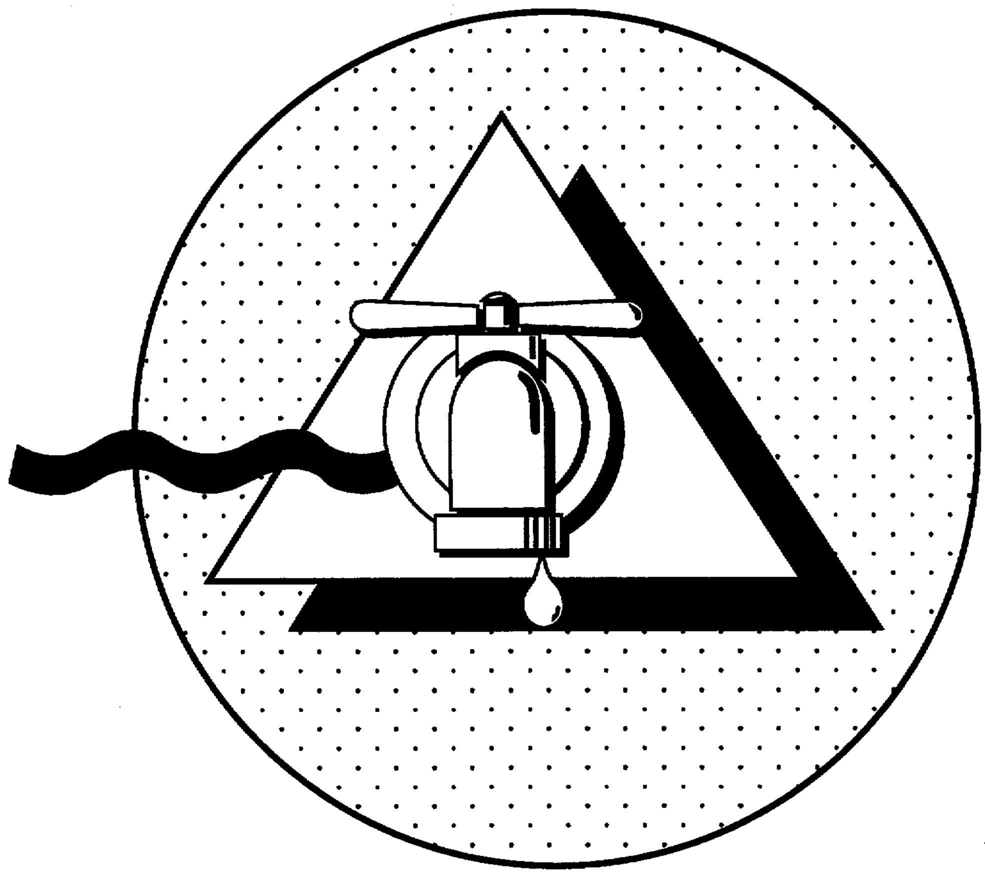

DELTA DRINKING WATER QUALITY STUDY
MAY 1989

EXECUTIVE SUMMARY

BROWN AND CALDWELL
CONSULTING ENGINEERS

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Los Angeles Department of Water and Power
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INTRODUCTION BY THE MANAGERS

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The report seeks to provide a documented basis for understanding and discussing Delta water quality. It does so by comparing the effectiveness and cost of various combinations of source quality improvement facilities and water treatment technologies. No specific alternative to improve Delta water quality is recommended. There may be significant differences among the participating agencies as to what water quality improvement alternative would best serve their individual needs. No attempt is made in this report, implicit or explicit, to resolve such differences. The study was undertaken by the participating agencies to provide a common basis of understanding.

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The report assumes levels of urban water needs and diversions through the year 2010 which are greater than existing. All of the participating agencies divert water directly from the Delta or upstream tributaries; our customers and local economies are dependent on these water supplies. We believe that increased water needs are inevitable even with significant amounts of additional water conservation and reclamation. Although urban use of Delta water represents only a small portion of total use, we agree that additional water diversions should be accompanied by appropriate protections for the San Francisco Bay/Delta Estuary. The scope of this report does not include the form or degree of such protections about which there is much disagreement. Levels of future water needs have been assumed in this study for comparative purposes. The water needs assumptions used in this report are not determinative of the findings of this study.

This report looks at various alternatives for meeting state and federal drinking water quality standards (existing and proposed). The participating agencies have, individually and collectively, criticized the Draft Bay/Delta Plan prepared by the staff of the State Water Resources Control Board, which stated that drinking water quality ("trihalomethanes and other compounds") is a treatment issue. At any level of treatment, reduced quality of a source of supply results in reduced quality of water at the tap. Improving the source water quality will have significant consumer cost and public health benefits which must be considered in planning and operating diversions from the Delta and its tributaries for urban supplies.

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Increasing evidence of water quality problems in using water from the Delta created interest in studying ways to operate existing water systems diverting from the Delta in ways that will minimize contamination. Individually, some California Urban Water Agencies' (CUWA) members have conducted testing and research which show that only with the installation of advanced and expensive treatment will Delta water be able to meet anticipated drinking water standards for trihalomethanes (THMs), which are suspected human carcinogens. THMs are formed in drinking water when chlorine used for disinfection during water treatment reacts with organic precursor compounds in the water. Additional drinking water standards, including those anticipated for disinfectants and disinfection by-products other than THMs, will also be difficult to meet with Delta water.

A clear indication of the increasing concern of California citizens about the quality of their drinking water is the growing use of bottled water and home treatment devices, even though the tap water meets all state and federal drinking water standards. It is estimated that as many as half of all the urban residents in the state now use bottled water or some form of home treatment, at an aggregate cost of more than $1 billion per year.

As a result of these concerns, CUWA undertook this study of Delta drinking water quality. The project was conducted by Brown and Caldwell Consulting Engineers, with continuing involvement and guidance from a project Advisory Committee composed of senior professionals from each of the sponsoring agencies, the California Department of Water Resources (DWR), and the U.S. Bureau of Reclamation. The objective of the study was to bring together all relevant technical information about Delta water quality, and then to assess the degree to which alternative concepts for management of the major Delta water systems affect drinking water quality. The concepts studied for this purpose intentionally range widely in their approach, cost, and impacts. Maximum use was made of management concepts which had been previously studied by water resources planning agencies to take advantage of this carefully developed information, and because people are familiar with how previously developed concepts would function.

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Water Quality Study is to examine concepts for the management of the Delta water supply systems and their abilities to protect and improve drinking water quality. As used in this statement of the study objective, Delta water supplies are supplies which are derived from the Delta and its tributaries.

The goal of this study is to characterize those Delta management concepts, qualitatively and quantitatively with respect to their abilities to achieve desired drinking water quality, considering technical and economic requirements. Desired drinking water quality is that quality which meets present and anticipated drinking water standards with an adequate margin of safety, and enhances consumer acceptance to minimize the perceived need for bottled water and home treatment devices.

Current and Anticipated Problems

Water quality is degraded, both naturally and through the activities of man, as the water runs from Sierra mountain streams, through the valleys, and through the Delta to the pumps of the State Water Project (SWP), the federal Central Valley Project (CVP), and the Contra Costa Water District. The Bay-Delta hydrologic system serves many beneficial uses. Six of these water uses (municipal, industrial, agricultural, fishery, wildlife, and recreation), must be considered both for (a) uses within the Bay-Delta estuary, and (b) water pumped from the estuary. Several of the beneficial uses pose conflicts in setting water quality objectives or achieving optimum use of the water resources. Some examples of this are (1) an important function of the rivers tributary to the Delta is to carry the minerals derived from the watersheds to the ocean, but this natural function contributes a large mineral load to the Delta water supplies; (2) a vigorous plankton crop is needed to sustain a healthy fishery, but imposes a difficult particulate and organic load problem on water treatment facilities; and (3) high turbidity in the nutrient-rich Delta moderates undesirable algal blooms, but increases the difficulty and cost of water treatment. These examples show the difficulty of balancing the needs of all uses of Delta water, but a reasonable balance must be diligently sought in order to protect the Delta's unique environmental values while benefitting from its essential water supply.

Water diverted from the Delta contains relatively high concentrations of total dissolved solids (TDS), chloride, sodium, bromide, and organic carbon. Plankton blooms cause frequent taste and odor problems. The secondary (nonmandatory) TDS drinking water standard of 500 mg/l is occasionally exceeded in water diverted from the Delta. Also, the 250-mg/l secondary standard for chloride is exceeded at times. Waters pumped from the Delta sometimes contain sodium concentrations in excess of the 100-mg/l limit recommended by the National Academy of Sciences for persons on moderately restricted sodium diets. Organic compounds dissolved in Delta water, mainly humic and fulvic acids derived from vegetation and vegetal debris, are precursors to the formation of disinfection by-products. The best known of these by-products are the THMs. During periods of relatively low Delta outflow, the bromide concentration is high enough to form large amounts of brominated THMs, and to significantly increase the total THM concentrations.

Water utilities are most concerned with, and consumers most potentially affected by, the THMs which are formed upon chlorination of Delta water supplies. Delta water contains high concentrations of organic precursors. These precursors will result in the formation of toxic by-product compounds upon the use of any known practical disinfection process. However, the focus here is on THMs because they are the first such by-products to be regulated. Other disinfection by-products, such as chloro-furanone (MX), chloropicrin, and dichloroacetonitrile (DCAN) are expected to be regulated in the future.

The amount of THM precursors in a drinking water source is measured by chlorinating the water and forcing the THMs to form. This gives the THM formation potential (THMFP), and is essentially a worst-case indicator. This study primarily uses THMFP data from DWR because it is the most comprehensive set of THMFP data available. However, the DWR formation potentials are analyzed under severe conditions, and the values are up to three times those analyzed by most water utilities using test conditions that simulate the conditions in water distribution systems. Without advanced treatment processes, chlorinated drinking water could be expected to have THMs of 15 to 25 percent of the THMFP (DWR) values. Tests of THMFP made by DWR range up to 1,500 micrograms per liter (ug/l) in the lower San Joaquin River. Maximum and average values of THMFP at the state pumps are about 900 and 500 ug/l, respectively. The current drinking water standard for THMs in urban water distribution systems is 100 ug/l (annual average), but a lower standard is expected in the early 1990s.

The urban water supply agencies will be faced with an urgent need for new and upgraded treatment facilities to meet new drinking water standards. Not only will the average drinking water treatment cost rise, but the range of treatment cost between that for the higher quality sources and lower quality sources will widen. The range of costs is defined by data presented in the report. The California Department of Health Services has a long standing policy that:

> "Water utilities should seek to obtain and provide all reasonable protection of [their drinking water] supply from any known or potential source of contamination hazard."

For the reasons discussed in this report, the importance of providing the best quality drinking water source will increase in the future. While cost is an important consideration, and most California water suppliers deliver water at low cost, this report emphasizes drinking water quality.

Alternative Concepts

The alternatives analyzed in this study were developed in a series of discussions with the study Advisory Committee. Existing Delta water supply management was used as the baseline for comparison of alternatives. Alternative concepts ranging from modifications in water project operations through minor modifications of water project facilities to major modifications of water project facilities were considered. Study of existing Delta water management, and discussion of system operations with SWP and CVP operating agencies, did not reveal any significant drinking water quality improvements which can be achieved simply by modifying current operating practices, however, additional operational studies are warranted. A screening process reduced the number of concepts studied. The following six alternative concepts were selected by the Advisory Committee for analysis in this study on the basis that they reflect the range of concepts.

Alternative 1. Delta Transfer System Improvements. This alternative represents the North Delta and South Delta improvements currently proposed by DWR to improve Delta hydraulics. These improvements would increase the efficiency of Sacramento River water transfer, provide sufficient capacity to carry increased flows to the state and federal pumps, and improve water quality. This alternative is shown on Figure S-1. As a subalternative, the ability of this improved Delta system to support an altered seasonal pumping pattern to yield higher quality water is considered.

Alternative 2. San Joaquin Conjunctive Use Project. In addition to completion of the proposed Delta Transfer System Improvements, large volumes of water from New Melones Reservoir would be used to supply users in the Stanislaus River and Calaveras River Basins during periods of plentiful supply. These users would switch to groundwater for a major portion of their supply during dry years, making New Melones water available for downstream release to the San Joaquin River system during these dry periods. This concept provides further water quality enhancement at the pumps because it would help to maintain water quality in the downstream portion of the San Joaquin River during dry years.

Alternative 3. Delta Agricultural Drainage Management. In this concept, the proposed Delta Transfer System Improvements (Alternative 1) would be supplemented by a system to collect all, or a major portion of, the agricultural drainage from the Delta islands. The drainage would be conveyed to a point of discharge in the San Francisco Bay estuary to eliminate this source of discharge of organic precursors into Delta waters.

Alternative 4. Peripheral Canal. This is the 42-mile-long isolated channel first proposed by the Interagency Delta Committee in 1965, then rejected by California voters in 1982. It would convey water from the Sacramento River around the Delta, releasing a portion of it for Delta channel flow improvement, and delivering the remaining water to Clifton Court Forebay, and thence to the Delta export pumps. This alternative is shown on Figure S-2.

Alternative 5. Dual Transfer System. About half of the water being diverted from the Delta would be conveyed through existing channels, and the remainder in this new isolated channel extending from Hood on the Sacramento River to the Clifton Court Forebay. This alternative is shown on Figure S-3. A subalternative, shown on Figure S-4, would provide a bifurcated transmission system south of the Delta so that only high quality water would be delivered to the A.D. Edmonston Pumping Plant.

Alternative 6. Sierra Source-to-User System. New conveyance facilities would be constructed to convey water for municipal and industrial (M&I) urban water users from the Feather River/Sacramento River confluence around the Delta and directly to the Tracy Pumping Plant. The Delta Mendota Canal and a new canal south of San Luis Reservoir would be used to convey this water south for M&I use, and the SWP facilities would be used for conveying water from the Delta to agricultural users. The Sierra Source-to-User System is shown on Figure S-5.

