenium and other trace element sources. A summary of these activities is presented below.

1. San Joaquin River Discharges

A field and aerial survey was made of all discharge points along the San Joaquin River from the Mendota Pool to the Mossdale Bridge. In addition to the segments of the main channel that were surveyed, special surveys were conducted on Bear Creek, the West Stanislaus Irrigation District Main Intake Channel, and the Grayson Slough Channel which was formerly the main branch of the San Joaquin River. All of these special surveys were conducted as significant inflow and outflow points occur on these channels and the main channels are not monitored as they enter the San Joaquin River. The survey included locating all sites and determining the main source of water being discharged. For the major discharge points from the western side of Stanislaus County, the approximate area serving each drain discharge point was determined. The survey information has formed the basis for the San Joaquin River input-output model developed by the State Board. This information is also being utilized by the local Resource Conservation Districts to assess the magnitude of the sediment discharge problem.

A final report on the survey has been prepared [43]. For discharges, the report has been prepared in two volumes--the main text and Appendix A. The main text summarizes information from both the discharge points to the San Joaquin River as well as the diversions from the River. Appendix A provides detailed descriptions of each discharge and diversion point. The report shows that:

a. Flow in the River from Mendota Dam to the Salt Slough inflow (75 River miles) consists exclusively of irrigation water diversions from the Mendota Pool and operational spill waters. The River is often dry beyond points of diversion for irrigation, thus flow, although highly variable, is dependent upon irrigation operations and localized seepage.

b. Flow in the River from the Salt Slough inflow to the Merced River (11 River miles) is principally irrigation return flows from Mud Slough (north) and Salt Slough.

c. The remainder of the River downstream of the Merced River is influenced by natural flow from the main east side tributaries and numerous diversions and discharges.

d. The 150-mile reach of the San Joaquin River surveyed in this study (Mendota Dam to Mossdale Bridge) has 193 discharge points.

e. The greatest concentration of discharge points occurred from Hills Ferry Bridge to Vernalis. In this reach, 66 discharge points occurred in the 46 River miles, nearly twice the density found in any other River section. This is the section of the River immediately downstream of the subsurface tile drainage entering through Mud Slough (north) and Salt Slough.

Results from this survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C) which was amended on December 1988.

2. Tuolumne River Discharges

A field and aerial survey was made of all discharge points along 16 miles of the Tuolumne River from the Highway 99 Bridge to the San Joaquin River. The survey included locating all sites and determining the main source of water being discharged. A final report [44] on this survey has been prepared by the Central Valley Regional Board. The report shows that:

a. Flow in the Tuolumne River within the study area was found to be highly regulated and strongly influenced by discharges or diversions into the River.

b. The 16-mile section of the Tuolumne River surveyed in this study (Highway 99 to mouth) has 14 discharge points to the River.

c. The greatest concentration of discharge points occurs near the mouth of the River. In this section there are seven discharge points, the most significant of which is operational spill from Modesto Irrigation District.

d. The other significant discharge on the River is an operational spill from Turlock Irrigation District.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

3. Merced River Discharges

A field and aerial survey was made of all discharge points along a 28-mile reach of the Merced River from the Cressey Bridge to the San Joaquin River. The survey included locating all sites and determining the main source of water being discharged. A final report on this survey has been prepared [45]. The report describes:

a. The 28-mile section of the Merced River surveyed in this study as having 14 discharge points.

b. All but four of these are tailwater drains that serve localized small areas and only flow water when the fields are being irrigated. The remaining four; Stevinson Water District Drain, Turlock Irrigation District Faith Home Road Canal Spill, Merced Irrigation District Garibaldi Lateral Spill, and the Merced Irrigation District Livingston Canal Spill consist primarily of good quality operational spills from irrigation district canals. These latter four contribute a significant flow to the Merced River during the irrigation season.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

4. Stanislaus River Discharges

A field and aerial survey was made of all discharge points along a 16-mile reach of the Stanislaus River from the Highway 99 Bridge to the San Joaquin River. The survey included locating all sites and determining the main source of water being discharged. A final report on this survey has been prepared [46]. The report shows that:

a. Flow in the Stanislaus River was found to be highly regulated and strongly influenced by discharges or diversions into the River.

b. The 16-mile section of the Stanislaus River surveyed in this study (Highway 99 to mouth) has eight discharge points.

c. The greatest concentration of discharge points occurs near the mouth of the River. The other significant discharge occurs from Modesto Irrigation District Supply Lateral No. 6 closer to Highway 99.

The survey has been used as part of the basis for review of the San Joaquin Basin Plan (5C).

5. Delta-Mendota Canal Survey

Concern was raised that discharges, including those containing selenium into the Delta-Mendota Canal downstream of the O'Neill Forbay, may be affecting beneficial uses including municipal supply. Central Valley Regional Board staff investigated the check drains of the Delta-Mendota Canal as potential sources of selenium to this canal and the Mendota Pool between canal mile posts 70.00 and 115.57 (O'Neill Forbay and the Mendota Pool). A report on this initial survey has been prepared [54]. The report shows that:

a. The water being discharged was for the most part agricultural tail water, however, in some instances subsurface drainage was mixed with the tail water.

b. A drainage area study was made for each check drain. In some instances, these drainage areas include subsurface drainage sumps.

c. Nineteen (19) check drains are suspected of receiving subsurface drainage.

d. Follow-up monitoring will continue at selected sites as well as ongoing USBR monitoring.

e. In at least one instance, agricultural chemicals were suspected of being present.

Because of the close proximity of the irrigated fields to the Delta-Mendota Canal, a high potential exists for the check drain discharges to contain agricultural chemicals. The canal and discharge survey have been expanded to include areas upstream of the O'Neill Forbay as several complaints have been received regarding discharges to these reaches. Initial surveys of the location and cropping patterns of the drainage basins have been conducted. This will be followed by on-site discharge monitoring during the 1990 irrigation season. A report on the expanded survey will be prepared after the 1990 irrigation season.

6. Mud Slough (North) Discharges

A field and aerial survey was made of all discharge points along Mud Slough (north) from its origin to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.3.1). A full report on this survey has been prepared [47]. The report shows that:

a. Mud Slough (north) drains the area west of the San Joaquin River.

b. During the winter and early spring its flows are a mixture of subsurface agricultural drainage, precipitation runoff, and discharges from local duck clubs and wildlife refuges.

c. During the summer and fall its flows are made up of agricultural tail water, irrigation district spill water and subsurface agricultural drainage.

d. Mud Slough (north) has 42 discharges. Most discharges are from wetlands areas, either private duck clubs or federal refuges, and are seasonal discharges of low volume.

e. Half of the discharges enter Mud Slough (north) prior to Gun Club Road, i.e., in the first 3.4 of 16 miles.

f. The major discharges are the tributaries; Kesterson Ditch, Fremont Canal, Santa Fe Canal, and Los Banos Creek. The latter three of which enter downstream of Gun Club Road.

g. All four tributaries may carry agricultural subsurface drainage and irrigation district spill water at one time or another. However, the majority of the subsurface agricultural drainage reaches Mud Slough (north) via the Santa Fe Canal and the majority of the flows in Los Banos Creek are irrigation district spill water.

Results from this survey have been used as part of the basis for review of the San Joaquin Basin Plan (5C).

7. Salt Slough Discharges

A field and aerial survey was made of all discharge points along Salt Slough from its origin to the San Joaquin River. The survey was conducted similar to the one conducted on the main stem of the San Joaquin River (see Section 1.2.1.4.3.1). A full report on this survey has been prepared [48]. This report shows that:

a. Salt Slough drains the area west of the San Joaquin River. The majority of its flow originates in the San Luis Canal Company Water District. However, major inputs are received from the Central California Irrigation District, Poso Canal Company and the Grassland Water District.

b. During the winter and early spring its flows are a mixture of subsurface agricultural drainage, precipitation runoff, and discharges from local duck clubs and wildlife refuges. During the summer and fall its flows are made up of agricultural tailwater, irrigation district spill water, and subsurface agricultural drainage.

c. Salt Slough currently has 71 discharges and 12 natural channels. The majority of discharges are small field drains draining small areas of field crops and pasture land, or drain duck ponds from the San Luis NWR or private duck clubs.

d. The major discharges to Salt Slough all enter south of the refuge and within the first four miles. These are the tributaries; Salt Slough Ditch, West Delta Drain, and Mud Slough (south).

e. Both Salt Slough Ditch and Mud Slough (south) may carry subsurface agricultural drainage as well as irrigation district spill water.

f. The West Delta Drain does not carry any subsurface agricultural drainage but may carry some irrigation district spill water or ground water seepage.

Results from this survey have been used as part of the basis for review of the San Joaquin Basin Plan (5C).

8. Kings River Discharge Survey

Agricultural discharges including over 50 on the South Fork of the Kings River alone, have raised concern that subsurface drainage water discharges may cause the Kings River to exceed established water quality objectives and impact beneficial uses. An instream water quality survey has been initiated and will be continued throughout the 1990 irrigation season. A progress report has been prepared in cooperation with the Kings River Resource Conservation District. A full report will be prepared in late 1990 or early 1991.

9. Grassland Area Discharge Survey, WYs 85, 86, and 87

As part of the San Joaquin River agricultural drainage water investigations, staff conducted a water quality monitoring program between May 1985 and March 1988 to evaluate the effects of subsurface agricultural drainage on the water quality of the drains in the Grassland Area of western Merced County. A report on this survey was prepared [55]. The report describes the present water quality in the Grassland Area in WYs 85, 86 and 87 and will be utilized in development and evaluation of future agricultural drainage reduction programs in the San Joaquin River Basin. Specific findings are:

a. Four inflow drains into the southern Grassland Area carry a substantial portion of subsurface drainage water. These sites carry the highest concentrations of salts, boron, and selenium. Other inflows contain little selenium, however, elevated concentrations of salts and boron are present in these other drains.

b. Concentrations at the internal flow monitoring points and the monitoring stations for outflow from the Grassland Area showed comparable quality to each other. Differences reflect the amount of mixing and dilution that takes place as drainage water moves through the Grassland Area.

10. Grassland Area Discharge Survey, WYs 88 and 89

As part of the San Joaquin River agricultural drainage water investigations, staff conducted a water quality monitoring program between October 1987 and September 1989 to evaluate the effects of subsurface agricultural drainage on the water quality of the drains in the Grassland Area of western Merced County. This work is a continuation of the work conducted in the Grassland Area in WYs 85, 86, and 87. A report on this survey has been prepared by the Central Valley Regional Board [56]. The report describes the water quality in the Grassland Area in WY 88 and will be utilized in development and evaluation of future agricultural drainage reduction programs in the San Joaquin River Basin as well as provides a long-term database for assessing the effects of future regulatory actions. Specific findings are:

a. The current study shows that water quality continues to vary widely with the highest constituent concentrations found at the inflow monitoring stations near the southern boundary of the study area. This inflow water is generally a blend of subsurface tile drainage and surface runoff (tailwater) or operational spills from irrigation canals.

b. Four of these inflow points carry a substantial portion of subsurface drainage water.

c. The sites inflowing from the south and southeast continue to carry the highest concentrations of salts, boron, and selenium. Other inflows contain little selenium; however, elevated levels of salt and boron are present.

d. Concentration at the internal flow and outflow monitoring stations were comparable to each other and were substantially lower than the southern inflows. The water quality reflects the amount of mixing and dilution that takes place as drainage water moves through the Grassland Area.

e. The two main outflows, Mud Slough (north) and Salt Slough were monitored during the study. The quality of both sloughs varied widely depending upon which slough was carrying the greatest portion of subsurface tile drainage water.

f. Concentrations for all the drains and sloughs were routinely higher during the critical WYs 87 and 88 than they were during the wet WY 86.

g. Seasonal variations in constituent concentrations occurred in WY 1988 in a manner similar to the previous two WYs, with the highest levels occurring during the nonirrigation season (October to March).

Because of the continuing discharges into the Grassland Area and the San Joaquin River, and the low flow conditions occurring in these areas as a result of the drought extending into WY 89, monitoring at selected stations continued through the 1989 irrigation season. A report on the monitoring conducted in WY 89 will be prepared in late 1990.

11. Grassland Area Discharge Survey, WY 90

Because of the continuing discharges into the Grassland Area and the San Joaquin River caused by the fourth year of drought, monitoring at selected river and grassland area stations will continue through the WY. Emphasis will be on the evaluation of the effectiveness and achievability of the critical dry year water quality objectives adopted into the Basin Plan for the San Joaquin River. Emphasis also will be on setting a baseline condition prior to new management schemes such as the Zahm-Sansoni Plan being implemented. A report on the monitoring will be prepared in late 1990 or early 1991.

12. 48-Hour Drain Survey

All dischargers of tile drainage in the Grassland Basin take grab samples for determining selenium concentrations of the drain water. Concern has been expressed that these grab samples are not representative of the total load when analyzed with daily and weekly flow records. Central Valley Regional Board staff conducted a 72-hour water quality test on four of the main discharge drains and have concluded that grab samples are adequate to represent quality leaving various districts and leaving the Grassland Area. A report on this test has been prepared (57). The result of the study showed that:

a. The larger drains, Firebaugh and Panoche, showed relatively little fluctuation throughout the day.

b. The constituent concentrations in the much smaller Charleston Drain fluctuated much more, deviating from mean concentrations by as much as 65 percent.

c. Changing to a six-hour composite sampling method for these larger drains should have very little affect on data accuracy.

d. Only a small gain in accuracy would be obtained at the smaller drains in changing methods.

e. The present grab sample method is sufficiently accurate and the composite sampling method is not necessary.

13. Grassland Basin Discharge Loads

As part of the Basin Plan amendment process, Central Valley Regional Board staff have evaluated the various loads of salt and trace elements that are leaving the Grassland Basin through Mud Slough (north) and Salt Slough. In addition, preliminary load estimates were made for various points entering the Grassland Water District. These remain preliminary because flow data leaving the districts is still preliminary. Future work will include concentration monitoring to upgrade and refine these preliminary estimates. A report on the Grassland Basin loads will be prepared in 1990.

14. San Joaquin River Toxicity Testing

Central Valley Regional Board staff are finishing up a two year survey of biotoxicity in the San Joaquin River watershed. The purpose is to characterize both temporally and spatially water quality as measured by bioassay organisms. Water samples are collected at eight River sites from Mendota Pool to Mossdale and at seven River inputs. The inputs were chosen because they were either major sources of River water or were thought to be representative of other common sources of River water. Principally, these were agricultural tail and spill water and tile drain water inputs.

EPA's three species protocols are employed for assessing toxicity. These procedures estimate the acute and chronic responses of organisms from three phyla (fish, zooplankton, and algae). EPA has evaluated the utility of the tests and has determined at the eight sites investigated that instream toxicity, as measured by the three species test, was correlated with aquatic community degradation (as measured by decreases in both the number and kind of organisms present).

Thirteen biotoxicity surveys have been conducted to date on the San Joaquin River. Five additional surveys are scheduled to be completed between now and the end of June 1990 when the program will finish. The principal finding to date is that there is an invertebrate toxicological problem in the main stem River. About 25 percent of the water samples collected from the River produced 30 percent or greater mortality in seven days than both the laboratory control water and water samples collected on the same date from Mendota Pool (the present headwaters of the San Joaquin River). The suspected cause of toxicity is pesticides emanating from agricultural tail water.

Test results and conclusions will be presented in a final report to be prepared this spring. Planned follow-up studies for 1990-91 are to begin to identify the precise pesticides and agricultural crops producing the off-target movement of pesticides in the San Joaquin River watershed.

15. Drain Locations - San Joaquin River Basin

As part of the assessment of the impacts of tile drainage, Central Valley Regional Board staff, in cooperation with the irrigation and drainage districts in the area, collected information on the location of all subsurface drains in the San Joaquin River Basin. This information was used to design monitoring programs as well. The information was used by the San Joaquin Valley Drainage Program (SJVDP) to determine the rate of installation of subsurface drains. No further assessment of drain locations is anticipated. The SJVDP has combined this information with other data and developed a considerable number of maps which show the results of the Central Valley Regional Board work.

16. Solano Irrigation District Discharges

Past monitoring of Cache and Lindsay Sloughs have shown detectable levels of selenium. Although these concentrations are below the drinking water standard, a primary beneficial use of these sloughs, they may be impacting wildlife uses as these sloughs normally have poor outflow characteristics, thus acting as impounded waters. Initial Central Valley Regional Board efforts are directed at identifying and monitoring the sources of this selenium. Preliminary results to date indicate that NPS runoff and seepage, especially during the irrigation season, may be the key factor in the present selenium levels in the sloughs. Additional confirmation monitoring is planned for the 1989 irrigation season with a report on this effort planned for mid 1990.

1.2.1.4.4 - Basin Planning - Water Quality Objectives

The State Board, as part of State Board Order No. WQ 85-1, directed the Central Valley Regional Board to adopt water quality objectives for the San Joaquin River and implement a program to regulate agricultural subsurface drainage water discharges. As part of that effort, the Central Valley Regional Board was asked to conduct several studies, especially on agricultural water quality needs. Two studies, one on animal drinking water and another on trace element limitations for water utilized for irrigation of crops, are in progress and the initial Basin Plan Amendments have been prepared. The following summarizes these efforts:

1. Animal Drinking Water Guidelines

One of the designated beneficial uses of most waters in the San Joaquin River Basin is for animal drinking water supply. Many of these waters currently have agricultural subsurface drainage water in them containing elevated levels of selenium, molybdenum, and other trace elements. At the present time, the only known guidelines for establishing safe levels of these trace elements for animal drinking water are the 1972 National Academy of Sciences (NAS) guidelines prepared for EPA. Central Valley Regional Board staff are concerned that these guidelines may not reflect the latest in research findings. In particular, we know of many studies on selenium uptake by living organisms which were initiated after 1984 - the year toxicity problems were discovered in Kesterson Reservoir.

The Central Valley Regional Board contracted with researchers from South Dakota State University in Brookings and Colorado State University at Fort Collins to review animal drinking water guidelines for selenium and molybdenum based on the prior data and current literature. The review also identified factors in the San Joaquin Valley which may influence the guidelines. These factors include, but are not limited to, semi-arid environment, general poor quality water, including water high in sulfate, and extensive feedlot operations combined with large tracts of rangeland. A final report has been prepared and received for review [58]. The report shows that:

a. Based on the current review, the researchers have recommended 50 microg/L selenium and 50 microg/L molybdenum as guidelines for safe animal drinking water concentrations.

b. The researchers also recommend that regional guidelines take into account the concentration of the element of concern in livestock feed and be adjusted accordingly.

c. The researchers recommend that future studies for both elements focus on long-term effects of lower concentrations on farm animals.

We will use this information as the basis for modifying water quality objectives for these two elements.

The Central Valley Regional Board is also in the final stages of developing a contract with NAS to review the animal drinking water guidelines for the remainder of the trace elements found in the agricultural drainage water. This review will include:

a. A review of the basis for existing guidelines for safe levels of selected trace elements in animal drinking water as established in 1972 by the NAS for the EPA, and a review of the recent literature on mineral nutrition and tolerance.

B. An evaluation of the need for establishing separate guideline values for each class of livestock (beef, dairy, sheep, swine, poultry, and horses).

C. Recommendation for guidelines for safe levels of selected trace elements in the drinking water of the most sensitive classes of livestock. These guidelines must differentiate between arid and semi-arid areas (western United States) and the more humid areas.

D. An outline of the studies needed to provide the necessary data for establishing guidelines when such data are missing or insufficient.

It is anticipated that this information will be available in final form in mid-1992.

2. Trace Elements in Irrigation Water

Reuse of drainage water and irrigation use of blended water currently occurs in the San Joaquin River Basin. Irrigation use is a designated beneficial use on almost all waters in the basin. Many of these waters currently have agricultural subsurface drainage water in them containing elevated levels of selenium, molybdenum, boron, and other trace elements. At the present time, the only known guidelines for establishing safe levels of these trace elements for irrigation waters are the 1972 NAS Guidelines prepared for EPA.

Because of concern that these guidelines may not reflect the latest in research findings nor reflect the conditions in the western portion of the San Joaquin Valley, the Central Valley Regional Board initiated a contract with the University of California at Riverside to review the existing guidelines, the data used to develop these guidelines and current research information to see if changes in the guidelines are needed for west side San Joaquin Valley conditions. The University has submitted their report and recommended guidelines. During review of the report, however, it was found that there was considerable difference of opinion among professionals in this field on the needed safety limits for certain trace elements. Part of this difference results from site-specific studies conducted by researchers that may or may not apply to the San Joaquin Valley (west side). Finalization of the draft report has been placed on hold and the Central Valley Regional Board will review in FY 1990-91 the need to develop a more comprehensive review of portions of the report. The guidelines for selenium and molybdenum--two elements which have been detected at elevated concentrations as a result of agricultural return flows are in a final form. Two mini reports have been published in the Journal of Environmental Quality (59). These reports show that selenium and molybdenum can be used in most irrigation instances if they do not exceed 100 microg/L and 50 microg/L, respectively.

It is presently anticipated that a contract will be developed with NAS or the University of California to prepare the review and update of the remaining trace elements.

3. Basin Plan Amendments - San Joaquin River Basin

The State Board adopted State Board Order No. WQ 85-1 on February 5, 1985. That Order, in part, required that a Technical Committee be formed to look into the regulation of agricultural drainage discharges in the San Joaquin Basin and that the Central Valley Regional Board adopt appropriate Basin Plan amendments and implement a program to regulate agricultural drainage flows in the San Joaquin Basin.

The Technical Committee was charged with the specific tasks of developing: (1) proposed water quality objectives for the San Joaquin River Basin. (2) proposed effluent limitations for agricultural drainage discharges in the basin, and (3) a proposal to regulate these discharges. The Technical Committee has completed its work and issued a report that includes recommended water quality objectives and a recommended plan of implementation.

Proposed amendments to the Basin Plan for the San Joaquin Basin (5C) have been developed based upon: (1) the Technical Committee Report; (2) two workshops on potential Basin Plan amendments; and (3) comments received on two staff reports on potential Basin Plan amendments. The amendments are directed at the control of the discharge of toxic pollutants, principally selenium, in agricultural subsurface drainage. The basin plan amendments consist of identification of the two tributaries of the San Joaquin River that carry the majority of the agricultural subsurface drainage pollutant load as separate waterbodies, designation of their beneficial uses, water quality objectives for them and the San Joaquin River, a program of implementation and cost and funding information required by Section 13141 of the California Water Code.

The proposed amendments to the Basin Plan were adopted on December 8, 1988. The adopted amendments and the supporting information were transmitted to the State Board for adoption. The State Board approved the amendments, and follow-up and implementation are in progress.

4. Panoche Fan Ground Water Hydrology

To meet the water quality objectives, those areas that influence the quantity and quality of flows into the San Joaquin River must be regulated. Areas known to have a strong influence on river water quality and flow volumes are the tiled areas that discharge subsurface agriculture drainage water into the River. In addition, areas that are upslope from the tile drained areas may indirectly influence the quality and quantity of the subsurface agricultural discharges. Water moving past the crop root zone in these areas eventually moves downward into the ground water and then downslope, thus increasing the volume and loads of the tile drainage water.

The Central Valley Regional Board has begun preliminary efforts to evaluate the hydrogeology in the west-central San Joaquin Valley in order to determine how irrigation practices influence ground water levels and flow directions and how these practices may contribute to the drainage problem in the tile drained areas. The study area is the two major water-bearing zones present in the western San Joaquin Valley between Los Banos and Tranquility (Panoche Fan area).

A number of ongoing studies by the USGS and others will be utilized to conduct this study. If features can be defined well enough, specific areas that are likely contributing or might contribute to the problem will be identified. A report on this effort is expected in late 1990.

1.2.1.5 - Regulations for Treatment and Disposal

1.2.1.5.1 - Evaporation Basin in the San Joaquin Valley

With the lack of a cost effective outlet for subsurface drainage water from the southern San Joaquin Valley, more farmers are installing evaporation basins (ponds) as a means of disposing of the drainage water. These basins remain an interim disposal method that must be worked into the long-term disposal plans. Because a salt outlet to the ocean continues to have major environmental problems, the evaporation basins are becoming a more permanent solution. Experience in managing these facilities, however, is limited and concern is now being raised that these basins may be building up toxic levels of trace elements. The Central Valley Regional Board has begun efforts to characterize these basins and utilize this information in setting regulatory requirements. The following six studies are involved in this effort.