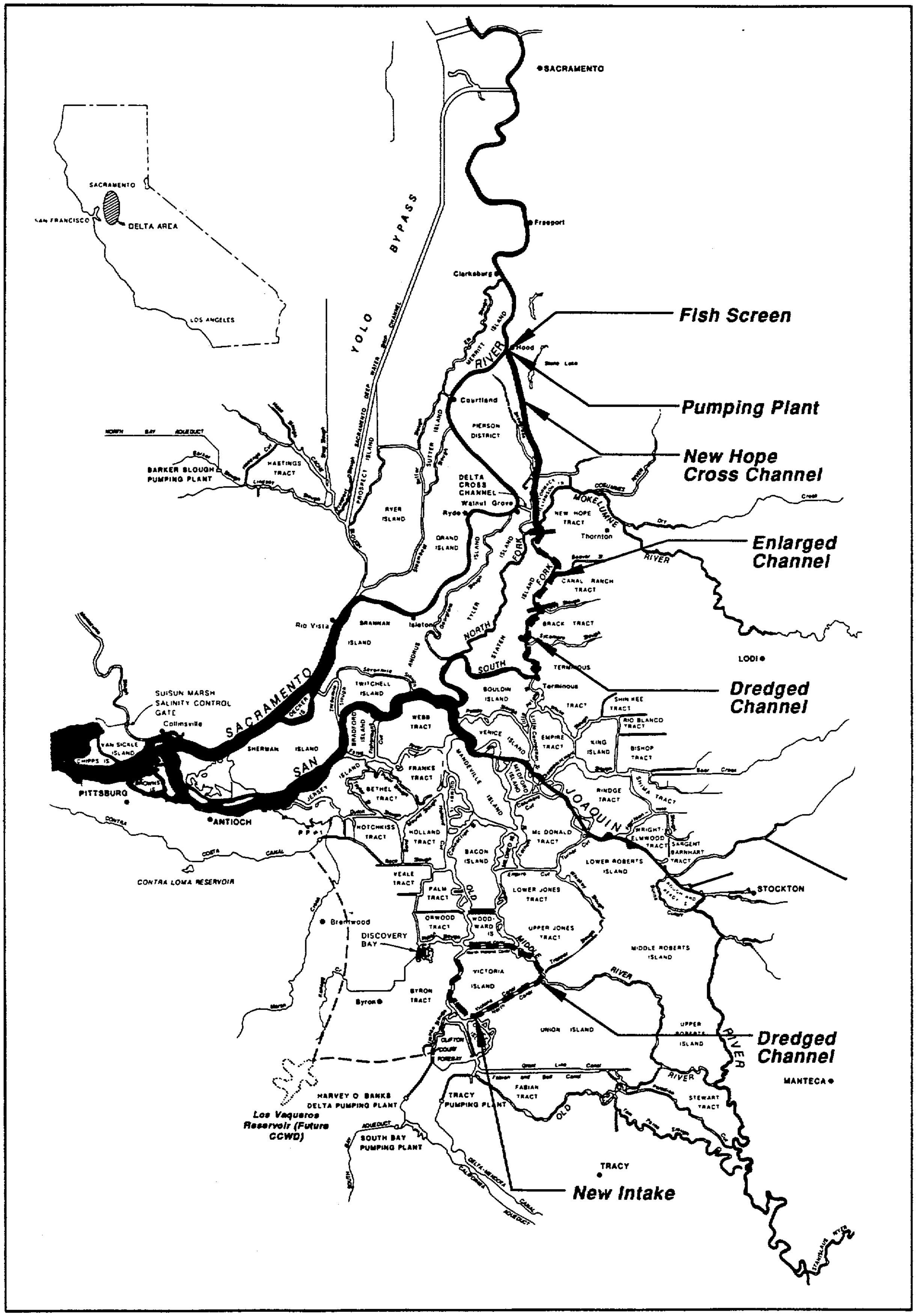


Figure S-1. Delta Transfer System Improvements

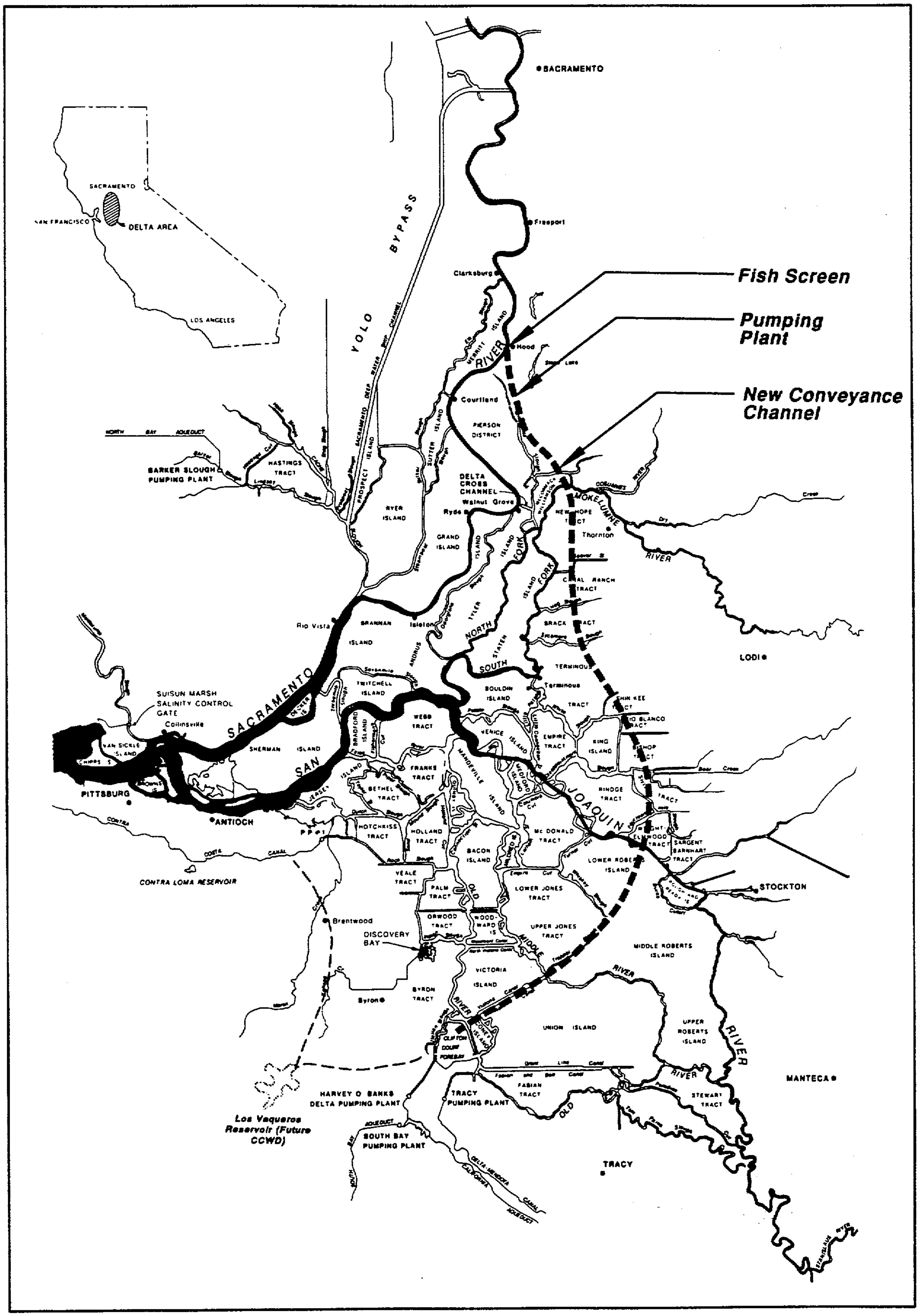


Figure S–2. Peripheral Canal

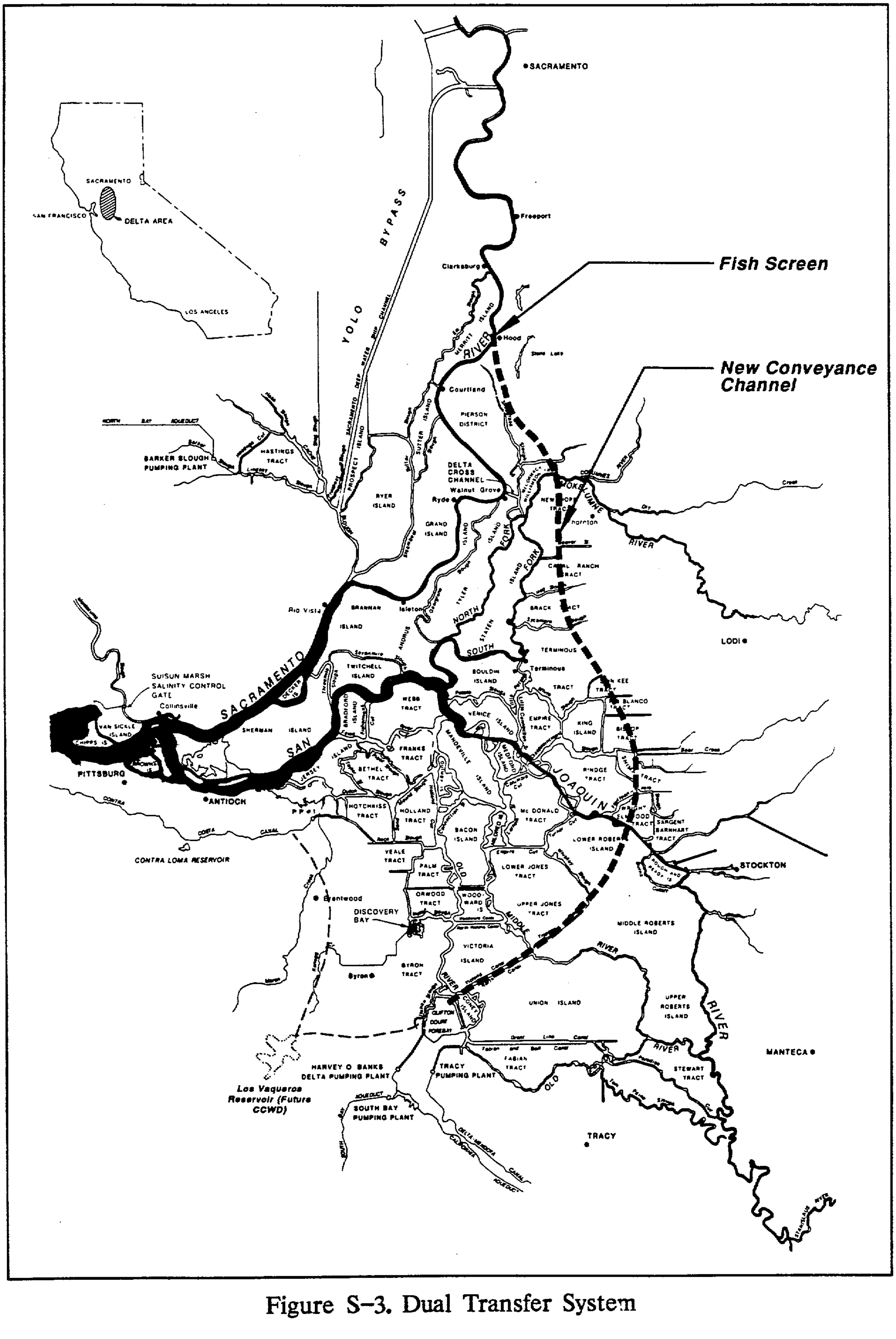


Figure S-3. Dual Transfer System

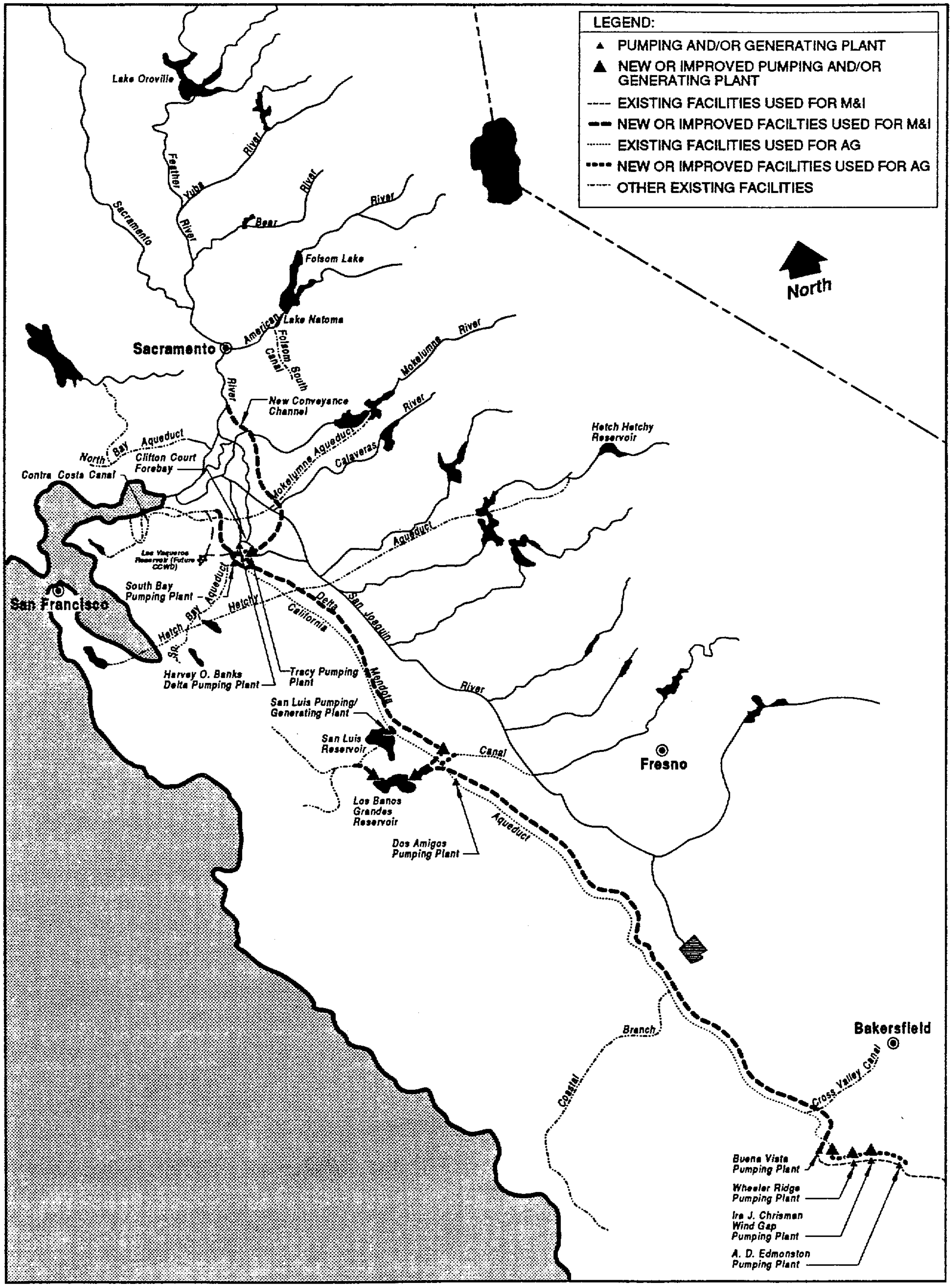


Figure S-4. Bifurcated Dual Transfer System

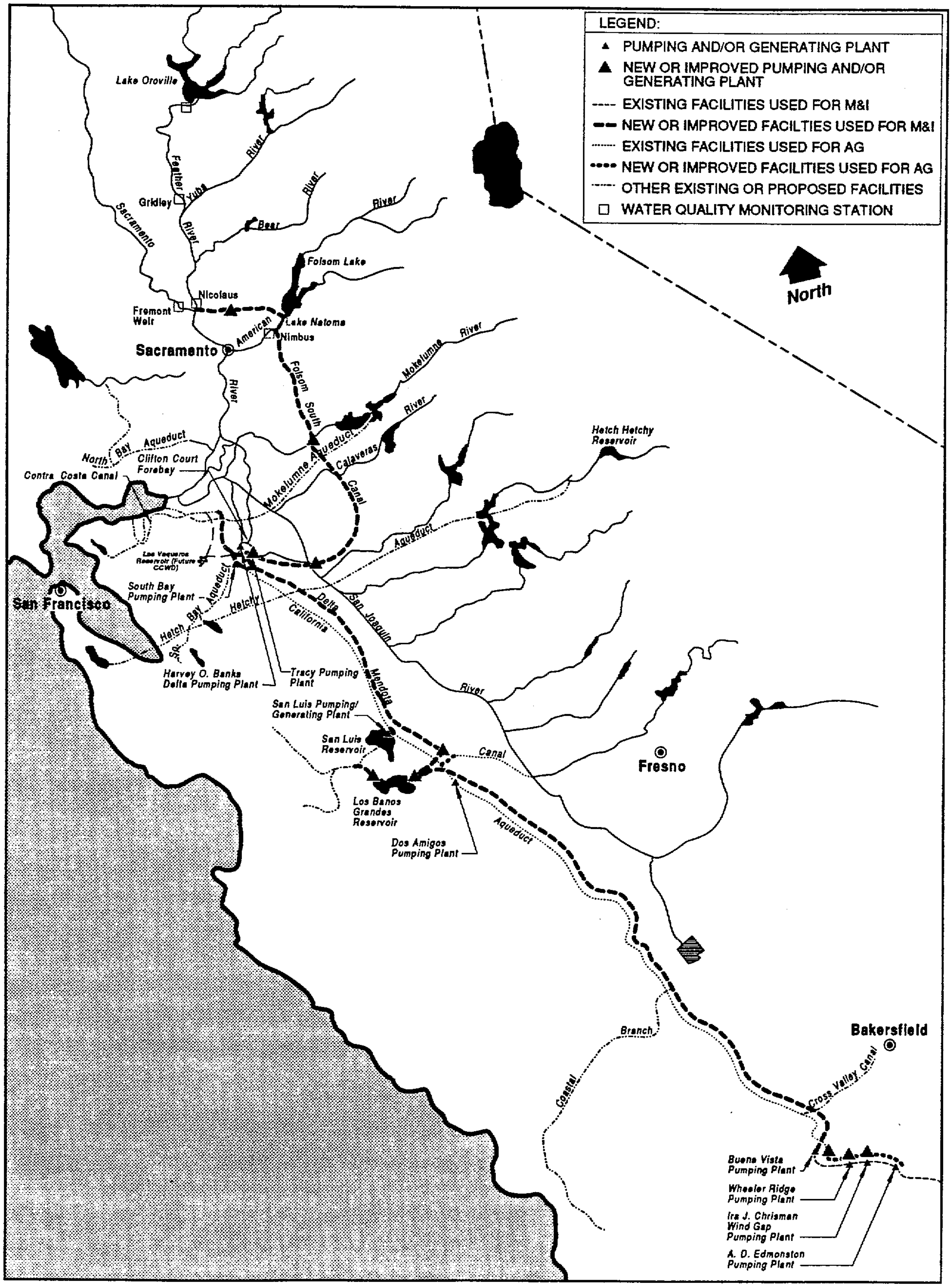


Figure S-5. Sierra Source-to-User System

For each of the conceptual alternatives, the following information is presented in Chapter 4:

1. A description of the physical facilities and how they would function to improve drinking water quality.

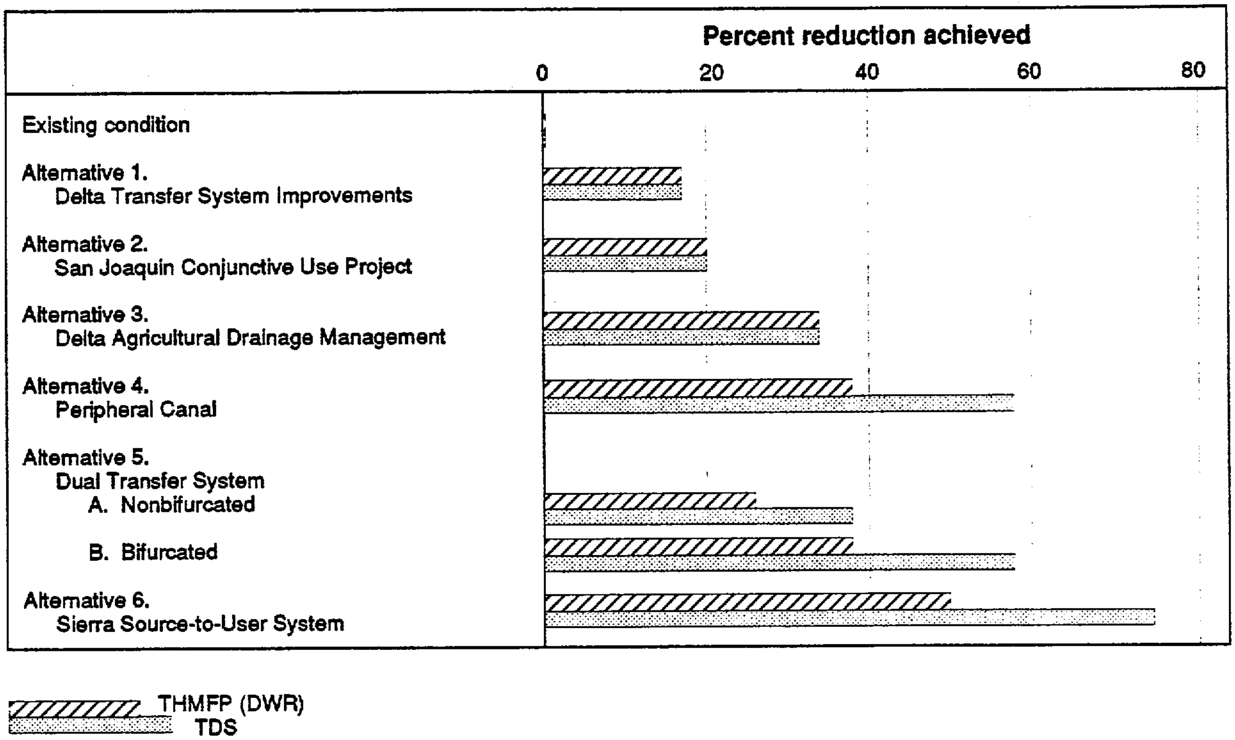
2. The water quality that would result from its implementation and the expected level of treatment that would be required to comply with anticipated drinking water regulations.

3. Preliminary (reconnaissance-level) estimates of costs for construction and operation and the associated costs for treatment. Also, the economic benefits to consumers of improvements in mineral quality of water are estimated. The future cost to treat water currently diverted from the Delta is also shown.

The report includes a summary of the expected water quality improvement, cost, and resultant consumer benefits of each of the six alternatives. The future cost to treat water currently diverted from the Delta is also shown. Urban M&I water quality which can be achieved by each alternative concept, and the base case of existing conditions, is characterized in the following tabulation by the average THMFP and the average TDS or total mineral content of the water, and the total organic carbon (TOC) level:

Alternative concept	Average source water quality achieved		
	THMFP (DWR), ug/l	TDS, mg/l	TOC, mg/l
Existing condition	500	240	8
Alternative 1--Delta Transfer System Improvements	420	200	7
Alternative 2--San Joaquin Conjunctive Use Project	400	190	7
Alternative 3--Delta Agricultural Drainage Management	330	160	7
Alternative 4--Peripheral Canal	310	100	6
Alternative 5--Dual Transfer System			
A. Nonbifurcated	370	150	7
B. Bifurcated	310	100	6
Alternative 6--Sierra Source-to-User System	250	60	3

Effectiveness of the alternative concepts in reducing THM precursors, expressed as THMFP (DWR), and TDS is more clearly visualized from a bar chart:



Here the water quality improvements achieved are expressed as percentage reductions from the existing average values.

Conclusion

The results of this study show that the water currently diverted from the Delta contains relatively high concentrations of TDS, especially sodium and chloride ions. In addition, due to high concentrations of THM precursors and other organics yet to be regulated in Delta water supplies, the urban water agencies will have to use costly treatment techniques to meet anticipated drinking water standards. As drinking water standards are developed for more constituents, as mandated by the amendments to the federal Safe Drinking Water Act, expensive chemical treatment of Delta water supplies will be required to meet the future standards. Less treatment will be required for waters diverted closer to their sources. The most desirable drinking water is provided by adequately treating the highest quality source available. The Delta watershed is highly developed for urban, industrial, and agricultural uses; all of these activities contribute contaminants to the Delta waters. The amounts of contaminants entering waters upstream of the Delta are lower because less of the watershed is developed in the upstream reaches.

The State Water Resources Control Board (1988a) concluded in its report as referee in the case EDF et al v. EBMUD, "Prudence requires that public water suppliers should minimize treatment uncertainties by seeking water from the best available source and as removed from the potential for degradation as possible". Treatment of lower quality sources can be extremely costly and there is always the risk that treatment plants will fail to reliably remove contaminants from lower quality sources. Also, the quality and value of water to urban users are reduced when more chemical treatment is used.

This study shows that the alternatives that would take water upstream of the Delta would provide higher quality drinking water than the existing Delta supply. The cost studies show that the cost of achieving improvements in source water quality would be offset to varying degrees by avoiding increasingly complex and expensive treatment that will be needed to meet more stringent drinking water requirements. The Sierra Source-to-User alternative would provide the highest quality source water, would require the least complex treatment to meet anticipated drinking water standards, and would have the most beneficial impact on consumer confidence. Isolated transfer concepts would provide less improvement in source water quality than the Sierra Source-to-User alternative. The existing Delta supply system plus more advanced treatment would provide the least drinking water quality improvement. Consumer benefits from higher quality water would also offset, to varying degrees, the cost of implementing the quality-enhancement supply concepts.

The purpose of this study is not to recommend a specific physical system for providing drinking water to the urban water agencies, nor to assess alternatives with respect to overall effects on environmental, economic, or other factors relative to management of the state's waters or the Delta in particular. The study does identify and compare selected alternative concepts for their ability to protect and enhance drinking water quality. The study recognizes that there would be many environmental, institutional, and other impacts of the alternative concepts, and that much more study and assessment of these factors is needed.

Reference

California State Water Resources Control Board. 1988a. Report of Referee, Lower American River Court Reference (EDF et. al., v. EBMUD).

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SUMMARY

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Water utilities are most concerned with, and consumers most potentially affected by, the THMs which are formed upon chlorination of Delta water supplies. Delta water contains high concentrations of organic precursors. These precursors will result in the formation of toxic by-product compounds upon the use of any known practical disinfection process. However, the focus here is on THMs because they are the first such by-products to be regulated. Other disinfection by-products, such as chloro-furanone (MX), chloropicrin, and dichloroacetonitrile (DCAN) are expected to be regulated in the future.

The amount of THM precursors in a drinking water source is measured by chlorinating the water and forcing the THMs to form. This gives the THM formation potential (THMFP), and is essentially a worst-case indicator. This study primarily uses THMFP data from DWR because it is the most comprehensive set of THMFP data available. However, the DWR formation potentials are analyzed under severe conditions, and the values are up to three times those analyzed by most water utilities using test conditions that simulate the conditions in water distribution systems. Without advanced treatment processes, chlorinated drinking water could be expected to have THMs of 15 to 25 percent of the THMFP (DWR) values. Tests of THMFP made by DWR range up to 1,500 micrograms per liter (ug/l) in the lower San Joaquin River. Maximum and average values of THMFP at the state pumps are about 900 and 500 ug/l, respectively. The current drinking water standard for THMs in urban water distribution systems is 100 ug/l (annual average), but a lower standard is expected in the early 1990s.

The urban water supply agencies will be faced with an urgent need for new and upgraded treatment facilities to meet new drinking water standards. Not only will the average drinking water treatment cost rise, but the range of treatment cost between that for the higher quality sources and lower quality sources will widen. The range of costs is defined by data presented in Chapters 3 and 4. The California Department of Health Services has a long standing policy that:

> "Water utilities should seek to obtain and provide all reasonable protection of [their drinking water] supply from any known or potential source of contamination hazard."

For the reasons discussed in this report, the importance of providing the best quality drinking water source will increase in the future. While cost is an important consideration, and most California water suppliers deliver water at low cost, this report emphasizes drinking water quality.

Alternative Concepts

The alternatives analyzed in this study were developed in a series of discussions with the study Advisory Committee. Existing Delta water supply management was used as the baseline for comparison of alternatives. Alternative concepts ranging from modifications in water project operations through minor modifications of water project facilities to major modifications of water project facilities were considered. Study of existing Delta water management, and discussion of system operations with SWP and CVP operating agencies, did not reveal any significant drinking water quality improvements which can be achieved simply by modifying current operating practices, however, additional operational studies are warranted. A screening process reduced the number of concepts studied. The following six alternative concepts were selected by the Advisory Committee for analysis in this study on the basis that they reflect the range of concepts.

Alternative 1. Delta Transfer System Improvements. This alternative represents the North Delta and South Delta improvements currently proposed by DWR to improve Delta hydraulics. These improvements would increase the efficiency of Sacramento River water transfer, provide sufficient capacity to carry increased flows to the state and federal pumps, and improve water quality. This alternative is shown on Figure 4-3. As a subalternative, the ability of this improved Delta system to support an altered seasonal pumping pattern to yield higher quality water is considered.

Alternative 2. San Joaquin Conjunctive Use Project. In addition to completion of the proposed Delta Transfer System Improvements, large volumes of water from New Melones Reservoir would be used to supply users in the Stanislaus River and Calaveras River Basins during periods of plentiful supply. These users would switch to groundwater for a major portion of their supply during dry years, making New Melones water available for downstream release to the San Joaquin River system during these dry periods. This concept provides further water quality enhancement at the pumps because it would help to maintain water quality in the downstream portion of the San Joaquin River during dry years.

Alternative 3. Delta Agricultural Drainage Management. In this concept, the proposed Delta Transfer System Improvements (Alternative 1) would be supplemented by a system to collect all, or a major portion of, the agricultural drainage from the Delta islands. The drainage would be conveyed to a point of discharge in the San Francisco Bay estuary to eliminate this source of discharge of organic precursors into Delta waters.

Alternative 4. Peripheral Canal. This is the 42-mile-long isolated channel first proposed by the Interagency Delta Committee in 1965, then rejected by California voters in 1982. It would convey water from the Sacramento River around the Delta, releasing a portion of it for Delta channel flow improvement, and delivering the remaining water to Clifton Court Forebay, and thence to the Delta export pumps. This alternative is shown on Figure 4-14.

Alternative 5. Dual Transfer System. About half of the water being diverted from the Delta would be conveyed through existing channels, and the remainder in this new isolated channel extending from Hood on the Sacramento River to the Clifton Court Forebay. This alternative is shown on Figure 4-15. A subalternative, shown on Figure 4-16, would provide a bifurcated transmission system south of the Delta so that only high quality water would be delivered to the A.D. Edmonston Pumping Plant.

Alternative 6. Sierra Source-to-User System. New conveyance facilities would be constructed to convey water for municipal and industrial (M&I) urban water users from the Feather River/Sacramento River confluence around the Delta and directly to the Tracy Pumping Plant. The Delta Mendota Canal and a new canal south of San Luis Reservoir would be used to convey this water south for M&I use, and the SWP facilities would be used for conveying water from the Delta to agricultural users. The Sierra Source-to-User System is shown on Figure 4-17.

For each of the conceptual alternatives, the following information is presented in Chapter 4:

1. A description of the physical facilities and how they would function to improve drinking water quality.

2. The water quality that would result from its implementation and the expected level of treatment that would be required to comply with anticipated drinking water regulations.

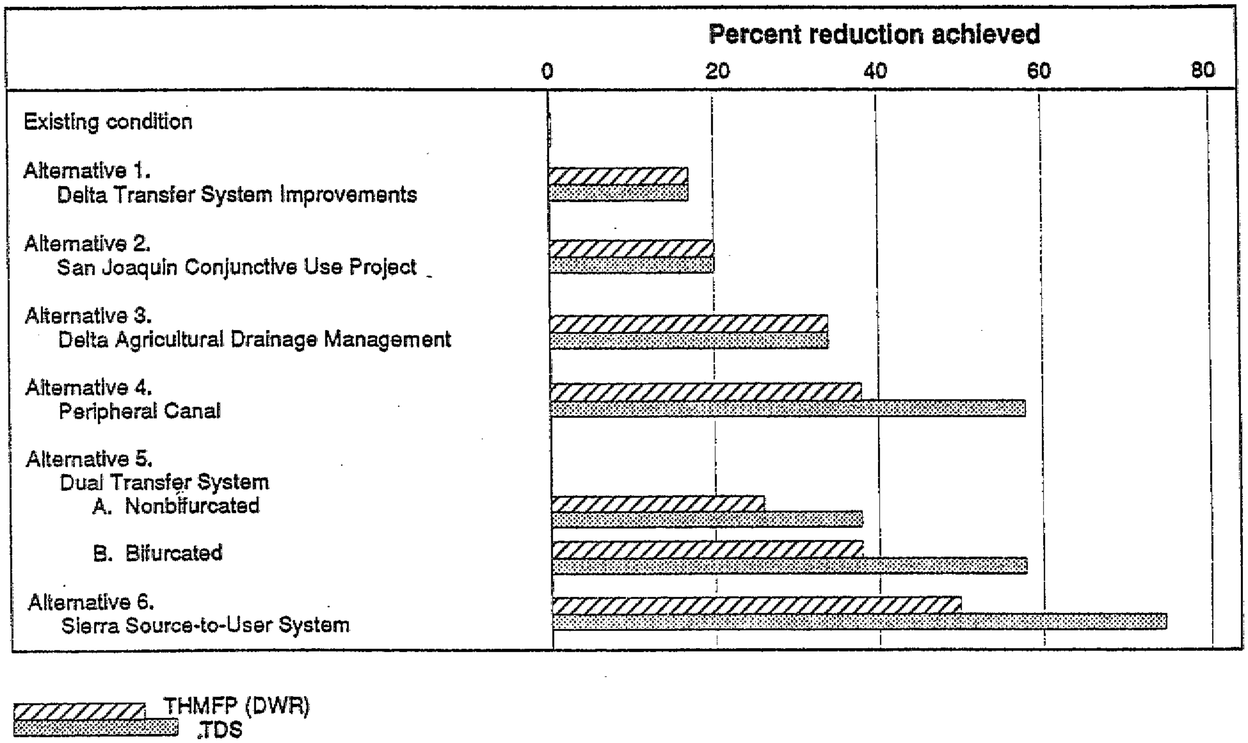
3. Preliminary (reconnaissance-level) estimates of costs for construction and operation and the associated costs for treatment. Also, the economic benefits to consumers of improvements in mineral quality of water are estimated. The future cost to treat water currently diverted from the Delta is also shown.

The report includes a summary of the expected water quality improvement, cost, and resultant consumer benefits of each of the six alternatives. The future cost to treat water currently diverted from the Delta is also shown. Urban M&I water quality which can be achieved by each alternative concept, and the base case of existing conditions, is characterized in the following tabulation by the average THMFP and the average TDS or total mineral content of the water, and the total organic carbon (TOC) level:

Alternative concept	Source water quality achieved[a]		
	THMFP (DWR), ug/l	TDS, mg/l	TOC, mg/l
Existing condition	500	240	8
Alternative 1--Delta Transfer System Improvements	420	200	7
Alternative 2--San Joaquin Conjunctive Use Project	400	190	7
Alternative 3--Delta Agricultural Drainage Management	330	160	7
Alternative 4--Peripheral Canal	310	100	6
Alternative 5--Dual Transfer System			
A. Nonbifurcated	370	150	7
B. Bifurcated	310	100	6
Alternative 6--Sierra Source-to-User System	250	60	3

[a]Average source water quality; see Chapter 4 for quality variations.

Effectiveness of the alternative concepts in reducing THM precursors, expressed as THMFP (DWR), and TDS is more clearly visualized from a bar chart:



Here the water quality improvements achieved are expressed as percentage reductions from the existing average values.

Conclusion

The results of this study show that the water currently diverted from the Delta contains relatively high concentrations of TDS, especially sodium and chloride ions. In addition, due to high concentrations of THM precursors and other organics yet to be regulated in Delta water supplies, the urban water agencies will have to use costly treatment techniques to meet anticipated drinking water standards. As drinking water standards are developed for more constituents, as mandated by the amendments to the federal Safe Drinking Water Act, expensive chemical treatment of Delta water supplies will be required to meet the future standards. Less treatment will be required for waters diverted closer to their sources. The most desirable drinking water is provided by adequately treating the highest quality source available. The Delta watershed is highly developed for urban, industrial, and agricultural uses; all of these activities contribute contaminants to the Delta waters. The amounts of contaminants entering waters upstream of the Delta are lower because less of the watershed is developed in the upstream reaches.

The State Water Resources Control Board (1988a) concluded in its report as referee in the case EDF et al v. EBMUD, "Prudence requires that public water suppliers should minimize treatment uncertainties by seeking water from the best available source and as removed from the potential for degradation as possible". Treatment of lower quality sources can be extremely costly and there is always the risk that treatment plants will fail to reliably remove contaminants from lower quality sources. Also, the quality and value of water to urban users are reduced when more chemical treatment is used.

This study shows that the alternatives that would take water upstream of the Delta would provide higher quality drinking water than the existing Delta supply. The cost studies show that the cost of achieving improvements in source water quality would be offset to varying degrees by avoiding increasingly complex and expensive treatment that will be needed to meet more stringent drinking water requirements. The Sierra Source-to-User alternative would provide the highest quality source water, would require the least complex treatment to meet anticipated drinking water standards, and would have the most beneficial impact on consumer confidence. Isolated transfer concepts would provide less improvement in source water quality than the Sierra Source-to-User alternative. The existing Delta supply system plus more advanced treatment would provide the least drinking water quality improvement. Consumer benefits from higher quality water would also offset, to varying degrees, the cost of implementing the quality-enhancement supply concepts.

The purpose of this study is not to recommend a specific physical system for providing drinking water to the urban water agencies, nor to assess alternatives with respect to overall effects on environmental, economic, or other factors relative to management of the state's waters or the Delta in particular. The study does identify and compare selected alternative concepts for their ability to protect and enhance drinking water quality. The study recognizes that there would be many environmental, institutional, and other impacts of the alternative concepts, and that much more study and assessment of these factors is needed.

CHAPTER 1

THE PROBLEM AND THE STUDY

Drinking water quality is an issue of growing interest and concern in California and across the nation. In California, the elevated concentrations of minerals in urban water supplies continues to be of concern. However, much greater public attention is now focused on organic contamination from synthetic organic chemicals and by-products of disinfection in the water treatment process. The latter issue is of special concern to the agencies who serve nearly 20 million Californians with water from the Sacramento-San Joaquin Delta (Delta) as part or all of their drinking water supply.

An impressive recent example of consumer concern about drinking water quality occurred in the Contra Costa Water District. In November 1988, two-thirds of the District's voters endorsed the $350 million Los Vaqueros project, which was presented to the voters mainly as a Delta water quality enhancement program. For this 350,000 population district, this project is equivalent in cost burden to a $25 billion undertaking by all urban water users in California.

The California Urban Water Agencies undertook this study of Delta drinking water quality to identify water quality issues and management concepts to deal with these issues. This report is intended to provide an overview of drinking water issues and a clear view of how Delta drinking water quality studies should move forward from the present level of understanding.

Current and Anticipated Problems

Water quality is degraded, both naturally and through the activities of man, as the water runs from Sierra mountain streams, through the valleys, and through the Delta to the pumps of the State Water Project (SWP), the federal Central Valley Project (CVP) and the Contra Costa Water District. There is a significant increase in the concentrations of some contaminants of concern to drinking water supplies along the way.

Total dissolved solids (TDS) indicates the total amount of minerals or salts which the water has dissolved from soil and rocks, or which has been discharged into the streams from urban and agricultural activities. The Sierra streams have very low TDS levels, generally in the range of 40 to 60 milligrams per liter (mg/l). By the time that water enters and flows through the Delta, the TDS has increased significantly. As a result, the supply pumps of both the SWP and the federal CVP, divert water with an average TDS of 240 mg/l. About two-thirds of the mineral mass which is pumped out of the Delta is eventually recycled into the Delta system at Vernalis via the San Joaquin River. This recycling occurs through leaching of salts from irrigated lands, and flow of agricultural drainage into the San Joaquin River. High TDS (saline) waters pose problems for most urban uses and are objectionable to drinking water consumers. The secondary (nonmandatory) drinking water standard for TDS includes several levels; the lowest is a suggested limit of 500 mg/l. This limit was set primarily on the basis of taste thresholds.

Chloride is the major element in common salt and the oceans' dissolved minerals. The chloride relationships in the Delta tributary systems are similar to those described for TDS but the ranges of concentrations are proportionately even wider. That is because there is very little chloride in the Sierra streams, but seawater intrusion and mixing provide a massive source of chloride in the western Delta. A significant portion of this chloride finds its way into the Delta water supplies. Chloride is very important in Delta water quality management; California State Water Resources Control Board (SWRCB) Water Rights Decision 1485 permits a maximum chloride level of 150 mg/l at Rock Slough at certain times and conditions. The recently published Draft Water Quality Control Plan for Salinity would eliminate the 150 mg/l chloride criterion, and a 250 mg/l criterion would be the new maximum level at all times (SWRCB, 1988). The proposed chloride level corresponds to the secondary drinking water standard for chloride (see Chapter 3), but urban water utilities that suffer wide swings of chloride find that customer complaints increase when the chloride level reaches 100 to 150 mg/l. Some industrial and commercial water uses are economically damaged with even lower levels. The economic benefits of better mineral quality in urban water supplies can be a large factor in evaluating alternative water sources.

Sodium, like chloride, is mainly ocean derived and is nearly proportional to chloride. There is a wide range of sodium tolerance in drinking water and no maximum contaminant level or formal limit has been set. Sodium action levels have been set on a case-by-case basis. For example, in 1977, the East Bay Municipal Utility District, in consultation with the California Department of Health Services agreed on 70 mg/l sodium as a trigger level for public notification. The Sierra streams contain almost no sodium, but the waters pumped from the Delta sometimes rise to sodium peaks of 100 mg/l or more.

Sea water incursion also introduces bromide into the estuary. During periods of relatively low Delta outflow, the bromide concentration is high enough to form large amounts of brominated trihalomethanes (THMs), and to significantly increase the total THM concentrations.

Organic degradation in the Delta water derives from the following sources, in decreasing order of amounts: (1) natural materials, including vegetation and organics in soils; (2) agriculture, as vegetative organics in drainage (percolation and runoff); (3) urban runoff; (4) urban wastewater effluent; (5) spills and illicit disposal of petroleum products and man-made chemicals; and (6) biocide application residue, including pesticides and herbicides. Water utilities are most concerned with, and consumers most potentially affected by, the THMs which are formed upon chlorination of Delta water supplies. Delta water contains high concentrations of organic precursors. These precursors are mainly the fulvic and humic acids and they derive from vegetation, such as native wild plants, or vegetal debris such as peat soil.

The amount of THM precursors in a drinking water source is measured by chlorinating the water and forcing the THMs to form. This yields the THM formation potential (THMFP), and is essentially a worst-case indicator. This study primarily uses THMFP data from the California Department of Water Resources (DWR) because it is the most comprehensive set of THMFP data available. However, as described on page 3-16, the DWR formation potentials are analyzed under severe conditions, and the values reported by DWR are about three times those analyzed by most water utilities using test conditions that simulate the conditions in water distribution systems. Without advanced treatment processes, chlorinated drinking water could be expected to have THMs of 15 to 25 percent of the THMFP (DWR) values.

Because natural vegetation is a major source of THM precursors, even the clean Sierra streams have significant THMFP levels. The Feather, American, and Mokelumne Rivers have an average concentration of about 250 micrograms per liter (ug/l) of THMFP (DWR). On the other hand, drainage into the San Joaquin River causes THMFP in the river at Vernalis to rise to an average of about 500 ug/l and a maximum of 1,500 ug/l. Maximum and average values of THMFP at the state pumps are about 900 amd 500 ug/l, respectively. The current drinking water standard for THMs in urban water distribution systems is 100 ug/l (annual average), but a lower standard is expected in the early 1990s.

Continuing urban development and increasing demand for available water supplies could cause the quality of Delta water to be further degraded. However, there are other factors which can moderate further degradation. The factors which will tend to counter further water quality degradation are:

1. Consumer demands and legislative policy calling for highest quality drinking water.

2. Public demands, and the regulatory system, will provide tighter controls and mitigation of wastewater discharges, industrial spills, discharge of urban wastes through unregulated storm drains, and over-application or careless disposal of pesticides.

3. Rising costs of drinking water treatment to meet more stringent standards will increase the pressure to maintain and improve source water quality.

4. Agricultural drainage will be more controlled and better managed, and, if further studies demonstrate that "hot spot" areas exist, these areas that produce pollutant extremes can be managed to reduce pollutant loadings.

5. A survey of the SWP to define sources of pollutants (sanitary survey) will be completed and recommended improvements will be made to minimize pollutant loads which drain into the major water storage and conveyance facilities.

Some adverse effects of urbanization on water quality are almost certain. Accidental spills will increase in frequency, and likely, in impact. Urban storm drainage systems will bring more bacteriological load and urban organic contamination into the waterways in surge loads during storms. For the purposes of this study and for assessing the drinking water quality benefits of each of the alternative management concepts examined, it is assumed that growth and development will cause no net change in Delta quality over the period of the study (to 2010).

The San Francisco Bay (Bay)-Delta hydrologic system serves many beneficial uses. Six of these water uses (municipal, industrial, agricultural, fishery, wildlife, and recreation), must be considered both for (a) uses within the Bay-Delta estuary, and (b) water pumped from the estuary. Several of the beneficial uses pose conflicts in setting water quality objectives or achieving optimum use of the water resources. Some examples of this are (1) an important function of the rivers tributary to the Delta is to carry the minerals derived from the watersheds to the ocean, but this natural function contributes a large mineral load to the Delta water supplies; (2) a vigorous plankton crop is needed to sustain a healthy fishery, but imposes a difficult particulate and organic load problem on water treatment facilities; and (3) high turbidity in the nutrient-rich Delta moderates undesirable algal blooms, but increases the difficulty and cost of water treatment. These examples show the difficulty of balancing the needs of all uses of Delta water, but a reasonable balance must be diligently sought in order to protect the Delta's unique environmental values while benefitting from its essential water supply.

The urban water supply agencies will be faced with an urgent need for new and upgraded treatment facilities to meet new drinking water standards. Not only will the average drinking water treatment cost rise, but the range of treatment cost between that for the higher quality sources and lower quality sources will widen. The range of costs is defined by data presented in Chapters 3 and 4. For the reasons discussed in this report, the importance of providing the best quality drinking water source will increase in the future.

Objective of the Study

The objective of the Delta Drinking Water Quality Study is to examine concepts for the management of the Delta water supply systems and their abilities to protect and improve drinking water quality. As used in this statement of the study objective, Delta water supplies are supplies which are derived from the Delta and its tributaries. The goal of this study is to characterize those Delta management concepts, qualitatively and quantitatively with respect to their abilities to achieve desired drinking water quality, considering technical and economic requirements. Desired drinking water quality is that quality which meets present and anticipated drinking water standards with an adequate margin of safety, and enhances consumer acceptance to minimize the perceived need for bottled water and home treatment devices.

Protection and improvement of drinking water quality is defined as:

1. Protecting the chemical and biological quality of the major drinking water sources against degradation. In determining the level of protection that is warranted, it is recognized that additional treatment of the drinking water supply may be more economical than complete protection of the source from degradation (i.e., there are reasonable economic balances between treatment of some constituents and source protection measures).

2. Improving the source water quality as economically, institutionally, and technically feasible so that present and anticipated drinking water quality standards and consumer preferences can be met, using available, reliable, and economical treatment technology.

Conduct of the Study

The Delta Drinking Water Quality Study was conducted by Brown and Caldwell Consulting Engineers and was sponsored by the nine urban water supply agencies listed below:

Alameda County Water District
East Bay Municipal Utility District
Los Angeles Department of Water and Power
Metropolitan Water District of Southern California
Municipal Water District of Orange County
San Diego County Water Authority
City of San Diego Water Utilities Department
San Francisco Public Utilities Commission
Santa Clara Valley Water District

A project Advisory Committee, composed of senior staff members representing each agency and staff from the two cooperating agencies, DWR and the U.S. Bureau of Reclamation (USBR), directed the progress of the study. In a series of six meetings during the conduct of the study, the Advisory Committee helped develop the study work plan and formulate alternatives. The Advisory Committee also reviewed and commented on the progress reports, report outline, and presentations on key study findings.

Several Advisory Committee meetings were devoted to identifying the alternatives to be analyzed in this study. A number of alternatives were identified, ranging from reliance on treatment of existing quality Delta water through minor modifications of water project facilities, such as DWR's currently proposed Delta Transfer System Improvements, to major modifications of water project facilities, such as the Peripheral Canal and the Sierra Source-to-User System described in Chapter 4. In identifying alternatives, the concept was to determine how much improvement in Delta drinking water quality could be achieved by operational or minor modifications to existing facilities, compared to the improvement in quality from major modifications of water project facilities. After much discussion, six alternatives were identified.

Brown and Caldwell staff met with many of the Advisory Committee members individually to gather documents and data on source water quality and discuss water quality problems experienced by the agencies. In addition, Brown and Caldwell staff met with DWR staff on several occasions to gather data and discuss the results of the Interagency Delta Health Aspects Monitoring Program and the Agricultural Drainage Investigation. Brown and Caldwell staff also met with USBR staff to discuss possible operational changes that could improve water quality. Input was solicited from all participants to provide information on which to develop and analyze alternatives for Delta water quality protection.

Report Organization

The draft report contains five chapters. Chapter 1 is the introduction to the study. Chapter 2 contains an extensive discussion of the physical and operational characteristics of the CVP/SWP system and the independent water supply projects. The projected water demands of each agency for the year 2010 are also presented in Chapter 2. The current and anticipated drinking water regulations and the existing quality of the Delta and Delta source waters is described in Chapter 3. Chapter 4 contains a physical description, the expected improvement in drinking water quality, and the costs of each alternative. Chapter 5 contains a discussion of the environmental and institutional factors that must be considered in a complete analysis of the alternatives. Additional investigations needed to answer some of the current questions about Delta drinking water quality are also described in Chapter 5.

Study Participants

Study participants from the sponsoring agencies, federal and state agency staff who participated in the study, and the Brown and Caldwell project team are listed in this section.

California Urban Water Agencies

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CHAPTER 2

THE MAJOR DELTA WATER SUPPLY SYSTEMS

The systems that provide Sacramento-San Joaquin Delta (Delta) water supplies for urban use in California are described in this chapter. These systems include the federal Central Valley Project (CVP) and California State Water Project (SWP) contractors; the Contra Costa Water District; and the San Francisco Water Department and the East Bay Municipal Utility District, who import urban water supplies from Delta tributaries. The water supply systems are described with emphasis on:

- The major elements of the existing water supply system,
- the purposes that its planners intend it to serve,
- the nature of its current obligations, and
- the interrelationships between the major elements of the system.

In examining the existing water supply system, attention is directed at the features and operational aspects that relate to possible drinking water quality improvement. The quality of water that the existing system is capable of delivering to its drinking water users is described in Chapter 3.

One value of a Delta drinking water quality improvement program that works within the framework of existing facilities lies in the relative speed with which quality improvements might be obtained with the existing water supply system, as compared to a program which requires extensive new facilities. Also, a drinking water quality improvement program that works with existing facilities may be considerably less expensive than one requiring major new works.

Delta water is currently served to most of the study participants via the SWP and the CVP. Accordingly, examination of the Delta drinking water quality issue and the search for potential actions to improve Delta drinking water quality appropriately begins with examination of the existing SWP and CVP facilities and their operation.

THE MAJOR SYSTEM FACILITIES

The CVP was built by the U.S. Bureau of Reclamation (USBR). The major part of the water supply it produces and distributes is used to meet the full or supplemental irrigation requirements within an authorized service area of 3,757,000 acres, chiefly in the Central Valley. The project is also an important source of municipal and industrial (M&I) water supply to urban areas in portions of the Central Valley and San Francisco Bay Area. Its major reservoirs on rivers around the rim of the valley also perform other important functions such as flood control, hydroelectric power generation, fish and wildlife protection, recreation, and assisting in control of water quality in the Delta.

The SWP was constructed by, and is operated by, the California Department of Water Resources (DWR). Its purposes include M&I and agricultural water supply, flood control, hydroelectric power generation, recreation, fish and wildlife protection and enhancement, and water quality control in the Delta. Water supplies are currently, or will be, provided on a wholesale basis for 30 agencies from the upper Feather River area in Plumas County to the San Francisco Bay Area, Central Coastal area, San Joaquin Valley, and Southern California. The sum of current maximum annual entitlements of all contractors is approximately 4.22 million acre-feet per year (AF/yr).

The features of the SWP and CVP are described together for the following reasons:

1. Under the Coordinated Operation Agreement (COA) of November 1986, the CVP and SWP share responsibility for meeting Sacramento Valley in-basin use of stored water withdrawals and divide water available for pumping from the Delta.

2. There is day-to-day coordination between the operators of the two projects.

3. San Luis Reservoir and transport facilities south to the vicinity of Tulare Lake are joint-use facilities operated by DWR for conveyance of both SWP and CVP water.

4. The possibility of further CVP/SWP integration and operation of more CVP facilities by DWR is being explored, and is an important aspect of alternatives considered in this study.

The existing conveyance systems are shown on Figure 2-1. These systems are described by geographical area to facilitate the discussion of the interrelationships among them. The geographical areas are:

1. Sacramento Valley and Stanislaus River
2. Sacramento-San Joaquin Delta
3. San Francisco Bay Area
4. San Joaquin Valley
5. Central Coastal Area
6. Southern California

Sacramento Valley and Stanislaus River

The Sacramento Valley and Stanislaus River have been subdivided into four streams or stream reaches to assist in the discussion of system operation.

Sacramento Valley Above the Mouth of the Feather River. In this area, CVP regulatory storage consists of two major facilities: the 2.5 million acre-foot (AF) Clair Engle Lake on the Trinity River, which is tributary to the Klammath River and thence to the ocean; and the 4.5 million AF Shasta Lake on the Sacramento River. Annual diversions from the Trinity River averaged about 1.2 million AF/yr from 1981 through 1984. These two reservoirs augment the Sacramento River supply to the Red Bluff Diversion Dam, and the Corning and Tehama-Colusa Canal service areas, and provide supplemental water to

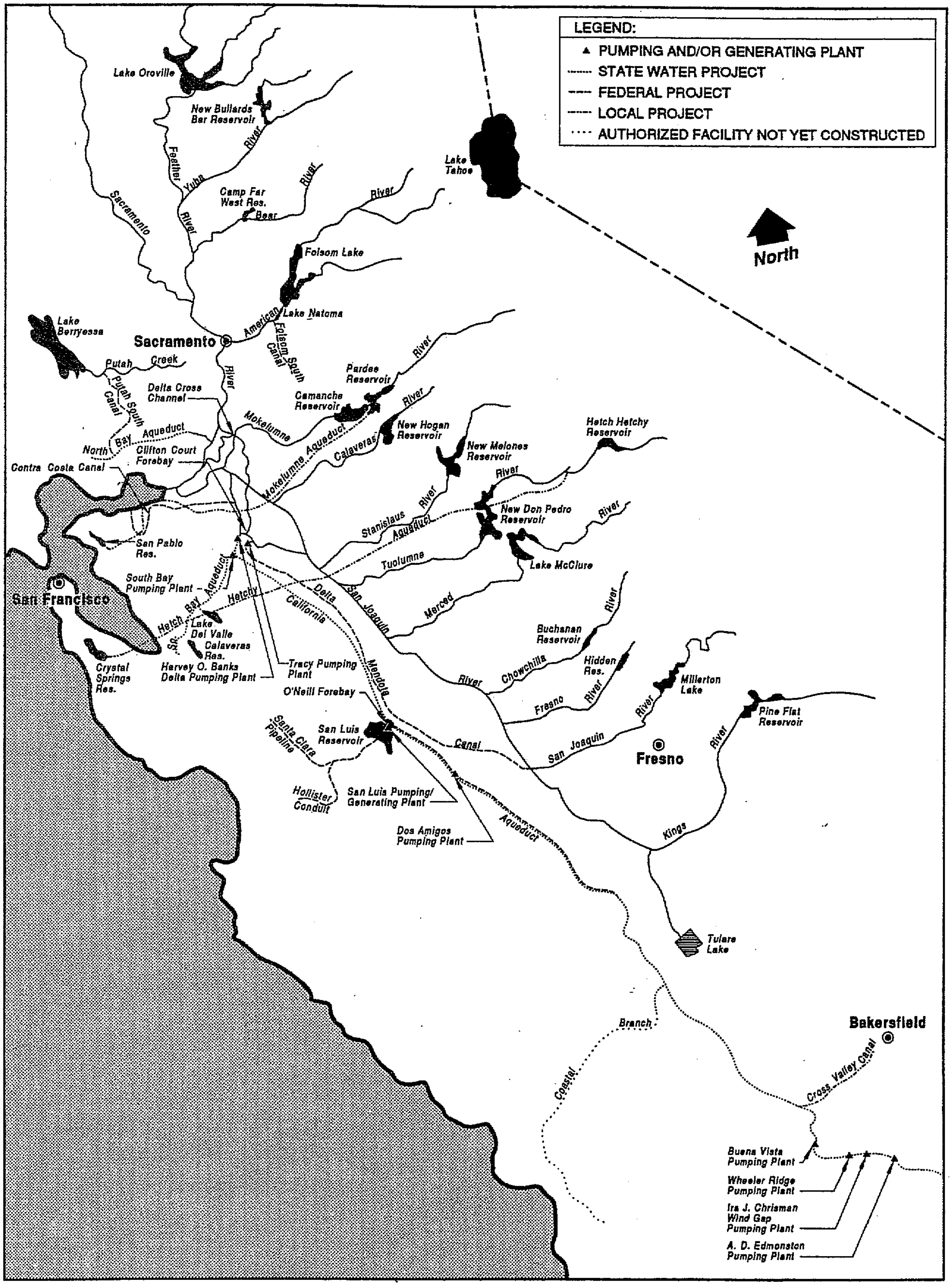


Figure 2–1. Existing Conveyance Systems

many downstream Sacramento River water rights holders, and supply other water users. Maximum contract obligations total about 2.4 million AF/yr.

SWP regulatory storage in this area is contained in the 3.5 million AF Lake Oroville, which directly supplies two SWP contractors and provides water to several irrigation districts and individuals to meet Feather River water rights. Contract obligations in the Feather River service area total about 1 million AF/yr.

The pattern of irrigation drainage above the confluence of the Sacramento and Feather Rivers is significant. Return flows from most Sacramento River diversions downstream from the vicinity of Chico are conveyed parallel to the river in the Colusa Basin Drain west of the river, and in Butte Creek and the borrow pits for Sutter Bypass levees east of the river. They re-enter the Sacramento River through Colusa Basin Outfall Gates and Sacramento Slough, respectively, just above the Feather River. Similarly, the large west side Feather River diversions from Thermalito Afterbay flow to Butte Creek and the Sutter Bypass channels, returning through Sacramento Slough. This has two major consequences: (1) the flow in the Sacramento River is depleted by diversions to a minimum point not far above the mouth of the Feather River, which becomes the navigation control point and determines how much water must be released from upstream CVP reservoirs for that purpose and (2) the quality of the Sacramento River is affected where the two drains enter.

Mouth of the Feather River to the Delta. The CVP regulatory storage is contained in the 1 million AF Folsom Lake. The Folsom South Canal with an initial capacity of 3,500 cubic feet per second (cfs) diverts water from Lake Natoma below Folsom Lake. Contracts to supply water from the American River above and below Folsom Lake total about 181,000 AF/yr. The two existing contractors for deliveries from the Folsom South Canal, the Sacramento Municipal Utility District and the East Bay Municipal Utility District (EBMUD), have maximum contract entitlements of 75,000 and 150,000 AF/yr, respectively, for a total of 225,000 AF/yr. The CVP has no project facilities on the Sacramento River in this reach, but it serves a number of parties under water right settlement contracts whose diversions total about 228,000 AF/yr.