1. Water and Sediment Quality, 1985-87

   Concern was expressed at the State Board Kesterson Hearings that other sites within the San Joaquin Valley used to store and evaporate agricultural subsurface drainage water may be creating similar hazards to the environment. Upon direction of the Central Valley Regional Board, staff conducted a program to evaluate water quality at each site and determine whether high selenium or other trace element levels were present or would occur. Between 1985 and 1987, Central Valley Regional Board staff conducted three water and sediment quality surveys of the 27 existing evaporation basins. A report on this investigation has been prepared [60]. The report describes the present water quality situation at each site and will be utilized in future regulatory work. Specific findings are:

   a. Inflow trace element concentrations, although varying widely between sites, appeared to show a relationship with the geologic setting of the basins. None of the basin inflow water concentrations exceeded the hazardous waste levels established in Title 22, California Code of Regulations (CCR), Section 66699.

   b. Future monitoring efforts should be directed at four trace elements: selenium, molybdenum, arsenic, and boron. Each of these elements occurs in high concentrations in one or more of the basins. Concentration of selenium in pond water, only one basin exceeded the hazardous waste limit (1000 ppb). The water quality data will be used in determining application of Subchapter 15 of Title 23, Chapter 3 of the CCR.

   c. Trace element concentrations in sediments were low in relation to the hazardous waste limits. Further monitoring will be needed to establish trends that will determine if the sediments will eventually exceed established hazardous waste levels.

   e. Analytical work in highly concentrated samples from these basins is extremely difficult and the analytical data derived from these basins should be checked closely to ensure its reliability.

2. Water and Sediment Quality, 1988-89

   As a follow up to the previously mentioned study, staff conducted an annual water and sediment quality monitoring at the 27 existing evaporation basins.

A report on this additional sampling is under preparation and will be completed by mid 1990. In addition numerous presentations have been made on the results of our findings.

The Central Valley Regional Board will continue to do an annual water quality compliance monitoring at each evaporation basin. It is anticipated that sediment monitoring will be concentrated on those basins showing elevated levels of trace elements in the sediments, especially selenium. Further work on the layering of trace elements in sediment will be conducted as well as periodic sampling on the cycling of trace elements daily and seasonally from sediment to the water.

3. Uranium in Evaporation Basins

Concern has been expressed that evaporation basins used to dispose of agricultural subsurface drainage water may be creating a hazard to the environment. Staff has conducted a program to evaluate water quality at each site and have determined that natural uranium is present. Because of the concern that uranium may be present in high concentrations in certain basins, a special water quality survey of the 24 basins in the Tulare Lake Basin was conducted. A report on this investigation has been prepared [61]. The report describes the present uranium, concentrations at each site and will be utilized in future regulatory work. Specific findings are:

a. Inflow uranium concentrations varied widely but appeared to be related to the geologic setting of the basins. Those basins located in the southern Tulare Lake bed south to the Goose Lake bed showed the highest concentrations.

b. Uranium concentrations were strongly associated with the molybdenum concentrations in certain basins.

c. Future monitoring should include uranium as this water quality survey shows that as much as 60 percent of the presently ponded acreage approaches or exceeds the 500 microg/L criterion established by the Canadian Government for protection of wildlife in salt water environments.

d. A review of the present criterion for protection of various beneficial uses is recommended as the only regulations for uranium are those of Subchapter 15 of Title 23, Chapter 3 of the CCR.

The Central Valley Regional Board will continue a monitoring program for uranium. This effort has been expanded to include an evaluation of the radium levels present as these present a much greater threat than the uranium. Preliminary information available shows that very low radium levels are present in the evaporation basins. This has now been attributed to a non-equilibrium environment in the basins between breakdown products. A full report on this work will be prepared in late 1990.

The Central Valley Regional Board has also asked for the assistance of the State Board in evaluating the available criteria for uranium and its applicability to the San Joaquin Valley conditions. A report [62] has been prepared by State Board staff and forwarded to the Central Valley Regional Board for use in regulatory work. The report conclusions are:

a. Elemental uranium does not occur in water because it reacts with oxygen to form uranyl ions, the principal form of uranium in the aquatic environment.

b. The principal health concern to humans from uranium in the environment is not from its radioactivity but chemical toxicity to the human kidney.

c. Biomagnification is not expected because uranium concentrations decrease with increasing trophic status.

d. The extent to which uranium poses a threat to Central Valley wildlife is unknown.

e. The Canadian aquatic life criteria of 500 microg/L for saltwater was derived in 1972 based on very limited toxicity data.

f. The existing toxicity database for uranium is not sufficient for derivation of criteria protective of aquatic life.

g. There is no evidence to date that uranium is responsible for toxicity in the evaporation basins.

4. Biological Characterization of the Evaporation Basins

Since the closure of the San Luis Drain and Kesterson Reservoir, the use of evaporation ponds for the disposal of subsurface agricultural drainage water in the southern San Joaquin Valley is likely to increase. There is concern whether contamination problems, similar to those experienced at Kesterson Reservoir, will arise as the result of using evaporation ponds for the disposal of tile drainage water. Moreover, it will likely become necessary to identify ways, through proper design and management of evaporation ponds, to minimize the potential for such contamination problems to develop.

This study, through the University of California, Davis, was initiated to investigate the biological characteristics within and among selected evaporation ponds currently being used as sites for disposal of tile drainage. Such characterization is a first step towards identifying factors that play important roles in determining the potential for contamination to waterfowls, shorebirds and other wildlife resulting from food chain bioaccumulation of toxic constituents present in these effluents. There were two phases to this study. The first was a descriptive, seasonal evaluation of different types of evaporation ponds currently being used in the San Joaquin Valley. The second phase concentrated on evaluating key aquatic organisms, identified in the first phase, particularly with respect to their tolerance to important environmental factors (e.g., salinity and temperature) and interactions with trace elements common in agricultural drainage.

Three reports have been prepared. The first report (63) deals with the biological component of the study and includes: (1) results of a one-year biological survey; (2) a general description of evaporation pond biological communities and foodweb structure; (3) identification of information gaps concerning pond biota and recommendations for future research, and (4) recommendations for evaporation pond design features and management procedures likely to be effective in reducing contamination risk to waterfowl and shorebirds.

The second report [64] is a comprehensive bibliography of the literature dealing with highly saline aquatic environments, biota inhabiting such environments, environmental tolerances of these common organisms and management of shallow, saline ponds for use in the disposal of agricultural return water. The bibliography is divided into four sections dealing with each of these topics. A specific list of the organisms of interest in this study was derived from the catalogue of biota found in farm evaporation ponds in the San Joaquin Valley.

The third report [65] was primarily funded by the Department of Water Resources. This funding expanded the Central Valley Regional Board's initial request to the contractor. The report reviews the information available on the tolerances of commonly occurring aquatic organisms to salinity, temperature, pesticides and several specific metals and trace elements (As, B, Cr, Hg, Mo, and Se). The organisms of concern in this study were derived from a study monitoring the biota found in farm evaporation ponds in the San Joaquin Valley.

Further monitoring and site characterization is presently under way to define the best sampling methodologies and procedures to further characterize the basins and their food chain. A final report on this activity will be prepared in early 1990.

5. Physical and Chemical Characterization of Evaporation Ponds

The rapid expansion of evaporation ponds has resulted in several thousand acres of basins with which there is little experience in managing these facilities. This project was started to begin to develop answers to environmental questions such as the rates of toxic constituent accumulation, especially to hazardous waste levels, seepage from the basins to underlying ground water, and the ultimate buildup of salts that may precipitate and contain hazardous substances.

A final report has been prepared [25]. The report describes the physical and chemical characteristics of selected evaporation basins. The report utilizes this knowledge to describe a Pond Seepage Model that can be utilized to evaluate basin seepage rates and the use of subsurface drainage systems and interceptor drains for capturing this seepage. The project report also describes pond bed materials and how these are affected by pond water chemistry. A significant achievement of the project report is the development of a brine chemistry model that can be used to predict the rate and type of salt precipitation in the basins. Significant findings include:

a. Both interceptor drains and subsurface drainage systems can be very effective in capturing the seepage from the basins if appropriate boundary conditions exist.

b. Actual measured seepage rates did not reflect predesign estimates and recommendations are given on modifying the predesign evaluation.

c. The basins tended to seal themselves as they aged with a steady state seepage rate likely to occur with one to two years.

d. Brine chemistry model was effective in predicting the type of salt likely to be precipitated as the basins concentrated.

e. Pond water chemistry had a significant effect on pond hydraulic properties with greater sealing as salinity increased.

f. Trace elements in the water did not necessarily show up in the pond sediment pore water indicating that the trace elements are likely being absorbed onto the sediment thus increasing in concentration in the first few centimeters.

6. Analytical Methods for Evaporation Basin High Salt Water

Central Valley Regional Board staff began an extensive program to characterize water quality at evaporation basin sites in the San Joaquin Valley. The data, however, for some elements, showed inconsistent analytical results for water quality samples taken from similar sites or basins and raised serious concern for the accuracy of data being collected by agencies and dischargers.

The difficulty in analysis appears to be that standard laboratory procedures used for drinking and irrigation water encounter considerable salt matrix interferences when working with the highly saline waters of the evaporation ponds. Observed differences in reported concentrations of a particular trace element from different analytical laboratories are sometimes orders-of-magnitude. The difficulty may lie with salt matrix effects, viscosity, predominant salts present, or other factors. Because of these interference effects, the detection levels that can be achieved are far above the levels that are being reported as having harmful effects. The interferences caused and the high detection levels make the present database inadequate or unreliable. Even modified procedures used for sea water analysis are unproven for reliable trace element analysis in highly saline water which shows predominant salts different from those of sea water.

Central Valley Regional Board staff initiated a study with the University of California, Riverside, to develop reliable analytical techniques for trace elements to be used in monitoring agricultural subsurface drainage water evaporation ponds. These guidelines may be used to establish monitoring programs, define analytical contract specifications, establish discharge limitations and receiving water standards.

A preliminary report (66) on this effort has been submitted. The report shows that:

a. The best approach is to use a preconcentration of 23 trace elements from the saline water buffered with ammonium acetate to pH 5.0 then to use a multielement chelation with ammonium pyroidine dithiocarbomate (APDC) and extraction into chloroform.

b. Recovery ranges were found to be 90-100 percent.

c. Arsenic, boron, molybdenum, vanadium, uranium, and selenium are the only trace elements out of the 23 that were detected at elevated levels in the basins.

Work on this project is proceeding and a final report is scheduled for early 1990.

7. Environmental Impact Report (EIR) on the Cumulative Impact of Evaporation Basin in the San Joaquin Valley

   The Central Valley Regional Board, because of its regulatory role over subsurface agricultural drainage evaporation basins (basins), has been caught up in mitigation of wildlife impacts. Reduced hatchability or abnormal deformities of birds have been noted by the USFWS at some of the basins. When an environmental assessment and a proposed negative declaration were circulated for one of the pending Water Discharge Requirements (WDRs), Department of Fish and Game (DFG) objected. Although the project proponents had entered into agreement with the DFG to mitigate adverse effects of pond operation on waterfowl, DFG responded that completion of the actions in the agreement would not mitigate cumulative impacts.

   The Central Valley Regional Board responded by conducting public meetings for exchange of information on wildlife impacts. In August 1989, the Central Valley Regional Board directed staff to have pond operators prepare a technical report (TR) to serve as a draft EIR focused on cumulative wildlife impacts.

   The pond operators formed a nonprofit corporation called "Central Valley Agricultural Pond Operators" (CVAPO). A small "advisory" group (staff, DWR, DFG, CVAPO) was also formed and met to define the scope of the TR and draft a Request For Proposal (RFP).

   Technical proposals addressing cumulative impacts to wildlife from basins were submitted and reviewed by the advisory group. The advisory group selected two consulting firms jointly as the qualified low bidder. The TR is expected to be completed in December 1990. DWR is funding 75 percent of the TR with the remaining 25 percent being funded by CVAPO.

   The TR will serve as the first tier of environmental review for basin WDRs. The TR will identify and assess the beneficial and adverse cumulative environmental effects on wildlife. The TR will also propose and evaluate alternative methods for mitigation of any potential adverse cumulative impacts. Environmental assessment will be completed on each basin to address site-specific impacts. The mitigation actions identified in the reports will be considered by the Central Valley Regional Board for inclusion in WDRs.

1.2.1.6 - Laboratory Quality Control Program (see # 6 above and 1.1.1.6).

1.2.1.7 - Regulatory Activities

The Board has undertaken several regulatory actions recently in addition to work already described.

1. WDR's

   Preparation has begun on WDR's on several of the evaporation basins in the Tulare Lake Basin. Draft requirements on one facility have been issued, however, adoption of these has been delayed because of environmental concerns raised about the cumulative impact of a large number of evaporation basins being located in the San Joaquin Valley. An environmental document is now under preparation and adoption of WDRs will proceed immediately thereafter.

WDRs have been prepared for the closure of Kesterson Reservoir. These requirements were placed in abeyance by the State Board when the final closure method was changed. A portion of the requirements remained in effect for the needed wetlands mitigation. The discharger has submitted a mitigation plan that provides for no net loss of wetlands habitat values or acreage. This plan was approved by the Central Valley Regional Board and implementation is underway.

The Central Valley Regional Board also adopted waste discharge requirements for the one-time dewatering of Kesterson Reservoir. This was needed to allow the USBR the needed time to close the site per the State Board's order. Additionally, a six-month permit was adopted to allow for the discharge of ground water that accumulated in the San Luis Drain. This discharge is needed to avoid over topping of the drain and flooding of adjacent farmlands.

2. Basin Plan Implementation

   As described in Section 1.2.1.4.4, a basin plan amendment was adopted for the regulation of agricultural drainage in the San Joaquin River Basin. The amendment included water quality objectives and an implementation plan. The implementation plan called for the submission of drainage operation plans (DOPs) by each district discharging subsurface or surface agricultural drainage. These plans are just now being received. They will be reviewed by the Regional Board and used as a basis to assess accomplishments toward drainage reduction.

1.2.1.8 - Coordination (see Section 1.1.1.8).

Chapter 2

San Joaquin Valley Drainage Program and Kesterson Program Activities

Following the USFWS discovery of waterfowl deaths, birth defects, and reproductive failures at the Kesterson Reservoir in 1983 [3], the Department of Interior (DOI) developed a program to respond to the problem. A report [67] outlining DOI strategy on water quality problems was submitted to the U.S. Congress in December 1985. The program included identifying and addressing irrigation induced contamination problems in the following areas:

1. DOI irrigation and drainage facilities
2. NWR
3. Other migratory bird/endangered species management areas receiving DOI water

The plan involves five phases:

1. Site identification
2. Reconnaissance investigations
3. Detailed studies
4. Planning
5. Remediation

To date, 22 sites in 13 states have been identified as having potential for irrigation induced contamination problems. Reconnaissance investigations have been completed on 11 of the 22 sites, seven of which have been identified for further action under the five-phase process. Six sites are located in California. One of them, the lower Colorado River, has been removed from the process and is under long-term monitoring. Five other sites are upper Sacramento River (Reconnaissance phase), Salton Sea and Tulare Lake (detailed studies to be completed in 1990), San Joaquin Valley (planning phase to be completed in 1990, Section 2.1), and Kesterson Reservoir (Remediation phase, Section 2.2 and Table A6).

2.1 - San Joaquin Valley Drainage Program

The San Joaquin Valley Drainage Program (Drainage Program) was established in 1984 to investigate agricultural drainage and drainage related problems and find and recommend alternatives to solve immediate and long-term agricultural drainage-related problems in the west side of the Valley. The Drainage Program is a joint federal/State sponsored cooperative activity. The cooperators are the DWR, DFG, USBR, USGS, and USFWS.

The Drainage Program's goals are:

1. To minimize potential health risks associated with subsurface agricultural drainage;

2. To protect existing and future reasonable and beneficial uses of surface and ground water from impacts associated with drainage water;

3. To sustain agricultural productivity on the west side of the valley; and

4. To protect, restore, and to the extent practicable, improve valley fish and wildlife resources.

A Policy and Management Committee consisting of the Directors of the five cooperating agencies provides guidance on the direction and priorities for the Drainage Program. An Interagency Technical Advisory Committee (ITAC) and subcommittees thereof composed of State and federal agencies' liaisons provides technical advice to the Drainage Program. A Citizens Advisory Committee (CAC) provides information and viewpoints from individuals interested in or affected by the drainage and drainage related problems. The National Research Council of the NAS provides scientific oversight of the Drainage Program through its Committee on Irrigation-Induced Water Quality Problems. In addition to the Drainage Program member agencies, several other State and federal agencies have contributed and/or conducted studies to help solve the Valley's problem. First activities of member agencies are described. Then the Drainage Program accomplishments are discussed.

Activities of Member Agencies:

2.1.1 - USFWS

In 1986, the USFWS and the USBR entered into an agreement for the purpose of supporting research on the effects of agricultural drainage contaminants on fish and wildlife population. The purpose of the agreement was to support the Drainage Program. USFWS projects are listed in Table A2. Five major areas of research were included in the agreement. The five research projects and their findings are as follows [68]:

1. Accumulation and loss of selenium in waterfowl

   Selenium was found to be an element that is rapidly taken up by birds and is rapidly lost once exposure ends. If waterfowl or other birds were feeding in a selenium-contaminated area, harmful concentrations in adult tissues could be reached quickly. With liver, selenium concentrations could peak in a week or two if a bird survived selenium exposure in a contaminated area and left, its body burden of selenium would drop rapidly. Loss from liver is especially fast; the majority of selenium is lost within the first week. There are two important conclusions that relate to concerns in the field. The first is that if an aquatic environment were contaminated with high levels of selenium, even brief exposure could adversely affect birds. The second conclusion is that birds are unlikely to be harmed by a previous exposure to selenium if the earlier exposure did not have significant effects on them at that time.

2. Determination of maximum safe levels of selenium and other contaminants for waterfowl under conditions of chronic exposure.

   The dietary threshold of selenium to affect reproduction of mallards falls between 4 and 8 ppm, on a dry-weight basis. Thus far, selenomethionine has been the most toxic form of selenium fed to mallards. Preliminary analyses indicate that screech owls are not as sensitive to selenium as are mallards. Earlier work had shown that black-crowned night-herons also were not as sensitive as mallards. In all three of the avian species listed above, varying degrees of food avoidance have been seen when selenium was mixed into the diet. In a small study with mallards, it was concluded that these species were able to detect and avoid as little as 10 ppm selenium in the diet. When high levels of selenium are fed to birds in laboratory studies, food avoidance may be at least partly responsible for sickness and death.

3. Accumulation and effects of contaminants in agricultural wastewater or wintering and migrating waterfowl in the San Joaquin Valley.

   Cessation of funding has resulted in this work being discontinued.

4. Development of predictive capability in assessing impacts of agricultural drainwater on wildlife species.

   Results from Tulare Basin, in conjunction with those from Kesterson Reservoir, indicate an agreement between selenium bioaccumulation measured in laboratory studies and field studies under certain field conditions. This is important because it means that laboratory-derived results for bioaccumulation can generally be applied to field situations. Another important conclusion is that the field estimates of the dietary effect threshold of selenium for reproductive impairment (about 5.6 ppm selenium, on a dry-weight basis) is in close agreement with estimates from the laboratory (about 4 to 8 ppm). Embryos from Tulare Basin showed deformities in 1989, as they did in 1987 and 1988. In 1989, these deformities were found, for the first time, in diving ducks. Exposure of shorebirds and ducks to selenium appears to be higher at Tulare Basin than it was at Kesterson Reservoir. Significant bioaccumulation of selenium at Tulare is occurring in ponds containing as little as 15 ppb selenium in water.

5. Interaction of elements in agricultural drainwater in producing effects on waterfowl species.

   Several studies were carried out to examine toxic interactions among selenium, boron, and arsenic, and between protein deficiency and selenium. These studies are in progress. Initial findings indicate that toxicity of selenium increased when protein is reduced in the diet.

   Under a separate agreement, USFWS is conducting a study entitled "Survey of Selenium Contamination in the Grasslands of the Northern San Joaquin Valley, Phase I and II [69]. Phase I of the study were initiated in 1985, when the Grasslands was flooded during the fall with primarily fresh water for the first time since 1960. The purpose of the study was two-fold: to determine the geographical extent of contaminants deposited in the West Grasslands as a result of the previous use of subsurface agricultural drainage water; and to determine contaminant concentrations in aquatic birds and select items of their food chain prior to and following the application of fresh water.

   Findings of this study reported during November 1987 indicated that algae, a waterfowl food collected from the Grasslands during March 1986, contained selenium levels above those thought to be safe for waterfowl consumption. In addition, mean liver selenium concentrations in aquatic birds collected from the Grasslands during May and June 1985 and February 1986 contained selenium levels, in some cases, similar to or greater than those concentrations associated with embryonic mortality and abnormalities in waterfowl nesting at the Kesterson Reservoir during 1983.

Phase II of the Grasslands study, is a multi-year program designed to monitor contaminant loads in the Grasslands under the new freshwater management system. Primarily fresh water has been used during the fall to flood the Grasslands for the last three years. Annual trends from baseline contaminant concentrations determined during Phase I as well as seasonal trends of food chain bioaccumulation will be evaluated.

A report summarizing the data collected during Phase I will be prepared during FY 1990. Statistical analysis and report of the data in Phase II will also be prepared in FY 1990.

2.1.2 - USGS

USGS as a member of the Drainage Program, has been the lead agency in studying the soils, geology, and hydrology of the westside of the Valley. USGS has completed numerous projects either funded through interagency agreements with the Drainage Program or direct congressional appropriations (see Table A3 for the list of USGS projects).

USGS released a report in 1989 [70] describing sources, distribution, and mobility of selenium in the San Joaquin Valley. Some of their findings are summarized here.

1. The highest levels of selenium in soils occur in alluvial fans near Panoche and Cantua Creeks (greater than 1.14 mg/kg) and area west of Lost Hills and Buena Vista Lake Bed.

2. The upper part of the semiconfined aquifer in the westside has selenium concentration in water which ranged from less than 10 ppb to more than 1,000 ppb. The source of selenium in the upper part of the aquifer is leaching from irrigation of soils. The concentration of selenium in confined aquifer (below corcorran clay) and Sierra Nevada of the semiconfined aquifer did not exceed 2 ppb.

   The concentration of selenium in water in the upper 10-20 feet of the semiconfined aquifer ranges from 10 to 50 ppb, but when the water table has been near the ground surface the concentration is 10-100 times greater due to evaporative concentration of selenium. Within 20 to 150 feet below the water table, selenium levels are 50 to more than 1,000 ppb. The concentration of selenium below 150 feet (native ground water) is less than 10 ppb. The concentration of selenium in semiconfined aquifer in the northern part of the San Joaquin Valley is generally low.

3. Drain water from 77,000 acres of tile-drained lands enters San Joaquin River. The major source of selenium to the River is Salt and Mud Sloughs. During 1985-1987, concentration of selenium exceeded 10 ppb ten percent of the time in San Joaquin River upstream of Merced River, but was not exceeded downstream of the Merced River. However, the concentration of selenium in Mud and Salt Sloughs exceeded 10 ppb more frequently.

2.1.3 - DWR

DWR is one of the Drainage Program member agencies. DWR has been the lead agency for the activities of the Agricultural Water Management Subcommittee. Responding to the findings of its own studies and those of other agencies, DWR has focused on four activities: (1) evaporation pond investigations; (2) drainage reduction; (3) drainage monitoring and evaluation; and

(4) drainage treatment and disposal. The objectives of these activities are to generate information on drainage occurrence, treatment, disposal, and management and transferring the knowledge to the agricultural interest, water agencies, and regulatory agencies. A brief description of these activities follows and a summary of these activities are found in Table A4.