Putah Creek. While facilities on this stream are not elements of the CVP, they are owned and operated by the USBR and may have significance from the standpoint of water exchanges to improve water quality for drinking water purposes in the southwest Sacramento Valley area and in the portion of the San Francisco Bay Area in Solano County. The regulatory storage is provided in the 1.6 million AF Lake Berryessa. Water conveyance is through the Putah South Canal with an initial capacity of 960 cfs. Water service contracts with agencies in Solano County total 186,750 AF/yr.

Stanislaus River. CVP regulatory storage is contained in the 2.4 million AF New Melones Reservoir. The long-term firm yield of this project is 180,000 AF/yr. Contracts of two San Joaquin County districts total 155,000 AF/yr, including 106,000 AF/yr of interim entitlements that are expected to diminish with time.

Sacramento-San Joaquin Delta

CVP facilities in the Delta include the Delta Cross Channel at Walnut Grove, which directs flow from the Sacramento River through the Mokelumne River to the more southerly parts of the Delta, the 4,600-cfs Tracy Pumping Plant and the 350-cfs Contra Costa Canal Pumping Plant. The Contra Costa Canal serves a portion of Contra Costa County under a CVP contract providing a maximum water supply of 195,000 AF/yr. The SWP has the 175-cfs North Bay Aqueduct Pumping Plant and the 6,400-cfs Harvey O. Banks Delta Pumping Plant (Delta Pumping Plant). The North Bay Aqueduct also includes capacity to deliver water to Vallejo to substitute for its original diversion from the Delta. The capacity of the Delta Pumping Plant is currently being increased to 10,300 cfs, and that will be considered existing capacity in this study even though full operation at this enlarged capacity requires a revised U.S. Army Corps of Engineers (Corps of Engineers) permit and some key Delta transfer improvements.

The CVP and SWP are operated to protect beneficial uses of water within the Delta according to the standards contained in Water Rights Decision 1485 (D-1485) of the California State Water Resources Control Board (SWRCB). The D-1485 standards are contained essentially in the COA which now governs the coordination of the two projects to satisfy the Delta standards. The Delta standards, described in Chapter 3, may be revised upon completion of current proceedings (Bay-Delta Hearings) before the SWRCB.

San Francisco Bay Area

This area is served by the CVP, SWP, and locally owned and constructed facilities. The San Francisco Bay Area water agencies have water rights or contract entitlements to about 1.3 million AF/yr of water from sources tributary to the Delta. Of this total, about 60 percent is provided via the CVP and SWP, and the remainder through systems owned and operated by local agencies.

CVP Facilities. The San Felipe Division conveys water from San Luis Reservoir through the 480-cfs Pacheco Pumping Plant, Tunnel, and Pipeline, northward through the 330-cfs Santa Clara Pipeline to Santa Clara Valley Water District, and southward via the Hollister Conduit. Water currently flows into Calero Reservoir of Santa Clara Valley Water District for regulation prior to release for groundwater recharge or for treatment and wholesale delivery to retail agencies. A pipeline is currently under construction that will bypass Calero Reservoir and allow water to flow directly to the treatment plants and percolation basins. The maximum CVP contract obligation to Santa Clara Valley Water District is 152,500 AF/yr.

SWP Facilities. The SWP has two facilities serving parts of the San Francisco Bay Area: the 175-cfs North Bay Aqueduct serving M&I water in Solano and Napa counties with total contract entitlements of 67,000 AF/yr; and the 300-cfs South Bay Aqueduct serving three contractors with a total entitlement of 188,000 AF/yr. The South Bay Aqueduct contractors are Alameda County Flood Control and Water Conservation District, Zone 7, with 46,000 AF/yr; Alameda County Water District with 42,000 AF/yr; and the Santa Clara Valley Water District in Santa Clara County with a SWP entitlement of 100,000 AF/yr.

Local Facilities. Portions of Alameda and Contra Costa counties are supplied water by EBMUD. EBMUD obtains its water supply from the Mokelumne River at Pardee Reservoir (210,000-AF capacity) in the foothills of the Sierra Nevada. EBMUD stores water in six reservoirs in addition to Pardee Reservoir. Five of these are within the East Bay service area and can hold up to 155,000 AF when full. The sixth is the 431,000-AF capacity Camanche Reservoir on the Mokelumne River immediately below Pardee. Camanche Reservoir provides storage and regulating space to maintain downstream flows for meeting prior rights and contractual commitments on the lower Mokelumne River. Camanche Reservoir also provides flood control for downstream communities and farmlands. Water is conveyed about 90 miles from Pardee Reservoir to the EBMUD service area in three aqueducts with a total capacity of 504 cfs.

The San Francisco Public Utilities Commission operates the Hetch Hetchy project which diverts water from the Tuolumne River, and the San Francisco Water Department which purchases water from Hetch Hetchy for delivery to residents in the City and County of San Francisco, San Mateo County, and in portions of Santa Clara and Alameda counties. The Hetch Hetchy project consists of Hetch Hetchy Reservoir and Lakes Lloyd and Eleanor (aggregate capacity 635,800 AF) in the upper Tuolumne basin and Hetch Hetchy Aqueduct, which has a capacity of 336,000 AF/yr. The San Francisco Water Department also operates six local storage reservoirs.

San Joaquin Valley

This area is discussed with primary emphasis on the west side of the valley, which is of particular concern to possible plans for improving drinking water quality in the CVP/SWP system.

Above O'Neill Forebay and San Luis Reservoir. In this area, the CVP has the Delta Mendota Canal supplied by the Tracy Pumping Plant and O'Neill Pumping Plant. The initial reaches of the canal have a capacity of 4,600 cfs, and at its Mendota Pool terminus on the San Joaquin River, the capacity is 3,200 cfs. At the latter point, the canal discharges up to 840,000 AF/yr of water under the exchange contract to the heads of the canals now owned by the Central California Irrigation District to replace water diverted by the CVP at Millerton Lake on the San Joaquin River to the Madera and Friant-Kern Canals. The Delta Mendota Canal also delivers water to agricultural and M&I contractors along the canal with contract entitlements of 404,000 AF/yr. The 4,200-cfs O'Neill Pumping Plant transfers water in winter months from the Delta Mendota Canal to O'Neill Forebay for storage in San Luis Reservoir and irrigation season use in the CVP San Luis service area. Recent operation of the Delta Mendota Canal has consisted of average Delta diversions of 2.3 million AF/yr, of which 1.2 million AF/yr were pumped into O'Neill Forebay, 0.7 million AF/yr were discharged to Mendota Pool, and the remaining 0.4 million AF/yr comprised deliveries along the canal and losses.

The SWP's Governor Edmund G. Brown California Aqueduct (California Aqueduct) has an initial capacity of 10,300 cfs, which decreases to 10,000 cfs south of the Bethany Reservoir. This capacity will be fully usable when the four additional pumps, now under construction, are in place, and operating under a revised Corps of Engineers permit. Delta channel improvements will also be required, and an Environmental Impact Report/

Environmental Impact Statement for this work is currently under preparation. Also, an agreement for fishery protection is required by the California Department of Fish and Game. This reach of the California Aqueduct is used both for helping to fill San Luis Reservoir and for pumping directly to the water supply contractors in the southern San Joaquin Valley and Southern California. Only one irrigation contractor, with a contract entitlement of about 6,000 AF/yr receives water directly from this reach.

O'Neill Forebay and San Luis Reservoir (Joint-Use Facilities of the CVP/SWP). The role of the 56,000-AF O'Neill Forebay is to receive and regulate varying inflows from the California Aqueduct and O'Neill Pumping Plant, power releases from San Luis Reservoir, and varying outflows pumped to San Luis Reservoir and released to the California Aqueduct to the south and at times through O'Neill Pumping Plant to the Delta Mendota Canal. The San Luis Pumping-Generating Plant has a capacity of 11,000 cfs for pumping and 17,600 cfs for generating. San Luis Reservoir has a capacity of 2.0 million AF, the use of which by the CVP and SWP is divided roughly half and half. Water storage is normally increased in the winter months and released in summer months to meet demands in the two service areas. The San Felipe Division of the CVP is supplied from San Luis Reservoir through Pacheco Pumping Plant and Tunnel as described previously.

San Luis Division (Joint-Use Facilities of the CVP/SWP). The facilities of this division are the California Aqueduct and Dos Amigos Pumping Plant. The capacity of the pumping plant and the initial capacity of the canal are 13,100 cfs, of which the SWP has the right to use 7,100 cfs, and the CVP, 6,000 cfs. The CVP's share decreases progressively to the terminus of the division near Tulare Lake, where the total capacity is 8,350 cfs. Diversions are made for CVP irrigation and M&I deliveries directly out of the canal and through the Coalinga Canal. The capacity for the SWP of 7,100 cfs through the San Luis Division is 1,000 cfs less than that in the California Aqueduct beyond. The lower reach was sized to meet SWP contract demands to the south. CVP maximum contract quantities in the San Luis Division total about 920,000 AF/yr.

South of San Luis Division. The main facility in this reach is the California Aqueduct which has a capacity of 8,100 cfs initially, and 4,400 cfs at the southern end where it enters the A.D. Edmonston Pumping Plant, which pumps water over the Tehachapis to Southern California. SWP deliveries are made through the Coastal Aqueduct Stub and from the aqueduct itself to six contractors. Contract entitlements in this reach total about 1,360,000 AF/yr of which 135,000 AF/yr is for M&I purposes, and the balance is for agriculture.

The Cross-Valley Canal west of Bakersfield is a locally built and operated facility which conveys both SWP project water and CVP water, the latter of which is wheeled in the California Aqueduct. CVP water is delivered to the Friant-Kern Canal where, through exchanges, it supplies contracts totaling 126,000 AF/yr, with agencies as far north as Fresno County.

Central Coastal Area

Both the CVP and the SWP have contracts to serve this area, but only the CVP has completed the necessary delivery facilities.

San Felipe Division. The CVP serves irrigation water to San Benito County in this area. The facilities consist of the 83-cfs Hollister Conduit, which is supplied from San Luis Reservoir through the Pacheco Tunnel, Pumping Plant, and Pipeline, and a terminal regulating reservoir. The maximum annual contract obligation is 44,000 AF/yr.

Coastal Aqueduct. San Luis Obispo and Santa Barbara counties have SWP contract entitlements totaling about 70,500 AF/yr. Studies are now in progress to determine the feasibility of extending the Coastal Aqueduct from the present terminus of its stub in the San Joaquin Valley to fulfill its original intent of serving these coastal counties. The initial capacity of this extended aqueduct would be 450 cfs.

Southern California

This area is considered to be all service areas south of the A. D. Edmonston Pumping Plant. It is served both by locally constructed and SWP import facilities.

Locally Constructed Import Facilities. Southern California has used its locally constructed water import facilities to substantially full capacity for many years. Since 1913, the City of Los Angeles has imported water from Owens Valley and since 1940, from the Mono Basin through its Los Angeles Aqueduct, which has a capacity of 710 cfs and delivers about 470,000 AF/yr. The 1,800-cfs Colorado River Aqueduct of the Metropolitan Water District of Southern California (MWD), which has been operated since 1941, can now convey more than MWD's Colorado River apportionment of 550,000 AF/yr (since the Central Arizona Project began operation).

SWP Facilities. The SWP facilities serving this area are the 4,480-cfs (maximum) A.D. Edmonston Pumping Plant at the southern end of the San Joaquin Valley; the tunnels and siphons through the Tehachapi Mountains with a capacity of 5,360 cfs; the Mojave and Santa Ana Divisions (East Branch California Aqueduct), the capacity of which begins at 3,150 cfs and ends at 585 cfs at 131,000-AF Lake Perris; and the West Branch of the California Aqueduct, with a basic capacity of 3,130 cfs, and a capacity for pump-back power operation between Pyramid and Castaic Lakes of 17,600 cfs. With these reservoirs of the West Branch, and Silverwood and Perris Reservoirs on the East Branch, regulating storage totals 701,000 AF. This is sufficient under full operating conditions to meet the contractual monthly peak deliveries of 11 percent of maximum annual entitlements with essentially constant flow over the Tehachapi Mountains. The total of such maximum annual entitlements is about 2.5 million AF/yr. Three contracting agencies, with maximum annual entitlements, all for urban purposes, totaling about 62,000 AF/yr, are located in Coachella Valley with no direct connection to the East Branch. Since they overlie a groundwater basin, which can be recharged by releases from the Colorado River Aqueduct to the Whitewater River, they are served in this manner, and MWD receives SWP water from the East Branch in exchange.

OPERATION OF CVP/SWP SYSTEM

In studying possible ways to improve drinking water quality in the CVP/SWP system, it is essential to consider the present objectives, constraints, and operating procedures of the system. The following paragraphs briefly describe them.

Coordinated Operation Agreement

This agreement for coordinated operation of the CVP and SWP was approved by Congress, executed by the USBR and DWR in November of 1986, and is now in full effect. The main purpose of the COA is to divide between the CVP and SWP the responsibilities for meeting Sacramento Valley in-basin uses, including requirements in the Delta, and to determine permissible diversions from the Delta by each project.

The major provisions for coordination of operations apply to balance water conditions when it is agreed by the two agencies that releases from upstream storage and unregulated flow approximate the supply needed to meet such in-basin uses and diversions. If total storage withdrawals by the two projects on a given day exceed total diversions, the difference is Sacramento Valley in-basin use of storage withdrawals, and the responsibility for meeting them is divided 75 percent to the CVP and 25 percent to the SWP. If total diversions exceed storage withdrawals, the difference is unstored water for export, and the sum of that and the total increase of storage in reservoirs of the two projects is divided 55 percent to the CVP and 45 percent to the SWP. From each project share so determined, permissible daily Delta diversions by each are calculated. The differences between these computed responsibilities for in-basin use of storage withdrawals and permissible diversions and corresponding actual quantities are accumulated as long as balanced conditions prevail with conditions specified for reduction or elimination.

Excess water conditions apply when it is agreed that releases from upstream reservoirs plus unregulated flows exceed Sacramento Valley in-basin uses plus diversions. During such periods, each party has the ability to divert and store as much water as possible within its physical and contractual limits.

These coordination provisions are based on operation studies of facilities of the two projects using the 1922 to 1978 historic hydrologic conditions and available water supplies. For operations firm yield analysis of the CVP/SWP systems, the 1928-1934 critical period was used. This analysis period results in the lowest firm yields. Under conditions of full development of the demands under the two projects and a repeat of the 1928-1934 hydrologic conditions, it is estimated that the CVP will have a supply of about 8.3 million AF/yr, and the SWP about 4.2 million AF/yr. With the joint responsibility for use in the Delta and outflow therefrom, the total supply produced by the two projects will be about 17.4 million AF/yr.

Among other provisions of the COA are (1) allowing either party to use the other party's storage withdrawals or unstored water available for diversion to the extent that party cannot do so, (2) providing for measurements to support the agreement, (3) establishing the procedures for one party to use the other's conveyance facilities, including reimbursement of appropriate costs and the supplying of power, (4) negotiating a contract for conveyance by the state of CVP water purchased by the state for SWP contractors (this contract must be approved by Congress), (5) setting forth Delta standards for protection of M&I and agricultural water uses and of fish and wildlife, and (6) allocating the yield of new facilities to the party constructing them.

The Delta standards named in the agreement are basically the same as those in D-1485 except for conditions applying to Suisun Marsh. They include the following elements: (1) maximum concentrations of chloride are specified at five key points for M&I uses, and maximum electrical conductivity (EC), relating to the concentration of total dissolved solids, is given at four points for agricultural uses, (2) Delta outflow indices and lower Sacramento River flows for fish and wildlife are provided, (3) the Delta outflow indices and maximum EC at the Delta outlet are specified for protection of water quality in Suisun Marsh, and (4) operational constraints, including maximum diversions from the Delta at certain times of the year and closing Delta Cross Channel gates at other times are specified. The Bay-Delta proceedings by the SWRCB, that commenced in 1987 and which will be completed by approximately 1993, may revise some of these standards, and possibly add some additional standards pertaining both to the Delta and San Francisco Bay.

The COA has solidified and formalized the relations between the two projects which have been guided for many years by informal and annual letters of agreement. Very importantly, the USBR, as operator of the CVP, has agreed to share with DWR, as operator of the SWP, the responsibility of meeting Delta water quality and flow obligations. COA is the essential framework for coordination of the water-producing facilities of the CVP/SWP system in the Sacramento Valley and on the Trinity and Stanislaus Rivers.

Mandatory Releases From System Reservoirs

Those releases that system storage facility operators must make because of agreements, contracts, regulations, and other factors which are nondiscretionary, are described by geographic area in the following paragraphs.

Sacramento Valley Above the Mouth of the Feather River. The major CVP facilities include Clair Engle Lake and Shasta Lake. Mandatory releases from Clair Engle Lake include those primarily to maintain minimum flows for anadromous and resident fish in the Trinity River and to share in providing mandatory releases below Shasta Lake. In the fall and winter, releases must be made from Shasta Lake to preserve flood control storage space in accordance with criteria set by the Corps of Engineers. Minimum flows for fish must be provided immediately below Keswick Dam (below where Trinity River imports enter the Sacramento River) and at downstream points where they are not supplied by accretions to the river. Agricultural and M&I diversions not supplied by accretions and return flows from upstream water applications must also be met. Finally, minimum flows for navigation in the lower portions of this reach of the Sacramento River must be provided.

The SWP facility concerned with mandatory releases is Lake Oroville. It is also governed by Corps of Engineers flood control criteria. Two points for minimum fish flows are observed: (1) immediately below Thermalito Diversion Dam a short distance above the City of Oroville and (2) below the river releases from Thermalito Afterbay some 5 miles downstream from Oroville. Most of the irrigation demands that must be met are released directly from Thermalito Afterbay through outlets to two large locally owned canals. There are also mandatory agricultural and SWP contract demands that must be supplied from the Feather River, but these can often be met from natural accretions, return irrigation flows, and other similar sources.

Mouth of the Feather River to the Delta. The principal mandatory release in this area pertains to operation of Folsom Lake. Flood control criteria must be satisfied, and minimum flows in the American River for recreation and anadromous fish propagation and protection must be released. The minimum flows required by the water rights permits for Folsom Lake are low, and in most years the flows are maintained above those levels. Contract deliveries from the lake itself and at diversion points downstream, as well as releases for satisfaction of water rights, must also be met. The CVP must also meet its contract demands in the Sacramento River in this reach above the mouth of the American River but, for the most part, the mandatory releases for other purposes provide sufficient water.

Putah Creek. While Lake Berryessa is not a CVP facility, it could be considered as a possible factor in water exchanges related to drinking water quality. Mandatory releases from the lake involve maintenance of flows for fish in Putah Creek between Monticello Dam and the diversion structure for the Putah South Canal, and flows below that point principally for recharge of groundwater.

Stanislaus River. Mandatory releases from New Melones Reservoir include first those to maintain fall and winter flood control space. Flows below the reservoir and in the San Joaquin River below the mouth of the Stanislaus River must also be maintained at specified levels for fish and wildlife, recreation, and water quality improvement. There are no final specific plans to supply CVP contracting agencies and Delta water users, which would provide mandatory release criteria for those purposes.

Meeting Delta Requirements and Providing for Delta Diversions

Through the COA, the CVP and SWP have agreed to meet Delta standards jointly. In maintaining specified levels of water quality, this meets the agricultural needs in the Delta manifested by net channel depletion or the difference between diversions and seepage to the islands and tracts of the area and the return flows from drainage discharges. M&I quality standards at the intakes to all diversion facilities and the quantities that must be delivered determine the quantities of water that must be provided in the Delta for those purposes.

A basic physical property of the Delta is that water in the northern or Sacramento River tributary is of better quality than that in the southern or San Joaquin River tributary. This is due to the better quality of the Sacramento River and the limited hydraulic capacity of Delta channels to transport that water southward. While only the Tracy and Contra Costa Canal Pumping Plants of the CVP were diverting water from the Delta, the Delta Cross Channel could adequately supplement natural channel capacity to provide this conveyance. But with the commencement of operation of the Delta Pumping Plant of the SWP, the Delta Cross Channel and the natural channels (Georgiana Slough and Three Mile Slough) were inadequate. Thus, during the spring, summer, and early fall months, while "balanced water conditions" prevail, sufficient Sacramento Valley system releases must be made to flow in the Sacramento River to the mouth of the Delta near Antioch and thence up the San Joaquin River in reverse of the direction of normal flow. Thus, to meet the water quality standards, the system operators must anticipate the channel depletion and project diversions by a week or more and vary the Sacramento Valley project releases to account for the cyclical variations of the ocean's salinity intrusion rates which are determined by tidal fluctuations. If these flows in the lower Sacramento River are not adequate to meet the requirements of D-1485 (or the COA), additional releases must be made and Delta diversions must be discontinued in accordance with other provisions of D-1485. Various north Delta channel improvements or bypass proposals are being designed to overcome these hydraulic deficiencies.

Operation of Sacramento Valley Reservoirs

Day-to-day operation of the CVP/SWP system reservoirs in the Sacramento Valley and on the Stanislaus River is determined by the COA, mandatory releases, Delta requirements, and Delta diversions. CVP and SWP reservoirs above the mouth of the Feather River are operated first to provide mandatory releases on the respective rivers below each facility. Similarly, Folsom Lake must first meet mandatory releases for the American River. If the flow of the Sacramento River below the mouth of the Feather River is insufficient to meet the mandatory release requirements from that point to the Delta, additional CVP releases are required. Either the CVP or SWP may then make additional releases if required to generate sufficient electrical energy to meet their respective contractual obligations. The sum of Sacramento River inflow to the Delta, Stanislaus River releases determined in a similar way, and other Delta inflow is then compared with Delta requirements and Delta diversions. If additional releases are needed, they are shared by the CVP and SWP according to the COA. Responsibility for meeting Sacramento Valley in-basin uses and permissible diversions are calculated and accumulated day-by-day, and adjustments are made by additional reservoir releases by the appropriate party if requested under terms of the COA.

Operation of the Putah Creek facilities is much simpler. Releases from Lake Berryessa are first made to meet mandatory requirements, and these are supplemented as necessary to provide water needs of contracting agencies in Solano County. Power generation is provided only incidentally to releases for the other purposes.

Operation of Reservoirs South of the Delta

The most northerly of system reservoirs beyond the Delta is Lake Del Valle on the South Bay Aqueduct. It regulates the natural flow of Arroyo Del Valle and acts as an off-aqueduct regulating reservoir to assist in providing SWP water on the contract monthly demand schedules. Since it often contains water of better quality than Delta diversions, releases are made to improve quality of supplies delivered to the project contractors in Alameda and Santa Clara counties.

San Luis Reservoir is used primarily to receive water diverted from the Delta through the California Aqueduct and Delta Mendota Canal during winter months to meet demands in the state and federal service areas to the south in summer months. Since it materially contributes to the yield of the SWP, contractors in the Feather River service area and on the North and South Bay Aqueducts also benefit. In accordance with the COA, when water is available in the Delta under excess conditions, the SWP and CVP divert at maximum permissible rates to fill the reservoir as quickly as possible. In some years when yield would not be diminished, the quality of water diverted from the Delta might be improved if diversions were delayed until winter runoff cleared much of the poor quality water from the south Delta channels. The value of outflows from San Luis Reservoir for power generation is enhanced by scheduling releases to correspond as much as possible to peak power demand periods (daytime and weekday hours) and regulating the fluctuating flows in O'Neill Forebay. These reservoirs can also be used conjunctively in a pump-back power operation mode.

The SWP reservoirs in Southern California are used for emergency storage, but mainly to regulate pumping discharges over the Tehachapi Mountains to a monthly delivery pattern required by the water supply contracts. Because Southern California demands have not reached the maximum under the contracts, off-peak operation of the A.D. Edmonston Pumping Plant to minimize power costs is currently varied to the extent this is compatible with power recovery in other plants south of the Tehachapi Mountains, particularly in the William E. Warne Powerplant on the West Branch and Devil Canyon Power Plant on the East Branch. As demands by contractors approach the maximum in their contracts, the A. D. Edmonston Pumping Plant will operate steadily except for outages, when the reservoirs will supply demands, and the off-peak pumping opportunity will be diminished. Releases from Silverwood Lake can now be made largely during peak power demand hours, and the fluctuating flows in the Santa Ana Pipeline can be regulated in Lake Perris. As contractual water deliveries increase, this opportunity will also diminish.

WATER REQUIREMENTS

M&I and agricultural water demands on the CVP/SWP systems (Delta diversions) were estimated for the year 2010 using projections provided by the study participants, DWR, and USBR. Users were grouped into service areas to simplify the analysis. Table 2-1 shows the water contractors within each service area, the M&I and agricultural water demands, and the assumed peak month factors for each contractor as a percentage of the annual demand. No effort is made in this study to identify future supply shortfalls, or the best ways for the major suppliers to meet their present or future contract obligations.