1. Evaporation Pond Investigations

   DWR released a report[26] on the progress of investigations on evaporation ponds. DWR involvement in the evaporation pond activities is to assess the environmental impact of the ponds, to come up with the optimum design criteria for the ponds, and disseminate the information to the pond operators. The 27 ponds in the San Joaquin Valley have a total area of 7,070 acres. Twenty-two ponds consisting of 6,800 acres are currently active. All but one of the active ponds are in Tulare Lake Basin. One pond has reached the level to be considered toxic pit, one pond has been issued a draft WDR and there are 23 applications for WDRs. The total pond area is expected to grow to 9,000 acres.

   Another report [71] describing methods to minimize wildlife contamination from ponds was released by DWR in 1989. This report indicates that shorebirds and waterfowl are currently exposed to selenium contamination from ponds. Among twenty-one general methods investigated, four methods were recommended for implementation: (1) deepening the ponds; (2) eliminating existing windbreaks; (3) removing levee vegetation; and (4) bird hazing. Other methods either require more investigation or have poor prospects.

2. Drainage Reduction

   DWR's Water Conservation Office (WCO) is involved in several activities related to agricultural drainage problems. Staff of WCO has been actively involved in the Drainage Program's Agricultural Water Management Subcommittee. WCO continues to promote the use of California Irrigation Management Information System (CIMIS) among growers. The information from CIMIS helps growers for their irrigation programming. WCO's mobile labs visit farms to evaluate the grower's irrigation system and make recommendations to improve irrigation efficiency. Westside Resource Conservation District's Water Conservation and Drainage Reduction Program is a joint effort funded by DWR, Westlands Water District, and local growers. This program also provides assistance to the growers to improve their irrigation efficiency.

   The WCO has been actively involved in conducting studies on reduction of agricultural drainage. The status of their projects are briefly discussed.

   The following three projects are funded jointly by the State Board (one time $400,000 State Assistance Program (SAP) Fund) and DWR for a three year duration. The projects are administered by WCO staff.

   a. Demonstration of Emerging Irrigation Technologies for Drainage Reduction:

      This contract was signed in October 1988. The project includes: (1) Low Energy Precision Application (LEPA); (2) subsurface drip;

(3) improved furrow (irrigation scheduling); and (4) historical furrow (as managed by growers in the area). Data collection has started and progress reports have been submitted to DWR. Data so far collected includes irrigation water applied, deep percolation, salinity, selenium, depth of shallow ground water, crop yield, and economics of irrigation systems. This work will continue for at least one more irrigation season. Preliminary data indicate that subsurface drip irrigation result in higher water use efficiency. Even though subsurface drip had the highest production costs, the net benefits were the highest among four irrigation methods studied.

b. Shallow Ground Water Management for Drainage Reduction:

This project includes: (1) design and installation of a shallow tile drain; and (2) modification of an existing tile drain with flow control valves. The contractor was not able to fulfill the terms of the contract and DWR has terminated this contract. Contract process with another contractor has been initiated.

c. Load/Flow Relationships:

The work statement for this contract has been finalized. Contract preparation with Panoche Water District in cooperation with U.S. Department of Agriculture, Agricultural Research Service (USDA/ARS) and USGS was initiated in 1989. The USDA/ARS and USGS start working on this project in April 1990.

d. Ground Water Contribution to the San Joaquin River

This project is funded by the State Board ($145,000 SAP fund) to WCO with USGS as subcontractor. USGS investigates the quantity and quality of ground water flows to the San Joaquin River along a 19-mile reach of the river. This work is near completion and the final report is expected in 1990.

The following projects are funded and administered by WCO.

a. Irrigation Efficiency and Regional Subsurface Drainage Flow

The Panoche Water District, in cooperation with USDA/ARS has conducted this study. The work is completed and a final report is expected in 1990. This work addresses relationships between irrigation management and drain flows, the source of subsurface drainage flows on a regional basis, correlation between drain flows, and irrigation and/or rainfall.

b. Water Conservation Coordinator

The water conservation coordinator is developing both educational and implementation programs to assist growers in eight irrigation districts in the Grasslands area. Central California Irrigation District is the contractor of the project.

The New Irrigator, a monthly newsletter, provides information to the growers on how to better manage their irrigation. Seminars that are tailored to needs of each district are conducted to help growers to improve on-farm irrigation practices.

c. Tiered-Water Pricing

The contractor is Broadview Water District. The District has developed a tiered water pricing which is crop specific. The work will continue for one more year. For more information see Section 4.3.1.

d. Agroforestry

CDFA, with cooperation from University of California Davis is conducting this study. Evaluation of water and salt balance in 28-acres of eucalyptus and five-acres of a triplex is underway. Also, measurements of actual evapotranspiration of eucalyptus is being conducted.

3. Drainage Monitoring and Evaluation

DWR continues to monitor groundwater, drainage water, and surface waters in the valley, Sacramento-San Joaquin Delta, and San Francisco Bay-Delta Estuary. Monitoring activities are briefly described in Table A4. For example, Interagency Delta Health Aspects Monitoring Program is a continuous program collecting water quality data from the Delta since 1983. The program has several monitoring stations including locations along the Sacramento and San Joaquin rivers (Vernalis). Se is one of the constituents measured in water samples. The concentration of Se has exceeded 3 microg/liter twice at Vernalis, once at Delta-Mendota Canal intake, and once at H.O. Bank pumping plant [72] during a four year sampling.

4. Drainage Treatment and Disposal

DWR has been actively pursuing several options of drainage water treatment. DWR, in cooperation with USBR, are planning to build a pilot plant (20-30 gallon per minute) to remove selenium from drainage water using anaerobic bacterial process.

2.1.4 - DFG

DFG continues to provide a full-time staff person to act as the chair of the ITAC and the State Studies Coordinator for the Drainage Program. DFG has participated in the 1989 efforts to enhance fish and wildlife resources in the San Joaquin River and Grasslands wintering waterfowl areas (Los Banos and Volta Wildlife areas) (see Table A5). DFG has developed Proposed Interim Guidelines for Agricultural Subsurface Drainage Evaporation Ponds [26] and has requested that the Central Valley Regional Board incorporate the guidelines in WDRs for evaporation ponds. Under the proposed guidelines, owners and/or operators of evaporation ponds are required to participate in efforts to control selenium uptake in waterbirds by appropriate design, construction, and operation of evaporation ponds. The guidelines include provisions for hazing, vegetation removal, and selenium monitoring programs. DFG has also expended resources in establishing mitigation agreements between DFG and several pond operators in the Valley.

2.1.5 - The San Joaquin Valley Drainage Program-Progress and Status

In 1987, the Drainage Program, directed by the Policy and Management Committee and CAC, focused its efforts on the in-valley options to solve the drainage related problems. Utilizing technical services from various State, federal, university, local, and consulting firms as well as its own technical staff, the Drainage Program has created a substantial wealth of information on the nature of the problem in the Valley and potential options to solve it. The Drainage Program has produced more than 25 technical reports during 1989-90 on various drainage-related issues. A brief description of six studies with interesting findings are as follows:

1. Sources and Concentrations of Dissolved Solids and Selenium in the San Joaquin River and its Tributaries, California, October 1985 to March 1987 (73)

   Sources and concentrations of dissolved solids and selenium in the San Joaquin River and its tributaries were assessed by a mass-balance approach to determine the effects of tile-drain water and irrigation-return flows on the River. The study included low-flow periods from October 1985 to mid-February 1986 and mid-May 1986 through March 1987, and a high-flow period, from mid-February to mid-May 1986.

   a. During the high-flow period, the relative contributions of flow from the eastside tributaries and the sloughs decreased to 53 and 3 percent, respectively, and the contribution of the upper San Joaquin River increased to 41 percent. Proportional within-reach gains were minimal.

      Despite the greater quantity of streamflow during the three-month high-flow period, 76 percent of the dissolved-solids load and 65 percent of the selenium load occurred during the 15-month low-flow period. During the combined low-flow period, the dissolved-solids load from eastside tributaries and the upper San Joaquin River accounted for only 18 percent of the total load at Vernalis, located farthest downstream, even though they accounted for 71 percent of streamflow.

   b. Salt and Mud Sloughs contributed 40 percent of the dissolved-solids load but only nine percent of streamflow. Measured sources (within reach sources of surface and ground water) of dissolved solids contributed about 42 percent of the total load during low flow. In contrast, Salt and Mud Sloughs, which receive most of the tile-drain water that enters the River, contributed almost 80 percent of the total selenium load to the River, and loading from unmeasured sources was minimal. Dissolved solids concentrations were highest in Salt and Mud Sloughs and decreased downstream with dilution from eastside tributaries. Selenium concentrations also were highest in Salt and Mud Sloughs.

c. The State Board salinity objective of 500 mg/l was also exceeded 11 percent of the time in the San Joaquin River near Vernalis.

2. Trace Elements in Bed Sediments of the San Joaquin River and its Tributary Streams (74)

The purpose of this study was to assess the occurrence and distribution of trace elements in bed sediments of the San Joaquin River and its tributaries. The study was undertaken because of concerns that high concentrations of selenium or other trace elements from subsurface agricultural drain water or other sources may be concentrated in bed sediments. Composite samples were collected of the upper 6 cm of bed sediment from representative cross sections at each of 24 sites.

a. Concentrations of elements were higher and less variable in the <62-microm size fraction of bed sediments compared to whole samples. Bed sediments from eastside tributaries were much coarser compared to westside tributaries. San Joaquin River sediments were a mixture from eastside and westside sources.

b. Only a few individual elements were distinctly different in concentration in different parts of the River system. Sediments of eastside tributaries, derived solely from Sierra Nevada sources, typically have low lithium and high manganese and zinc in the <62-microm size fraction. Selenium was highest in bed sediments of Salt and Mud Sloughs, where the highest selenium concentrations in water also have been measured.

c. Concentrations of elements in San Joaquin River bed sediments were similar to those of Valley soils and were well below hazardous waste criteria which is a potential issue related to the disposal of dredge spoils from contaminated areas. Concentrations were lower than in sediments from polluted urban rivers and were more comparable to those of rivers in other rural agricultural areas.

d. These results indicate that selenium and other trace elements are not at hazardous levels in the bed sediments of the San Joaquin River.

3. Biological Residue Data for Evaporation Ponds in the San Joaquin Valley, California (75)

The purpose of this work was to compile all the available data on contamination of plants and animals from evaporation ponds in the Valley.

Some of the findings of this report are:

a. The subsurface agricultural drainage water disposed of in evaporation ponds originates from a number of different geographic areas on the west side and southern end of the San Joaquin Valley. The geologic origin, and more recent environmental and anthropological forces, have influenced the physical and chemical characteristics of the soils in these areas. As a result, the quality of drainage water produced and disposed of in the evaporation ponds varies.

b. Studies have found elevated concentrations of total dissolved solids, arsenic, boron, molybdenum, selenium, uranium, and other constituents in pond waters. Investigations have revealed elevated levels of these elements in the pond sediments.

c. Evaporation pond waters are shallow, warm, saline, and nutrient enriched. Hence, the ponds are biologically very productive which attracts certain species of wildlife.

d. Investigations have revealed significant frequencies of adverse biological effects that are traced to contamination of pond water. This report also lists numerous references on the subjects of pond water quality, pond sediments characteristics, biological characteristics of ponds, wildlife uses of ponds, and measures that could be taken to reduce wildlife hazards.

4. Techniques to Restore Fish and wildlife Habitats Contaminated by Subsurface Agricultural Drainage Water, January 1990 (76)

This report identifies 14 techniques that can be used singly or in combination for restoration of drainage contaminated habitats. Advantages and shortcomings of these techniques are discussed in the report. Five mechanisms of volatilization, leaching, dilution, harvesting, and immobilization are addressed. The report finds microbial volatilization from soil, seasonal application of noncontaminated water, cultivation of plants for uptake and volatilization of selenium having promise for removal of selenium from contaminated lands.

5. Overview of the Use of the Westside Agricultural Drainage Economic Model (WADE) for Plan Evaluation (77)

The Drainage Program has used a model to evaluate how alternative drainage management policies might affect the economy and hydrology of the west side of the San Joaquin Valley in California.

The WADE model simulates the interactions between agricultural decisions and ground water hydrology. The model can be used to evaluate the immediate and long-term effects of different drainage management strategies. The WADE model can be considered as two interacting models. One is an agricultural production model which simulates cropping decisions, farm revenue and profit, irrigation system selection, and drainage management. The other is the hydrosalinity model which estimates the effects of these management decisions on the water table, salinization in the crop root zone, and drainage quantity and quality. The WADE model also includes the management of wildlife habitat areas.

WADE is a regional model covering the entire west side of the San Joaquin Valley. The study area has been divided into more than 180 "polygon" cells, each representing a unique combination of soil, drainage, and water supply conditions. The WADE model assigns to each cell a set of numbers describing its soil and ground water characteristics, crop yields, water supply, and land use. The WADE agricultural production and hydrosalinity models interact sequentially. The hydrosalinity model provides data to the agricultural model on the depth to ground water, drainage flow and quality, and salt concentrations in the root zone and semi-confined aquifer. The production model then solves for cropping, irrigation, and other management choices that maximize net farm income under the given constraints. The production model feeds the resulting data on surface water application, ground water pumping, drainage water, crops grown by soil type, irrigation technologies used, drains installed, deep percolation, and other relevant information back to the hydrosalinity model.

6. Agricultural Drainwater Management Organizations in the Drainage Problem Area of the Grasslands Area of the San Joaquin Valley (78)

This report describes the structure of agricultural water organizations in order to determine whether and to what extent water policy proposals should be addressed to individual on-farm water users or to agricultural water management organizations. This report is the result of a study in the Grasslands area of the Valley. The key findings of this work are as follows:

a. A variety of special district forms under existing California law may provide for the administration of local agricultural water resources. California water districts, irrigation districts, drainage districts, and resource conservation districts are the four main types of special districts that currently provide most of the formal organizational framework for local drainage water administration in the drainage problem area.

b. Under existing California law, the incorporation, modification, or dissolution of a special district requires ratification by local constituencies and approval by the county's Board of Supervisors and Local Agency Formation Commission.

c. Alteration of existing districts or incorporation of new special districts to restructure administrative authority and accountability for agricultural drainwater monitoring and management will require a special act of the State Legislature if local water users oppose this action.

d. Currently, individual water utility districts cooperate to monitor and manage agricultural drainwater in the drainage problem area. With the exception of the resource conservation district form, a new special district to manage drainage problems could be superimposed on existing district boundaries, even if the new district were incorporated as the same type of district.

e. The organization of regional agricultural drainwater management in the drainage problem area is best understood as a system in which formal organizations fall into distinct, interdependent categories, depending upon their specialized role in regional drainwater generation, use, and management. The three functional roles in the organization of problem area drainwater management are draining entity, drainwater conveying entity, and drainwater receiving entity.

f. Drainwater management in the drainage problem area is based on both formal and informal arrangements, which shape and organize water use decisions by individual water users, water managers, and special districts. Therefore, the analysis of agricultural drainwater management in the problem area cannot be restricted to an examination of formal institutions and organizations (e.g. special districts, laws, contracts, and water rights).

2.1.5.1 - San Joaquin Valley Drainage Program Planning Alternatives

In August of 1989, The Drainage Program released its interim report. After distributing the report to the interested public, the Drainage Program held public meetings at eight locations in the Valley during September 25 to October 3, 1989. The purpose was to present the Drainage Program's findings and available solutions to the public and to solicit response on the alternative plans proposed by the Drainage Program. The public meetings were hosted by CAC members, the Program Manager, and the Study Team presented the technical information and responded to the questions from the participants. The summary of the public meetings including the Program Manager's written responses to the individuals' comments were published by the Drainage Program in October 1989[79].

The Drainage Program's efforts have been focused on the west side of the San Joaquin Valley where the agricultural drainage is found to be the cause of environmental concern and agricultural production constraints. The west side of the valley consists of portions of the San Joaquin River Basin which has a surface drainage outlet to the San Joaquin River and Tulare Lake Basin which does not have a natural surface drainage outlet except through Fresno Slough in very wet years.

The total irrigable lands in the west side of the valley is 2,474,000 acres and the total irrigated lands in 1988 was 2,235,000 acres. The gross market value of crops from the area is about $2 billion annually. The area is hot and dry with an average annual rainfall of about five inches in the south to 10 inches in the north. Underlying almost the entire west side of the valley is the low permeable Corcoran Clay layer which horizontally divides the ground water basin into semiconfined and confined aquifers.

The Drainage Program's study area is divided into five subareas: Northern, Grasslands, Westlands, Tulare, and Kern (Figure 1). Table 2 contains some relevant data on these subareas.

The drainage and drainage-related problems in the Valley are due to shallow ground water, salinity, and potentially toxic trace elements. Rising shallow ground water with poor quality (high dissolved solids) is creating both water logging and salinity situations that constrains the agricultural practices and production. The concentration of total dissolved solids in shallow ground water exceeds 5,000 ppm, (not suitable for irrigation of crops unless diluted with freshwater) under about 400,000 acres in Westlands, Tulare, and Kern subareas. Using a computer model, the Drainage Program estimated that the net increase in the salts in the semiconfined aquifer is 3.3 million tons per year. The sources of the salt in the aquifer are imported water, agrochemicals and naturally occurring salts in the agricultural soils. Additionally, selenium is of primary concern because of its potential toxicity. However, boron, molybdenum, and arsenic are also investigated by the Drainage Program.

Table 2. The Drainage Program Study Area Information *

		SUBAREAS				TOTAL
	Northern	Grasslands	Westlands	Tulare	Kern	
1. Irrigated Area (A)	157,000	310,000	576,000	506,000	685,000	2,235,000
2. Water Supply (AF)	510,000	1,150,000	1,580,000	990,000	2,000,000	6,230,000
(feet)	(3.25)	(3.69)	(2.74)	(1.95)	(2.92)	
3. Area with groundwater within 5 feet (A) 1987	51,000	308,000	104,000	320,000	64,000	847,000
2000	51,000	308,000	169,000	366,000	100,000	994,000
4. Net Salt Accumulation 1000 Tons/year 1988	1	122	615	1,472	1,098	3,309
5. Estimated Drained Area (A) 2000	26,000	116,000	108,000	126,000	60,000	436,000
6. Estimated Problem Water (AF) 2000	–	86,000**	84,000	92,000	45,500	307,500
7. Lands with Se in groundwater exceeding 50 ppb (A) 2000	–	72,000	96,000	1,000	54,000	223,000
8. Costs						
Source Control $/AF	–	$103	$107	$107	$107	–
Reuse Disposal, GW Management $/AF	–	$42	$99	$122	$103	–
Average $/AF	–	$63	$103	$115	$105	–
Average $/A	–	$47	$77	$86	$79	–

* Adopted and exerpted from S.J. Valley Drainage Program Prelim. Planning Alt. Report, 1989

** In Grassland 35,000 AF can be Discharged to the SJ River

A=Acre

AF=Acre-feet

The major sources of selenium in the River are Salt and Mud sloughs, located in Grasslands subarea. Even though Salt and Mud sloughs contribute most of the selenium load to the River, nine other points of agricultural drainage discharge [80] from the West side contributing to the boron and salt load to the River. Based on estimates obtained by the San Joaquin River Model [12, 14], a 30 percent reduction of agricultural drainage from the Drainage Study Area would reduce the selenium load in the River to the level that meets the water quality objectives of 5 ppb.

The Health Officers Association of California (HOAC), under a contract with the Drainage Program, has prepared a report [81] that provides toxicological and human exposure assessments of selenium, boron, and molybdenum. No excessive selenium concentrations in produce or drinking water supply in the Valley and no adverse effects of selenium on human health have been reported. Similarly, no adverse effects of boron and molybdenum have been identified. However, information on the potential adverse effects of long-term consumption of food and fiber containing selenium in excess of nutritional requirements is inadequate. A second report by HOAC, due in 1990, will update the information on selenium, boron, and molybdenum and will also address arsenic, nitrates, vanadium, uranium and mercury.

The Drainage Program's Preliminary Planning Alternatives Report discusses the shortcomings of a No-Action Scenario and the currently available possible in-valley options for each subarea. The options are as follows:

1. Source control to reduce drainage,
2. Management of shallow ground water by pumping,
3. Drainage water treatment,
4. Drainage water reuse,
5. Drainage water disposal in the Valley,
6. Fish and wildlife measures, and
7. Institutional changes.

Various drainage water treatment studies have been funded by the Drainage Program and other state agencies (see 1.1.3, 2.1.3, and 4.3). The topics addressed are: (1) reverse osmosis and desalting; (2) anaerobic bacterial treatment; (3) ferrous hydroxide treatment; (4) microalgal bacterial treatment; (5) iron filing; (6) microbial volatilization; (7) in-situ attenuation of selenium; and (8) ion exchange. The Drainage Program is not currently considering treatment methods for the removal of trace elements and salts from drainage water in its available technology alternatives because an economically feasible technique is not available. However, further research is recommended.

The preliminary alternative plan for each subarea is made of a combination of options using available technology.

To solve the drainage and drainage-related problems, the following steps are considered by the Drainage Program:

1. Drainage reduction by improving irrigation efficiency.

2. Disposal of drainage water from the northern subarea and northern portion of the Grasslands subarea to the River; to the extent that the water quality objectives set for the River are not exceeded.

3. In areas with no discharge to the River, the drainage water will be used to irrigate salt tolerant crops. In turn, the drainage water from the salt tolerant crops will be used to irrigate eucalyptus trees and drainage from the eucalyptus plantation will be used to irrigate saltbush.

4. The resulting highly concentrated drainage water from saltbush areas will be disposed of in bird-safe existing or new evaporation ponds or stored in the semiconfined aquifer by pumping shallow ground water from below the saltbush areas.

The costs for the anticipated 307,500 acre feet of annual drainage by the year 2000 is estimated to be about $70 per acre of drained land (see Table 2).

In the southern part of the Grasslands subarea (where the concentration of selenium in drainage water limits its discharge to the River) and in the Westlands, Tulare, and Kern subareas evaporation ponds are considered by the Drainage Program for disposal of drainage water. Evaporation ponds attract waterfowl and wildlife. Because of selenium's adverse effects observed in wildlife from affected areas, the Drainage Program in its plans considers measures that include protection and restoration of wetlands, acquisition and management of new wetland, hazing practices, monitoring, and pond-optimum design and management (see also Chapter 1 and Section 3.1). However, the long term environmental impacts of evaporation ponds and potential accumulation of trace elements and wildlife contamination from agroforestry plantations are not adequately known.

Also, the long term impact of concentrated drainage water, percolating below the root zone, on the quality of semiconfined and confined aquifers is uncertain. Ongoing investigations on evaporation ponds and biology and wildlife impact of agroforestry plantation will provide information on the potential use of these techniques to dispose of selenium tainted drainage waters.

Major effects of the available technology to deal with 307,500 acre-feet of drainage water by the year 2000 are:

1. The salt balance will be maintained in the valley.

2. About 200,000 acre-feet of water will be conserved from drainage reduction and pumping from semiconfined aquifers. The water will be used for wildlife areas and for improving conditions in Merced and San Joaquin rivers.

3. Approximately 28,000 acres of cropland will be used to grow eucalyptus trees and saltbush to be irrigated by drainage water.

4. Approximately 600 acres of new evaporation ponds would be constructed.

The Drainage Program has analyzed the data from the investigations which were designed to provide specific information for planning, formulation, and evaluation of alternatives. Other options, such as land idling (temporary removal of land from production), land retirement and ground water pumping are being considered and mechanisms of implementation, socioeconomic factors, and institutional changes needed to bring about the solution to the Valley's problems, are considered by the Drainage Program which will be included in the final report. The draft final report was distributed to the public for review and comment in June 1990 and will undergo revision by the Drainage Program prior to its completion anticipated in September 1990.

2.1.5.2 - San Joaquin Valley Drainage Program Technical and Advisory Committees

Interagency Technical Advisory Committee (ITAC)

The ITAC, consisting of representatives of various State and federal agencies, continues to meet approximately on a bi-monthly schedule. During 1989, the Committee had invited speakers to present seminars on topic related to a selenium and agricultural drainage problems. The Committee members also reviewed the Drainage Program report released in August 1989.

ITAC Subcommittee on Public Health

This Subcommittee has provided input to and review of a report by the Health Officers Association of California: "Agricultural Drainage Water Contamination in the San Joaquin Valley: A Public Health Perspective for Selenium, Boron, and Molybdenum".

ITAC Subcommittee on Treatment and Disposal

This Subcommittee has provided an assessment of the current research being conducted on the treatment of saline agricultural drainage. Their input is reflected in a two part report titled; "Technical Report: Agricultural Drainage Water Treatment, Reuse, and Disposal in the San Joaquin Valley", released in September 1988. The 1988 report concludes that treatment and removal of undesirable salts is currently unavailable at a price that would be affordable by agriculture. The Subcommittee is preparing a two part report on treatment and disposal alternatives for the Drainage Program study subareas.

Citizens Advisory Committee (CAC)

Members of the CAC hosted the Drainage Program public meetings held in the Valley during September and October of 1989. The CAC met in January 1990. The Committee felt that follow up activities including monitoring of short-term actions are needed after the Drainage Program termination in September 1990. The Committee made recommendation to the Policy and Management Committee (PMC) on federal-State cooperation to continue to solve the drainage related problems and to preserve the Drainage Program database.

National Research Council (NRC) U.S. Committee on Irrigation Induced Water Quality Problems

NRC Committee was formed in 1985 to assist the Department of the Interior and State of California to develop a research program on irrigation induced water quality problems in general and the San Joaquin Valley in particular. The Committee published its findings in a report released in 1989[82]. The recommendations of the Committee on policy and planning issues are briefly described here.

Policy Issues:

Federal and State agencies should: (1) design and implement management strategies to minimize adverse impacts of irrigation; (2) monitor all major irrigation projects for toxic substances; (3) inform the public of environmental costs and agricultural benefits; (4) enforce regulatory actions to agricultural drainage flow; (5) provide suitable water for wildlife and protect biological and recreational values of stream flows; (6) identify the lands contributing to degradation of water quality and try to minimize its adverse impact, this effort would include taking the offending lands out of production; and (7) no major irrigation project should start unless appropriate measures are taken to maintain the system.

Planning Issue:

Federal and State agencies should: (1) use sound study design, emphasize on systems approach, and consider the dynamic nature of hydrologic systems when trying to solve irrigation induced water quality problems; (2) develop an action plan to evaluate alternative responses to the problem; (3) promote public participation; (4) balance economic and non-economic costs; (5) consider feasibility of implementation, adequate funding, coordination among agencies, effective enforcement; and (6) skilled staff are recommended as an essential element of a study team.

2.2 - USBR Kesterson Reservoir Program

Kesterson Reservoir, located east of Gustine, was originally designed for the purpose of flow regulation. The Reservoir consists of 12 ponds with a total surface area of approximately 1,280 acres. Kesterson Reservoir was also a part of the 5,900 acre Kesterson NWR. Between 1978 to 1985 Kesterson Reservoir received subsurface agricultural drainage water from about 42,000 acres of irrigated land in the Panoche Fan area of Westlands Water District. Field observation in 1983 [3] at Kesterson Reservoir indicated mortality and deformities in newborn birds. The selenium poisoning was identified as the cause of death and deformities of embryos. State Board, in its Order WQ 85-1, directed the USBR, operator and owner of the Reservoir, to cleanup the pollution at the site. USBR closed Kesterson and all discharges of drainage water were terminated in June 1986. Following the State Board Orders No. WQ 85-5, WQ 87-3, the State Board issued Order No. 88-7. As a result of Order No. 88-7, the Bureau awarded a contract for grading and filling of seasonal wetland areas of the Kesterson Reservoir. The work was completed in 1988. USBR then submitted a final cleanup plan which was approved by State Board (September 21, 1989 - WQ 89-16). USBR's final cleanup plan includes active site management, continued monitoring, and continued research. The continued site management was suggested to prevent potential threats to wildlife and water quality. USBR was directed to prepare, annual site management plan based on research and monitoring results. Prior to its implementation, the annual site management plan should be approved by the Central Valley Regional Board. The Regional Board also reviews the monitoring program for its adequacy. If the seasonal wetlands and aquatic pathways reoccur, USBR will take appropriate action to remedy the situation. The activities of the USBR are listed in Table A6.

2.2.1 - Lawrence Berkeley Laboratory-Kesterson Cleanup

Scientists and engineers from the Earth Sciences Division of Lawrence Berkeley Laboratory (LBL) have been studying the Kesterson environment and participating in developing remediation techniques since 1985. The Kesterson cleanup plan involved cessation of discharges of drainwater to the Reservoir, filling the low-lying areas of the Reservoir to eliminate the formation of seasonal wetlands, active site management, continued monitoring, and continued research. The researchers of the Division of Agriculture and Natural Resources (DANR) of the University of California are involved in the research activities of the cleanup plan.

The following information is extracted from a report [83] prepared by LBL and DANR. Kesterson Reservoir related research activities were conducted under a cooperative program between LBL and DANR during FY 1989-90.

The progress made in this program is as follows:

Ground water monitoring and numerical simulation studies have been carried out to assess the likelihood of forming ephemeral pools from rising ground water at Kesterson Reservoir. The primary conclusion from these activities is that formation of ephemeral pools due to rising ground water is unlikely in years of below-normal to slightly above-normal precipitation. In years of heavy rainfall (50 percent greater than a normal water year), the majority of unvegetated areas of the Reservoir may be covered with standing water during the late winter, but salt and selenium concentrations in these pools are expected to be considerably lower than in the ephemeral pools that occurred during the 1986-1987 period. Selenium and salt concentrations are expected to be lower because these pools form from surface accumulation of rainfall rather than rising pore water. In years of exceptionally heavy rainfall (100 percent greater than a normal year), ponding over much of the Reservoir is anticipated. Contingency plans for surface drainage of the Reservoir into local waterways may be desirable to minimize wildlife exposure to these temporary wetlands.

Migration of the plume of saline, but low selenium (<2 microg/L) water that seeped from the Reservoir into the underlying aquifer, was monitored using a non-intrusive electromagnetic technique. Data from two sequential surveys, conducted in October 1987 and 1988, indicate that the plume is confined to a band extending about 300 m from the San Luis Drain. No detectable migration of the leading edge of the plume was observed over the one-year period.

Vadose zone selenium and salt concentrations have been monitored at several locations in the Reservoir for a period of three years. Some of the observed changes are seasonal, being affected by the rise and fall of the watertable and meteorological conditions. Others appear to be a part of a long-term process of species redistribution, as controlled by biogeochemical processes. Current understanding of the processes affecting fate of selenium and the rates at which they occur suggest that:

1. Changes in the inventory of soluble selenium residing in the vadose zone take place relatively slowly (<10 percent of the total inventory per year) after the pond bottom soils are initially dried out.

2. Annual cycles of precipitation and evaporation transport selenium and soluble salts both upwards and downwards within the vadose zone. The long term trends created by these fluctuating conditions remain uncertain.

3. Bare soil evaporation rates are much lower than expected given the shallow depth to the watertable and fine-texured nature of the soils. Consequently, evaporative accumulation of selenium at the soil surface will be negligible or at least much slower than previously anticipated.

Beginning in 1988, scientists at the DANR and LBL initiated a new effort aimed at developing a soil water and vegetation management plan for Kesterson Reservoir. The plan is intended to result in a gradual depletion of the inventory of soluble selenium from near surface soils. Agriculturally oriented processes that will contribute to depletion include microbial volatilization from the soils, direct volatilization by living plans, decomposition and volatilization of selenium-bearing vegetation, harvest and removal of seleniferous vegetation, and leaching. The management plan is also intended to facilitate control over wildlife exposure to selenium contaminated biota by creating a well management environment.

The majority of research associated with this new effort is being carried out in test plots at Kesterson Reservoir. Through an intensive program of soil water sampling, soil gas sampling, vegetation sampling, ground water monitoring, and soil moisture monitoring, the mass balance for selenium under irrigated conditions is being evaluated. These studies, in conjunction with supplementary laboratory experiments, will provide the information needed to develop an optimal management plan for the site.

Early results from these investigations are summarized as follows:

1. A system for measuring volatile selenium emission rates from vegetated and unvegetated soils has been developed.

2. Establishment of crop plants at the test plot located on the fill site was relatively successful. Barley was the most successful in this plot.

3. Establishment of crop plants at the test plot in Pond 7, a grassland site, was not successful. The high salinity of the soil surface is most likely the source of failure. Steps to mitigate this problem, including flushing salts from the surface prior to seeding, are being evaluated.

4. Emission of volatile selenium from the soil surface is affected by a number of factors including the moisture regime, presence of plants, and fill material. Preliminary results suggest that a tri-weekly irrigation may result in higher cumulative emission rates than weekly or biweekly irrigation.

5. Laboratory and greenhouse germination studies have been unsuccessful in identifying candidates species for crop plants in the Kesterson Reservoir soils. High salinity has been identified as the primary source of this problem, but, the presence of high concentrations of trace elements may also inhibit germination.

6. Volatile emission rates from a number of crop and selenium accumulator plants have been measured in the Laboratory. In general, emission rates are small compared to soil emission rates. Amongst those tested, barley and cotton had the highest per plant emission rates.

Chapter 3

University of California and California State University Research and Coordination Activities

3.1 - University of California Salinity/Drainage Task Force Activities

The mission of the University of California Salinity/Drainage Task Force (Task Force) is to develop, interpret, and disseminate research knowledge addressing critical agricultural and environmental problems on salinity, drainage, and toxic trace elements (Table A7).

The Task Force was formed in January 1985. In July 1985, a $1.05 million (State fund and Kearney Foundation of Soil Science) research program was implemented. Thirty-four projects were funded through a competitive grant process for one to two periods. The 1985-86 technical progress reports of research projects and principal accomplishments of the Task Force were distributed in September 1986 [84].

An in-house planning conference was held to identify research needs and priorities for the Task Force in March 1985. The Task Force briefed the NAS's Board on Agriculture in March 1985 and the NRC's Committee on Irrigation-Induced Water Quality Problems in May 1985 to participate in the Drainage Program's ITAC and its subcommittees. The Annual Task Force Research conference was held in March 1986 to present a six-month progress report. The Task Force also sponsored a conference on Decision Criteria on Residuals Management in Agriculture in April 1986. The proceedings of this conference addressing salinity by scientists and economists was widely distributed in September 1986 [85].

The 1986-87 budget (State funds) for the Task Force was $651,000. A call for research proposals in February 1986 resulted in the approval of 19 new and/or continuing projects supported for one-to-two years duration. In addition, there were seven continuing projects, supported by the Kearney Foundation in July 1985, with termination dates of December 1986 and June 1987.

The Second Annual Task Force Research Conference was held March 1987, attended by 120 invited participants. Technical progress reports were presented as was a special session on selenium bioaccumulation in food and forage crops and evaluation of selenium in the human food chain. A University of California publication on "Selenium Contents in Animal and Human Food Crops Grown in California" [86], October 1988. A workshop on Analytical Methods and Quality Control/Quality Assurance was also held in March 1987 for 60 invited participants [87]. A lengthy draft proceedings of the workshop had been produced for internal use. In 1986-87, 19 projects were allocated a total of $558,614. As in 1985-86, the area of bioaccumulation of selenium and other toxic ions by food and forage corps, as well as trace element chemistry and microbiology, received slightly more than half of the research funds. Technical progress reports for each of these projects are included in the 1986-87 Technical Progress Report [88].

Task Force and affiliated members participated in a number of activities such as the ITAC and its subcommittees in the Drainage Program, University of California Committee of Consultants, and the Drainage Issues Policy Committee. The Task Force is represented in ITAC, the Subcommittee on Data Management, the Subcommittee on Geochemistry, the Subcommittee on Treatment and Disposal, the Subcommittee on Valley Biology, the Subcommittee on Public Health, and the Subcommittee on Agricultural Water Management. Several members of the Task Force were heavy contributors to "Farm Water Management Options for Drainage Reduction" [89], August 1987, prepared by the Subcommittee on Agricultural Water Management.

In April 1986, the Board of Directors of Westlands Water District and growers in the drainage-impacted west side of the San Joaquin Valley requested the Task Force to develop interim assessments of critical agricultural and environmental problems. The Division of Agriculture and Natural Resources responded with the formation of University of California Committee of Consultants. Three such committees have been appointed to address on-farm drainage reduction, San Joaquin River water quality objectives, and San Francisco Bay-Delta water quality problems.

The Committee of Consultants on Drainage Water Reduction was appointed in April 1987 to: (1) evaluate the potential for reducing regional drainage water in the west side of the San Joaquin Valley; and (2) to estimate the anticipated costs of drainage water reduction practices and methods, and potential benefits to agriculture and other sectors of society. Two "mini reports", [90, 91] have been distributed.

The Committee of Consultants on San Joaquin River Water Quality Objectives was appointed in June 1987 to: (1) evaluate the salinity, boron, selenium and molybdenum water quality criteria required to protect the beneficial uses of water in the San Joaquin River and Delta; and (2) assess how the recommended water quality objectives could be met by irrigated agriculture on the west side of the San Joaquin Valley. Two "mini reports" [92, 93] were issued in 1988.

The Committee of Consultants on San Francisco Bay-Delta Water Quality Problems was appointed in July 1987. This committee has been charged with: (1) review ongoing studies in the Bay-Delta system and ascertain gaps on research knowledge; (2) identify research areas in which the University of California could potentially provide significant contributions in expertise and research activities; and (3) recommend a coordinated, multidisciplinary research program for estuarine systems for five- and ten-year periods. Progress to date is pending on the Bay-Delta hearings.

A Drainage Policy Issues Committee was formed in December 1986 to inform the public of University of California activities on this topic and provide accurate and relevant information on drainage and water-borne toxics. This committee produced a paper on "Resources at Risk: Agricultural Drainage in the San Joaquin Valley" [94], distributed in July 1987. The second volume, "Resource at Risk: Selenium, Human Health, and Irrigated Agriculture", [95] was released in December 1987. Volume III, "Resources at Risk: Drainage Source Control on the Farm", [96] was distributed in July 1988. The 1987-88 budget allocation was $671,218, of which $558,802 was awarded to 20 research projects. The 1987-88 Technical Progress Report was issued by the University of California Salinity/Drainage Task Force in October 1988 [97].

The Third Annual Task Force Research Conference was held in March 1988 with an attendance of 160 invited participants. In addition to reports on research projects, this conference featured the "University of California Committee of Consultants Minireports" and a panel on "Selenium Reactivity and Mobility in Salt-Water Systems". Several members of the Task Force helped develop the request for proposals for field-scale demonstration projects supported by DWR and the State Board. One member served as the chair of the Peer Review Task Group for these demonstration project proposals to develop and administer the competitive contract process.

In addition, the USBR and its principal research contractor, University of California's Lawrence Berkeley Laboratory, invited the Task Force to assist in researching containment and dissipation strategies based on soil water and vegetation management options. A team of researchers were provided $470,000 (USBR funds) in 1988-89 to conduct field trials complemented by campus-based research (see Section 2.2.1).

A member of the Task Force served on the panel of experts convened by the U.S. Committee of Irrigation and Drainage to address "How Can Irrigation Agriculture Exist with Toxic Waste Regulations" (98). The panel's report was published in 1988 and was featured in the 1987 National Meeting on "Toxic Substances in Agricultural Water Supply and Drainage, Searching for Solutions", sponsored by the U.S. Committee on Irrigation and Drainage and held in Las Vegas, Nevada in December 1987.

The 1988-89 budget for the Task Force allocated $539,475 to 19 research projects with an emphasis on bioaccumulation and chemistry/microbiology of selenium in agricultural soils. The 1988-89 Technical Progress Report (99) was widely distributed in September 1989.

The Fourth Annual Task Force Research Conference was held in March 1989 and attended by 160 invited participants. In addition to the annual reports from funded projects, this conference featured a "Panel Discussion of Research Needs" as perceived by State, federal, and local agencies. The 16 major points on research needs identified by the panel are compiled in the September 1989 Technical Progress Report. Dr. Jan van Schilfgaarde, Chair of the NRC Committee on Irrigation-Induced Water Quality Problems, gave a speech on "Sustained Irrigation - Is There a Solution?". This conference also featured a half-day session of the "USBR Kesterson Program".

Members of the Task Force are participating for the second year in the USBR Kesterson Program which focuses on field trial plots on soil water and vegetation management options to contain and dissipate selenium in upland and filled areas. Three members of the Task Force were invited participants in a "Nonpoint Source Pollution Control Workshop - Technical Issues" sponsored by the Western States Governor's Water Council in July 1989 at Irvine, California (100). The three participants presented an "Overview on Agricultural Drainage from Crop Production", "Status of Agricultural Drainage in California", and "Research Role of University of California in Understanding Technical Issues Related to NPS Pollution", and served on the "Round table Discussion and Recommendations", chaired by Darlene Ruiz, of the State Board.

A fourth University of California Committee of Consultants has been appointed on "Potential Usage of Evaporation Pond Materials as Soil Amendments". The Committee is charged with exploring the possible beneficial use of residual pond materials in the east side of the San Joaquin Valley where soils are deficient in trace elements and grazing animals suffer from selenium deficiency. The 1989-90 Task Force Budget is providing $472,700 of funds to 19 research projects.

Several members of the Task Force are serving as editors and contributors to the American Society of Civil Engineer's Manual on "Agricultural Salinity Assessment and Management". This salinity manual consists of 28 chapters, 51 contributing authors, and 10 sections addressing Nature and Extent of Salt Problems, Effects of Salts on Soils, Effects of Salts on Plants, Sampling, Monitoring and Measurement, Diagnosis of Salt Problems, Salinity Management Options, Land Treatment and Disposal of Drainage Waters, Use of Models in Salinity Assessment, Environmental, Legal and Economic Issues, and the Future of Irrigated Agriculture. The salinity manual is expected to be released in 1990.

Four ongoing investigations by the Task Force researchers with particularly interesting results are as follows:

1. Biochemistry of Microbial Selenium Volatilization in Soils and Water (Table A7, Study No. UC-38)

   This study focuses on the optimum environmental conditions affecting processes to reduce selenium content in seleniferous soils. The optimum conditions or additions of moisture, pH, temperature, and protein for gaseous selenium production were, 35°c; L - methionibne, 100 ppm; galacturonic acid, 3.6 gC kg^{-1} soil; and protein sources, 2.0 gC kg^{-1} soil.

   The results show that microbial methylation of Se can be stimulated in Se-contaminated sediments by specific amendments and on conditions which favor aerobic microbial processes. Field application of these findings may be possible, provided that similar conditions can be maintained on a large scale over a sufficient period of time. A remediation program would consist of adding a specific carbon source, frequent tilling, and irrigation with intense management being practiced in the warm summer months.

2. Determination of the Toxicity and Bioaccumulation Potential of Agricultural Drain Water Contaminants in Aquatic Food Chains (Table A7, Study No. UC-20)

   The bioaccumulation and resultant toxicity of Se in aquatic organisms results from two processes: bioconcentration, which is the uptake of Se from the water column; and biomagnification, which is the uptake of Se through the food chain which can include organic Se compounds biosynthesized by primary producers. This work involves investigations into the toxicity, bioaccumulation, biotransformation, and transfer of Se in algae (primary producers), invertebrates (primary consumers) and fish (secondary consumers), which constitute the three major trophic levels present in aquatic food chains. Some of the findings of this work are:

   a. The bioconcentration factors and toxicities of the selenium forms evaluated (selenate, selenite and selenomethionine) are different. The relative toxicities of the Se forms examined, ranked from most to least toxic, are usually selenomethionine, selenite, and selenate. The relative toxicities of these Se forms are species specific.

b. The interactions of several forms of Se and water quality parameters were evaluated. The toxicological interactions of selenate, selenite, and selenomethionine are strictly additive. Increasing water hardness attenuated the toxicities of selenate and selenite but did not affect selenomethionine toxicity. Increasing sulfate concentrations decreased, varied, and left unaffected the toxicities of selenite and selenomethionine, respectively.

c. Studies evaluating the transfer and bioaccumulation of Se by aquatic invertebrates fed seleniferous algal diets exhibit two patterns. Daphnia magna fed Se-containing S. capricornutum showed no Se accumulation and no toxic effects when compared to controls. In similar experiments with the midge Chironomus decorus, animals fed seleniferous freeze-dried algal diets exhibited elevated Se concentrations and reduced growth rates.

d. Fathead minnows exposed to a seleniferous prepared diet demonstrated that Se uptake in the fish was rapid with whole-body equilibrium essentially being reached by 14 days. Growth was significantly inhibited at the highest selenium treatment levels evaluated. An analysis of the comparative tissue selenium levels indicates that ovarian tissues accumulated significantly greater levels of selenium than did other tissues. There were no significant treatment effects on any of the reproductive parameters measured.

e. Experiments determining the comparative Se accumulation from waterborne (bioconcentration) and foodborne (biomagnification) sources by fathead minnows and bluegill are currently being conducted. The bioconcentration experiments are completed and demonstrate that fathead minnows exposed to selenate and selenite do not accumulate significant levels of Se. Bluegill did not accumulate selenate but selenite uptake was significant.

f. Preliminary studies examining the transformation and biochemical supposition of Se by the alga Selenastrum Capricornutum indicate that selenite is accumulated and transformed into selenoamino acids. Evaluation of the comparative metabolism of selenate, selenite, and selenomethionine by S. capricornutum is continuing.

3. Saline Drainage Water Reuse in the San Joaquin Valley (Table A7, STUDY No. UC-16)

The purpose of this work is to evaluate the potential for reuse of saline water for irrigation as a partial solution to the disposal of saline drainage water. The study findings indicate that drainage water as high as 4500 mg/L TDS can be used for irrigation of cotton for at least three years as long as preplant irrigations with good quality waters are used for cotton and sunflower in the rotation. After four years of application of saline drain water, a significant reduction in yield of seed cotton and lint at all levels of salinity above 4000 mg/l TDS have been observed. There was no harvestable seed cotton at 6000 and 9000 mg/l TDS treatment levels. A similar reduction in yield is apparent in the safflower crop planted in 1988. The primary effect on the cotton crop has been on stand establishment. The presence of Na in the irrigation water has caused a dispersal of soil particles when good quality water is applied which results in a very dense soil structure that inhibits seed germination and emergence. Continued use of saline drain water will require intensive management of the soil which focus on seed bed preparation.

4. Potential for the Long-Term Cyclic use of Saline Drainage Water for Irrigation of Vegetable Crops (Table A7, Study No. UC-29)

Although most of the growers considering drainage water reuse view salt-tolerant crops (e.g., eucalyptus and cotton) as the preferred crop to irrigate, others are considering more salt-sensitive crops such as tomato and melon because they are economically more attractive. Earlier studies have shown that tomato fruit quality can be improved by saline drainage water application without reducing crop yield. This experiment was designed primarily to study drainage water irrigation of the tomato crop. A three-year rotation of tomato typical of the westside areas was initiated in 1986.

After completion of a three-year cycle, there was no detrimental effect of any drainage treatment on either tomato fruit yield or cotton lint production. Tomato green fruit yield and vegetative biomass were higher in plots receiving saline water than in those receiving fresh water for all three years. This effect was probably caused by the high nitrate levels in the drainage water (approximately 330 Kg N per hectar) and is reflected in higher tissue N levels in the saline-treated plants. Selenium concentrations in tomato tissues were increased between two- and three-fold by drainage water application, with the highest levels found in leaves, intermediate levels in stems and lowest in fruit. However, the selenium levels in tomato tissue were not high enough to cause health concerns.

The data indicate that overall soil salinity can be managed in a reuse scheme such that moderately sensitive crops can be incorporated into the rotations and benefit from the supplemental nitrogen and quality improvement induced by some degree of salt stress. Potential limitations suggested by this study are the long-term buildup of boron in the soil, particularly if only one year of fresh water is used to leach the profile, and secondly, stand establishment problems in previously salinized plots. Future work is needed to consider potential accumulation of other trace elements such as Cr, U, Mo, and As which also limit the feasibility of cyclic reuse regimes.