Peaking factors and load factors were developed to estimate the peak monthly water demand of each user and the resultant flow requirements for each element in the system. These peaking factors are based on SWP water contract provisions and the interpretation of those contracts applied by DWR. The general interpretation is to limit the peak monthly delivery to an M&I contractor to 11 percent of the annual delivery requested by that contractor (thus, the peak rate of delivery is 132 percent of the annual rate), and the peak monthly delivery to an agricultural contractor to 18 percent (peak rate is 216 percent of the

Table 2-1. Year 2010 Delta Diversion Water Requirements

Service area	Water supplier [a]	Water using agencies and flow summary	M & I water demand, AF/yr	M & I peak month, percent of annual flow	Agricultural water demand, AF/yr	Agricultural peak month, percent of annual flow	Total water demand,[b] AF/yr
East Bay Municipal Utility District	CVP	Annual delivery	--[c]	--	0	--	--
San Francisco Water Department		Annual delivery	0[d]	--	0	--	0
		Peak flow, cfs	**0**		**0**		**0**
Contra Costa Water District	CVP	Annual delivery	167,600[e,f]	11.00	0[g]	--	167,600
		Peak flow, cfs	**306**		**0**		**306**
South Bay Aqueduct	SWP	ACFC & WCD Zone 7	41,875	11.00	4,125	18.00	46,000
	SWP	Alameda County WD	40,200	11.00	1,800	18.00	42,000
	SWP	Santa Clara Valley WD	100,000	11.00	0	--	100,000
	Subtotal	Annual delivery	182,075		5,925		188,000
		Peak flow, cfs	**332**		**18**		**350**
San Joaquin Valley north of San Luis Reservoir	SWP	Oak Flat WD	0	--	5,700	18.00	5,700
	CVP	City of Tracy	10,000	11.00	0	--	10,000
	CVP	Eagle Field WD	0	--	4,550	18.00	4,550
	CVP	Banta-Carbona ID	0	--	25,000	18.00	25,000
	CVP	Centinella WD	0	--	3,000	18.00	3,000
	CVP	The West Side ID	0	--	7,500	18.00	7,500
	CVP	Davis WD	0	--	6,500	18.00	6,500
	CVP	Del Puerto WD	0	--	10,000	18.00	10,000
	CVP	Hospital WD	0	--	34,105	18.00	34,105
	CVP	Kern Canon WD	0	--	7,700	18.00	7,700
	CVP	Plain View WD	0	--	20,600	18.00	20,600
	CVP	Salado WD	0	--	9,130	18.00	9,130
	CVP	Sunflower WD	0	--	16,625	18.00	16,625
	CVP	West Stanislaus ID	0	--	50,000	18.00	50,000
	CVP	Mercy Springs WD	0	--	13,300	18.00	13,300
	CVP	Mustang WD	0	--	14,680	18.00	14,680
	CVP	Orestimba WD	0	--	12,000	18.00	12,000
	CVP	Oro Loma WD	0	--	4,600	18.00	4,600
	CVP	Patterson WD	0	--	22,500	18.00	22,500
	CVP	Quinto WD	0	--	7,545	18.00	7,545

Table 2-1. Year 2010 Delta Diversion Water Requirements, continued

Service area	Water supplier [a]	Water using agencies and flow summary	M & I water demand, AF/yr	M & I peak month, percent of annual flow	Agricultural water demand, AF/yr	Agricultural peak month, percent of annual flow	Total water demand,[b] AF/yr
San Joaquin Valley north of San Luis Reservoir (cont.)	CVP	Romero WD	0	--	5,360	18.00	5,360
	CVP	Widren WD	0	--	2,990	18.00	2,990
	CVP	Foothill WD	0	--	10,840	18.00	10,840
	Subtotal	Annual delivery	10,000		294,225		304,225
		Peak flow, cfs	**18**		**878**		**896**
Pacheco Tunnel at San Luis Reservoir	CVP	Santa Clara Valley WD	113,700	11.00	28,000	18.00	141,700
	CVP	San Benito County WC & FCD	8,000	11.00	35,300	18.00	43,300
	Subtotal	Annual delivery	121,700		63,300		185,000
		Peak flow, cfs	**222**		**189**		**411**
San Joaquin Valley south of San Luis Reservoir	SWP	Kern County WA	134,600	11.00	1,018,800	18.00	1,153,400
	SWP	Tulare Lake B. WSD	0	--	118,500	18.00	118,500
	SWP	County of Kings	4,000	11.00	0	--	4,000
	SWP	Dudley Ridge WD	0	--	57,700	18.00	57,700
	SWP	Empire West Side ID	0	--	3,000	18.00	3,000
	CVP	Avenal CSD	3,500	11.00	0	--	3,500
	CVP	State of CA Fish and Game	0	--	10	18.00	10
	CVP	City of Coalinga	10,000	11.00	0	--	10,000
	CVP	Pacheco WD	0	--	5,070	18.00	5,070
	CVP	Panoche WD	0	--	47,000	18.00	47,000
	CVP	San Luis WD	0	--	62,540	18.00	62,540
	CVP	City of Huron	3,000	11.00	0	--	3,000
	CVP	Westlands WD	11,500	11.00	1,100,000	18.00	1,111,500
	CVP	Broadview WD	0	--	27,000	18.00	27,000
	CVP	Fresno Slough WD	0	--	4,000	18.00	4,000
	CVP	Hughes Melvin	0	--	72	18.00	72
	CVP	James ID	0	--	35,300	18.00	35,300
	CVP	Mason A. Loundy Trustee	0	--	5,200	18.00	5,200
	CVP	Reclamation District 1606	0	--	228	18.00	228
	CVP	Tranquillity ID 1606	0	--	13,800	18.00	13,800
	CVP	State of CA	0	--	19,000	18.00	19,000
	CVP	Laguna WD	0	--	800	18.00	800
	CVP	Pacheco WD	0	--	5,080	18.00	5,080
	CVP	Panoche WD	0	--	47,000	18.00	47,000
	CVP	San Luis WD	0	--	62,540	18.00	62,540

Table 2-1. Year 2010 Delta Diversion Water Requirements, continued

Service area	Water supplier [a]	Water using agencies and flow summary	M & I water demand, AF/yr	M & I peak month, percent of annual flow	Agricultural water demand, AF/yr	Agricultural peak month, percent of annual flow	Total water demand,[b] AF/yr
San Joaquin Valley south of San Luis Reservoir (cont.)	CVP	Westlands WD	0	--	50,000	18.00	50,000
	CVP	Dudley et al	0	--	2,280	18.00	2,280
	CVP	Grassland WD	0	--	50,000	18.00	50,000
	CVP	James Wilson et al	0	--	425	18.00	425
	CVP	DMC Exchange Contract	0	--	840,000	18.00	840,000
	Subtotal	Annual delivery	166,600		3,575,345		3,741,945
		Peak flow, cfs	**304**		**10,667**		**10,971**
Coastal Branch	SWP	San Luis Obispo County	25,000	11.00	0	--	25,000
	SWP	Kern County WA	0	--	114,200	18.00	114,200
	SWP	Devil's Den WD	0	--	12,700	18.00	12,700
	SWP	Santa Barbara County	45,486	11.00	0	--	45,486
	Subtotal	Annual delivery	70,486		126,900		197,386
		Peak flow, cfs	**129**		**379**		**508**
Cross Valley Canal	CVP	County of Fresno	0	--	3,000	18.00	3,000
	CVP	County of Tulare	0	--	3,000	18.00	3,000
	CVP	Tri-Valley	0	--	982	18.00	982
	CVP	Ducor ID	0	--	1,200	18.00	1,200
	CVP	Rag Gulch WD	0	--	13,300	18.00	13,300
	CVP	Lower Tule River ID	0	--	31,102	18.00	31,102
	CVP	Pixley ID	0	--	31,102	18.00	31,102
	CVP	Hills Valley ID	0	--	2,146	18.00	2,146
	CVP	Kern-Tulare	0	--	40,000	18.00	40,000
	Subtotal	Annual delivery	0		125,832		125,832
		Peak flow, cfs	**0**		**375**		**375**
Southern California south of A.D. Edmonston Pumping Plant	SWP	AVEK	68,427	8.33[h]	14,073	8.33[h]	82,500
	SWP	Castaic Lake WA	41,500	8.33[h]	0	--	41,500
	SWP	Coachella Valley WD	23,100	8.33[h]	0	--	23,100
	SWP	Crestline	4,287	8.33[h]	0	--	4,287
	SWP	Desert WA	38,100	8.33[h]	0	--	38,100
	SWP	Littlerock Creek ID	0	--	0	--	0
	SWP	Mojave WA	50,800	8.33[h]	0	--	50,800
	SWP	Metropolitan Water District [i]	2.140.000	8.33[h]	0	--	2.140.000

Table 2-1. Year 2010 Delta Diversion Water Requirements, continued

Service area	Water supplier [a]	Water using agencies and flow summary	M & I water demand, AF/yr	M & I peak month, percent of annual flow	Agricultural water demand, AF/yr	Agricultural peak month, percent of annual flow	Total water demand,[b] AF/yr
Southern California south of A. D. Edmonston Pumping Plant (cont.)	SWP	Palmdale WD	17,300	8.33[h]	0	–	17,300
	SWP	San Bernardino Valley	66,000	8.33[h]	0	–	66,000
	SWP	San Gabriel Valley	16,400	8.33[h]	0	–	16,400
	SWP	San Gorgonio Pass	8,650	8.33[h]	8,650	8.33[h]	17,300
	SWP	Ventura County	17,500	8.33[h]	2,500	8.33[h]	20,000
	Subtotal	Annual delivery	2,492,064		25,223		2,517,287
		Peak flow, cfs	3,442		35		3,477
Total		Annual delivery	3,210,525		4,216,750		7,427,275
		Peak flow, cfs	4,753		12,541		17,294

[a]SWP=State Water Project, CVP=Central Valley Project.
[b]Excludes water users upstream of major source impoundments; excludes water obtained from independently owned sources.
[c]EBMUD's need for a supplemental supply will vary from 0 to 150,000 AF/yr, depending on hydrologic conditions.
[d]Number derived from extrapolation of projected water demands through 2005.
[e]Assumes no pumping of off-shore water to Contra Costa water agencies.
[f]Number derived from extrapolation of projected water demands for 1985 and 2000.
[g]Neglects small agricultural deliveries.
[h]Assumes terminal storage available to equalize demand on the export system facilities considered in this study.
[i]Purchased water is supplemental to independent supply. Purchased quantity only is shown.

annual rate). Some variations in the peak delivery limit exist for certain contractors, but these are of little total significance and were ignored. The peak delivery limits defined for State water contractors were also applied to all Federal water contractors. All water contractors were assumed to request their maximum annual entitlements or their estimated water demands (shown in Table 2-1), whichever is least, in the year 2010.

There are two service areas which were assumed to have different peak delivery limits than the general criteria established for the other water contractors. These service areas are Southern California south of the A. D. Edmonston Pumping Plant, and EBMUD. These service areas were assumed to have adequate terminal storage to receive water at a constant rate year round (i.e., a peak monthly delivery limited to 8.33 percent of the annual request). This is thought to be a reasonable assumption even though both service areas will need additional terminal storage to meet all service and reliability goals.

A maximum annual operating load factor of 0.90 was used in this study for estimating the peak flow rate for layout of facilities. This assumed load factor was used to determine the "design" flow if it resulted in a greater flow than the monthly peaking factors shown in Table 2-1.

The projected water demands in 2010 were developed by different methods for Contra Costa Water District, San Francisco Water Department, EBMUD, and MWD. These projection procedures are explained below. Estimates of future water demands for the Contra Costa Water District, San Francisco Water Department, and EBMUD were not available from DWR or USBR information. The MWD projected demand used in this study is different than that tabulated in DWR information.

Contra Costa Water District

The Contra Costa Water District 2010 water demand was estimated by extrapolating the projected water demands for the years 1985 and 2000, as reported in, Tabulation of Annual Water Deliveries From Contra Costa Canal 1978-1986, Exhibit Number 26, Contra Costa Water District. The 2010 M&I water demand is estimated to be 167,600 AF/yr. It was assumed that new conveyance facilities, described in Chapter 4, would supply all of the water for the Contra Costa Water District. Agricultural deliveries were assumed to be negligible.

San Francisco Water Department

The 2010 water demand for the San Francisco Water Department was estimated by extrapolating the projected water demands through 2005, as reported in, San Francisco Water, Phase One, Bay/Delta Water Quality Hearings, July 16, 1987, Public Utilities Commission, City and County of San Francisco. The estimated 2010 water demand is 387,000 AF/yr.

The major portion of the San Francisco Water Department's water comes from Hetch Hetchy Reservoir. The firm yield from Hetch Hetchy is estimated to be at least 400 million gallons per day (450,000 AF/yr). The capacity of the conveyance system that carries water from Hetch Hetchy to San Francisco is about 336,000 AF/yr.

For this study it is assumed that the controlling factor for water supply to the San Francisco system is Hetch Hetchy's firm yield, rather than the capacity of the existing conveyance system. Assuming that the conveyance system will have adequate capacity to convey 2010 water demands, San Francisco Water Department will not require any water from the conveyance facilities described in Chapter 4. Thus, the San Francisco Water Department will have no impact on the conveyance facilities discussed in this report, and the 2010 demand on the state/federal water systems is shown as zero in Table 2-1.

East Bay Municipal Utility District

EBMUD currently gets most of its water from Pardee Reservoir on the Mokelumne River, where it has an entitlement to divert up to 364,000 AF/yr. This water is conveyed to the EBMUD service area through the Mokelumne Aqueduct. Firm yield from the Mokelumne River system, assuming a repeat of 1976-1977 hydrology, in the year 2010 is estimated to be 190,600 AF/yr. In most years, however, the full 364,000 AF/yr is available to EMBUD under its water rights. By the year 2010, EBMUD's need for a supplemental supply, in addition to the Mokelumne supply, will vary from 0 to 150,000 AF/yr, depending on the severity of the hydrologic period. For the purposes of this study, this deficit will be assumed to be supplied by the CVP under EBMUD's existing contract for American River water. This supply could be delivered to EBMUD via certain of the new conveyance facilities described in Chapter 4.

Metropolitan Water District of Southern California

MWD's projection of water demand for 2010 was used in this study, rather than the MWD demand projected by DWR. The DWR projected water demand is 1,534,700 AF/yr. The demand projected by MWD and used in this study is 2,140,000 AF/yr. The DWR and MWD projections differ because different population projection figures were used to calculate the demands. DWR used projections developed by the State Department of Finance. MWD used higher population figures developed by the Southern California Association of Governments and the San Diego Association of Governments. The SWRCB (1988) used the MWD projections in the Water Quality Control Plan for Salinity. The difference between the DWR and MWD projections is not large enough to affect the sizing or feasibility of facilities considered in this study. Agricultural use of water in MWD is decreasing and was assumed to be small in 2010.

CHAPTER 3

DRINKING WATER QUALITY IN THE DELTA

The challenges created by the federal Safe Drinking Water Act (SDWA) amendments and the resulting federal and state drinking water standards underscore the importance of providing urban systems with high quality source water. This chapter presents information regarding current drinking water standards and potential future standards. This discussion is followed by a description of the water quality of each of the major streams flowing into the Sacramento/San Joaquin Delta (Delta) and the water quality at various locations in the Delta.

DRINKING WATER STANDARDS

Contaminants of concern in a domestic water supply are those that either pose a health threat or in some way alter the aesthetic acceptability of the water. These types of contaminants are currently regulated by the Environmental Protection Agency (EPA) as primary and secondary maximum contaminant levels (MCLs). As directed by the SDWA amendments of 1986, signed into law on June 19 of that year, EPA is expanding its list of primary MCLs at a rapid rate. In response to the federal changes and specific concerns within the state, the State of California is also going through an extensive revision process of its drinking water regulations. This section summarizes the current status of federal and state regulatory actions.

Federal Regulations

The SDWA (Public Law 93-523) was passed in 1974 giving EPA the authority to protect public health by setting standards, called MCLs, for constituents of concern. The EPA completed the first step in developing the primary drinking water regulations mandated by the SDWA by promulgating the National Interim Primary Drinking Water Regulations (NIPDWR) on December 24, 1975. Subsequent amendments to the SDWA and resultant revisions to the NIPDWR created a total of 22 MCLs, including ten inorganic chemicals, seven organic chemicals, three radionuclides, coliform bacteria, and turbidity.

The regulations were called interim because every 3 years EPA was to review the list of regulated contaminants and revise or add to it based on any new research indicating that adverse health effects were caused by constituents found in drinking water. EPA had begun this process when the SDWA was again amended on June 19, 1986. These amendments called for dramatic changes in the process and rate by which standards are set.

These latest amendments require that maximum contaminant level goals (MCLGs), formerly termed recommended maximum contaminant levels (RMCLs), be set concurrently with MCLs for contaminants which may have an adverse effect on public health and which occur in public water supplies. MCLGs are unenforceable and set at a level at which no known or anticipated adverse health effects will occur, allowing for an adequate margin of safety. For demonstrated carcinogens and reproductive toxins, MCLGs are to be set at zero, acknowledging that no safe threshold exists for these chemicals. MCLs are enforceable and must be set as close to the MCLGs as feasible. Feasible means accounting for practical limits of treatment technologies, analytical methodology, and costs. Key features of the new SDWA amendments are discussed below.

Standard Setting. The primary requirement of the SDWA amendments is the promulgation of standards. It specified that a total of 83 contaminants be regulated during the initial 3-year period after the date of passage of the amendments. The original 22 MCLs in the NIPDWR except for total trihalomethanes (THMs) are part of the list of 83. Each MCL will be reviewed and reregulated based on current knowledge of its health significance and its interim status will be removed.

By the end of the first year (June 19, 1987) nine MCLs were to have been set. The promulgation of MCLs for eight volatile organic chemicals (VOCs) on July 8, 1987, together with the standard for fluoride set previously, fulfilled this requirement. Forty additional MCLs were to be set by June 19, 1988. EPA proposed standards for lead and copper on August 18, 1988, and proposed MCLs for eight additional inorganic chemicals and 30 organic chemicals on May 2, 1989. The balance of the 83 contaminants are to have MCLs by June 19, 1989, but EPA has indicated that the promulgation of these MCLs will be delayed.

The SDWA amendments require that after the initial 3-year period of standard setting, an additional 25 MCLs be set every 3 years thereafter. A Drinking Water Priority List containing 53 candidate contaminants was published on January 22, 1988. By January 1, 1991, 25 of these contaminants are to be regulated and a new Drinking Water Priority List published. This first Drinking Water Priority List contains contaminants removed by substitution from the original list of 83, as well as disinfection by-products and other contaminants of concern found in water supplies.

The initial 83 contaminants are listed in Table 3-1. The MCLs for the original 22 contaminants regulated prior to the SDWA amendments and the current MCLs and MCLGs in either proposed or final status are given. Also included are the contaminants for which the California Department of Health Services (DHS) has established or proposed MCLs. Constituents are arranged in the table in chemical groups.

A more comprehensive tabulation of all constituents of regulatory concern, including the constituents on the Drinking Water Priority List, is presented in Appendix B. This table (Table B-1) also shows concentrations of concern for many currently unregulated pollutants based on a variety of research sources.

Unregulated Contaminant Monitoring. On July 8, 1987, EPA promulgated a monitoring program for 51 contaminants that had not been previously regulated. The data generated from this effort will assist EPA in determining the necessity of future regulation of certain chemicals. EPA divided this list of unregulated contaminants into three

Table 3-1. Federal and State Primary Standards

Contaminants	Standard,[a] mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Inorganics				
Aluminum	-	-	-	1
Antimony[c]	-	-	-	-
Arsenic	0.05	-	-	0.05
Asbestos, million long fibers/l	-	7[d]	7	-
Barium	1.0	5.0[d]	5.0	1.0
Beryllium[c]	-	-	-	-
Cadmium	0.01	0.005[d]	0.005	0.010
Chromium	0.05	0.1[d]	0.1	0.05
Copper	-	1.3[e]	1.3	-
Cyanide[c]	-	-	-	-
Fluoride	1.4-2.4	4	4	1.4-2.4
Lead	0.05	0.005[e]	0	0.05
Mercury	0.002	0.002[d]	0.002	0.002
Nickel[c]	-	-	-	-
Nitrate, as N	10.0	10.0[d]	10.0	10.0
Nitrite, as N	-	1.0[d]	1.0	-
Selenium	0.01	0.05[d]	0.05	0.01
Silver	0.05	-	-	0.05
Sulfate[c]	-	-	-	-
Thallium[c]	-	-	-	-
Microbiology and Turbidity				
<u>Giardia lamblia</u>	-	SWTR[f]	0	-
Heterotrophic plate count	-	SWTR[f]	-	-
<u>Legionella</u>	-	SWTR[f]	0	-
Total coliform, MPN/100 ml	1	P/A concept[f]	0	1
Turbidity, NTU	1	SWTR[f]	-	0.5
Viruses	-	SWTR[f]	0	-
Radionuclides				
Beta particle and photon radioactivity,[g] millirems/yr	4	-	-	-
Gross alpha particle activity,[g] pCi/l	15	-	-	15
Gross beta particle activity, pCi/l	-	-	-	50
Radium 226/228,[g] pCi/l	5	-	-	5
Radon,[g] pCi/l	-	-	-	-
Strontium 90, pCi/l	-	-	-	8
Tritium, pCi/l	-	-	-	20,000
Uranium,[g] pCi/l	-	-	-	20

Table 3-1. Federal and State Primary Standards (continued)

Contaminants	Standard,[a] mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Volatile organics				
Benzene	-	0.005	0	0.001
Carbon tetrachloride	-	0.005	0	0.0005
o-Dichlorobenzene	-	0.6[d]	0.6	-
p-Dichlorobenzene	-	0.075	0.075	0.005
1,2-Dichloroethane	-	0.005	0	0.0005
1,1-Dichloroethylene	-	0.007	0.007	0.006
cis-1,2-Dichloroethylene	-	0.07[d]	0.07	-
trans-1,2-Dichloroethylene	-	0.1[d]	0.1	-
1,2-Dichloropropane	-	0.005[d]	0	-
1,3-Dichloropropene	-	-	-	0.0005
Ethylbenzene	-	0.7[d]	0.7	0.680
Methylene chloride[c]	-	-	-	-
Monochlorobenzene	-	0.1[d]	0.1	0.030
1,1,2,2-Tetrachloroethane	-	-	-	0.001
Tetrachloroethylene (PCE)	-	0.005[d]	0	0.005[h]
Trichlorobenzene[c]	-	-	-	-
1,1,1-Trichloroethane (TCA)	-	0.20	0.20	0.200
1,1,2-Trichloroethane[c]	-	-	-	0.032
Trichloroethylene (TCE)	-	0.005	0	0.005
Vinyl chloride	-	0.002	0	0.0005
Synthetic organics				
Acrylamide	-	Treatment technique[d]	0	-
Adipates[c]	-	-	-	-
Alachlor	-	0.002[d]	0	-
Aldicarb	-	0.01[d]	0.01	-
Aldicarb sulfone	-	0.04[d]	0.04	-
Aldicarb sulfoxide	-	0.01[d]	0.01	-
Atrazine	-	0.003[d]	0.003	0.003
Bentazon (Basagran)	-	-	-	0.018
Carbofuran	-	0.04[d]	0.04	-
Chlordane	-	0.002[d]	0	-
Dalapon[c]	-	-	-	-
Dibromochloropropane (DBCP)	-	0.0002[d]	0	0.0002[h]
2,4-Dichlorophenoxy acetic acid (2,4-D)	0.1	0.07[d]	0.07	0.1
Dinoseb[c]	-	-	-	-
Diquat[c]	-	-	-	-
Endothall[c]	-	-	-	-
Endrin[c]	0.0002	-	-	0.0002
Epichlorohydrin	-	Treatment technique[d]	0	-

Table 3-1. Federal and State Primary Standards (continued)

Contaminants	Standard,[a] mg/l			
	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA MCL (post-SDWA amendments of 1986)	EPA MCLG[b]	California MCL
Ethylene dibromide (EDB)	-	0.00005[d]	0	0.00002
Glyphosate[c]	-	-	-	-
Heptachlor	-	0.0004[d]	0	-
Heptachlor epoxide	-	0.0002[d]	0	-
Hexachlorocyclopentadiene[c]	-	-	-	-
Lindane	0.004	0.0002[d]	0.0002	0.004
Methoxychlor	0.1	0.4[d]	0.4	0.1
Molinate (Ordram)	-	-	-	0.02
Pentachlorophenol	-	0.2[d]	0.2	-
Phthalates[c]	-	-	-	-
Picloram[c]	-	-	-	-
Polychlorinated biphenyls (PCBs)	-	0.0005[d]	0	-
Polynuclear aromatic hydrocarbons[c]	-	-	-	-
Simazine[c]	-	-	-	0.01
Styrene	-	0.005/0.1[d,i]	0/0.1	-
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)[c]	-	-	-	-
Thiobencarb (Bolero)	-	-	-	0.07
Toluene	-	2[d]	2	-
Toxaphene	0.005	0.005[d]	0	0.005
2,4,5-Trichlorophenoxy propionic acid (Silvex)	0.01	0.05[d]	0.05	0.01
Trihalomethanes, total[j]	0.10	-	-	0.10
Vydate[d]	-	-	-	-
Xylenes (total)	-	10[d]	10	1.75

[a]All values are in mg/l, except as indicated.