On March 2 and 3, 1990 the University of California Salinity Drainage Task Force held its fifth annual conference in Sacramento with about 150 invited participants. The first day of the conference was devoted to trace elements chemistry and microbiology, irrigation drainage and salinity. The morning session on March 3 was devoted to agricultural evaporation ponds in the San Joaquin Valley. Several University, State, and federal agency researchers covered various aspects of evaporation ponds. A brief summary of the important findings provided at the meeting follows [101].

1. The active evaporation ponds in the western San Joaquin Valley of California range from 10 to 1,800 acres. The ponds are constructed of native soils by excavating the top one foot of the soil for embankment. Some of the ponds have been in operation as early at 1972.

2. The drainage water from 56,500 acres irrigated land in the Valley is disposed of via evaporation ponds. The area of the ponds comprises 13.0 percent of the drained lands. The volume of drainage water is 31,900 acre feet/year or approximately 0.56 acre-feet/acre of drain land per year. The mass of total dissolved solids (TDS) discharged to the ponds is estimated at 810,000 tons/year (approximately 26 percent of net salt accumulation in the

Western San Joaquin Valley). This amounts to 115 tons TDS/acre pond per year. The mass of selenium, arsenic, molybdenum, and boron discharged to the ponds are, 0.30, 0.50, 6.0, and 93.0 kg/acre of pond per year, respectively. (Note the mass of selenium discharged to Kesterson Reservior during 1981-1986 was approximately 1.5 kg per acre of pond per year).

3. The quality of water in the ponds is strongly correlated to the geologic setting of the ponds. The concentration of selenium, molybdenum, arsenic, boron, and uranium in pond waters exceed levels found in natural water. For example, selenium in pond waters ranges from 1-1,900 ppb compared to 0.09 ppb in sea water (designated waste level for Subchapter 15 is 1,000 ppb of selenium), similarly, concentration of arsenic ranges from 1-13,000 ppb compared to 3 ppb for sea water. The concentration of uranium in 60 percent of the ponds exceed 400 ppb.

4. The drainage water seepage rate from evaporation ponds even though spatially variable, is in the order of 3-4 mm/day. The ground water mound forms underneath the ponds with higher rates of seepage. Information was presented which indicates the high degree of biological activity in the pond waters and also bioaccumulation of trace elements by the pond organisms was noted.

5. The evaporation pond trace element impacts on waterbirds was noted by USFWS researchers. Based on 173 assessments, they have strong indications of dose-reponse relationships between selenium concentration in eggs and embryonic deformities. 63 percent of the 4,190 acres of ponds studied showed one or more species with mean selenium levels exceeding 20 ppm (dry weight) in eggs. Elevated incident of embryonic deformities and low hatchabilities were observed when selenium in eggs exceeded 20 ppm.

6. On the bright side, the work of several researchers on methods to minimize contaminant hazards to wildlife using evaporation ponds was presented. Deepening the ponds, eliminating windbreaks, removing levee vegetation, and bird hazing are suggested as interim measures. Methods that show promise and need to be investigated are treatment of pond water (dye or acidification), pond design, bird deterrence mechanisms (hazing), pond location (relative to fresh water habitat), and drainage water reduction and treatment to remove toxic constituents. DWR is currently funding several studies on toxicology of trace elements, agroforestry, and hazing methods. Future research needs include pond ecology to reduce pond organism abundance, wildlife contamination, develop pond management alternatives, pond research facilities, evaluation of wildlife benefits/detriments, alternative methods of providing off-site mitigation, evaluation of alternatives for long-term disposal of pond salts and brine.

3.2 - Lawrence Livermore National Laboratory (LLNL)

The biochemical-genetics of selenate conversion to non-toxic elemental selenium (Se°) has been investigated at LLNL. It was observed that agar-plate cultures or suspensions of C. pasteurianum, but not E. coli, can reduce ppm concentrations of selenate to Se°--manifested by the appearance of brick-red colonies or centrifuged cell pellets. This occurs despite the fact that the uptake of selenate is 80-100 times faster in E. coli than C. pasteurianum. The inability to transform selenate into Se° makes E. coli an attractive host cell for isolating the gene(s) involved in selenate reduction by other bacteria that are potentially useful for its removal. The ability to form brick-red colonies, or yield cell suspensions that turn red upon incubation with 10-25 ppm selenate was transferable into a new E. coli host cell (Table A8).

3.3 - California State University, Fresno (CSUF)

Researchers from CSUF are involved in a wide variety of projects including treatment of saline agricultural drainage, wildlife habitat provided by agroforestry, and on-farm management. Dr. Karl Longely has been actively involved in establishing a drainage water treatment research center in the Mendota area. CSUF researchers have also been involved in selenium volatilization studies and modification of a Hydrological Assessment Report needed for evaporation ponds (Table A7) (also see Section 1.1.3).

Chapter 4

Other Federal and State Agencies and Local Districts

4.1 - Other Federal Agencies

4.1.1 - U.S. Department of Agriculture- Agricultural Research Service (ARS)

The ARS has been actively investigating: (1) irrigation management for controlling salts and potentially toxic elements; (2) management and design of irrigation and drainage systems to reduce drainage from irrigated agriculture; and (3) irrigation water management to control water and solute stresses in crops. Descriptions of the 45 projects active in 1988 were presented in the 1988 Annual Report by the Water Management Research Laboratory in April 1989 (102) (Table A9).

4.1.2 - U.S. Committee on Irrigation and Drainage (USCID)

This body convened a panel of experts in 1987 to examine the toxic issues in irrigated agriculture. The panel released a report "How Can Irrigated Agriculture Exist With Toxic Waste Regulations?" (104). The panel identified economic incentives, education, and voluntary compliance with regulations for reduction of agricultural contaminants.

During November 1989, USCID held a conference in Sacramento. The subject of the conference was "Controlling Toxic Substances in Agricultural Drainage-Emerging Technologies and Research Needs". Invited speakers from USBR, USFWS, DWR, the State Board, and the San Joaquin Valley Drainage Program addressed various aspects of toxic substances in irrigated agriculture. During the technical session water quality aspects, institutional approaches, and biological and nonbiological processes of drainage water treatment were discussed. Source control, voluntary compliance, BMPs were identified as means that irrigated agriculture could respond to reduce contaminants and ensure compliance with water quality objectives. The conference proceedings is expected to be released in 1990.

4.2 - Other State Agencies

4.2.1 - DHS

DHS has funded studies to determine the contribution from vegetables grown on contaminated soils to the total body burden of selenium and background concentrations of elements in California soils subject to contamination from industrial wastewater. There are three projects funded by DHS (Table A10).

1. Uptake of selenium by vegetable crops. The objectives of the study are:

    a. To measure, under field conditions, uptake and distribution of selenium in vegetable crops grown in the San Joaquin Valley as affected by selenate level in irrigation water.

    b. To determine the effect of saline, high sulfate water on the uptake and distribution of selenium in these vegetable crops.

c. To model the impact of these variables on the diets of consumers of vegetables grown under various rhizoshere regimes.

d. To provide information necessary to make reliable health assessments at hazardous waste sites and permitted facilities.

The project is conducted by University of California, Davis (UCD) researchers and is anticipated to be complete in late 1990.

2. Correlation of soil selenium levels with selenium levels in edible portions of food crops. The objectives of the study are:

   To analyze soil samples collected from around the State for selenium and cadmium content and other soil chemical parameters and correlate data with existing data on tissue selenium levels for plants grown on these soils in order to quantify the relationship between soil selenium levels and selenium concentrations of edible tissues of these plants.

   This project is conducted by UCD researchers and will be complete in late 1990.

3. A survey of background levels of trace elements in Southern California soils. The objectives of this work are to develop an accurate and comprehensive data base of trace element levels in soil from selected locations throughout California. In the first year, the contractor will determine the background levels of trace elements in selected major alluvial valley soils of the greater Los Angeles basin area of Southern California.

   This work will be carried out by researchers at University of California, Riverside. A contract should be executed and work begun by February, 1, 1990 and be completed by March 1, 1991.

4.2.2 - DFA

DFA has studied the agroforestry plantation as a means of reducing the volume of saline drainage since 1985. By selecting salt tolerant plants, such as eucalyptus and casuarina, the saline water is reused. Through reuse of saline water the drainage water becomes highly concentrated, leaving smaller volumes of drainage water to be disposed of or treated by other methods.

The agroforestry plantation is being investigated to lower the high water tables, to intercept lateral ground water flows from upgradient, intercept seepage from water delivery canals, and to reduce the volume of drainage water collected for irrigated farms. The possibility of using eucalyptus and salt bush as selenium enriched diet for livestock in selenium deficient areas is also under study.

Approximately 180 acres of trees have been planted in Fresno, Kings, and Kern counties. The sites are monitored for salinity, water table depth, tree growth, and for levels of selenium in soil, water, and foliage.

Economics of agroforestry, selection, and propagation of trees, biomass characterizations, and wildlife impacts are being studied by researchers from the University of California Davis and Fresno State University [103]. The Drainage Program funded a study to determine the agroforestry plantations' adverse impact on wildlife in the San Joaquin Valley (Table A11).

4.3 - Local Irrigation and Drainage Districts

The Basin Plan Amendment prepared and approved by Central Valley Regional Board requires all generators and dischargers of agricultural drainage to submit Drainage Operation Plans (DOPs). The DOPs are designed to report past activities, immediate actions, and long-term opportunities for drainage reduction. All irrigation and drainage districts in the western San Joaquin Valley submitted DOPs (Central Valley Regional Board, 1990-Personal Communication). DOPs discuss various methods to help reduce drainage volume. The methods proposed are water conservation, tiered pricing, improved irrigation practices, treatment methods, reuse of drainage water, research and administrative needs. Activities of local irrigation and drainage districts are listed in Table A12.

4.3.1 - Broadview Water District (BWD)

BWD has monitored tile drain water for determining quality and quantity of drainage water. BWD has also participated in several studies analyzing: (1) the relationship between agricultural drainage flows and salt and selenium loadings; (2) The relationship between applied irrigation water and subsurface drainage flows; (3) using observed irrigation and drainage relations to select optimum management policies; (4) economic analysis and farm-level implications of regional drainage policies; and (5) an increasing block-rate pricing program to reduce drainage water in the District. The last project is funded by DWR. A description of tiered-pricing program and some of the important findings of this work are presented here [104].

The tiered-pricing program includes crop specific tiering levels at a price of $16 per acre-foot. Additional irrigation water is available at $40 per acre-foot. Tiering levels used in the BWD pricing program were determined by reducing crop specific three-year average irrigation depths by ten percent. Preliminary results indicate that the tiered pricing was successful in reducing the volume of drainage water for certain crops. Cotton, wheat, tomatoes, melons, sugarbeets, alfalfa seed, and rice were used in the program. Expect for cotton and wheat crop, specific irrigation depths during 1989 were less than 1986-88 crop specific average irrigation depths. Volume of drainage water collected in BWD sumps in 1989 were 6.3 percent less than three-year average values.

The farmers responded positively to the pricing program by improving irrigation scheduling, using shorter furrows, reduced set times, etc. The report also points out that the tiered pricing program needs to be adjusted to account for soil characteristic differences. For example, the farmer with light-textured soil would pay larger surcharges than farmers with heavy-textured soil. This is because the furrow irrigation efficiency on light-textured soils for a given level of effort is less than heavy-textured soil.

4.3.2 - Central California Irrigation District (CCID)

CCID conducts drainage monitoring for selenium, boron, salinity, and depth of water table within the District.

4.3.3 - Grasslands Water District (GWD)

GWD in cooperation with DFG and USBR supports studies to develop alternative water supplies for enhancement of waterfowl habitat. GWD also pursues studies to determine wetland water needs and potential sources of water.

4.3.4 - Westlands Water District (WWD)

WWD delivers approximately 1.3 million acre-feet of Central Valley project water to some 570,000 acres of agricultural lands. Prior to 1986, drainage water (totaling about 6,900 acre feet) from 42,000 acres was discharged to San Luis Drain. The terminus of the San Luis Drain was Kesterson Reservoir. Following the decision by USBR to close the Kesterson Reservoir, WWD commenced plugging the drains in 1985 and completed it in June of 1986.

With no access to San Joaquin River to discharge the drainage water, WWD investigated various options to deal with the drainage water. These options included evaporation ponds, recycling drainage water, land disposal, water conservation, on-farm water management, biological treatment and deep-well injection.

In response to a Central Valley Regional Board order, WWD prepared a drainage operation plan [105]. The activities proposed by WWD are detailed in the report. The highlights of the WWD activities for 1990 and later years are briefly described here.

1. The District's service area farmers will continue to recycle the drainage water on approximately 14,000 acres of the area.

2. The District will continue the Water Conservation and Management Program through updating and distributing its publications, sponsoring water management workshops/seminars, and providing technical assistance on irrigation management.

3. The deep-well injection project remains on hold until an upper injection formation has been tested and EPA's approval of using upper layer is obtained.

4. WWD will continue investigations on the co-generation process to examine if selenium can be removed from the salts produced when distilled water and salts are separated in the process. Should selenium removal be feasible, the salts can be disposed of in Class II landfills requiring less costs compared with selenium tainted salts that have to be disposed of in Class I landfills.

5. WWD will apply for a State Board loan for an agroforestry project to dispose of drainage water.

In August 1989, USBR formed the San Luis Unit Drainage Program (SLUDP). The goal of the program is to identify and implement a long-term solution to the drainage problems of the San Luis Unit of the Central Valley project. The formation of SLUDP was in response to a court decision involving the WWD service area. The drainage plan must provide for treatment and/or disposal of 60,000 - 100,000 acre-feet of drainage water from within WWD.

The USBR has initiated the planning process. Among alternatives considered are source reduction, environmentally safe evaporation ponds and agroforestry plantations, the co-generation process, and institutional changes. Among institutional changes considered are incentives for source control and land retirement. USBR is required to submit the plan to WWD by December 31, 1991.

Appendix A

Tables--Selenium and other Trace Elements Studies

Appendix B

Funding

Appendix C

Legislation and Litigation Related to San Joaquin Valley Drainage Issues

Appendix D

Researchers, Coordinators, and Cooperators

References Cited

List of Acronyms

TABLE A1. WATER RESOURCES CONTROL BOARD SELENIUM AND OTHER TRACE ELEMENT STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS*	STATUS
WB-1	Selenium in California	Summary of sources, movement, fate, and environmental and health.	SWRCB**	1985-1988	$162,000	Volume I is released. Volume II in preparation. Final expected mid-1990.
WB-2	Expanded Toxic Substances Monitoring (TSM) Program.	Expand and redirect existing fish monitoring to include Se analysis at selected locations.	SWRCB	1985-1989	$ 3,000	Annual Reports.
WB-3	Redirect State Mussel Watch (SMW) Program.	Redirect sampling to focus on Se analysis in mussels from existing monitoring stations.	SWRCB	1985-1986	No Cost	A report is available.
				1986-1987	No Cost	Report available.
				1987-1988		Samples collected and analyzed: report available.
WB-4	Survey of sources of Se and other trace elements.	Map sources of Se, As, Hg, Cd, Pb, Zn, Cu, Cr, Mo, Ag, Mn at high priority agricultural and industrial sites.	SWRCB/ RWQCB***	1985-1986	$216,400	Several reports available.
WB-5	Fish & Wildlife Se Verification Study.	Verify TSM and SMW findings and sample other biota for Se levels.	SWRCB	1985-1986	$384,300	Report published May 1987.
		Follow-up of 1985-1986 work.	SWRCB	1986-1987	$198,120	Final report available.
		Follow-up of 1986-1987 work	SWRCB	1987-1988	$210,400	Sampling & analyses completed: report available.
		Monitoring & food chain investigation	SWRCB	1988-1989	$210,400	Sampling completed.
		Monitoring & food chain investigation	SWRCB	1989-1990	$167,000	Sampling underway.

* Personnel cost not included, except where noted. ** State Water Resources Control Board. *** Regional Water Quality Control Board.

TABLE A1. WATER RESOURCES CONTROL BOARD SELENIUM AND OTHER TRACE ELEMENT STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WB-6	Analysis of Trace Elements Including Se	20% of all Verification Study samples were analyzed. 19 other trace elements of concern were analyzed.	SWRCB	1985-1988	$170,000	Report available.
WB-7	Laboratory Quality Control	Review and develop procedures for various analytical laboratories involved in state Se studies.	SWRCB	1985-1986	$ 35,000	Multiple contracts executed for quality control and analyses, referee laboratory, and inter-laboratory calibration. Interlaboratory calibration report completed.
		Verification of Se analyses.	CVRWQCB*	1986-1987	$ 7,500	Complete: reported in Study WB-5 report for 1987-1988.
				1987-1988	$ 4,900	Complete: reported in Study WB-5 report for 1987-1988.
		Develop improved analytical techniques.		1988-1989	$ 5,000	Completed.
WB-8	Analysis of Agricultural District Discharges.	Analysis of agricultural drainage from 91 Districts.	CVRWQCB	1985-1986	$ 26,000	Reports released October 1988 and December 1988.
				1986-1987	$ 26,000	
				1988-1989		Monitoring continued.
WB-9	Investigation of Unowned Sources.	Documentation of all discharges to and diversions from San Joaquin River.	CVRWQCB	1985-1986	$ 80,000	Documentation of all discharges to and diversions from SJ River is completed. Final reports released October and December 1988.

* Central Valley Regional Water Quality Control Board: CVRWQCB

TABLE A1. WATER RESOURCES CONTROL BOARD SELENIUM AND OTHER TRACE ELEMENT STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WB-10	Analysis of Agricultural, Municipal & Industrial discharges from Unowned Sources	Analysis of 1450 water samples from non-point sources.	CVRWQCB	1985-1986	$128,000	Sampling completed.
				1986-1987	$128,000	Continuation of source monitoring. Reports available.
				1987-1988	$ 94,000	Continuation of source monitoring. Reports released October and December 1988.
				1988-1989		Completed.
WB-11	San Joaquin River Model	Develop a model for accretion, depletion, agricultural/municipal/industrial discharges, and diversions for SJR and tributaries	SWRCB	1985-1986	$120,000	Model development completed.
				1986-1987	$ 45,000	Additional data input.
				1987-1988	$ 45,000	Model used to evaluate drainage reduction as method to achieve water quality objectives.
				1988-1989 1989-1990	$ 45,000 $ 45,000	Variability in water flow and quality to be incorporated.
WB-12	Se Standard for Agricultural Water Supply.	Develop Se Standards for crops irrigated and water stock.	CVRWQCB	1985-1987	$ 72,000	Final report completed.

TABLE A1. WATER RESOURCES CONTROL BOARD SELENIUM AND OTHER TRACE ELEMENT STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WB-13	Development of Water Quality Criteria	Evaluate known toxicity of Se, B, and Mo to plants, fish, and wildlife	SWRCB	1985-1986	$105,000	Report available.
		Se criteria will be developed for San Joaquin River Basin		1987-1988	$ 50,000	Completed.
				1988-1989	$ 55,000	Completed.
				1989-1990	$ 22,000	Ongoing.
WB-14	Development of Economic Model	Analysis of economic impacts of potential water quality objectives and physical facilities.	SWRCB	1985-1986	$200,000	Final report available.
WB-15	Evaporation Pond Investigations	To gather information needed to develop operational criteria for evaporation ponds used by wildlife.	CVRWQCB	1986-1988	$117,000	Three reports prepared and released 1988.
WB-16	Program Coordination & Management	Provide staffing for coordination and data management of Se studies.	SWRCB	1985-1987	$ 50,000	Progress reports issued December 1985, March 1986, October 1986, December 1987.
				1987-1988	$ 70,000	Management/Coordination.
				1988-1989	$ 75,000	Report issued March 1989.
				1989-1990		Report being prepared.
WB-17	San Francisco Bay Studies	Bagged bivalve monitoring near point source discharges to Bay and verification of selenium analyses.	SWRCB	1986-1987	$ 58,500	Completed. Data reported in 1987 Selenium verification Study Report (see WB-5).
WB-18	Investigation of Se Contamination in Imperial Valley.	To determine resources of Se entering surface waters from agricultural areas in Imperial Valley.	SWRCB/ USGS	1987-1988	$ 35,000/ $ 35,000	
			USGS	1988-1989	$ 43,000/ 27,000	Final report due 1990.

TABLE A1. STATE WATER RESOURCES CONTROL BOARD AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM (ADLP)

PROJECT NO.	TITLE SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WB-19	Miscellaneous data gathering	Monitoring water quality at San Joaquin River and its tributaries.	SWRCB/ CVRWQCB	1989-1990	$222,100	Many reports available.
WB-20	Characterization of evaporation ponds.	Phycical and chemical characterization of ponds.	SWRCB 205(j)	1989-1990	$62,000	Completed.
WB-21	Microgial volatilization of selenium from soil	Develop procedures for removing Se from agricultural evaporation ponds	SWRCB using EPA Grant Funds (205(j)(5)	1-4-88 to- 3-5-90	$292,000 219,000 (73,000)	On-going (UC Riverside)
WB-22	Same, Part II	Same	Same	1-90 to 5-31-90	$78,000 $58,500 (19,500)	On-going (UC Riverside)
WB-23	Determination of HAR** requirements for Agricultural Evaporation Pond	Modify TPCA**** HAR requirements for Agricultural Evaporation Ponds	Same	6-1-89 to 5-31-90	$127,000 $ 95,250 (31,750)	On-going (UC Davis, Fresno State)
WB-24	Evaporation ponds for the disposal of agricultural wastewater	Design evaporation ponds to protect ground and surface water quality	Same	6-1-86 to 10-30-88	$270,700 $210,700 (60,000)	On-going (UC Davis)
WB-25	United Water Conservation District Groundwater Nitrate Feasibility Study	Mitigation plan for groundwater nitrate problem	SWRCB-ADLP	8/89 to 8/90	$75,000	On-going
WB-26	City of Redlands DBCP Treatment Project	Wellhead treatment facilities for removal of DBCP from ground water	SWRCB-ADLP DHS	5/89 to 7/90	$4,000,000 (projected) SWRCB $2,000,000 DHS $2,000,000	On-going

* When more than one agency fund the project - Figures in paranthesis are in-kind services or matching funds.

** Hydrological Assessment Report

*** TPCA - Toxic Pits Cleanup Act

TABLE A1. - STATE WATER RESOURCES CONTROL BOARD AGRICULTURAL DRAINAGE WATER MANAGEMENT LOAN PROGRAM

PROJECT NO.	TITLE/ SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WB-27	Buean Vista Water Storage District Groundwater Feasibility Study	Shallow groundwater monitoring program and feasibility study	SWRCB-ADLP	1/90 - 2/92	$100,000 (projected)	Expected to begin 1/90
WB-28	Status of ADLP and agricultural drainage problems in California	Annual report to the Legislature on the ADLP, required by statute	SWRCB	8/88 - 8/89		completed
WB-29	Survey of agriucltural drainage problems in California	Contract with U.C. Davis supports ADLP Annual Report to the Legislature	SWRCB	12/87 - 6/90	$137,470	on-going

TABLE A2. U.S. FISH AND WILDLIFE SERVICE (USFWS) AGRICULTURAL RELATED STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS*	STATUS
FW-1	Aquatic Monitoring for Contaminants	Determine trace element concentrations in aquatic biota from Valley, Delta, & Bay	USBR/ USFWS	1986-1990 1989-1990	$823,000 $7,800	In progress - several publications available
FW-2	Toxicity of Contaminants to Fish & Aquatic Invertebrates	Lab studies with drain water & field verification studies to determine aquatic toxicity to fish and aquatic invertebrates	USBR/ USFWS	1986-1990 1989-1990	$1,713,000 $44,400	In progress - several publications available
FW-3	Bioaccumulation of Contaminants in Aquatic Ecosystems	Lab studies w/microcosms to evaluate accumulation effects, and fate of Se species in the aquatic food chain	USBR/ USFWS	1986-1990 1989-1990	$1,083,000 $73,000	In progress - several publications available.
FW-4	Accumulation and Loss Rates of Contaminants in Waterfowl	Determine factors affecting uptake and retention of Se, B, & As in caged mallards, relate to migratory movements of waterfowl.	USBR/ USFWS	1986-1990 1989-1990	$1,213,000 $90,900	In progress - several publications available.
FW-5	Maximum Safe Levels for Chronic Exposure of Waterfowl to Contaminants	Estimate Se, & As chronic toxicity tolerance levels in caged ducks during reproduction, growth, and overwintering	USBR/ USFWS	1986-1990 1989-1990	$922,000 $93,900	In progress - several publications available.
FW-6	Accumulation and Effects of Contaminants on Wintering and Migrating Waterfowl	Determine waterfowl migratory and overwintering distribution. Sample invertebrates and vegetation for drainwater contaminants and assess short and long-term effects on waterfowl mortality and recruitment.	USBR/ USFWS	1988-1990		Deferred

* Estimated FY 1990 budget $310,000 through USBR San Luis Unit appropriations. USFWS expends about $1,000,000 annually from their own funds.

TABLE A2. U.S. FISH AND WILDLIFE SERVICE (USFWS) AGRICULTURAL RELATED STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
FW-7	Interactive Effects of Contaminants on Waterfowl	Determine effects of trace elements (especially As, B, & Se) alone and together on waterfowl, feeding studies	USFWS	1987-1990	$686,000	In progress - publications in preparation.
FW-8	Development of Capability to Predict Contaminants Impacts upon Wildlife	Determine tissue burdens of contaminants associated with impacts on reproduction and mortality. Develop diagnostic indices to determine effects on fish and wildlife resources. Includes studies of biological effects of contaminants in evaporation ponds.	DWR/ USFWS	1986-1990 1989-1990	$1,107,000 $200,000-$500,000	In progress - several publications.
FW-9	Grasslands Contamination Study	Assess extent of drainwater contamination throughout Grasslands area	USFWS	1985-1990	$2,021,444	In progress - several publications.
FW-10	Kesterson Environmental Contamination Studies	Determine effects of drainwater in Kesterson on aquatic birds, fish, mammals, & other biota	USFWS	1983-1985	$700,000 (approx.)	Studies complete - several publications.
FW-11	Bird Condition and Health	Determine tissue and biochemical change in aquatic birds collected from Kesterson Reservoir	USFWS	1985-1988	$9,000	Study complete - publications in preparation.
FW-12	Pilot Marsh Study	Assess feasibility of using agricultural drainage for wetland habitat	USFWS		NA	Deferred.
FW-13	Migratory Bird Disease Study	Determine effects of drainwater constituents on disease resistance of migratory birds	USFWS	1987-1991	$255,000	Not funded for 1989-1990.
FW-14	Hazing at Kesterson	Birds are being hazed off ponds at Kesterson Reservoir	USFWS/ USBR	1984-1988	$1,400,000	Completed

TABLE A2. U.S. FISH AND WILDLIFE SERVICE (USFWS) AGRICULTURAL RELATED STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
FW-15	Closure of Kesterson Ponds	Kesterson ponds are closed to public assess for fishing and hunting	USFWS	1984-	NA	In effect now.
FW-16	Kesterson Cleanup	Cooperative program with USBR to develop cleanup plans for Kesterson Reservoir and San Luis	USFWS/ USBR	1985-1991	$350,000	Planning, environmental assessment information for post-clean-up biological monitoring and mitigation. No funding for 1990.
FW-17	Fish and Wildlife Water Supplies	Various activities at state and national wildlife refuges in San Joaquin Valley to obtain clean water supplies for waterfowl habitat and provide advice for best management	Various	1985-1991		Work going on throughout Valley, including Tulare Basin. Trying to get water for both wildlife areas and instream fishery flows. No funding in 1990.
FW-18	Water Quality Monitoring	Determine water quality of agricultural drainage waters to supply wetlands for pilot marsh study	USFWS	1985-1986	$84,000	Completed. Data released in USGS open-file report.
FW-19	Fish and Wildlife Resources Values	Identify and evaluate values associated with fish and wildlife resources in San Joaquin Valley that are/may be affected by management of irrigated lands.	USBR	1987-1990	$15,000	Waterfowl hunting report available. Report re values of wetlands restoration, San Joaquin River fisheries restoration, and evaporation pond management.
FW-20	Technical Review, Evaluation, and Recommendations for Alternatives	Participation in various committees and programs evaluating problems, management, and treatment alternatives	USFWS	1984-1991 1989-1990	$1,000,000 $50,000	In progress.
FW-21	Migratory Birds Exposure Hazard to Evaporation Ponds	Determine use of evaporation ponds by migratory birds	USFWS	1986-1990	NA	In progress - publications in preparation. No funding in 1990.

TABLE A2. U.S. FISH AND WILDLIFE SERVICE (USFWS) AGRICULTURAL RELATED STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
FW-22	Habitat Mapping	Determine past and present quantity and geographic location of key fish and wildlife habitats in the San Joaquin Valley	USBR/ USFWS	1987-1991	$700,000	Color infrared aerial photography of entire San Joaquin Valley flown in April 1987. Photo-interpretation, habitat mapping, and digitizing underway. All designated fish & wildlife areas & facilities and some land ownership mapping/digitizing complete. No funding in 1990.
FW-23	Kit Fox Study	Determine Kit Fox use of and exposure to contaminants in the Kesterson Reservoir area.	USBR/ USFWS	1986-1988	$200,000	Study complete - publication(s) in preparation.
FW-24	Habitat Restoration Study	Identify and evaluate methods to decontaminate and restore contaminated fish and wildlife habitats	USBR	1988	$30,000	Publication(s) in preparation
FW-25	Bio Res Data Base	Develop a computerized data base with all San Joaquin Valley drainwater contaminant values for biota	USFWS/ USBR	1985-1990	?	Data base operational - currently linking it to GIS with sampling sites. No funding in 1990.
FW-26	Agroforestry - Wildlife Study	Determine effects of agroforestry plantations in San Joaquin Valley upon wildlife	USBR/ USFWS	1987-1990 1989-1990	$150,000 $12,000	In progress - several publications.

TABLE A3. U.S. GEOLOGICAL SURVEY (USGS) SELENIUM AND TRACE ELEMENTS STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
GS-1	Geological Sources of Trace Elements	Identify and confirm processes of weathering, transport, and deposition of Se on west side San Joaquin Valley	USGS/USBR	1984-1987	$100,000	Identification of source formations, geochemical weathering products & prevalent geomorphological processes of transport, completed.
GS-2	Spatial and Temporal Distribution of Se and other Trace Elements	Idnetify occurance and mobility of Se and other trace elements in soils and ground water, San Joaquin Basin.	USGS/USBR USBR	1985-1989 1989-1990	$2,210,000 $50,000	Investigations reveal that selenium in shallow ground water result from long-term evaporation processes. Plan to quantify ground water flow & Se movement in drained fields.
GS-3	Geochemical Processes Controlling Se Mobility in Soils	Characterization of Se and other trace element phases, solubility, and mobility in soils	USGS/USBR	1985-1989 1989-1990	$1,200,000 $50,000	Work continues on selenium speciation & behavior under irrigation & drainage. Plan to derive quantitative regional assessment of future Se supply to ground water from irrigated soils.
GS-4	Selenium Speciation and Redox Parameters	Determine dominant species of Se, redox sensitive parameters, and speciation processes	USGS/USBR	1985-1989	$390,000	Methods development complete. Experiments on solute-particulate interactions undertaken. Identification of low-solubility Se bearing minerals and solubility controls continues. Reports published as phases completed.

TABLE A3. U.S. GEOLOGICAL SURVEY (USGS) SELENIUM AND TRACE ELEMENTS STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
GS-5	Areal and Depth Distribution of Se in Regional Ground Water System	Assess areal distribution of chemical constituents from 50-700 feet, assess ground water quality	USGS USBR	1985-1989 1989-1990	$1,514,000 $50,000	Valley-wide sampling of wells completed. Regional geochemical processes controlling trace element concentrations to be determined. Reports published as work is completed.
GS-6	Hydrogeology of Western San Joaquin River Valley	Develop geologic framework as basis for understanding regional hydrology	USGS/USBR USBR	1985-1989 1989-1990	$2,260,000 $135,000	Mappings of west side shallow deposits completed. Ground water model completed. Ongoing work includes synthesis & reduction of water use data, drilling additional test wells & investigation of hydraulic properties and refinement of predictive capabilties.
GS-7	Microbial Aspects of Biogeochemistry of Se	Identify sulfur-respiring & nitrate-reducing bacteria's ability to immobilize Se	USGS/USBR	1985-1989	$350,000	Completed demonstration of organic selenium metabolism & microbial selenium reduction. Studies of bacterial uptake of selenium continue.
GS-8	Characterization of Shallow Ground Water, Tulare Basin	Identify distribution of salts, Se, As, B, Cr, & Mo in the Tulare Basin	USGS/DWR/ USBR USGS/DWR	1988-1989 1989-1990	$275,000 $192,000/ 192,000	Evaluation of existing data completed. Planning for basin-wide synoptic sampling to be completed early 1989. Sampling conducted spring 1989.

TABLE A3. U.S. GEOLOGICAL SURVEY (USGS) SELENIUM AND TRACE ELEMENTS STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
GS-9	Occurrence and Transport of Se and other Trace Elements in San Joaquin River	Quantity, distribution, source, and transport of trace elements in San Joaquin River	USGS/USBR USBR	1985-1989 1989-1990	$2,610,000 $50,000	Electrical conductivity and flow monitoring continues at key stations.
GS-10	Rate Processes of Phytoplankton from North San Francisco Bay	Measure growth rate, photosynthesis, and respiration for abundant phytoplankton, develop empirical model	USGS	1986-	NA	Lab culture studies have demonstrated growth in artificial media.
GS-11	Toxic Metals in Sediment and Benthos	Establish present levels of trace elements in Suisun Bay	USGS/USBR	1984-1988	$306,000	Analysis of samples complete and report has been prepared.
GS-12	Distribution of Biologically Available Selenium, & related Trace Contaminants in the San Joaquin River & San Francisco Bay	Define distribution of aquatic species, selected trace elements in clams and water hyacinth, & impact of Se on function of aquatic communities in grasslands adjacent to San Joaquin River	USGS/USBR	1985-1988	$300,000	All sampling complete and much of chemical & biological processing is complete.
GS-13	National Water Quality Network	Monitor stream flow and water quality bi-monthly at Vernalis	USGS	Ongoing	NA	Periodic water quality data releases. Data on file.
GS-14	Regional Aquifer System Analysis	Physical/Chemical characterization of San Joaquin Valley ground water	USGS USGS	Ongoing 1989-1990	$1,700,000 $200,000	Well canvassing & sampling of existing wells completed for San Joaquin Valley. First report prepared.
GS-15	Digital Data Base Development & application	To develop a Geographic Information System (GIS) for use in automating, analyzing, and presenting diverse information resulting from USGS & San Joaquin Valley Drainage Program studies	USGS/USBR USBR	1988-1989 1989-1990	$250,000 $50,000	Data analysis and entry into GIS in progress and to continue. GIS is use in evaluation of data and illustration preparation.

TABLE A3. U.S. GEOLOGICAL SURVEY (USGS) SELENIUM AND TRACE ELEMENTS STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
GS-16	Water Use for Irrigation of Western San Joaquin Valley	To assess historical and present-day use of water for irrigation in western San Joaquin Valley	USGS/USBR	1988-1989	$400,000	Data collection and analysis completed.
GS-17	Mineralogy of Soils & aquifer Materials of the Western San Joaquin Valley	To determine minerology of solid phases present in soil & aquifer system	USGS/USBR	1988-1989	$140,000	Techniques for quantifying iron mineralogy are being developed in conjunction with trace element solubilities.

TABLE A4. DEPARTMENT OF WATER RESOURCES (DWR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WR-1	Treatment Research and Demonstration	Conduct applied research and provide pilot plant demonstrations of reverse osmosis and vapor compression evaporative desalting feasibility for reclaiming drain water and conduct applied research on solar pond system for containment and disposal of desalting plant brine	DWR	1986-1987 1987-1988 1988-1989 1989-1990	$3,300,000 $ 761,000 $ 782,000 $ 565,000	Operation of RO facility discontinued at existing site 12/86 due to lack of source water. A smaller plant will be established within Westlands Water District. 1988-89 work consists of (1) constructing new facilities within Westlands Water District, and (2) final closure of Los Banos facility. Final report on desalting facility due by mid 1990.
WR-2	San Joaquin Valley Agricultural Drainage	Periodic monitoring of perched ground water levels and drainage water quality & quantity on west side of San Joaquin Valley for purpose of siting treatment facilities, wildlife habitat & irrigation reuse areas	DWR	1986-1987 1987-1988 1988-1989 1989-1990	$ 520,000 $ 331,000 $ 349,000 $ 368,000	Ongoing project; recently expanded in Kings & Kern Co. Annual reports.
WR-3	San Joaquin River System Water Quality Monitoring	Monthly monitoring and evaluation of water quality at 12 stations on San Joaquin River and tributaries for all minerals and major trace elements including Se	DWR	1986-1987 1987-1988	$ 40,000 $ 40,000	Completed; data filed in DWR's Water Data Information system and the Federal Storet System.
WR-4	Inter-agency Delta Health Aspects Monitoring Program	Water quality monitoring of Delta water supplies for selenium and other agents of health significance	DWR	Continuous	$ 77,000	In progress. Program activities between 1/85 & 6/86 reported in 1986 Project Report (Dec. 1986). Subsequent activities summarized in yearly reports.

TABLE A4. DEPARTMENT OF WATER RESOURCES (DWR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WR-5	Delta Agricultural Drainage Investigation	Monitor quality of agricultural drainage water	DWR	1989-1990	$ 200,000	Ongoing - Annual Report.
WR-6	DWR Chemistry Lab Upgrade	Provide additional staff to operate analytical equipment for analysis of pesticide and trace elements	DWR	1986-1987	$ 72,000	Completed.
WR-7	Los Banos Grandes Seepage Study	Assess effect of a proposed storage reservoir on nearby drainage problems	DWR	1987-1988	$ 50,000	Results to be reported in project feasibility study.
				1988-1989	$ 25,000	
WR-8	Grassland Water District Distribution System	Improve operational system permitting flow separation to improve water quality for wildlife habitat	DWR	1985-1986	$1,100,000	Initial distribution systems modification completed in FY 1985-86, allowing fresh water distribution to grasslands. Final phase completed 1989.
			DWR/WCB/ Local	1987-1989	$ 985,000 $ 450,000 $ 159,450	
WR-9	Staff Support to Federal and State Se Studies	Support three full-time staff of San Joaquin Valley Drainage Program and others as needed	DWR	1988-90	$ 388,000	Continuing.
WR-10	State Water Project Monitoring	Monitoring and analysis of water quality in State Water Project system	DWR	1987-1988	$ 325,000	Ongoing. Reports available on SWP, other data in files.
				1988-1989	$ 350,000	
WR-11	National Academy of Science	To provide partial support to the National Academy of Science - National Research Council's Committee on Irrigation-Induced Water Quality Problems	DWR	1986-1987	$ 75,000	Completed.
WR-12	Evaporation Pond Investigation	Assist in Developing criteria and guidelines for design and operation of environmentally safe and economical evaporation ponds	DWR/DFG	1986-1987	$ 175,000*	
			DWR/DFG	1987-1988	$ 199,000*	
			DWR	1988-1989	$ 300,000	
			DWR	1989-1990	$ 620,000	In progress.

TABLE A4. DEPARTMENT OF WATER RESOURCES (DWR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WR-13	Evaporation Pond	Contract for technical report on cumulative impacts to wildlife from agricultural evaporation basins	DWR/ CVAPO[1]/	1989-1990	$ 96,600/ 32,000	Report due February 1991.
WR-14	Selenium Removal with Anaerobic Bacteria/Lab Studies	Provide additional necessary information on processes and problems involved in anaerobic removal of selenium from drainage water	DWR/USBR	1986-1987	$ 25,000/ $ 40,000	Completed. Progress and final Reports are available from San Joaquin Valley Drainage Program. Specific component of BR-1.
WR-15	Selenium Removal Pilot Plant	Anaerobic bacteria process	DWR/USBR	1990-1992	$ 500,000	Planning Phase.
WR-16	Microalga-Bacterial Removal of Selenium	Effectively remove selenium from agricultural drainage water	DWR/USBR	1986-1987	$ 5,000/ $ 60,000	Completed; Progress and Final Reports are available from San Joaquin Valley Drainage Program. Specific component of BR-1.
WR-17	Selenium Speciation in Sacramento-San Joaquin Estuary	Measurements of dissolved particulate selenium in water column at San Francisco Bay and Delta Stations	DWR	1986	$ 25,000	Monitoring of ambient water and point sources continues. One report completed. Final report due 1990.
				1987-1988	$ 36,000	
				1988-1989	$ 21,000	
WR-18	Westside Drainage Reduction	Conduct demonstration projects, carryout surveys and collect information to develop recommendations for the reduction of agricultural drainage.	DWR/SWRCB	1986-1987	$ 190,000/	In progress. Nine individual research and on-farm demonstration projects are in progress since late 1989. Preliminary results from first year irrigation season are being analyzed. These projects will continue for at least one more irrigation season.
				1987-1991	$1,658,000*	
			DWR/SWRCB	1989-1990	$ 419,000/ $ 133,000	

TABLE A4. DEPARTMENT OF WATER RESOURCES (DWR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
WR-19	Grasslands Water Quality Study	Collect water quantity and quality data in Grasslands; evaluate recent distribution system modification based on data collected by all entities in Grasslands area.	DWR Local	1987-1989	$ 214,000 $ 107,000	Complete. Expect to continue monitoring the area through other programs.

* $400,000 funding under 1978 Clean Water Conservation Bond Law (SWRCB)
Activities of existing staff: no budgeted augmentation

1/ CVAPO - Central Valley Agricultural Pond Operators

TABLE A5. DEPARTMENT OF FISH AND GAME SELENIUM AND AGRICULTURAL DRAINAGE ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
FG-1	Staff Support to San Joaquin Valley Drainage Program	Staffing to committees and study efforts, consultation etc.	DFG	1984-1987	$ 180,000*	Ongoing
				1987-1988	$ 71,000*	
				1988-1989	$ 71,000*	
				1989-1990	$ 71,000	
FG-2	Statewide Staff Support	Staff participation in meetings, hearings, public workshops, legislative analysis sample collection.	DFG	1985-1989	$ 60,000	Ongoing
FG-3	Fresh Water Supplies to Grassland Wetlands	Supply freshwater to public and private waterfowl areas, develop independent water supply instead of agricultural drainage.	DFG/USFWS	1985-1986	$ 236,000	Completed.
				1988-1989	$ 180,000	
FG-4	Pilot Selenium Removal Plant-Bacteria	Field testing to evaluate feasibility of use of anaerobic bacteria for selenium removal.	DFG/DWR/SWRCB	1986	$ 200,000**	Final report is out
FG-5	River Quality Monitoring	Monitor lower San Joaquin River quality	DFG/DWR	1986-1987	$ 125,000	Completed

* Activities of existing staff: no budgeted augmentation

** DFG $100,000; DWR $50,000; SWRCB $50,000

TABLE A6. U.S. BUREAU OF RECLAMATION (USBR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
BR-1	Drainage Treatment & Disposal	Study & develop various treatment technology & disposal alternatives	USBR	1985-1989	$300,000	Research completed preparing input for final drainage program report
BR-2	On-Farm Management	Develop on-farm practices for a comprehensive plan	USBR	1985-1989	$200,000	Agricultural Water Management Subcommittee is sponsoring programs to demonstrate the effectiveness of on-farm water conservation and drainage reduction measures. Research continues on ways to control groundwater elevations in artificially drained fields and use groundwater as water source for irrigation
BR-3	Social & Financial Investigation	To provide social assessment of plan alternatives	USBR	1986-1990 1989-1990	$150,000 $35,000	Ongoing
BR-4	Economic Investigation	Economic analysis of each plans benefits/costs including environment	USBR	1987-1989	$1,500,000	Westside Agricultural Drainage Economics (WADE) model is operational and is being used to simulate effects of alternative drainage management options on agricultural operations and drainage conditions. Environmental economics analyses are underway.
BR-5	Public Involvement	Public involvement program for comprehensive plan	USBR/DWR	1986-1990 1989-1990	$40,000 $6,000	Ongoing

TABLE A6. U.S. BUREAU OF RECLAMATION (USBR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
BR-6	NAS/NRC Overview	Independent technical review of all program activities	USBR	1986-1990 1989-1990	$933,000 $35,000	Continuing technical review by National Academy of Sciences (NAS)/National Research Council (NRC). Six subcommittees formed to assist SJVDP with public health, quality assurance/quality control, systems analysis, treatment technologies, economics, and data management.
BR-7	Kesterson Program	Remedial management of residual contamination at Kesterson Reservoir	USBR	1985-1989 1989 1990	$16,300,000 $7,400,000* $3,600,000**	Filling of low-lying areas in Reservoir completed in November 1988 to prevent winter formation of ephemeral pools. Final cleanup plan approved by SWRCB on 11/21/89. Continuing research on microbial volatilization and soil/water/vegetation management to dissipate or manage the selenium inventory. Mitigation plan to offset wildlife productivity losses was submitted to the Regional Board on 11/27/89.
BR-8	Surface and Ground water monitoring	Document water quality of water entering and leaving Kesterson Reservoir	USBR	1985-1989	NA	Completed
BR-9	Plan Development	Develop a comprehensive plan for San Joaquin Valley	USBR	1986-1990 1989-1990	$2,045,000 $50,000	Technical Information Record supporting document-preliminary planning alternative overview of the use of the WADE for plan evaluation

TABLE A6. U.S. BUREAU OF RECLAMATION (USBR) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
BR-10	Agricultural Drainage Water Contamination Project	To evaluate potential public health impacts from agricultural drainage in western San Joaquin Valley	USBR	FFY87-90 FFY 1990	$617,000 $166,000	Toxicological profile of substances of concern in agricultural drainage. Ongoing

* Does not include funds for long-term mitigation. Includes funding for Lawrence Berkeley Lab Studies (LB-1-LB-4)

** Includes funding for Lawrence Berkeley Lab and U.C. DANR studies. (See Section 2.2 and 3.1)

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS*	STATUS**
UC-1 (85-1)***	Sources and Distribution of Salts and Trace Elements in Soils of the San Joaquin Valley	Compile, evaluate, summarize, and map soil data and geologic sources of salinity and trace elements	Kearney Foundation	1985-1986 (1½ years)	$45,000	Completed
UC-2 (85-2)	Sources of Se and Salinity in Soils & Sediments of Westside San Joaquin Valley	Identify source of Se and other trace elements in soils and sediments of the west side San Joaquin Valley	Kearney Foundation	1985-1986 (1½ years)	$27,000	Completed
UC-3 (85-3)	Minor Element Composition of Irrigated Well Waters & Vegetable Crops near the Coast Range	Determine concentrations of selected trace elements in well waters. Document crops containing significant levels of elements	State	1985-1986	$39,000	Completed
UC-4 (85-4)	Movement and Quality of Shallow Ground water Relative to Irrigated Agriculture	Evaluate shallow groundwater flows in relation to agricultural practises. Improve hydrologic and water quality models	State	1985-1986	$30,500	Completed
(86-26)		Salinity-toxic constituents in shallow ground water: Movement, reuse, and impact on West Side Valley agriculture	State	1986-1987 1987-1988	$18,000 $23,000	UC-4 cont. Completed
UC-5 (85-5)	Synthesis and Analysis of Data on Lateral Ground water Flow in and near Westlands W.D. & Adjacent Districts	Compilation of all existing data from west side of San Joaquin Valley	Kearney Foundation	1985-1986	$22,000	Completed

* For FY 1985-86 only, the combined budget from State Budget Augmentation Funds ($651,000) and UC Kearney Foundation of Soil Service ($398,000) was $1,049,000 of which $998,000 was allocated for 1985-86 projects. Since then, the State Budget Augmentation Funds have provided funds to research projects at the following levels: $558,614 in 1986-87, $558,802 in 1987-88, $539,475 in 1988-89, and $472,700 in 1989-90.

** For technical details and list of publications, see "Technical Progress Reports, U.C. Salinity/Drainage Task Force", September 1986, October 1987, October 1988, and September 1989.