[b]Date and status of MCLG is the same as MCL, since they are required to be proposed and promulgated at the same time.

[c]MCLs and MCLGs are required by the SDWA to be set by June 1989. EPA has indicated that the promulgation of these MCLs will be delayed.

[d]A proposal to regulate 38 inorganic and organic chemicals was published on May 2, 1989.

[e]A corrosion by-product regulation, including MCLs for lead and copper, was published on August 18, 1988. Final regulations are projected for June 1989.

[f]Proposals for regulating coliform bacteria through a new presence/absence compliance calculation and microbial contaminants through a treatment technique outlined in the surface water treatment rule (SWTR) were published on November 3, 1987. Final regulations for these two proposals are expected about June 1989.

[g]A proposal to regulate radionuclides is expected in late 1989 or early 1990.

[h]California's proposed MCLs.

[i]EPA proposed an MCL of 0.1 mg/l and an MCLG of 0 mg/l based on a group C carcinogen classification and an MCL of 0.005 mg/l and an MCLG of 0.1 mg/l based on a B2 classification.

[j]The current MCL is scheduled to be reviewed, and probably revised by 1991.

categories. Category 1 contains 34 contaminants which can be readily analyzed. All systems must monitor for these. Category 2 contains two compounds having limited occurrence in drinking water but requiring specialized sampling procedures. Only vulnerable systems need monitor for the two pesticides listed under Category 2. Category 3 contains 15 compounds which only occasionally occur in drinking water but cause difficulties in treatment or analysis. Sampling for Category 3 compounds is at the states' discretion. Monitoring is required once every 5 years beginning on January 1, 1988. If a system serves between 3,300 and 10,000 persons, sampling need not begin until 1 year later. If the system serves less than 3,300 persons, sampling need not begin until 3 years later. The EPA expects to publish a new list of unregulated contaminants by the end of the first 5-year term.

Filtration and Disinfection. The 1986 SDWA requires that EPA establish criteria under which filtration is required for surface water supplies by December 19, 1987. Disinfection is required for all water supplies by June 19, 1989. The SDWA also provides that when it is not technologically or economically feasible to measure the level of a contaminant, then a treatment technique can be required in lieu of an MCL. This is the case for Giardia, viruses, and Legionellae. It has also been argued that turbidity and heterotrophic plate count are best regulated with a treatment technique. These five contaminants are on the list of 83 requiring standards. On November 3, 1987, EPA proposed a regulation known as the Surface Water Treatment Rule which addresses these requirements. It sets criteria by which surface waters shall be filtered and disinfected and serves in lieu of an MCL for the microbial contaminants listed above. The proposed EPA regulation includes broad exception criteria which, if met, may relieve a water utility from mandatory filtration. Disinfection of groundwater supplies is not addressed in the Surface Water Treatment Rule. A separate regulation including MCLs for disinfectants and disinfection by-products is expected to be promulgated by September 1991, along with other contaminants on the Drinking Water Priority List.

In a separate proposal on November 3, 1987, a coliform bacteria regulation based on a qualitative presence/absence concept rather than the current quantitative density method was introduced. Because of the relationship between the coliform rule and the Surface Water Treatment Rule, these regulations are tracking together and are expected to be promulgated by June 1989.

Public Notification. The 1986 SDWA mandated revised public notice requirements by September 19, 1987. The purpose was to reflect the severity of a drinking water regulation violation through better public notification. These new rules were published in the Federal Register on October 28, 1987. The final rule creates two classes of violations which require notification, Tier 1 and Tier 2. Tier 1 involves failure to comply with an MCL, a treatment technique, a variance, or an exemption schedule. Tier 1 violations can be further subdivided into acute or nonacute health risk. Tier 2 violations include operation under a variance or exemption, or failure to comply with a monitoring requirement or testing procedure.

Secondary Standards. Standards for 13 constituents that affect the aesthetic quality of drinking water currently exist. These are called secondary standards and are not enforceable at the federal level. An additional 11 secondary standards will soon be proposed along with the group of 39 primary MCLs. Table 3-2 lists the existing and expected secondary MCLs.

Table 3-2. Federal Secondary Standards

Constituent	EPA NIPDWR (pre-SDWA amendments of 1986)	EPA (post-SDWR amendments of 1986)
Chloride	250	-
Color, color units	15	-
Copper	1	-
Corrosivity	Noncorrosive	-
Fluoride	-	2[a]
Foaming agents	0.5	-
Iron	0.3	-
Manganese	0.05	-
Odor, threshold odor number	3	-
pH, standard units		6.5-8.5
Sulfate	250	-
TDS	-	-
Zinc	5	-
Aluminum	-	0.05[b]
o-Dichlorobenzene	-	0.01[b]
p-Dichlorobenzene	-	0.005[b]
1,2-Dichloropropane	-	0.005[b]
Ethylbenzene	-	0.03[b]
Monochlorobenzene	-	0.1[b]
Pentachlorophenol	-	0.03[b]
Silver	-	0.09[b]
Styrene	-	0.01[b]
Toluene	-	0.04[b]
Xylene	-	0.02[b]

[a]A secondary standard for fluoride was promulgated on April 2, 1986.
[b]A proposal for these 11 new secondary standards is expected in the spring of 1989.

Note: All values are in mg/l except where otherwise noted.

State Regulations

As provided by the SDWA, DHS was delegated primary enforcement responsibility (termed "primacy") for the drinking water program in 1977. Under this agreement, DHS receives an annual grant from EPA and is required to adopt and implement regulations that are at least as stringent as those set by EPA. The original 22 MCLs set by EPA were adopted almost identically by the DHS and incorporated into Title 22 of the California Administrative Code. Maintenance of the primacy status for California is contingent upon the State Legislature's adoption of their own SDWA amendments incorporating all of the requirements of the 1986 federal version.

Standard Setting. Prior to the 1986 SDWA, growing concern on the part of the public in California about drinking water quality prompted the State legislature to take aggressive steps to improve controls on contamination. They directed the DHS to begin promulgating MCLs independent of EPA using independent risk assessment analysis and reflecting those contaminants of greatest concern in California. This regulatory development program must also keep abreast of EPA's activity to ensure that any DHS MCL is at least as stringent as its federal counterpart.

To date, DHS has proposed MCLs for 24 constituents and adopted MCLs for 22 of these. Public hearings were held in July 1988 on a proposal to regulate 14 chemicals. An additional 10 MCLs were proposed in September 1988. These 24 chemicals include the eight VOCs regulated by EPA in July 1987 and required by primacy conditions to be adopted within 18 months. However, as allowed, DHS proposed more stringent MCLs for six of these eight chemicals. Six additional proposed MCLs from the group of 24 are for contaminants that EPA will regulate within the next year and three are more stringent than published federal levels. Seven other contaminants proposed by DHS have been named by EPA for future regulation. The remaining three proposed MCLs, for bentazon, (Basagran), molinate (Ordram), and thiobencarb (Bolero), are chemicals that EPA does not intend to regulate, at least in the next 5 years. In February 1989, 11 of the proposed MCLs became final MCLs and in April 1989, an additional 11 proposed MCLs became final MCLs. Final MCLs for dibromochloropropane and tetrachloroethylene will be published in July 1989. Table 3-1 shows the DHS proposed and final MCLs.

DHS also publishes action levels for contaminants of concern in California. These are strictly health-based numbers that guide DHS staff in dealing with incidents of contamination prior to the establishment of an MCL. An action level is not an official value so it requires only a scientific risk assessment rather than the comprehensive hearing and review process necessary to promulgate a regulation. DHS staff use action levels to trigger nonenforceable action on the part of a water system. In April 1989, DHS published a list of action levels for 40 contaminants. Action levels are shown in Table B-2 in Appendix B.

California applies all of the federal secondary drinking water standards (Table 3-2) but does so more rigidly than EPA. All new drinking water sources must meet the secondary standards for iron and manganese, and existing sources must meet these standards unless the utility makes a showing of public acceptance and cause for exemption. Other secondary standards are not mandatory unless 25 percent of the utility customers so petition and the majority of customers are willing to pay the necessary costs of meeting the secondary standards.

California's draft Surface Water Treatment regulation requires filtration of all surface waters. No exceptions are allowed in the state rule, unlike the EPA draft rule.

Proposition 65. The best evidence of the extent of concern for drinking water quality by the California public is their passage of Proposition 65 by a two to one margin in November 1986. Proposition 65 requires that the Governor maintain a list of chemicals known to the state to cause cancer or reproductive toxicity. This list must be revised and republished at least once a year. Beginning 12 months from the day a chemical is listed, businesses employing 10 or more employees are required to provide warnings to people if there is any potential exposure to harmful products. Within 20 months of the listing, a business must stop discharging a listed chemical into a source of drinking water. Twenty-nine chemicals were placed on the list on February 27, 1987, and the discharge prohibition on this list took effect on October 27, 1988. Since the original list, the Governor has published six additional lists of Proposition 65 chemicals, bringing the total to 242 chemicals (as of November 1, 1988). Emergency regulations to define "discharge or release to water or to land" of a listed toxicant were recently issued by the State Health and Welfare Agency, and took effect on October 27, 1988.

As originally passed, Proposition 65 does not apply to agencies operating public water systems. Attempts to remove this exemption were made in the last legislative session, but the two bills were vetoed by the Governor. In December 1988, Senator Kopp introduced a bill (SB 65) that would include public agencies, including public water systems, in both the warning and discharge provisions of Proposition 65.

QUALITY OF THE SOURCE WATER SUPPLIES

The water quality of the Delta and major rivers flowing into the Delta is discussed in this section. It is not possible in a study of this breadth to analyze data on each constituent that is, or soon will be, regulated by EPA and DHS. Data on many of the constituents, particularly organics, are simply not available or the number of data points is so small it is statistically unreliable. The limited number of constituents that have been shown to pose health concerns in Delta waters are discussed in this section.

Water Quality Database

The water quality monitoring locations selected for this study and the available data are described in this section. The locations are shown on Figure 3-1.

Locations. The water quality monitoring locations were selected at sites that best characterize the source waters of concern to this study. The selected sites are:

1. **Feather River**--Data were analyzed at various locations on the Feather River to identify the best diversion point for the Sierra Source-to-User Alternative. The

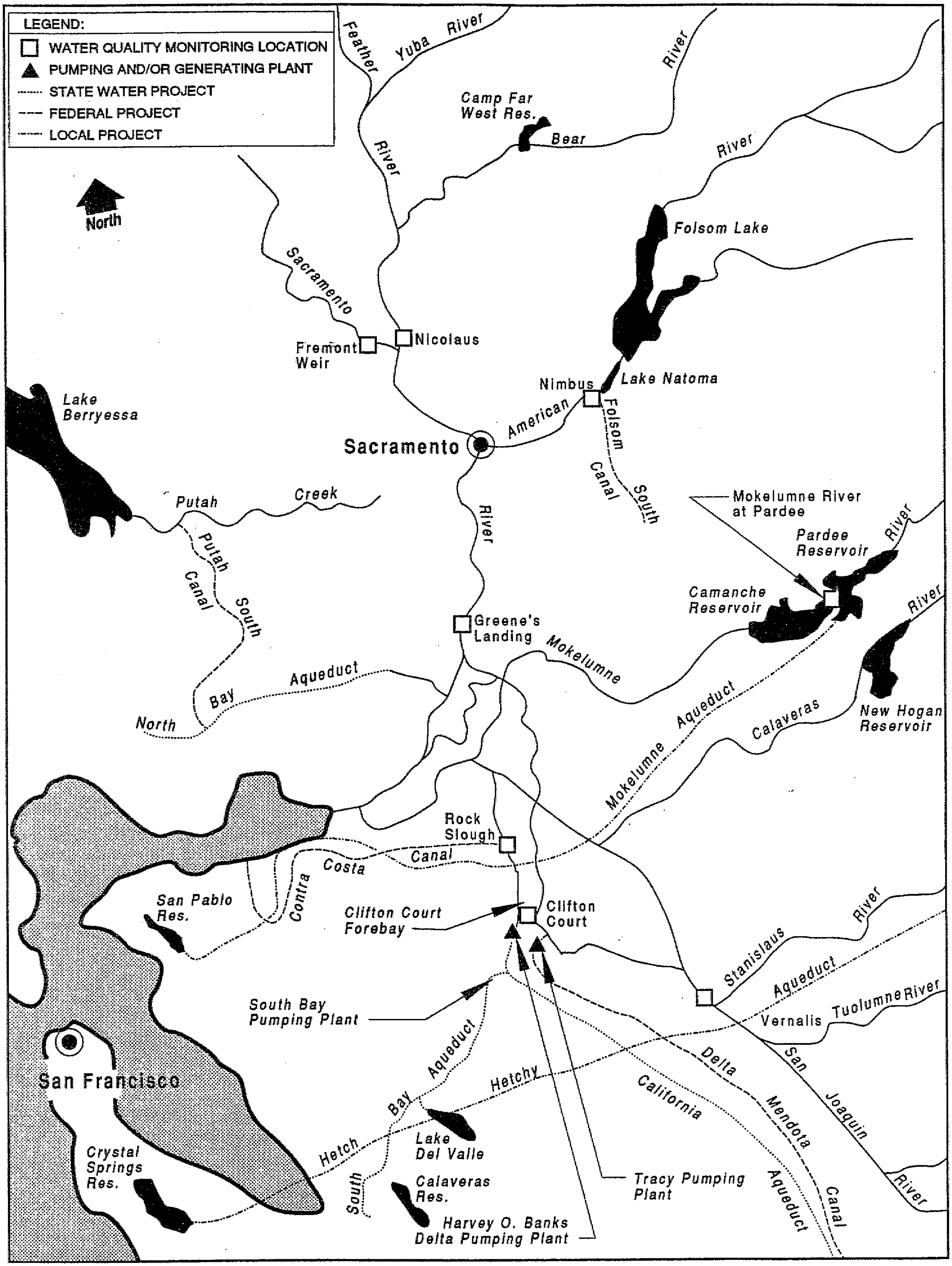


Figure 3-1. Delta Source Water Quality Monitoring Locations

Feather River at Nicolaus, immediately upstream of the confluence with the Sacramento River, was selected.

2. **American River**--The American River below the Nimbus Dam on Lake Natoma was selected. Water from the Sacramento and Feather Rivers would be blended with American River water in Lake Natoma with the Sierra Source-to-User Alternative. This is also the point at which water will be diverted by the East Bay Municipal Utility District (EBMUD) under its contract with the U.S. Bureau of Reclamation.

3. **Mokelumne River**--Data were analyzed from the Mokelumne River at Pardee Reservoir. This is the existing source of supply for EBMUD.

4. **Sacramento River at Fremont Weir**--This station is located immediately upstream of the confluence with the Feather River. Under the Sierra Source-to-User Alternative, water from this location would be blended with water from the Feather River.

5. **Sacramento River at Greene's Landing**--This station is located a few miles downstream from Hood, the point of diversion under the Peripheral Canal and Dual Transfer System alternatives. Data from this location were used to characterize the quality of the Sacramento River as it flows into the Delta.

6. **San Joaquin River**--Data collected on the San Joaquin River at Vernalis were used to characterize the quality of the San Joaquin River as it flows into the Delta.

7. **Rock Slough**--The intake for the Contra Costa Water District is located at Rock Slough.

8. **Clifton Court Forebay**--The quality of water at Clifton Court Forebay (Clifton Court) characterizes the quality of water diverted from the Delta through the State Water Project (SWP). The quality at the Central Valley Project (CVP) pumps is influenced by the San Joaquin River to a greater extent than the quality at the SWP pumps. In this study it was assumed that the quality at the CVP pumps was equal to the quality at Clifton Court.

Data Sources. Data were obtained primarily from four monitoring programs. Where data were available; the database analyzed in this study was extended back to 1975 to cover the 1976-77 drought.

1. **EBMUD Extended Monitoring Study**--In August 1983, EBMUD initiated its Extended Monitoring Study. Data are collected monthly on a variety of constituents, including trihalomethane formation potential (THMFP), minerals, nutrients, bacteriological constituents, and pesticides. Data collected by EBMUD on the American River at Nimbus, Sacramento River at Greene's Landing, and Clifton Court were used in this study.

2. **Interagency Delta Health Aspects Monitoring Program**--This study, sponsored by many agencies and conducted by the California Department of Water Resources (DWR), was started in July 1983. Data are collected monthly on THMFP, minerals, selenium, and asbestos at a number of locations in the Delta. The data collected on the Sacramento River at Greene's Landing, Mokelumne River, San Joaquin River at Vernalis, and Clifton Court were used in this study. The THMFP data collected on the American River at the City of Sacramento water treatment plant intake were also used.

3. **DWR Decision 1485 Compliance Monitoring Program**--Data designed to monitor compliance with California State Water Resources Control Board (SWRCB) Decision 1485 (D-1485) (the current Delta outflow and salinity directive) are collected monthly on a number of constituents at various locations in the Delta by DWR. Metals and pesticide data are collected twice a year. Data from the Sacramento River at Greene's Landing, San Joaquin River at Vernalis, and Clifton Court were used in this study.

4. **DWR Delta Agricultural Drainage Investigation**--In January 1987, DWR began a 30-month investigation of the THMFP and other characteristics of water discharged into the Delta channels from agricultural drains. The data and findings produced by this study were reviewed and used.

Other Sources of Data--Data from the EPA STORET system were the only available data on the Feather River and Sacramento River at Fremont Weir. These data were collected primarily by the U.S. Geological Survey and DWR. Data collected by the City of Sacramento on the American and Sacramento Rivers at the water treatment plant intakes were reviewed.

Contaminants of Principal Concern

The available data on organic, inorganic, and biological constituents of concern in the Delta and the Delta source waters are described and compared to drinking water standards in this section. Appendix C contains summary tables of all of the water quality data presented in this section. These tables contain information on the number of samples, range of values, mean, and standard deviation for the wet season, dry season, and the entire year. The period of record varies for each location; the data presented in this section were generally collected between 1975 and 1987.

Trihalomethanes. THMs are halogenated organic compounds formed in drinking water when chlorine used for disinfection during the water treatment process reacts with organic compounds in the water. These organic compounds, mainly naturally occurring humic and fulvic acids, resulting from plant decay, are generally referred to as organic THM precursors. Delta water supplies also contain bromides, which are mainly of seawater origin. Recent studies have shown that the presence of bromide greatly affects the species of THMs formed and also increases the total amount of THMFP (Luong et al., Amy et al.). There are four varieties of regulated THMs produced in drinking water diverted from the Delta; chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

EPA has determined that THMs are capable of causing cancer in test animals and are suspected human carcinogens. Accordingly, an MCL of 100 micrograms per liter (ug/l) of total THM has been established in drinking water. The current MCL is scheduled to be reviewed and revised in the early 1990s. The expectation is that, when final regulations are adopted, the new MCL for THMs will be considerably more restrictive, likely in the range of 20 to 50 ug/l. EPA is also considering setting an interim MCL for THMs at, say, 50 ug/l, then proposing a final MCL a few years later when more adequate toxicological information is available. The impact of this regulatory approach on water treatment requirements and costs is discussed in more detail in the next chapter. There is also the possibility that MCLs will be adopted separately for one or more of the four individual THM species found in drinking water.

It is also likely that EPA will propose MCLs for other disinfection by-products which are suspected carcinogens, mutagens, or teratogens, in addition to THMs. Likely candidate by-products for regulation are those included in EPA's Drinking Water Priority List: halonitriles; halogenated acids, alcohols, aldehydes, and ketones; chloropicrin; and 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX). MX is being found in current research to be the strongest mutagen commonly existing in chlorinated surface water supplies. Insufficient data are available on disinfection by-products (other than THM) in Delta waters to permit further assessment of their importance in this report. All the common drinking water disinfectants will also be considered for regulation at the same time.

Since untreated water does not generally contain significant THMs, waters of the Delta and its tributaries are analyzed for THMFP, which is a test of the capacity of a water source to form THMs upon chlorination. The analytical method for determining THMFP is not rigidly prescribed or clearly defined. The method used by DWR yields results which are indicative of the maximum amount of THMs that could be produced in a given source water. This analysis is useful for comparing water sources. Actual THM concentrations in treated drinking water are much lower than the values produced in the DWR THMFP test for a number of reasons, including lower chlorine dosages and shorter reaction times that generally occur in drinking water treatment and distribution systems. A potential problem with the DWR THMFP test is that the THM formation "driving force," as measured by the ratio of chlorine dose to organic carbon concentration, is much higher for cleaner waters (e.g., American River) than for water containing higher organic precursor concentrations. The urban water supply agencies generally tailor the THMFP test to take into account chlorine dose, temperature, pH, and other conditions present in their treatment processes and distribution systems. Their goal is generally to obtain a THMFP value that is similar to the THM that would be formed in their distribution systems with the same quality water. Such modified analyses are often termed Simulated Distribution System THMs. EBMUD has found that generally the THM concentrations in their distribution system are about 50 to 70 percent of the THMFP concentrations in the raw water. This is approximately equivalent to 15 to 25 percent of the higher DWR THMFP values, for the reasons discussed. Santa Clara Valley Water District THM concentrations are generally about 30 percent of their raw water THMFP concentrations, although the data are quite variable. Table 3-3 presents the DWR and EBMUD THMFP data at three locations for comparison.

Table 3-3. Comparison of DWR and EBMUD THMFP Data

Location	Concentration, ug/l			
	DWR data		EBMUD data	
	Mean	85 percent[a]	Mean	85 percent[a]
American River	240	300	60	75
Sacramento River at Greene's Landing	310	470	85	110
Clifton Court	500	640	160	200

[a]85 percentile is the mean plus one standard deviation.

Figure 3-2 presents the DWR THMFP data for the Delta and Delta source waters. The figure shows a statistical array of data from each source location, and indicates the mean (or average) value, the range from the observed maximum value to the observed minimum value, and the range which encompasses plus or minus one standard deviation from the mean. Because most water quality data are not normally distributed, the standard deviation range is not a precise measure, but it does indicate a practical range with about 70 percent of all data points falling within the range and only about 15 percent of the data falling above, and 15 percent below, this range (precisely 15.9 percent for normally distributed data).