*** University Project Number

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-6 (85-6)	Optimal Irrigation and Drainage Strategies in Regions with Saline High Water Tables	Development of management optimization model for salinity control and cost effectiveness	State	1985-1986	$22,000	Completed
(86-23)			State	1986-1987	$28,000	UC-6 Cont. Completed
				1987-1988	$27,000	
UC-7 (85-7)	Se Transport in San Joaquin Valley Soils: Influence of Physical Properties	Investigation of physicochemical processes in Se movement through soils	State	1985-1986	$28,000	Completed
(86-33)			State	1986-1987	$27,700	Completed
UC-8 (85-8)	Shallow Groundwater Chemistry & Hydrology in Panoche Fan Alluvium	Investigate relationship between shallow groundwater flows into drains and distribution of salts and trace elements	Kearney Foundation	1985-1986	$21,000	Completed
UC-9 (85-9)	Physical & Chemical State of Se in Western San Joaquin Valley Soils	Measure & model Se transformations and transfers	Kearney Foundation	1985-1986 (1½ years)	$23,000	Completed
UC-10 (85-10)	Modeling Boron Adsorption-Desorption Processes	Evaluate high boron effects on plants & soils, & boron desorption under leaching conditions: develop & test models predicting boron adsorption & desoprtion in soil	State	1985-1986	$28,500	Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-11 (85-11)	Microbial Transformations in Seleniferous Soils	Study Se transformations; identify & quantify volatile Se products from soils and determine factors affecting Se biomethylation	Kearney Foundation	1985-1987	$38,000	Completed
(86-7)		Removal of selenium fro ag drainage water through soil microbial transformations by optimizing environmental parameters and employing salinity-adapted microorganisms	State	1986-1987 1987-1988	$21,000 $28,000	UC-11 Cont. Completed
UC-12 (85-12)	Sorption & Desorption of Selenite & Selenate by Soils of Western San Joaquin Valley	Quantify sorption and desorption of Se as a function of various parameters, develop models	State	1985-1986	$21,000	Completed
(86-1)			State	1986-1987 1987-1988	$25,500 $26,000	UC-12 cont. Completed
UC-13 (85-13)	Solubility of Se & other Hydride Forming Elements	Determine effect of salinity on solubility of hydride-forming elements	State	1985-1986	$24,000	Completed
UC-14 (85-14)	Se & Toxic constituents Distribution in Soils and Crops	Evaluate distribution of Se in experimental fields; evaluate Se accumulation in crops & relationship to changing irrigation management	State	1985-1986	$34,500	Completed
UC-15 (85-15)	Evaluation of Se Accumulation and Se and Salinity Tolerance in Grass Species	Evaluate salt & Se tolerance of commercial grasses for use in improving land & water quality	State	1985-1986	$20,000	Completed
(86-6)		Determine Se accumulation and Se/salinity co-tolerance in turf, forage grasses, & marsh plants	State	1986-1987 1987-1988	$22,400 $23,000	UC-15 cont. Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-16 (85-16)	Saline Drainage Water Reuse	Evaluate effect of irrigation drainage waters on crop yields & determine effect on soil, plant, and water	Kearney Foundation & State	1985-1986	$30,000	Completed
(86-20)			State	1986-1987	$30,000	UC-16 cont.
				1987-1988	$29,000	Completed
UC-17 (85-17)	Se Uptake by Forage Crops	Develop procedures for determining Se soil species & their availability to plants	State	1985-1986	$25,000	Completed
(86-24)		Determine Se uptake in forage plant and soil characteristics which influence Se uptake	State	1986-1987	$26,300	UC-17 cont. Completed
UC-18 (85-18)	Se Absorption & Transport by Plants	Investigate Se absorption and translocation to shoots; incorporation into organic metabolities	Kearney Foundation & State	1985-1986	$28,500	Completed
(86-8)			State	1986-1987	$19,000	UC-18 cont.
				1987-1988	$20,000	Completed
UC-19 (85-19)	Prediction of Se Transfer into Crops from Seleniferous Soils	Determine Se transfer into crops & develop a transfer function to predict Se content based on soil & water analyses	State	1985-1986	$50,000	Completed
(86-27)			State	1986-1987	$36,000	UC-19 cont.
				1987-1988	$32,000	Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-20 (85-20)	Bioaccumulation and Toxicity of Salt and Trace Elements in Aquatic Food Chain of Central Valley	Determine Se toxicity in lab under varying conditions & verify in field; determine toxicity of other return water toxicants	Kearney Foundation	1985-1986	$28,000	Comparative bioaccumulation and toxicity studies with primary producers and primary consumers completed; experiments with fish are underway Completed
(86-9)			State	1986-1987	$27,000	UC-20 cont.
				1987-1988	$28,000	Completed
UC-21 (85-21)	Se Availability & Phytotoxicity in Relation to Chemical Form & Concentration	Determine Se crop uptake & accumulation in relation to species & form; determine concentration associated with phytotoxicity	Kearney Foundation & State	1985-1987	$60,000	Completed
UC-22 (85-22)	Quantities & Species of Toxic Elements in Soils & Sediments of Panoche Fan & Uptake by Plants	Locate sources of toxic elements, determine soil conditions influencing transformation of Se & find soil treatments to reduce levels in drainage; assess plant uptake of trace elements	Kearney Foundation & State	1985-1987 (2 years)	$107,000	Completed
(86-29)	Selenium & Other Trace Elements Transformation & Disbursements in Soil/Plant Systems and in the Field	Measure fluxes of Se and As State from root zone into drainage & plants; determine effects of plants & irrigation regime on mobility and bioavailability of these elements; explore feasibility of using pasture & fodder plants to deselenify soils	State	1986-1987	$30,000	Ongoing
				1987-1988	$29,000	Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-23 (85-23)	Utilization of Blue-Green Algae to Remove Se	Investigate the use of various blue-green algae to treat drainage water	State	1985-1986	$25,000	Completed
UC-24 (85-29)	Se in Deciduous Fruit & Nut Crops	Establish Se range in various plant parts & components for fruit & nut orchards	State	1985-1986	$24,000	Completed
UC-25 (85-25)	Protection of Nutrient Uptake in Salt Stressed Barley	Assess relationship between nutrient uptake and salt stress	State	1985-1986	$40,000	Completed
UC-26 (85-26)	Salt Tolerance of Deciduous Fruit Trees	Determine effects of various levels of salinity on fruit yield, quality, & vegetative growth; determine components of vegetative & reproductive responses	State	1985-1986	$16,000	Completed
UC-27 (85-27)	Characterization of N Metabloism During Salinity Stress for Muskemelon Varieties	Assess mitrogen uptake and metabloism under salinity stress	State	1985-1986	$18,500	Completed
UC-28 (85-28)	Cloning Salt Tolerant Genes from _Elytrigia elongata_	Obtain, characterize, & map salt tolerant genes from _E. elongata_	State	1985-1986	$10,000	Completed
UC-29 (85-29)	Potential for Reuse of Saline & Se Drainage Waters for Irrigation of Vegetable Crops	Assess effect of drainage water used to irrigate crops, interaction between Se & specific components of water, Se accumulation in crops, & test crop genotypes for tolerance	State	1985-1986	$13,500	Completed
(86-28)			State	1986-1987	$33,300	UC-29 cont.
				1987-1988	$33,000	Completed
UC-30 (85-30)	Furrow Irrigation using Drain Water for Processing Tomatoes	Evaluate effects of saline drainage water on soluble solids & yields of tomatoes & determine Se increases in soil, plant, & fruit	State	1985-1986	$11,000	This study combined with UC-29 above

TABLE A7. UC SALINITY/DRAINIAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-31 (85-31)	Effect of Irrigation Quality and Application Uniformity on Crop Yield & Se Uptake	Evaluate effects of irrigation water quality and application on crops & soil rooting zone	State	1985-1986	$30,000	Sugar beet experiment complete; cotton experiment underway
(86-2)			State	1986-1987	$30,000	UC-31 cont.
				1987-1988	$29,000	
UC-32 (85-32)	Optimal Sizing of Subsurface Drain System Beneath Cotton Crops	Develop model to simulate salt & Se transport through root zone; develop optimal size & placement of subsurface drains	State	1985-1986	$17,000	Completed
UC-33 (85-33)	Integrated approach to Farm Water Management: Irrigation Scheduling, Salinity, Shallow Water Table, Drainage	Develop optimal irrigation schedules, considering yield, soil moisture, salinity, and drainage; assess interaction between on-farm management & regional constraints on salt & drainage management	State	1985-1986	$20,500	Completed
UC-34 (85-34)	Conference on Long Range Management Strategies for Soil Salinity in San Joaquin Valley	Establish salinity management criteria for San Joaquin Valley; develop procedures to determine physical & economic data needs; develop & evaluate various salinity management strategies	State	1985-1987	$20,000/yr.	Conferences held April 1986 to determine research needed to develop long-range economically efficient salinity management strategies in California Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-35 (86-3)	Influence of Competitive interactions on Trace element Bioavailability	Determine effect of competitive interactions between As, Mo, & Se on crop availabiliy at varying chloride & sulfate salinity	State	1986-1987	$24,400	Completed
UC-36 (86-5)	Geophysical Approach to Evaporation Pond Siting & Drainage Design Surveys	Evaluate potential of elctromagnetic conductivity meter for use in siting drainage systems & evaporation ponds	State	1986-1986	$5,000	Completed
UC-37 (86-18)	Regional Management of Agricultural Drainage Water	Application of economic & hydrologic models to determine economically efficient management plan for west side San Joaquin Valley	State	1986-1987	$28,300	Completed
				1987-1988	$28,300	Completed
UC-38 (86-30)	On-Farm Demonstration of Surface & Subsurface Irrigation Systems	Demonstration operational costs & yeild effects of "best managed" surface & subsurface irrigation	State	1986-1987	$30,000	Ongoing
				1987-1988	$29,000	Completed
(87-1)	Biochemistry of Microbial Selenium Volatilization in Soil & Water	Examine effects of soil type, organic amendment, & Se source and species on volatilization of Se from soils	State	1987-1988	$10,000	Completed
(87-4)	Transport & Transformation of Selenium in Soils: Influence of Aeration & Water-Logging	Evaluate reaction rates of Se transformation & adsorption, study Se transport in soil, develop model	State	1987-1988	$24,500	Completed
(87-5)	Crop response to non-uniformities of soil water and salinity for subsurface drip, surge, and furrow irrigation systems	Determine if inherent non-uniformity of soil properties and infiltration can be partially overcome by well-managed irrigation systems	State	1987-1988	$11,500	Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
(87-6)	Effect of Competitive Interactions of As, Mo, & Se under Cl and SO_4 Salinity on Crop Yield & Bioavailability	Examine effect of competitive interactions as As(V), Mo(VI), & Se(VI) on alfalfa yield & composition	State	1987-1988	$25,400	Completed
(87-11)	Economic Incentives and the Management of Selenium Emissions	Evaluation of two incentives to reduce drainage quanity: (1) surcharge on applied water & (2) water reduction requirement for cotton commodity program	State	1987-1988	$18,682	Completed
UC-39 (86-32)	Models of Selenium Processing by Aquatic Organisms	Determine Se uptake, accumulation & excretion processing	State	1986-1987	$22,100	Ongoing
				1987-1988	$23,000	Completed

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE (UC S/D TF)

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS
UC-40 88-1	Selenium accumulation by grasses	Effects of chloride and sulfate on selenium uptake	UC S/D TF	1988-1989 1989-1990	$16,800 $17,000
UC-41 88-3	Selenium transformations in soils	Effects of redox conditions	UC S/D TF	1988-1989 1989-1990	$25,000 $31,000
UC-42 88-7	Selenium transformations and transport	Influence of waterlogging and fluctuating water tables	UC S/D TF	1988-1989 1989-1990	$29,800 $38,400
UC-43 88-9	Water surcharges and selenium control	Role of water pricing as option for source control	UC S/D TF	1988-1989	$18,800
UC-44 88-12	Movement and quality of shallow ground water	Selenium and sulfate at West Side Field Station	UC S/D TF	1988-1989	$9,600
UC-45 88-13	Salt emission and drainage reduction	Effects of soil spatial variability	UC S/D TF	1988-1989 1989-1990	$20,000 $29,000
UC-46 88-15	Microbial transformations of selenium	Effects of redox conditions	UC S/D TF	1988-1989 1989-1990	$20,000 $25,000
UC-47 88-16	Soil organic interactions with selenium	Determine of organic ligand complexation	UC S/D TF	1988-1989 1989-1990	$9,000 $5,100
UC-48 88-17/18	Uranium and associated trace elements	Presence in San Joaquin Valley waters	UC S/D TF	1988-1989 1989-1990	$40,000 $49,300
UC-49 89-3	Microbial volatilization of arsenic	Volatilization rates from soils and waters	UC S/D TF	1989-1990 1990-1991	$35,800
UC-50 89-5	Modeling water table management	Simulation and validation with lysimeters	UC S/D TF	1989-1990 1990-1991	$18,800
UC-51 89-6	Selenium volatilization from food crops	Determine magnitude growth chambers	UC S/D TF	1989-1990 1990-1991	$27,600

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE (UC S/D TF)

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS
UC-52 89-7/8	Competitive interactions on selenium plant uptake	effects of arsenic, sulfate & phosphate on selenium uptake	UC S/D TF	1989-1990 1990-1991	$30,200
UC-53 89-11	Remote sensing of salt-affected lands	Transects in Kings County	UC S/D TF	1989-1990 1990-1991	$28,800
UC-54 89-14	Microbial purification of agricultural waste waters	Genetic and biochemical approach	UC S/D TF	1989-1990	$25,000
UC-55 89-15	Toxicity and biomagnification in aquatic food chains	Complete MS thesis	UC S/D TF	1989-1990	$10,000
UC-56 89-16	Uptake of boron and selenium by vegetables	Effects of sulfates on uptake	UC S/D TF	1989-1990 1990-1991	$27,100
UC-57 89-18	Trace metal chemistry in evaporation ponds	Interaction of metals with salinity	UC S/D TF	1989-1990 1990-1991	$30,500
UC-58 89-19	Spatial and temporal analyses of selenium in San Joaquin River	Quantify past, current and future trends	UC S/D TF	1989-1990	$6,400
UC-59 89-20	Movement and modeling of selenium, boron, and salt	Shallow ground water at West Side Field Station	UC S/D TF	1989-1990	$12,800
UC-60 89-21	Effects of salinity on selenium accumulation in vegetables	Lab study to quantify mechanisms	UD S/D TF	1989-1990 1990-1991	$24,900

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE (UC S/D TF)

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS
UC-61 89-7/8	Competitive interactions on selenium plant uptake	Effects of arsenic, sulfate, and phosphate on selenium uptake	UC S/D TF	1989-1990 1990-1991	$30,200
UC-62 89-11	Remote sensing of salt-affected lands	Transects in Kings County	UC S/D TF	1989-1990 1990-1991	$28,800
UC-63 89-14	Microbial purification of agricultural waste waters	Genetic and biochemical approach	UC S/D TF	1989-1990	$25,000
UC-64 89-15	Toxicity and biomagnification in aquatic food chains	Complete MS thesis	UC S/D TF	1989-1990	$10,000
UC-65 89-16	Uptake of boron and selenium by vegetables	Effects of sulfates on uptake	UC S/D TF	1989-1990 1990-1991	$27,100
UC-66 89-18	Trace metal chemistry in evaporation ponds	Interaction of metals with salinity	UC S/D TF	1989-1990 1990-1991	$30,500
UC-67 89-19	Spatial and temporal analyses of selenium in San Joaquin River	Quantify past, current, and future trends	UC S/D TF	1989-1990	$6,400
UC-68 89-20	Movement and modeling of selenium, boron, and salt	Shallow ground water at West Side Field Station	UC S/D TF	1989-1990	$12,800
UC-69 89-21	Effect of salinity on selenium accumulation in vegetables	Lab study to quantify mechanisms	UC S/D TF	1989-1990 1990-1991	$24,900
UC-70 88-1	Selenium accumulation by grasses	Effects of chloride and sulfate on selenium uptake	UC S/D TF	1988-1989 1989-1990	$16,800 $17,000
UC-71 88-3	Selenium transformations in soils	Effects of redox conditions	UC S/D TF	1988-1989 1989-1990	$25,000 $31,000

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE (UC S/D TF)

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS
UC-72 88-7	Selenium transformations and transport	Influence of waterlogging and fluctuating water tables	UC S/D TF	1988-1989 1989-1990	$29,800 $38,400
UC-73 88-9	Water surcharges and selenium control	Role of water pricing as option for source control	UC S/D TF	1988-1989	$18,800
UC-74 88-12	Movement and quality of shallow ground water	Selenium and sulfate at West Side Field Station	UC S/D TF	1988-1989	$9,600
UC-75 88-13	Salt emission and drainage reduction	Effects of soil spatial variability	UC S/D TF	1988-1989 1989-1990	$20,000 $29,000
UC-76 88-15	Microbial transformations of selenium	Effects of redox conditions	UC S/D TF	1988-1989 1989-1990	$20,000 $25,000
UC-77 88-16	Soil organic interactions with selenium	Determine of organic ligand complexation	UC S/D TF	1988-1989 1989-1990	$9,000 $5,100
UC-78 88-17/18	Uranium and associated trace elements	Presence in San Joaquin Valley waters	UC S/D TF	1988-1989 1989-1990	$40,000 $49,300
UC-79 89-3	Microbial volatilization of arsenic	Volatilization rates from soils and waters	UC S/D TF	1989-1990 1990-1991	$35,800
UC-80 89-5	Modeling water table management	Simulation and validation with lysimeters	UC S/D TF	1989-1990 1990-1991	$18,800
UC-81 89-6	Selenium volatilization from food crops	Determine magnitude growth chambers	UC S/D TF	1989-1990 1990-1991	$27,600

TABLE A7. UC SALINITY/DRAINAGE TASK FORCE SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

PROJECT NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
UC-82	Evaporation ponds for disposal of agricultural wastewaters	Develop/evaluate pond seepage & brine chemistry models, characterize salinity, selenium and boron and evaporites	SWRCB 205(j) CVRWQCB	1986-1988	$60,000	Completed in 1988
UC-83	Biological characterization of agricultural evaporation ponds	Determine phytoplankton and invertebrates in ponds	SWRCB CVRWQCB	1986-1988	$117,000	Completed in 1988
UC-84	Efficacy of evaporation ponds for disposal of saline drainage waters	Determine limiting physical and chemical variables & conditions	DWR USBR	1987-1989	$80,000	Interim report filed
UC-85 FS-4	Determination of HAR requirements for evaporation ponds	Need for amendments to HAR as applied to evaporation ponds	SWRCB 205(j)	1989-90	$95,250	Ongoing

TABLE A7. UNIVERSITY SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
*SC-1	Se Speciation in Kesterson Reservoir	Characterization and distribution of 5 Se species from San Luis Drain and Kesterson pond waters including an organo- Se ion	Various	Completed	NA	Publication of thesis by Terence Cooke describing Se species from Kesterson water. Project completed.
*SC-2	Chemical Species of Se in Waters of the San Joaquin & Imperial Valleys	Examination of selenium speciation in representative surface waters & sediments of San Joaquin & Imperial Valleys to further define the processes responsible for the cycling of Se between organic & inorganic forms	*SWRCB	1986-1988	$82,500	A review "Aquatic Selenium Speciation in California" has been submitted to SWRCB. Final report has been completed.
*FS-1	Test an in-line Pre-Treatment Method to Remove Turbidity prior to Reverse Osmosis	Small pilot plant at DWR's Los Banos Demonstration Desalting Facility to test anthracite filtration to remove turbidity prior to reverse osmosis	*DWR	NA	$2,000	Completed.

* SC- U.C. Santa Cruz
FS- Fresno State University
DWR- Department of Water Resources
SWRCB- State Water Resources Control Board

TABLE A8. LAWRENCE BERKELEY LABORATORY (LB) AND LIVERMORE NATIONAL LABORATORY (LL) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
LB-1	Geochemistry and Hydrology at Kesterson	Characterize extent of contamination and collect and evaluate hydrologic and chemical data	USBR	1985-1988	$1,950,000	Investigations continue. Field measurements and sampling continue. Current efforts focus on the drainage water plume, on selenium distribution and dynamics, and on techniques for Se management.
				1989	$450,000	
LB-2	Biology of Kesterson Reservior	Investigation of Se levels in aquatic and upland habitat biota	USBR	1985-1988	$750,000	Investigations focused on food chain populations, seasonal changes, and comparison of Se concentrations in water and biota. Pond 5E experiment results generally indicated declines in Se levels in that controlled aquatic environment. The experiment is now completed.
				1989	$150,000*	
LB-3	Sediment characterization	Analysis of Se and partitioning between different forms in water and sediments	USBR	1985-1988	$700,000	Focus on selenium dynamics and speciation in dry area soils.
				1989	$250,000	

* For Kesterson clean up see Section 2.2 and Table A6.

TABLE A8. LAWRENCE BERKELEY LABORATORY (LB) AND LIVERMORE NATIONAL LABORATORY (LL) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
LB-4	Ecological Modifications of Kesterson Reservoir to Isolate Se	Evaluate methods to modify the Kesterson environment to facilitate rapid, irreversible removal of Se from biosphere	LBL	1985-1988	$200,000	Microbial volatilization.
				1989	$500,000	Focus on optimal management of soil water and vegetation, and on continued evaluation of microbioal volatilization.
LL-1	Bacterial reduction and removal of Se	Evaluate bacterial species efficiency and biochemical-genetic mechanism of selenate conversion to elemental selenium	LLNL	1985 -1986	$ 95,000	Completed. Several publications available.
				1986 - 1987	$ 95,000	Genetic material responsible for conversion of selenate to elemental selenium has been identified & transferred from Clostridium into E. coli.

TABLE A9. U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE (ARS) AND SOIL CONSERVATION SERVICE (SCS) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS*
AR-1	Nonuniform Irrigation Evaluations with a Linear Travel System: System Design, Water Application Patterns and Uniformity	To determine the utility of a modified linear travel irrigation system for use in evaluating irrigation nonuniformity, including and evaluation of water application patterns and nonuniformity	ARS	1986-1988		Completed
AR-2	Trickle Irrigation of Cotton with Saline Drainage Water: Effects of Application Amount and Trickle Lateral Spacing	To evaluate effects of (1) use of saline irrigation water during growing season, and (2) the influence of long-term saline drainage water use on growth and yield of cotton	ARS	1983-1987		Completed
AR-3	Effects of Shallow, Saline, Groundwater and Drainage Water Reuse on Plant Nitrate, Boron, Chloride, and Selenium Uptake	To determine the impact of saline drainage water versus nonsaline water for irrigation on the uptake of nitrate, boron, chloride, and selenium in plants grown in the presence of saline groundwater	ARS	1983-1987		Field study completed. Manuscript to be prepared.
AR-4	Pre-plant Irrigation Comparison Under Cotton at Murrieta Farms	To compare different pre-plant irrigation levels and their effects on yield of furrow-irrigated cotton	ARS	1987-1988		Completed
AR-5	Crop Water Uptake from Shallow Groundwater: Measurements in Small Weighing Lysmieters	To establish the time sequence of the groundwater contribution to plant water use, and to establish functional relationships between groundwater salinity and crop use of groundwater	ARS	1986-1987		Completed
AR-6	Nonuniform Irrigation Evaluations with a Linear Travel Sprinkler System: Cotton Growth and Yield Responses	To determine growth and yield effects of nonuniform irrigation applications as a function of irrigation water quantity and quality with a linear travel sprinkler system	ARS	1986-1987	$100,000	Completed

* Results to date are discussed in annual report (1987) of USDA-ARS Water Management Research Laboratory

TABLE A9. U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE (ARS) AND SOIL CONSERVATION SERVICE (SCS) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS*
AR-7	Effect of the Ca^{2}/Na^{+} Ratio and Solution pH on the Apparent Sorption of Selenite by a Panoche Fine Loamy Soil	To determine the significance of calcium and sodium ion and solution phase pH on the apparent sorption of selenite in a predominantly chloride anion matrix by west side San Joaquin Valley soils	ARS	1985-1987		Completed. Future lab studies planned.
AR-8	Assessment of Selenium Analytical Procedures for Soils and Plant Tissue	To establish reliable analytical procedures for the determination of selenium content of soils and plant tissues	ARS	1987		Ongoing
AR-9	Uptake of Selenium in Selenium Accumulator Plants and Selected Vegetables	To determine extent to which certain vegetables and plant species accumulate selenium in relation to the species of selenium in the irrigation water	ARS	1987		Ongoing. Future experiments are anticipated.
AR-10	Drainage Reduction Potential of Subsurface Drip Irrigation Systems	Demonstration of potential for drainage reduction	ARS	1986-1989		Report completed on tomato research. Cotton (1988) and sweet corn (1989) research will be conducted.
AR-11	Panoche Water Management Study	To assess irrigation efficiency and regional subsurface drainage flow in the west side of the San Joaquin Valley in the Panoche Drainage District	DWR SWRCB	1987-1988 1989-1990	$171,000 $ 50,000	Monitoring completed. Report in preparation.

* Results to date are discussed in annual report (1987) of USDA-ARS Water Management Research Laboratory

TABLE A9. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE (ARS) AND SOIL CONSERVATION SERVICE (SCS) SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	1989-90 FUNDING	COSTS	STATUS*
AR-12	Relationships Between Contaminant Loads and Drain Flows for Drainage Systems in the Western San Joaquin Valley	Study load-flow relations drain water on west side of the San Joaquin Valley	DWR SWRCB	1/90 -3/91		$185,000	Just begun
	Relationships Between Selected Plant species & the Removal of Selenium from Westside Soils and Drainage Waters	To lower Se concentrations with plants		Currently			
AR-13	Se and AS solid-solution partitioning in calcite and gypsum	To determine Se and As removal from solution due to precipitation with calcite and gypsum. These two solids are the major precipitating phases during plant water uptake in arid and semiarid lands.	ARS	1989-1990		N.A.	
CS-1	South Fork Kings River Project	Development of agricultural drainage collection and disposal system	SCS	1984		$36,000	Samples of drainage and irrigation water collected July and December 1984 by USGS. Report prepared. Work on this project resumed in early 1989.
CS-2	South Fork Kings River Project	Survey of biota associated with selected evaporation ponds in the San Joaquin Valley	SCS & KRCD*	1986-1987		$7,000	Study and report completed
CS-3	South Fork Kings River Project	Biological impacts of selected evaporation ponds in the San Joaquin Valley	SCS & KRCD*	1987		$10,000	Study and report completed

** Kings River Conservation District

TABLE A10. DEPARTMENT OF HEALTH SERVICES SELENIUM AND OTHER TRACE ELEMENTS STUDIES AND ACTIVITIES

PROJECT NO.	TITLE SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	TOTAL FUNDING	PROJECT STATUS
DHS-1	Uptake of selenium by vegetable crop	(See Section 4.2)	DHS	1/27/89-6/30/90	49,080	on-going
DHS-2	Correlation of soil selenium levels with crop levels	"	DHS	8/8/88-5/3/90	15,000	on-going
DHS-3	A survey of background level of trace elements in Southern California soils	"	DHS	2/1/90-3/1/91	75,000	

TABLE A11. DEPARTMENT OF FOOD AND AGRICULTURE (DFA) ACTIVITIES RELATED TO SELENIUM AND AGRICULTURAL

STUDY NUMBER	TITLE/SUBJECT	PURPOSE	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
FA-1	Agroforestry Demonstration Program in San Joaquin Valley	Test and evaluate feasibility of utilizing trees to reduce the amount of agricultural drainage	USBR/SWRCB /DFA/SJVDP /USDA/DWR/ CDF	1985-1990	$134,658	Program underway. Progress reports issued October 1987 and March 1988. Several other publications.

TABLE A12. LOCAL AGENCY SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
*WW-1	Prototyep Deep Well Injection of Drainage	Construct prototype well to demonstrate feasibility of deep-well injection	WWD*	1986-1990 1989-1990	$1,700,000 $ 100,000	Project on hold. Low permeability in injection zone. Will review higher injection zone with EPA.
WW-2	Removal of Se and boron using bacteria ratitled Se removal & evaporation project ("Bennie process")	Construct prototype system WWD using bacterial cultures to remove Se and B prior to futher treatment and disposal	WWD	1985-1986 1986-	$ 180,000 $1,200,000	Terminated
WW-3	Water Conservation Program	Development of water conservation techniques to reduce drainage	WWD	1986-1987 1988-1989 1989-1990	$ 85,000 $ 100,000 $ 100,000	Continuing. WWD plans an increased level of effort.
PD-1***	Pilot Selenium Removal Plant	Portable plant using iron filins to reduce selenium in agricultural drainage water	PD/BW/CCID /FCC/CDD/ PWD	1985-1987	$ 75,000- $ 100,000	First stage of Pilot Study complete.
			SWRCB/ SJVDP/ PD	1987-1988	$ 150,000	Investigation of process principles and construction & operation of pilot plant.

*WWD-Westlands Water District

**For FY 1986-1987 DFG/WDR/SWRCB - $200,000

***GWD-Grassland Water District
GWTF-Grassland Water Task Force
DWR-Department of Water Resources
BWD-Broadview Water District
PD-Panoche Drainage District
SJVDP-San Joaquin Valley Drainage Program

CCID-Central California Irrigation District
SWRCB-State Water Resources Control Board
FCC-Firebaugh Canal Company
CDD-Charleston Drainage District
PWD-Pacheco Water District

TABLE A12. LOCAL AGENCY SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
MC-1	Human Exposure to Se at Kesterson Reservoir	Analyzed blood, urin, and tissues of Kesterson residents for elevated Se	Cooperative* (MCHD, DOHS, UCSF, USFDA	1985-1986	NA**	Two completed reports available: (1) Kesterson area residents; (2) immigant foragers.
MC-2	Selenium in Freshwater Clams at Kesterson	Analyzed freshwater clams for Se and selected trace elements	Cooperative* (MCHD, DOHS, DFG)	1985-1986	NA**	Complete. Results included in human epidemiology study (MC-1).
MC-3	Monitoring Airborne Se at Kesterson	Monitoring Airborne Se at kesterson Reservoir	Air Resources Board/MCHD/USBR	1987		Monitoring completed.
FC-1	Se Content of Maternal and Fetal Tissues	Determine Se levels in aborted fetuses from "low" and "high" Se areas and relationship between maternal blood Se and fetal tissue Se and spontaneous abortion rates.	FCH/USFDA***	1985-1986	NA**	Sample collection completed. Project on hold.

*MCHD=Merced County Health Dept.
DOHS=Dept. Health Services
USBR=U.S. Bureau of Reclamation

** Not Available: These studies conducted with existing staff & within existing budget.

***FCH=Fresno Community Hospital/USFDA=U.S. Food & Drug Administration

TABLE A12. LOCAL AGENCY SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
GW-1	Wetland Enhancement	Using flood waters under temporary water right permit to supply fresh water to waterflow habitat	GWD*		N/A	Application for permanent water right permit to divert from Mendota Pool has been filed.
GW-2	Technical Reporting	Consulting services to prepare technical reports and develop drainage solutions for the Grassland area	GWTF*	1985-1986	$ 265,000	Completed. 2 reports on ecological characteristics and water management of Grassland has been prepared and submitted to SWRCB. Study of economic impact to upslope agriculture of meeting selenium objectives in San Joaquin R. released July 1986. Economic impact to GWD study released March 1987.
GW-3	Interim Water Management Program	Development of fresh water delivery system and bypass of agricultural drainage in Grassland area	State Resources Agency and Local*	1985-1989 1989-1990	$2,700,000 $ 450,000 $ 50,000	Completed September 1989.
GW-4	Alternative Supplies	Develop alternative supplies from CVP to provide additional water supplies for water fowl habitat, augment instream flows for migrating salmon/offstream storage of water in wetlands	DFG/GWD/ USBR/Local	1987-1990	$750,000 $100,000 GWD $ 50,000 DFG	Third year of study of winter storage of water in wetlands.
GW-5	Refuge Water Supply Investigation	Study to determine wetland water needs and potential sources of water	USBR/GWD/ Others	1987-		Investigative study completed; Planning report underway.
BW-1	Subsurface Drainage Monitoring	Monitoring of irrigation & tile flows. Analysis of tile drainage for Se, B, and salinity.	BWD	1985		Ongoing monitoring. Analysis of flows completed. Several papers re relationship of flows to salt and selenium loadings published.

TABLE A12. LOCAL AGENCY SELENIUM AND TRACE ELEMENT STUDIES AND ACTIVITIES (Cont.)

STUDY NUMBER	TITLE/PURPOSE	SUBJECT	FUNDING AGENCY	STUDY PERIOD	COSTS	STATUS
BW-2	Economic Analysis	To assess economic/agronomic responses to increased salinity in irrigation water.	BWD	1987-1988		Two reports prepared. Completed June 1989.
LA-1	Subsurface drainage monitoring	Monitoring of tile flows, analysis of tile drainage for Se. Boron. EC	C.C.I.D.	1986 -	N.A.	On-going
LA-2	Shallow observation well monitoring	Monitoring of shallow 18 ft. observation wells for depth, Boron. EC.	C.C.I.D.	1981 -	N.A.	On-going

* GWD=Grassland Water District
GWTF=Grassland Water Task Force
CCID=Central California Irrigation District
BWD=Broadview Water District

Appendix B-Funding

1989-1990 FUNDING

State	Budget
Department of Water Resources	$2,518,600
State Water Resources Control Board	$1,400,060
University of California	$ 472,700
Department of Health Services	$ 139,080
Department of Fish and Game	$ 120,000
State Subtotal	$4,650,440

Federal		Budget
U.S. Bureau of Reclamation		
San Joaquin Valley Drainage Program		$13,000,000
Kesterson Reservoir Program		$3,600,000
U.S. Fish and Wildlife Services		$1,000,000
U.S. Geological Survey		$ 392,000
Federal Subtotal		$17,992,000
Local Agencies		$ 350,000
	Total	$22,992,440

Appendix C

Legislation and Litigation Related to San Joaquin Valley Drainage Issues

1. AB 583, Costa Drainage water management projects. Chapter 934. The bill authorizes a loan in the amount of $100,000, pursuant to the Water Conservation and Water Quality Bond Law of 1986, to the Buena Vista Water Storage District for a groundwater feasibility study.

2. AB 444, Isenberg. Water Conservation and Water Quality. Chapter 715. The bill adds Chapter 7.7, Environmental Water Act of 1989, to part 6 of Division 6 of the Water Code. The bill authorizes Department of Water Resources to expend money appropriated to it from the Environmental Water Fund for water resources projects on programs that will contribute significant environmental benefits. The bill would authorize the City of Los Angeles to submit grant application to the Department of Water Resources to protect and preserve Mono Lake Basin. The bill also creates the Water Quality Program and requires the Department of Water Resources to expend money appropriated to it for Environmental Water Fund for projects to reduce the amount of agricultural drainage water or to improve quality of the water. However, not more than 5 million dollars of the funds can be appropriated to water quality program.

3. Contra Costa Water District v. Secretary of Interior, Civ. No. C-75-2508 SW (N.D. Cal.) This is an action based on the National Environmental Policy Act, filed in 1975, seeking to enjoin the Department of Interior from executing a long-term contract with Westlands Water District for the delivery to the District of an additional annual supply of 250,000 acre-feet of water until the Department completes additional environmental documentation addressing the potential effects of such watr deliveries on the Sacramento-San Joaquin Delta. The parties have stipulated to a stay of the action until December 31, 1990, to allow the Department additional time to complete the environmental impact statement.

4. Firebaugh Canal Company v. United States, C-V-F-88-634-REC (E.D. Cal.) Action, filed in December 1988 pursuant to Federal Tort Claims Act and Federal Administrative Procedures Act, seeks damages for alleged harm from drainage from certain lands within Westlands Water District. Suit also seeks injunction against delivery of irrigation water to those lands until drainage controls are in place. This case is pending judgement in the court.

5. Robert J. Claus vs Emanuel Lujan Secretary of the Interior. CV-89-0975 - LKK. Complaint was filed in U.S. District Court on July 17, 1989 in Sacramento, California. The petitioner seeks court action against the Secretary of Interior based on the Migratory Bird Treaty Act (MBTA). The petitioner requires the Secretary to enforce the MBTA in San Joaquin Valley. On March 8, 1990 the plentif's claims on injury to his property located in the vicinity of Kesterson Reservoir were dismissed with prejudice. The plentif's claims with respect to San Joaquin and Tulare Basin were dismissed without prejudice.

For information on litigation, and legislations in previous years see State Board, 1989 progress report [22].

Appendix D

1- Researchers, Coordinators, and Cooperators

Benson, S.
Lawrence Berkeley Laboratory
1 Cyclotron Road Bidg. 50E
Berkeley, CA 94720
415- 486-5875

Brown, R.
Department of Water Resources
Central District
3251 S Street
Sacramento, CA 95816
916-445-5487

Cervinka, V.
Department of Food and Agric.
1220 N Street
Sacramento, CA 95814
916-445-6719.5

Cone, D.
Broadview Water District
P.O. Box 95
Firebaugh, CA 93622
209-659-2004

Davidoff, B.
Water Conservation Office
Department of Water Resources
1416 9th Street
Sacramento, CA 94236
916-445-9958

Delamore, M.
Kesterson Program
U.S. Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95825
916-978-5046

Deverel, S.
U.S. Geological Survey
2800 Cottage Way
Sacramento, CA 95825
916-978-4648

Falaschi, D.
Panochi Drainage District
52027 West Althea
Firebaugh, CA 93622
209-364-6136

Frampton, J.
Department of Health services
Toxic Substances Control Div.
400 P S.street
Sacramento, CA 94234-7320
916-322-0507

Garvey, T.
Westlands Water District
3130 North Fresno Street
Fresno, CA 93703
209-224-1523

Gilliom, R.
U.S. Geological Survey
2800 Cottage Way
Sacramento, CA 95825
916-978-4648

Hoffman-Floerke, D.
Department of Water Resources
3374 E. Shield Ave.
Fresno, CA 93726
209-445-5487

Imhof, E.
San Joaquin Valley Drainage Program
2800 Cottage Way
Sacramento, CA 95825-1898
916-978-4975

Kratzer, C.
Bay-Delta
State Water Resources Control Board
901 P Street
Sacramento, CA 95814
916-324-5752

Longely, K.
Civil/Surveying Engr. Dept.
California State University
Fresno, CA 93740
209-294-2889

Marciochi, D.
Grasslands Water District
P.O. Box 1443
Los Banos, CA 93635
209-826-5188

Minard, D.
Division of Water Quality
State Water Resources Control Board
901 P Street
Sacramento CA 95814
916-324-5635

Moore, S.
U.S. Fish and Wildlife Services
2800 Cottage Way
Sacramento, CA 95825
916-978-4978

Pfitzer, R.
Central California Irrigation District
P.O. Box 1231
Los Banos, CA 93635
209-826-1421

Phene, C.
USDA-ARS
2021 South Peach Street
Fresno, CA 93727
916-453-3100

Puckett, L.
Department of Fish and Game
2800 Cottage Way
Sacramento, CA 95825
916-978-4975

Rasmussen, D.
Division of Water Quality
State Water Resources Control Board
901 P Street
Sacramento, CA 95814
916-324-1261

Rhoades, J.
US Salinity Lab
4500 Glenwood Drive
Riverside, CA 92501
714-369-4816

Roefs, T.
US Department of Interior
2800 Cottage Way
Sacramento, CA 95825
916-978-4923

Smith, B.
Department of Water Resources
3374 E. Shield Ave.
Fresno, CA 93726
209-445-5487

Stevens, T.
State Mussel Watch
Division of Water Quality
State Water Resources Control Board
901 P Street
Sacramento, CA 95814
916-322-0216

Sykes, W.
U.S. Soil Conservation Service
2121 C Street Suite 120
Davis, CA 95616
916-449-2874

Sylvester, M.
U.S. Geological Survey
345 Middlefield Road MS-470
Manlo Park, CA 94025
415-329-4415

Tanji, K.
Department of Land, Air, and Water Resources
UC Davis
Davis, CA 95616
916-752-8255

Tylor, R.
Biomedical Sciences Division L-452
Bldg. 361, Room 1241
Lawrence Livermore Nat'l Lab.
Livermore, CA 94550

Urqhart, K.
DFG
4001 North Wilson Way
Stockton, CA 95205
209-466-4221

Watkins, D.
Division of Water Quality
State Water Resources Control Board
901 P Street
Sacramento, CA 95814
916-322-2867

Westcot, D.
Central Valley Regional Board
3443 Routier Road
Sacramento, CA 95827-3098
916-361-5688

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3- List of Acronyms

A	Acre
AB	Assembly Bill
ADLP	Agricultural Drainage Loan Program
AF	Acre Feet
ARS	Agricultural Research Service
BMP	Best Management Practice
BWD	Broadview Water District
CAC	Citizen Advisory Committee
CCID	Central California Irrigation District
CCR	California Code of Regulations
CDFA	California Department of Food and Agriculture
CIMIS	California Irrigation Management Information System
CVAPO	Central Valley Agricultural Pond Operators
CVRWQCB	Central Valley Regional Water Quality Control Board
DANR	Division of Agriculture and Natural Resources (University)
DFG	Department of Fish and Game (California)
DHS	Department of Health Services (California)
DOI	Department of Interior (US)
DOP	Drainage Operation Plan
DWR	Department of Water Resources (California)
EC	Electrical Conductivity
EIR	Environmental Impact Report
EPA	Environmental Protection Agency (US)
FY	Fiscal Year
GWD	Grassland Water District
HAR	Hydrological Assessment Report
HOAC	Health Officers Association of California
ICP	Inductively Coupled Plasma Spectroscopy
ITAC	Interagency Technical Advisory Committee
LBL	Lawrence Berkeley Laboratory
LEPA	Least Energy Precision Application
LLNL	Lawrence Livermore National Laboratory
MA	Million Acre
MAF	Million Acre Feet
MBTA	Migratory Bird Treaty Act
NAS	National Academy of Sciences
NPS	Nonpoint Source
NRC	National Research Council
NWR	National Wildlife Refuge
PMC	Policy and Management Committee
PPB	Parts Per Billion
PPM	Parts Per Million
RFP	Request For Proposal
RWQCB	Regional Water Quality Control Board
SJVDP	San Joaquin Valley Drainage Program
SMWP	State Mussel Watch Program
SVS	Selenium Verification Study
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
TPCA	Toxic Pits Cleanup Act

TR	Technical Report
TSMP	Toxic Substances Monitoring Program
UCD	University of California Davis
USBR	United States Bureau of Reclamation
USCID	United States Committee on Irrigation and Drainage
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Services
USGS	United States Geological Survey
WADE	Westside Agricultural Drainage Economic (model)
WCO	Water Conservation Office (DWR)
WDR	Waste Discharge Requirement
WMA	Wildlife Management Area
WPCL	Water Pollution Control Laboratory (DFG)
WQ	Water Quality
WWD	Westland Water District
WY	Water Year

STATE WATER RESOURCES CONTROL BOARD
P. O. Box 100, Sacramento, CA 95812-0100
(916) 322-3132

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARDS

REGION 5 - Redding Branch Office
415 Knollcrest Drive
Redding, CA 96002
(916) 224-4845

LAHONTAN REGION (6)
2092 Lake Tahoe Boulevard Suite 2
South Lake Tahoe, CA 96150
(916) 544-3481

NORTH COAST REGION (1)
1440 Guerneville Road
Santa Rosa, CA 95403
(707) 576-2220

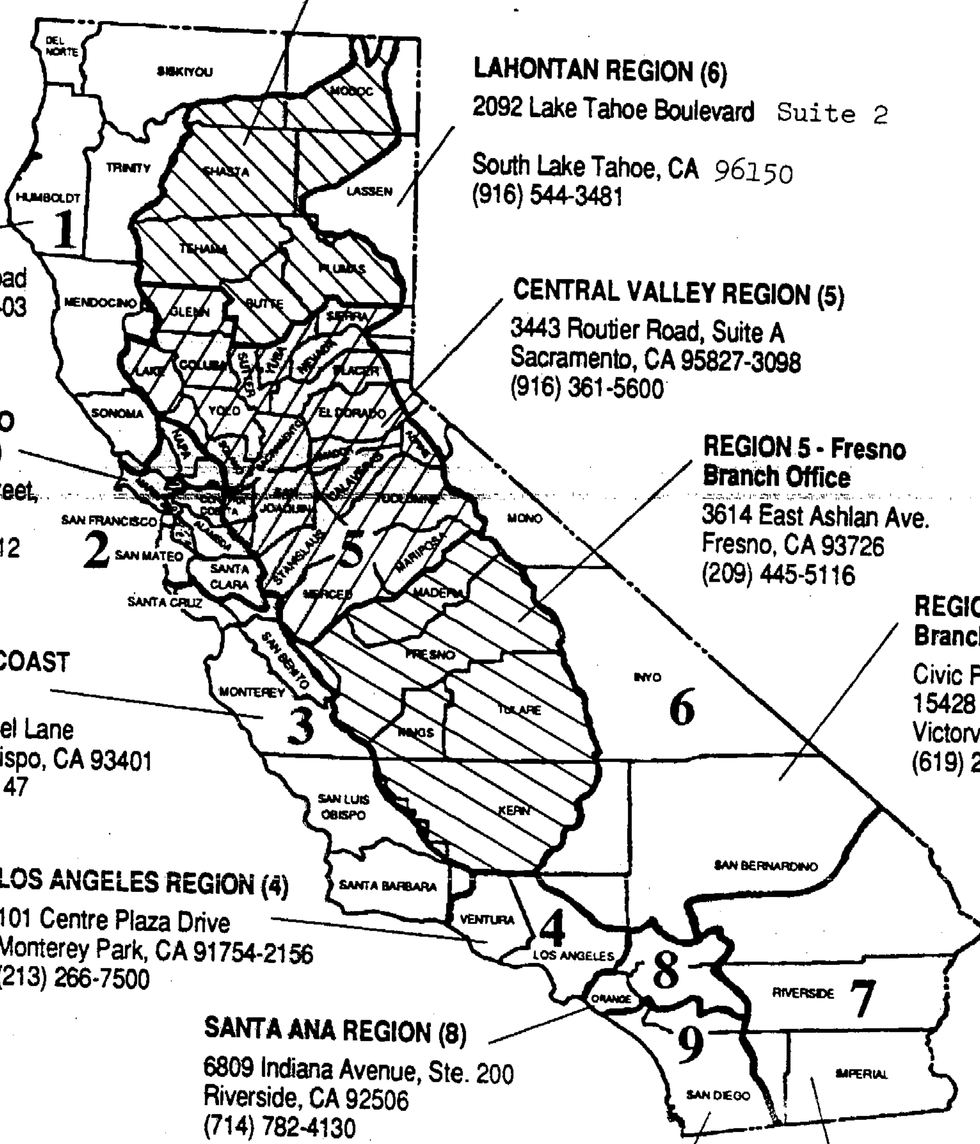
CENTRAL VALLEY REGION (5)
3443 Routier Road, Suite A
Sacramento, CA 95827-3098
(916) 361-5600

SAN FRANCISCO BAY REGION (2)
1800 Harrison Street,
Suite. 700
Oakland, CA 94612
(415) 464-1255

REGION 5 - Fresno Branch Office
3614 East Ashlan Ave.
Fresno, CA 93726
(209) 445-5116

REGION 6 - Victorville Branch Office
Civic Plaza
15428 Civic Drive, Suite 100
Victorville, CA 92392-2359
(619) 241-6583

CENTRAL COAST REGION (3)
1102-A Laurel Lane
San Luis Obispo, CA 93401
(805) 549-3147



LOS ANGELES REGION (4)
101 Centre Plaza Drive
Monterey Park, CA 91754-2156
(213) 266-7500

SANTA ANA REGION (8)
6809 Indiana Avenue, Ste. 200
Riverside, CA 92506
(714) 782-4130

SAN DIEGO REGION (9)
9771 Clairemont Mesa Blvd.
Suite. B
San Diego, CA 92124
(619) 265-5114

COLORADO RIVER BASIN REGION (7)
73-271 Highway 111,
Suite. 21
Palm Desert, CA 92260
(619) 346-7491