These data show that the THMFP of the American and Mokelumne Rivers is low with mean values of 240 and 250 ug/l, respectively. The THMFP of the Sacramento River at Greene's Landing is slightly higher with an average value of 310 ug/l. The mean THMFP concentrations in the San Joaquin River, Rock Slough, and Clifton Court are about equal, ranging from 480 to 500 ug/l. These data show that THMFP increases dramatically as the waters of the Sacramento and Mokelumne Rivers travel through the Delta. Figure 3-3 shows the EBMUD THMFP data. As discussed previously, the analytical method used by EBMUD and other water supply agencies results in lower (and more realistic) THMFP values than the DWR method. The EBMUD data show the same trend of increasing THMFP as the water travels through the Delta. Assuming that the distribution system THM concentrations represent about 50 to 70 percent of the EBMUD THMFP concentrations, it can be seen from Figure 3-3 that water taken from the American and Sacramento Rivers would generally meet the THM standard of 100 ug/l upon chlorination without other treatment. The City of Sacramento is currently able to consistently meet the current THM standard of 100 ug/l without additional treatment of American and Sacramento River water. Clifton Court water would have to receive additional treatment to reduce the THM concentration to acceptable levels. This is supported by the experience of the water supply

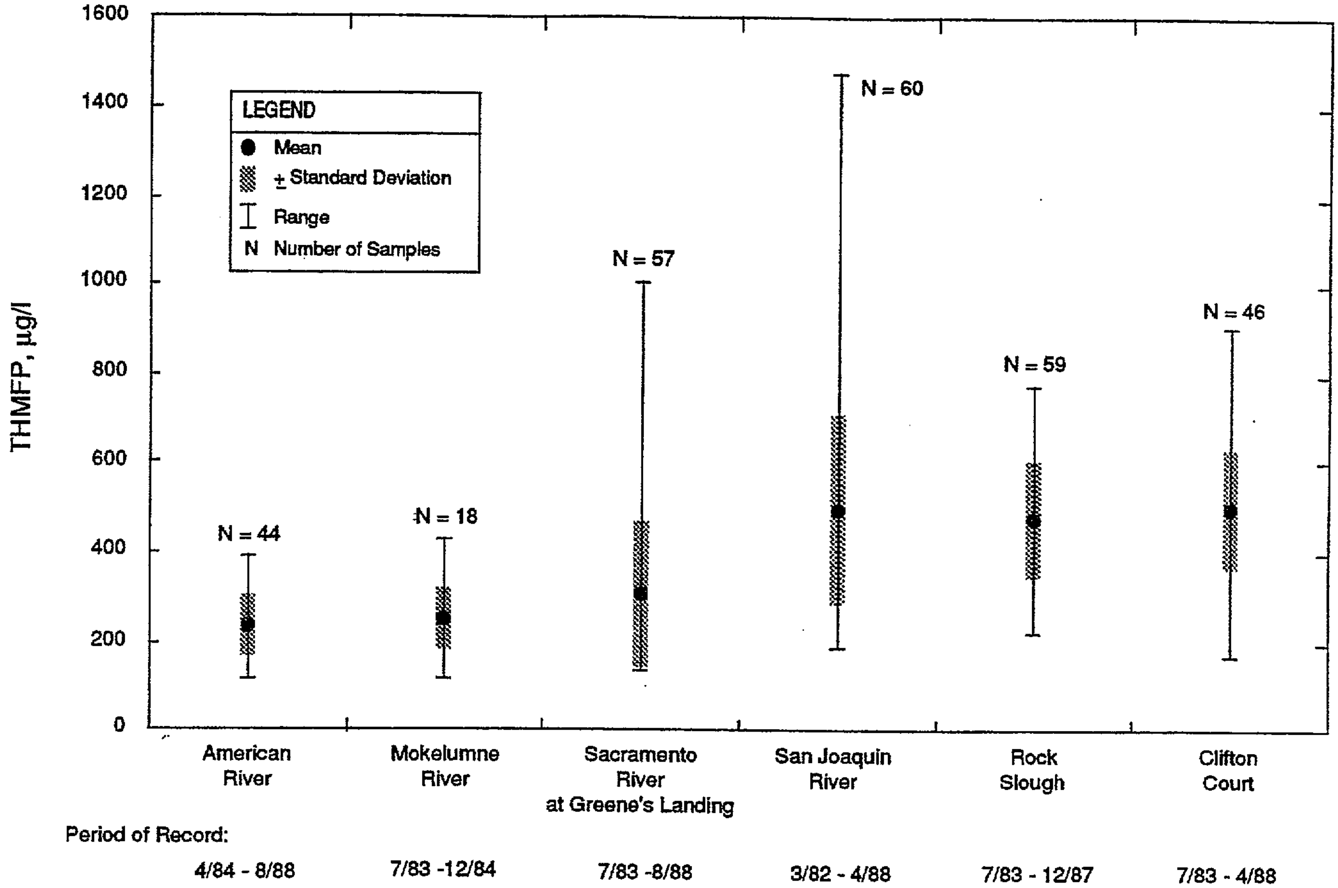


Figure 3-2. THMFP (DWR) in the Delta Source Waters

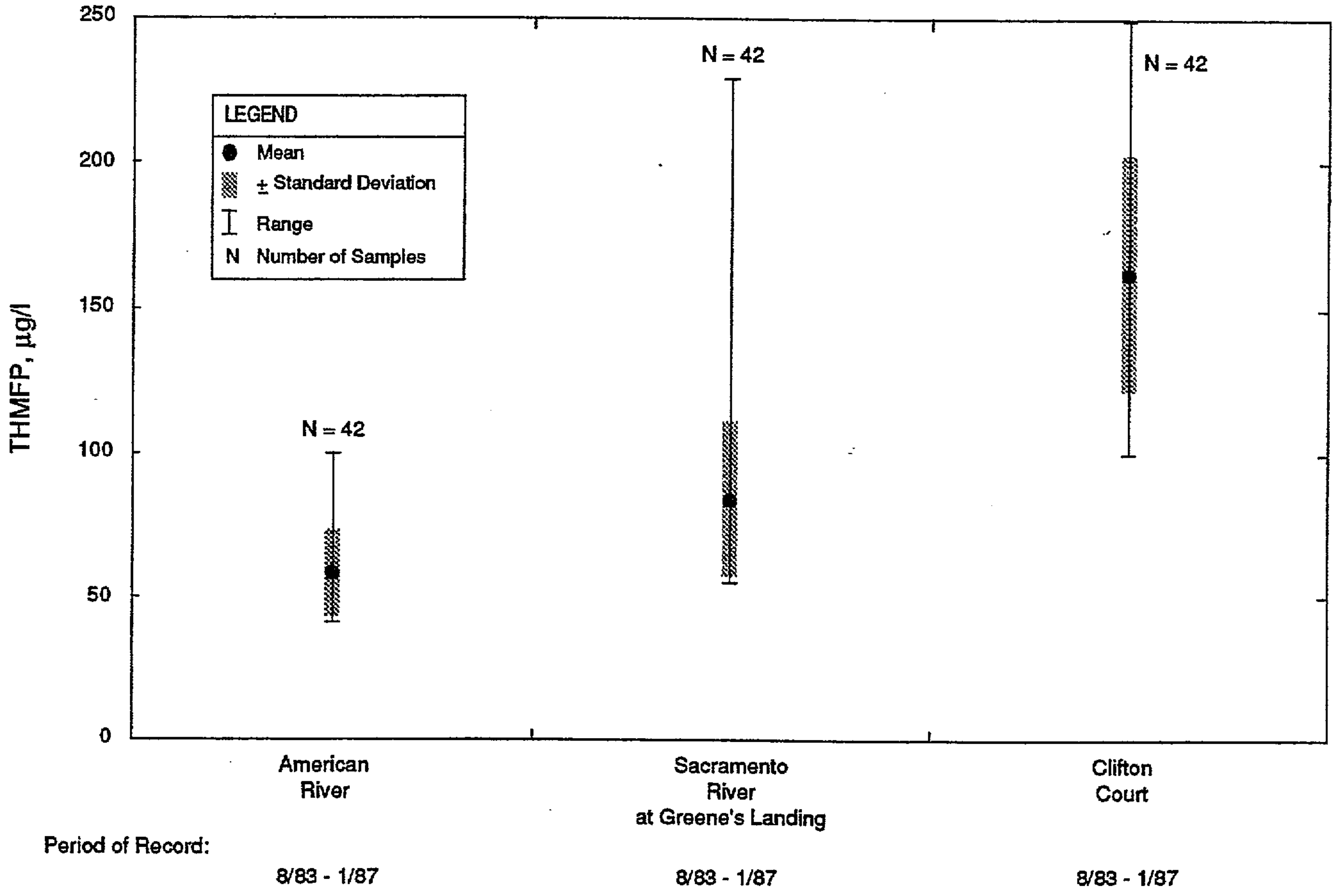


Figure 3-3. THMFP (EBMUD) in the Delta Source Waters

agencies; however, because treatment is provided for all these supplies the distribution system THM is always lower than the raw water THMFP, usually by half or more.

The increase in THMFP in the Delta is likely due to the increased organic carbon content of Delta waters compared to Sacramento River water and to the presence of bromide in seawater that intrudes into the Delta during periods of low outflow. Figure 3-4 presents the total organic carbon (TOC) data for the Delta and source waters. The average TOC concentrations generally increase as the water flows through the Delta with the highest TOC concentrations found at Clifton Court. The TOC concentration of a water supply source is a rough indication of the potential to form THMs, since the TOC measurement includes the organic THM precursors.

The increased organic carbon content of Delta waters is partially due to the discharge of agricultural drainage into the Delta. Some is also contributed by municipal and industrial dischargers. An additional amount results from the growth of algae and aquatic plants in Delta waters and the contact between the water and the rich organic peat soils of the Delta channels and levees. The exact contribution from each of these sources is largely unknown. The DWR agricultural drainage study is addressing some of these unknowns.

During periods of reduced freshwater outflow, the operation of water project pumps in the southern Delta causes the flow of the San Joaquin River and other channels to reverse their normal direction. When this occurs, water containing bromides more easily enters the Delta from the estuary and mixes with Delta waters. Recent studies have shown that the presence of bromide greatly affects the species of THMs formed and also increases the total amount of THMFP (Luong et. al., Amy et. al.). The presence of bromide results in the formation of brominated THM species.

Figure 3-5 presents the concentrations of brominated THMFP in the Delta and source waters. The mean brominated species concentration ranges from 2 to 7 ug/l in the American, Mokelumne, and Sacramento Rivers. The San Joaquin River, Rock Slough, and Clifton Court have mean concentrations ranging from 60 to 80 ug/l and maximum values above 200 ug/l. These data show the influence of seawater intrusion on the species of THMs formed in the Delta waters.

Total Dissolved Solids and Hardness. Total dissolved solids (TDS) is a measure of the residue present after filtering and evaporating a water sample. Although it is not precisely equivalent to the technical definition of salinity, TDS is often termed the salinity of water. Excess dissolved solids are objectionable in drinking water because of possible physiological effects, unpalatable mineral tastes, and higher costs because of corrosion or the necessity for treatment for corrosion control and softening. The federal and state secondary (nonmandatory) standard for TDS includes several levels; the lowest is a suggested limit of 500 mg/l. This limit was set primarily on the basis of taste thresholds.

Hardness is an important constituent of concern in drinking water supplies. It is defined as the sum of the polyvalent metallic ions dissolved in water, expressed as calcium carbonate. In fresh waters these are principally calcium and magnesium, although other ions such as iron and manganese contribute to the extent that appreciable concentrations are

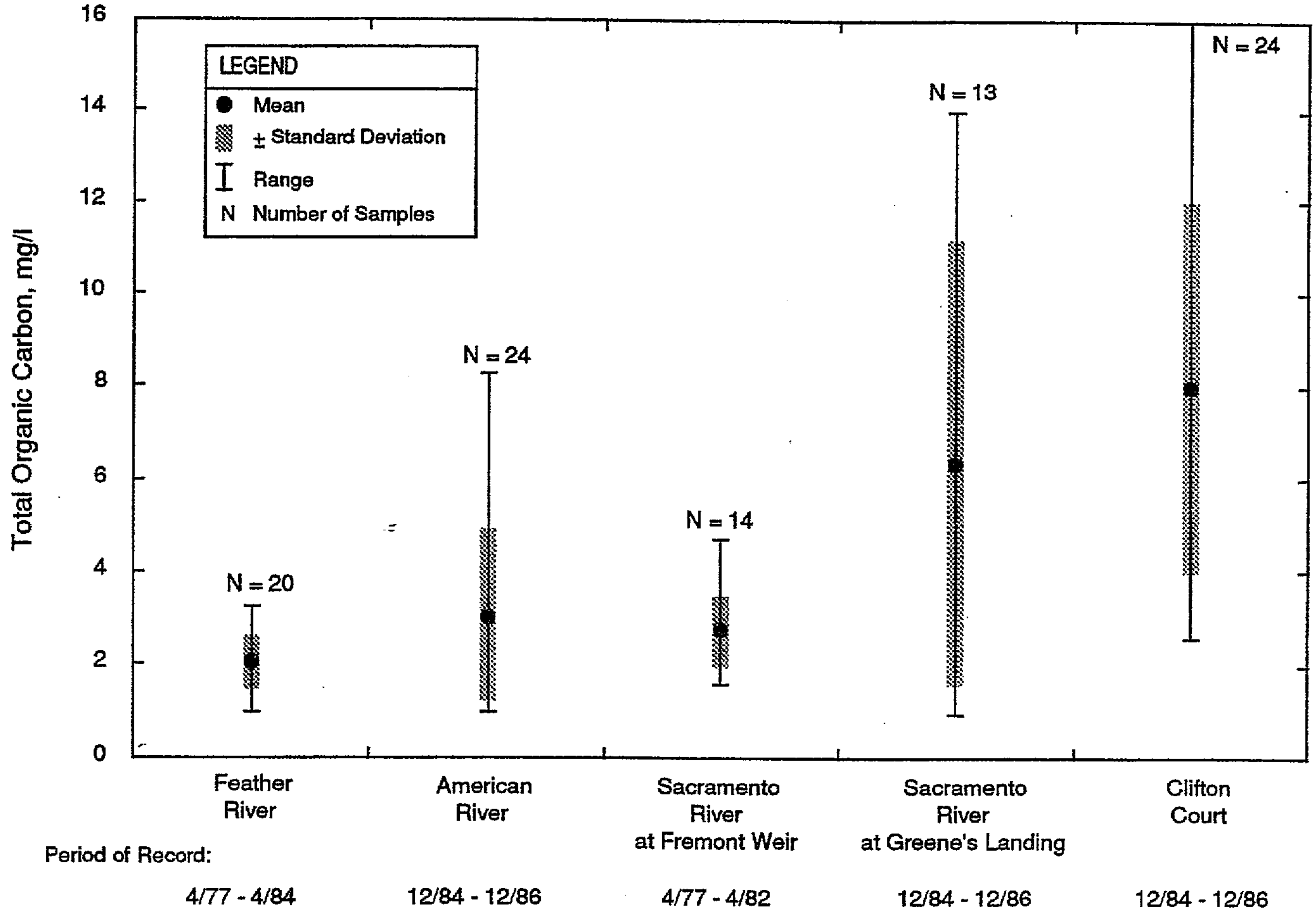


Figure 3-4. Total Organic Carbon in the Delta Source Waters

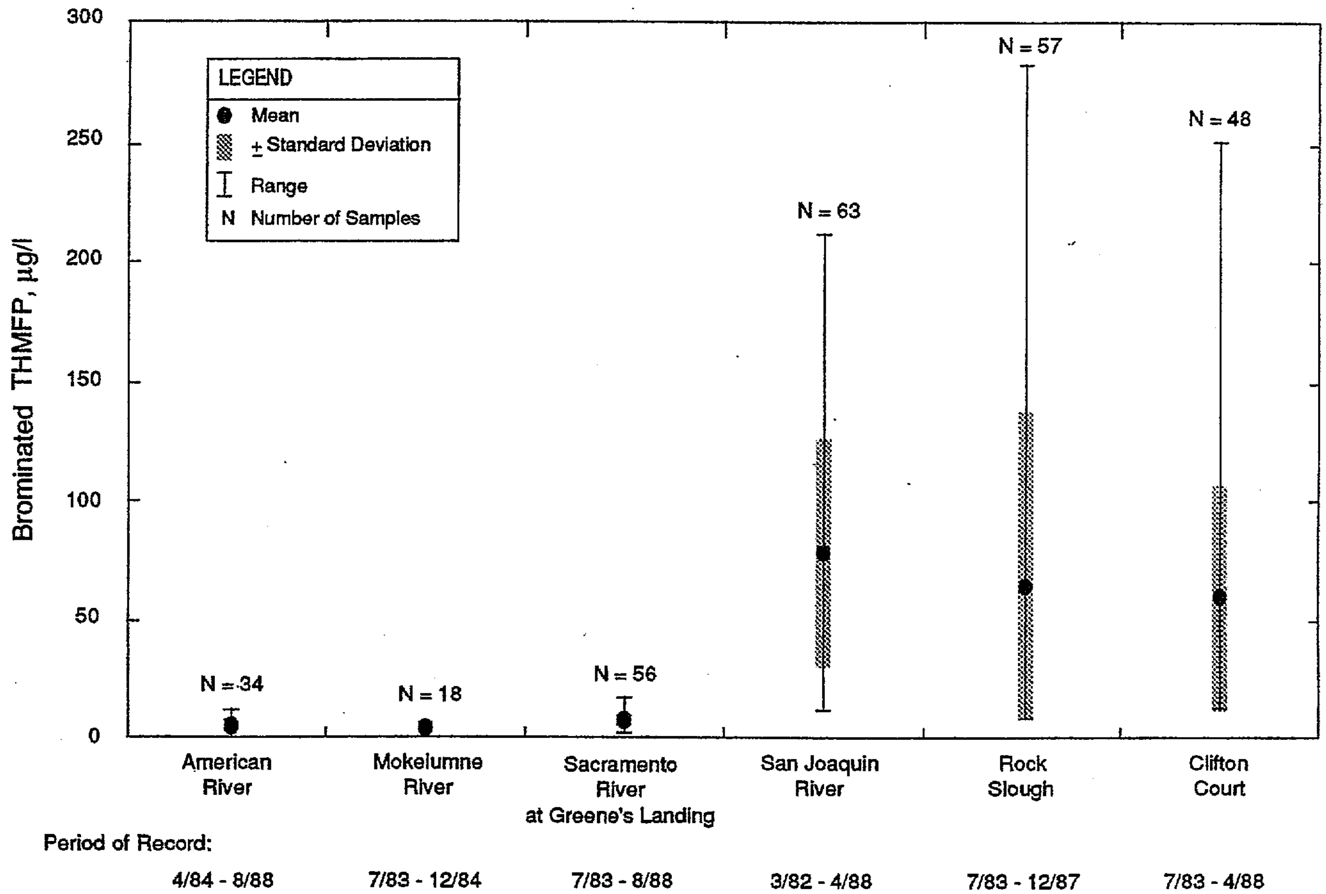


Figure 3-5. Brominated THMFP (DWR) in the Delta Source Waters

present. There are not extensive data on hardness in the source waters so TDS is used in this study as the mineral constituent of main concern.

TDS is the constituent used in the DWR water quality model of the Delta. Figure 3-6 presents the TDS data for the source waters and the Delta. The mean TDS concentrations vary from 36 mg/l in the American River to 370 mg/l in the San Joaquin River. The Feather and Mokelumne Rivers have low TDS concentrations, comparable to the American River. The Sacramento River concentrations are slightly higher than the Sierra streams. The mean TDS concentrations in Rock Slough and Clifton Court are 260 and 240 mg/l, respectively. None of the average concentrations exceeds the secondary standard of 500 mg/l; however, TDS concentrations above the secondary standard occur in the San Joaquin River, Rock Slough, and Clifton Court.

The watersheds of the American, Mokelumne, and Feather Rivers are sparsely developed compared to other Delta tributaries. This is one factor reflected in the low TDS concentrations found in these rivers. The Sacramento River receives urban and agricultural runoff which results in higher TDS concentrations than in the Sierra streams. The high TDS concentrations in the San Joaquin River are largely due to the extensive amount of agricultural drainage that is discharged into the river. The TDS concentrations found at Clifton Court are due partially to the influence of the San Joaquin River, partially to seawater intrusion, and partially to salt concentrations in Delta agricultural discharges. The influence of sea water intrusion is particularly evident in the Rock Slough TDS data.

Highly mineralized water imposes significant economic burdens on water users. The concentrations of mineral salts, and the ratios among the key minerals are critical considerations for irrigated agriculture, but irrigation problems are not explored further in this study. Many urban water-using activities are economically impacted by TDS and its usual mineral companion, hardness. The collective cost burden of water mineralization to an urban community can be large. Urban water studies have shown that the total consumer costs related to poorer quality water can be equal to, or exceed, the total utility billings for urban water supply.

The cost burden related to drinking water quality is not equally affordable by all urban water users. A recent (January 6, 1989) letter to the SWRCB from the mayors of California's five largest cities pointed out that "Many of our city's residents are low income families which can ill afford costly and unreliable substitutes for safe high quality water at the tap."

Water with high levels of TDS and hardness shortens the life of appliances and plumbing systems, requires the use of more soap and detergents, and increases energy costs because appliances are operated longer to get items clean (Curry, 1983). It also requires more frequent cleaning of swimming pools, increases lawn watering and fertilizer applications, and requires more frequent cleaning and replacement of clothing. The TDS in water also has an adverse effect on industrial operations such as cooling towers, boilers, demineralization, and food processing operations. Complaints generally increase when there are dramatic changes in the quality of water delivered to consumers. Some utilities, including the Alameda County Water District and the Metropolitan Water District of

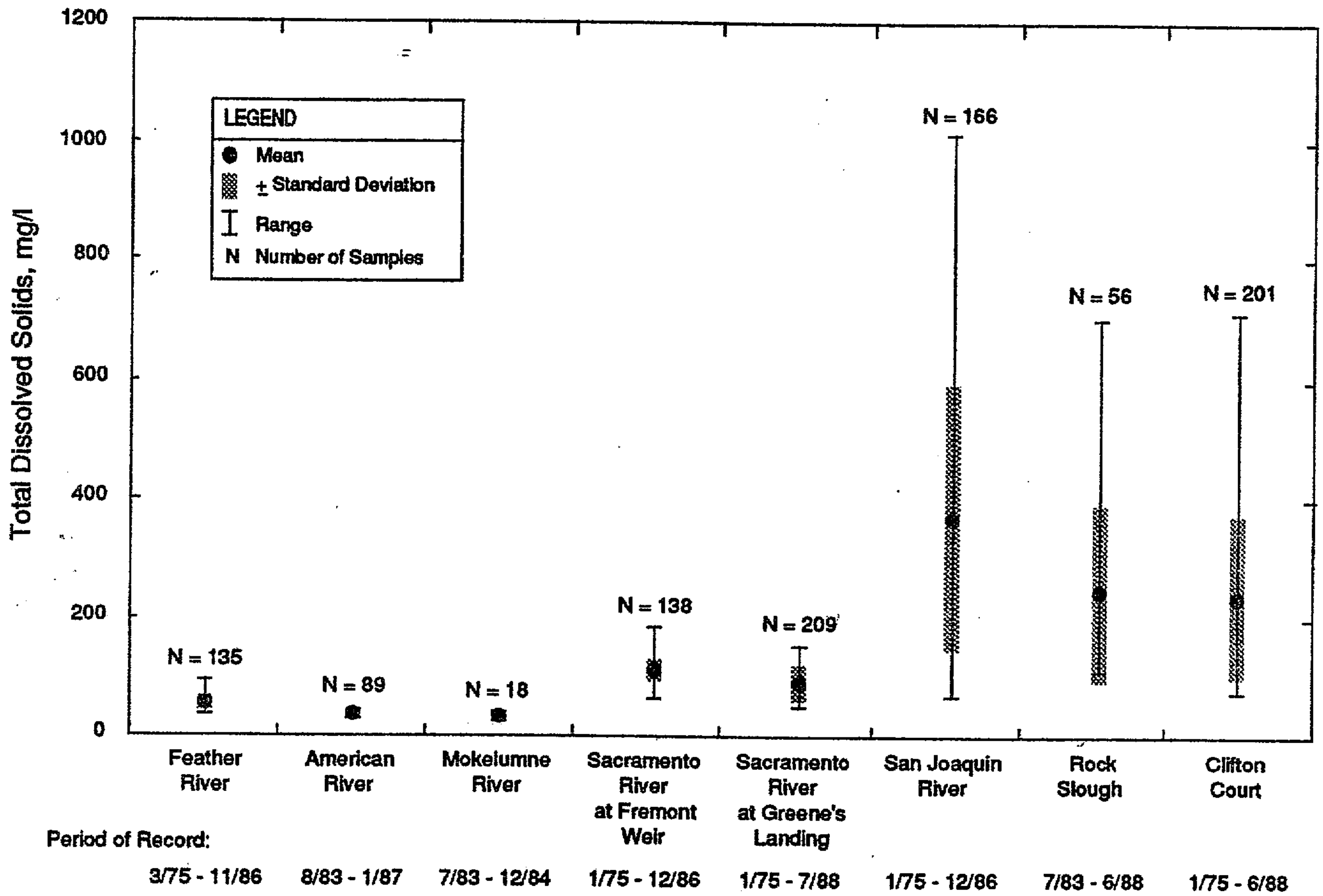


Figure 3-6. Total Dissloved Solids in the Delta Source Waters

Southern California have carefully planned programs to blend waters from various sources to minimize changes in mineral quality.

Most water softening in California is accomplished by the ion exchange process in which sodium is exchanged for the calcium and magnesium ions which cause the undesired hardness. This process uses large amounts of sodium chloride, common salt, and the residual salt must be discharged. Where these waste salts can be sewered and flow to the ocean, no further mineral damage is done. But where softener regeneration wastes are discharged to septic tanks, or to rivers or lands through any other pathway, significant mineral degradation of usable water occurs. For typical home softeners, each pound of hardness removed from the water supply requires about 6 pounds of regeneration salt, and about 15 gallons of regeneration rinse water. In this same case, about 6 pounds of TDS and about 2 pounds of sodium are discharged. If the water supply has 200 mg/l hardness and one-fourth of the home supply is softened, then the data cited are equivalent to mineral increments of about 300 mg/l TDS and 100 mg/l sodium in the total domestic water supply.

Increasingly, home water softeners are being supplemented, or replaced, by bottled water service or on-site water conditioning systems. Generally, the percentage of homes using one or more of these types of water service varies from 10 to 25 percent in higher water quality communities of average income level, up to 50 to 70 percent in affluent communities which receive highly mineralized water or in which water-related health issues have been highly publicized. Surveys have indicated that the main reasons that many consumers avoid tap water for drinking purposes are (1) health concerns, and (2) taste and aesthetics, in about equal proportions (Stammer, 1986). Generally, consumers install water softeners to alleviate problems caused by hardness and the general mineral content of the tap water. Consumers concerned abut the health effects or aesthetics of the tap water generally use bottled water or sophisticated water conditioning devices, such as reverse osmosis demineralization or activated carbon filtration. In large portions of Southern California, bottled water use has been estimated at 50 percent or more of households. This practice likely represents total annual consumer expenditures of over $500 million. Some of the consumers would continue to use bottled water or treatment devices regardless of the quality and demonstrated safety of the public water supplies.

The effect of water quality on the use of water softeners, bottled water, and home treatment devices has been evaluated in several studies. A survey of domestic water users in Orange County, California found definite relationships between (1) water hardness and the number of homes using a softener, (2) water hardness and the cost of cleaning products, (3) total mineral content of the water and the number of households using bottled water, and (4) total mineral content and water heater service life (Orange County Water District, 1972). At 400 mg/l of total hardness, 35 percent of homes used softeners. However, with 200 mg/l of hardness, 20 percent of homes had softeners. Bottled water use varied from 13 to 27 percent for a TDS range of 200 to 800 mg/l. Water heater life for the same TDS range went from 10 years to 7 years. A study conducted to evaluate the impact on consumers of water supplies of different mineral content in three communities in the Lompoc area in western Santa Barbara County resulted in a conclusion that a water supply of poor quality imposes a cost burden on consumers (DWR, 1978). The use of home water softeners varied from 25 percent to 80 percent for a hardness value of 200 and 400 mg/l, respectively. Bottled water use varied from 10 to 35 percent for a TDS variation of 500 to 800 mg/l.

Since both the Orange County and Lompoc studies were based on the water habits of communities which had been supplied with a water of consistent quality for a number of years, a question is raised as to the impact on consumers of a significant change in water quality. A survey conducted by the City of Palo Alto (1961) concluded that 86 percent of homes using softeners would discontinue their use if served a soft municipal supply. The Palo Alto report stated that only a small portion of the households might continue the use of softeners over a long period of time.

The problems associated with mineralized water have also been addressed in industry publications. Excessive hardness is one of the most common and annoying water quality problems encountered, with levels over 150 mg/l being particularly objectionable (McFarland, November 1985). The economic impacts of mineral concentrations on industrial operations varies widely and is not considered in this study.

Several studies have been conducted to estimate the cost to urban users of a more mineralized water supply. Some of these investigations emphasize residential costs, and some commercial/industrial effects. Some are mainly concerned with water softening, while others take a more comprehensive water conditioning viewpoint. Residential water quality impacts are emphasized in this study because the large majority of the urban water use is for residential purposes, and consumer impact data are more readily available for this use. Most of the available studies gave little attention to the impact of lower quality water on the cost of operating the more sophisticated treatment units, such as membrane filters, which are becoming more popular for residential use. This factor would tend to increase the cost data reported here.

A study prepared for the Modesto-Ceres area estimated the consumer costs of urban water supplies of differing quality based on a review of data from previous studies, and on survey information or estimates for home softening units and bottled water in the Modesto-Ceres area (J.M. Montgomery, 1984). The cost impact to consumers of improving the water quality from an average hardness of 173 mg/l to 56 mg/l, and a TDS of 355 mg/l to 124 mg/l was estimated at an average of $125 per household per year for all households. Updating this cost to current prices and expressing the cost for the increment of TDS on a unit basis results in $0.23 per pound of TDS.

DWR (1978) estimated that households receiving water with a hardness of 200 mg/l spend $28 more per year for soap and detergent than homes using water with a hardness of 50 mg/l. The cost of soap and detergent calculates to approximately $0.50 per pound of TDS in current dollars. The cost has been converted to a TDS basis by using the comparable TDS concentration in the water supply for the total hardness in the communities surveyed. Homes receiving water with a hardness of 400 mg/l spend $49 more per year (average for all homes) for water softening than homes using water with a hardness of 200 mg/l. This cost of water softening calculates to approximately $0.58 per pound of TDS in current dollars. This cost was converted to a TDS basis by using the comparable TDS concentration for the two water sources evaluated in the report. The Orange County study estimated that the overall impact on consumer costs of improving the water quality from a hardness of 349 mg/l to 79 mg/l, and a TDS of 746 mg/l to 199 mg/l would be $144 per household per year (Orange County Water District, 1972). Updating the cost to current dollars and changing units results in an estimated $0.36 per pound of TDS.

The data from several studies of water quality costs to residential consumers have been composited and converted to an expression of total cost burden in cents per pound of incremental TDS. For studies where consumer costs were based on hardness, a conversion was made to TDS using the same cost data and the water quality characteristics. These studies cover a wide range of water quality conditions. These results varied from $0.23 to $0.58 per pound of TDS. In this study, a value of $0.25 is used; that is, the assumed total cost to all residential users of using a water supply of lesser mineral quality is $0.25 per pound of increased TDS, or $0.68 per acre-foot (AF) per mg/l of TDS increase. Although imprecise, this is a reasonable broad-brush estimate of the consumer value of improved mineral quality, and is near the low end of a range of costs calculated from several consumer impact studies. In the later assessment of alternative concepts, this cost factor is included for comparative use, and is applied to the total volume of water delivered for urban use.

Low TDS water has an additional value because it can be used to prolong or restore the use, as an urban water supply, of water stored in groundwater basins. Without remedial measures, the quality of the groundwater degrades due to mingling with water containing the residues of fertilizer and urban wastewater, and to the lateral migration of saline groundwater. The feasibility of wastewater reclamation and the ability of reuse projects to conform to Basin Plan salinity objectives are directly related to the TDS of the regional water supplies. For example, Colorado River water cannot be used for urban purposes and then be reused for groundwater basin recharge because of its relatively high TDS.

When the salinity of a body of groundwater degrades below the limit of potability, the cost penalty associated with its use changes from the TDS incremental cost described above to loss of the supply. A measure of this latter penalty might be the cost of providing a new substitute supply or the cost of desalting to restore the water to use as drinking water. This aspect of the value of low TDS water will not be evaluated in detail here because much additional study would be required. Nevertheless, the benefit of the availability of low TDS water to help manage groundwater basins is substantial and could be of the same magnitude as the above-described consumer savings. For example, for a lost supply of 100,000 acre-feet/year of groundwater, and an assumed cost of developing new substitute water supplies of $200 per AF, the salinity penalty cost could be $20 million per year. In the Southern California service area, about 1.3 million AF/yr of groundwater is used for urban purposes.

Chloride. Chloride has traditionally been used as the water quality constituent for evaluation of the Delta water supplies. The chloride levels in drinking water sources supplied from the Delta are directly related to seawater intrusion. High chloride levels are associated with high levels of cations, mainly sodium, and a saline taste is noticed by customers when chloride levels increase. High chloride levels also result in increased corrosion of distribution systems, home plumbing systems, and industrial facilities.

The secondary (nonmandatory) drinking water standard for chloride is 250 mg/l. Decision 1485 requires that the chloride concentration not exceed 150 mg/l at the Contra Costa Water District intake at Rock Slough, at certain times and conditions. The recently published Draft Water Quality Control Plan for Salinity would eliminate the 150 mg/l chloride criterion and the 250 mg/l criterion would be the new maximum level at all times (SWRCB, 1988b). The experience of Contra Costa Water District shows that customer complaints increase when the chloride level reaches 100 to 150 mg/l. There is no practical treatment for reduction of chloride in urban supplies, so the proposed relaxation of the Delta chloride standard would impose a significant water quality degradation on Delta water users.

Figure 3-7 presents a summary of chloride concentrations in the source waters and the Delta. With the exception of the San Joaquin River, chloride levels are extremely low in all of the source waters. The average concentrations of chloride in the San Joaquin River, Rock Slough, and Clifton Court are less than 100 mg/l; however, the maximum concentrations at these locations exceed the secondary standard of 250 mg/l.

Sodium. Evidence from epidemiologic, clinical, and animal studies suggests that there is a relationship between daily dietary intake of sodium and high blood pressure (hypertension). Drinking water generally contributes only a small portion of total dietary intake of sodium, but that portion can be important for persons on restricted sodium diets. EPA has not established an MCL for sodium. In fact, EPA removed sodium from the list of 83 contaminants to be regulated by 1989. The National Academy of Sciences (NAS, 1977) recommends that persons on moderately restricted sodium diets should drink water containing no more than 100 mg/l of sodium. EPA (1976) and NAS (1977) recommend a sodium limit in drinking water of 20 mg/l for persons on severely restricted diets. Such people generally understand the role of drinking water sodium in their total diet, and use demineralized water if appropriate. Individual utilities have adopted self-imposed action levels to notify their consumers of sodium levels above that which is typically delivered. For example, in 1977, EBMUD in consultation with DHS set 70 mg/l as the trigger level for public notification. Other utilities are conscious of the sodium issue and respond to it in a variety of ways. There is currently no official regulatory position on it, however.

The mean sodium concentrations in the source waters and the Delta vary considerably with location, as shown on Figure 3-8. The average and maximum sodium concentrations in the Feather, American, and Mokelumne Rivers, and the Sacramento River at Greene's Landing are well below the 20 mg/l level recommended for people on severely restricted sodium diets. The San Joaquin River, Rock Slough, and Clifton Court have average sodium concentrations in excess of the 20 mg/l level, but well below the NAS recommendation of 100 mg/l for persons on moderately restricted diets. The increased sodium concentrations at Rock Slough and Clifton Court relative to the Sacramento River result from a number of causes. Agricultural drainage and seawater intrusion are the major contributors. However, domestic and industrial discharges and evaporation also contribute to increased sodium concentrations in the Delta.

Asbestos. Asbestos is a fibrous siliceous material that is present in serpentine and amphibole materials. Chrysotile asbestos is the type most frequently found in California waters and is derived largely from erosion of the serpentine rock that is present throughout

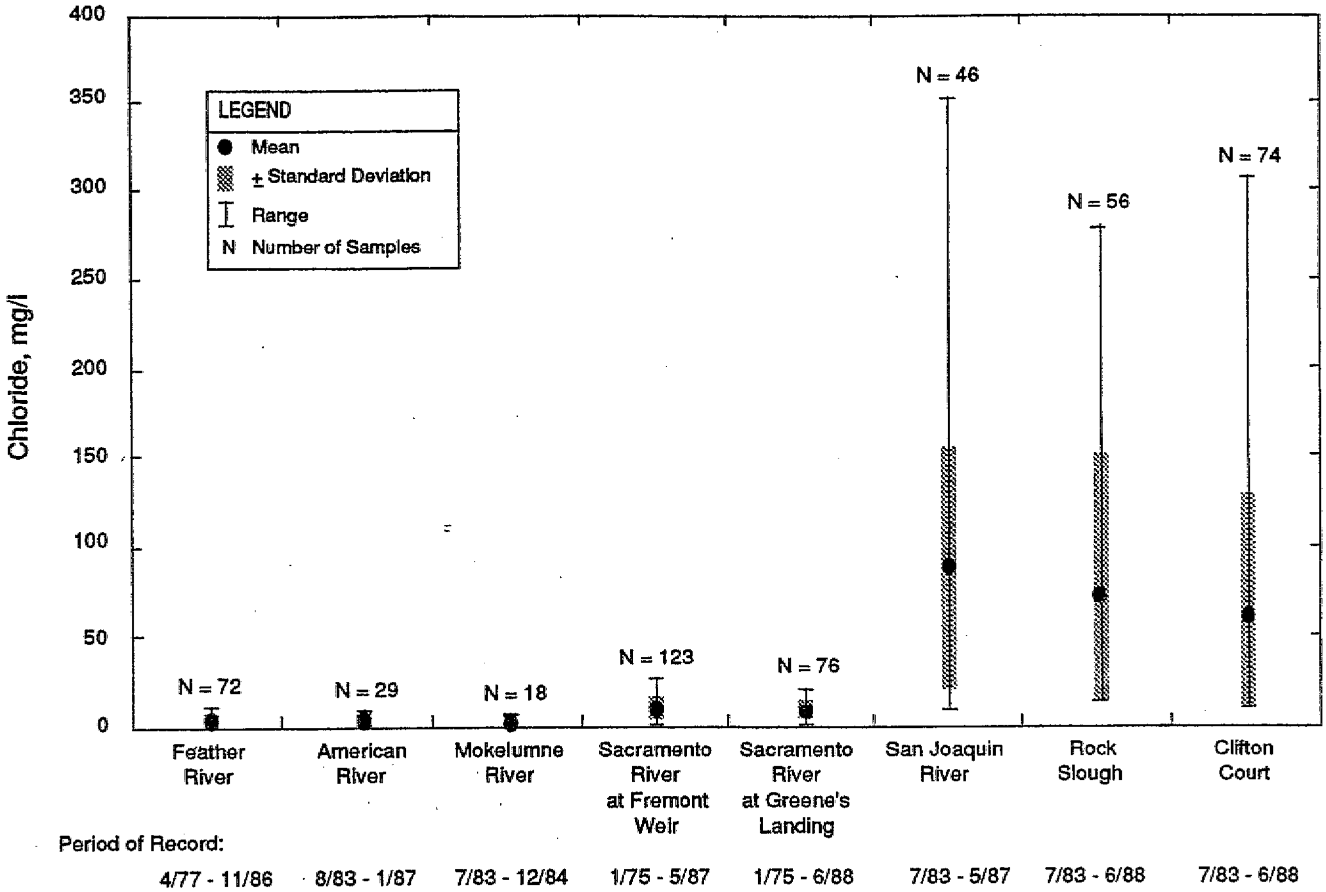


Figure 3-7. Chloride in the Delta Source Waters

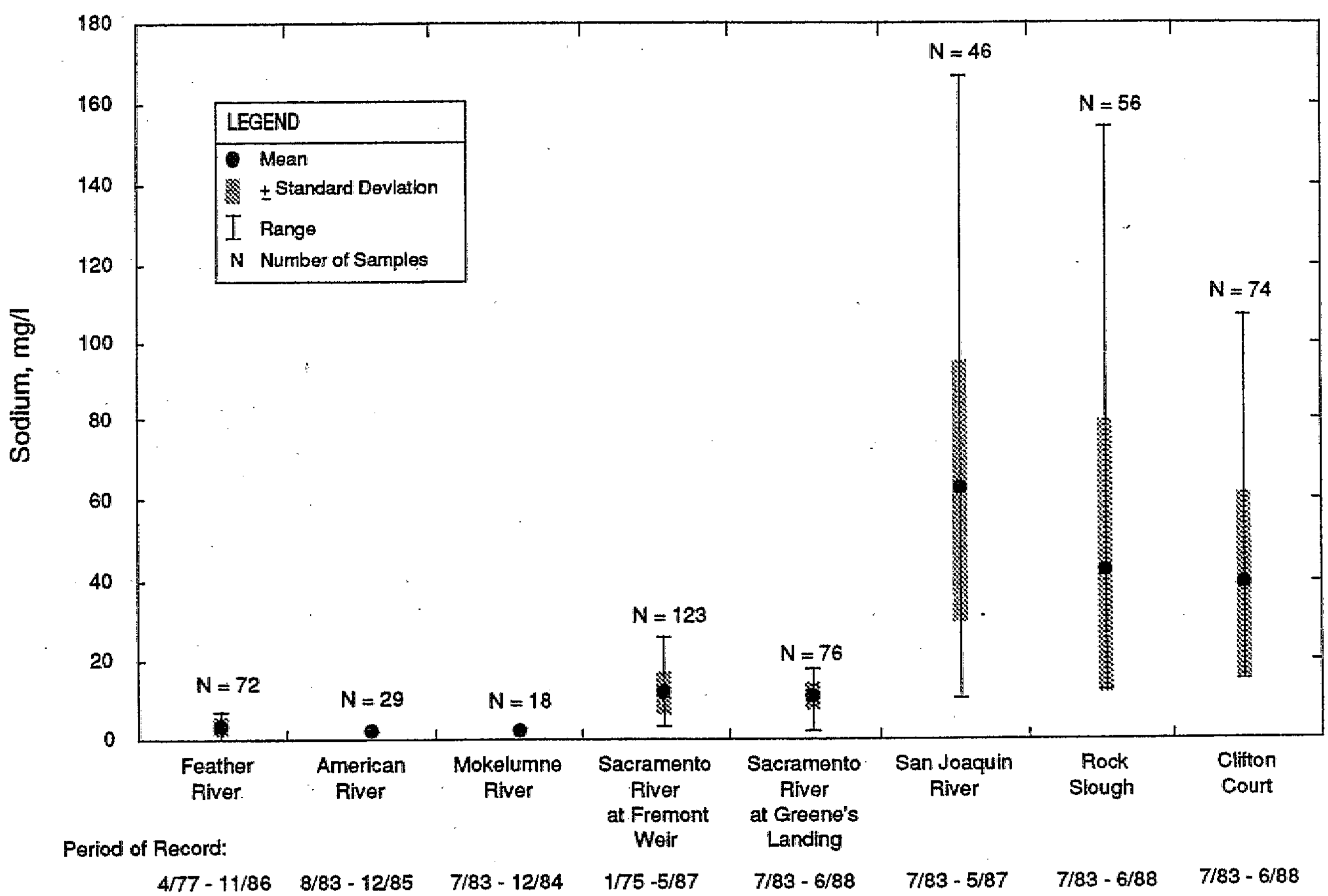


Figure 3-8. Sodium in the Delta Source Waters

the state. Asbestos has been demonstrated to be a carcinogen when asbestos fibers greater than 5 microns in length are inhaled. There has been concern that ingestion of asbestos in drinking water might be a cause of gastrointestinal cancer in humans. Although epidemiologic and animal studies have failed to demonstrate any consistent relationship between asbestos ingestion and increased incidence of cancer, the possibility of long-delayed effects of asbestos ingestion through water has led EPA to propose an MCLG of 7 million medium and long fibers/l (10 or more microns in length).

Asbestos data have been collected by DWR on some of the source waters. The mean concentrations vary from 56 million fibers/l in the Mokelumne River to 1,100 million fibers/l in the San Joaquin River. Maximum concentrations of 3,000 million fibers/l were found in both the Sacramento River at Greene's Landing and the San Joaquin River. The value of the asbestos data has been questioned by DWR (1986a) because asbestos analyses done in triplicate on the same water samples differed significantly. The analytical techniques for measuring asbestos need to be improved before the asbestos data will be considered reliable. The data cannot be compared to the proposed MCLG of 7 million medium and long fibers/l because the DWR monitoring results are for total asbestos fibers. Also, the proposed MCLG refers to treated water, whereas the DWR analyses were done on untreated water. Treated water concentrations of asbestos are much lower because conventional treatment processes are quite effective in removing asbestos.

Selenium. The discovery that reproductive failure in water fowl using Kesterson Reservoir was due to high levels of selenium has focused attention on the possibility that the San Joaquin River is a source of selenium in Delta waters. Selenium, in high concentrations, can cause liver and kidney damage in humans; however, selenium is also an essential nutrient. The current MCL for selenium is 10 ug/l. EPA is expected to soon publish a revised proposed MCL of 50 ug/l, because the bulk of scientific data indicate that selenium concentrations in drinking water are generally lower than is desirable from a nutritional perspective.

The selenium concentrations in source waters and the Delta have been below the current MCL of 10 ug/l and have generally been below the detection limit of 1 ug/l. According to DWR (1986a), the highest concentrations of selenium have been detected in the lower San Joaquin River, Mud Slough, and Salt Slough. Dilution and natural removal processes result in lower concentrations in the San Joaquin River at Vernalis. Although selenium has the potential to cause ecological problems in the San Joaquin River watershed, it appears to present no problems currently in Delta waters used for drinking water.

Heavy Metals. As discussed in a previous section of this chapter, there are drinking water standards for several metals. Many of the metals cause liver and kidney damage. Lead is a probable human carcinogen and can cause irreversible brain damage.

There are a limited amount of data on metals concentrations in the source waters and Delta. Selenium is the one exception and it has been discussed previously. EBMUD has analyzed samples for lead from the American River, Sacramento River, and Clifton Court. The concentrations have all been at or below the detection limit and always less than 5 ug/l. Metals samples are collected twice each year from various locations in the Delta, Sacramento River, and San Joaquin River as part of the D-1485 Compliance Monitoring Program. Iron and manganese are the only metals that have been found at greater than trace levels. Based on the limited amount of data available, it appears that metals concentrations do not currently pose a problem in drinking water taken from the Delta or source waters. However, a study conducted by DWR (1987a) on metals and organics concentrations in fish, benthic organisms, and sediment at various locations in the SWP, showed that metals were found in the sediment samples and that cadmium, copper, mercury, selenium, and zinc were found in all fish samples.

Pesticides. The San Joaquin River has the reputation of being heavily laden with pesticide residues due to the agricultural nature of its watershed. However, pesticide monitoring conducted by DWR has failed to detect pesticides either frequently or in concentrations exceeding drinking water standards or state action levels. The DWR monitoring program is based on extensive data on pesticide usage patterns and environmental behavior rather than random sampling for pesticides. The program is designed to document the worst-case conditions. EBMUD has collected data on pesticides in the American River, Sacramento River, and Clifton Court. All pesticides have been below or near the limits of detection in these samples.

Certain toxics accumulate and greatly concentrate in fish flesh and organs, so fish studies have provided early warning of pesticide contamination at levels below drinking water concern. For example, DHS recently issued a nonconsumption advisory for trout and sucker fish in the upper Sacramento River due to elevated concentrations of dioxin, a powerful toxicant thought to originate mainly in waste discharges from pulp mills and wood preserving plants. DWR has found chlordane, dacthal, dieldrin, DDT, lindane, and toxaphene in fish taken from the SWP (DWR, 1987a). Continuance of the DWR and EBMUD pesticide monitoring programs will provide additional data on the occurrence, transport, and chronic health significance of these toxic compounds. There is no current evidence that pesticides constitute a threat to the health of humans presently consuming Delta or source waters.

Other Synthetic Organics. EPA has proposed MCLs for a number of synthetic organic chemicals. DWR and EBMUD have collected a limited amount of data on synthetic organics in the Delta and source waters. The DWR monitoring program has failed to detect their presence, with the exception that phthalate esters have been found at a number of locations and in significant concentrations. Phthalate esters are organic chemicals widely used in the manufacture of plastics. EPA has not established an MCL for phthalate esters and is not likely to do so in the near future. EBMUD has detected toluene and xylene in the American River, Sacramento River at Greene's Landing, and Clifton Court, but the concentrations have been significantly lower than the proposed MCLGs. Trichloroethylene (TCE) has been routinely detected at about 0.2 ug/l in the American River at the City of Sacramento's water treatment plant intake. The source of the TCE is thought to be the inflow of contaminated groundwater from the Aerojet site in Rancho Cordova. The MCL for TCE is 5 ug/l.

Turbidity. Turbidity is a nonspecific measure of suspended matter such as clay, silt, organic particulates, plankton, and microorganisms. Turbidity is of concern in drinking water because it can render water aesthetically unacceptable to the consumer;

reduce the efficiency of disinfection by shielding microorganisms; and act as a vehicle for the concentration, transport, and release of organic and inorganic toxicants, bacteria, and viruses. EPA is proposing to regulate turbidity under the Surface Water Treatment Rule, rather than with an MCL. According to the proposed Surface Water Treatment Rule, the maximum filtered water turbidity level must be less than or equal to 0.5 nephelometric turbidity units (NTU) in 95 percent of the measurements taken every month.

Figure 3-9 presents a summary of the turbidity data in the source waters and the Delta. The mean turbidity levels in the Feather, American, and Mokelumne Rivers range from 3 to 6 NTU, which is significantly lower than the other sites. The mean turbidity levels in the Sacramento River at Greene's Landing, Rock Slough, and Clifton Court are comparable, ranging from 11 to 13 NTU. The San Joaquin River and the Sacramento River at Fremont Weir have the highest mean turbidity levels. Turbidity in the rivers is highly variable and varies seasonally in relation to flow. As the flow of the river increases, the amount of sediment suspended in the river increases leading to higher turbidity levels, especially for several days following major storms.

Coliforms. Total coliform bacteria measurements indicate the general level of urban and animal contamination of a water supply. EPA is proposing to regulate coliform bacteria by a new presence/absence determination. The present state and federal standard is 1 bacterium per 100 milliliters (ml); the units are most probable number. With coliform bacteria, it is not appropriate to compare a raw source water measurement to a standard for treated drinking water. Raw water values are generally vastly higher and are valuable in the selection of treatment processes to provide bacteria-free finished water.

Figure 3-10 presents the limited amount of total coliform data available on the source waters and the Delta. These data show that the American River is least affected by waste contamination. The total coliform numbers in the Sacramento River at Greene's Landing are quite high. This may be due in large part to the upstream discharge from the Sacramento Regional Wastewater Treatment Plant, the Sacramento combined (sanitary/ storm) sewers, and many urban storm drains. The coliform numbers are reduced by the time the water reaches Clifton Court, probably due to dilution and die-off of the bacteria.

Chlorophyll a. The concentration of chlorophyll a in a water source is generally indicative of the amount of algal biomass present. Large algal populations can lead to taste and odor problems, increased turbidity, increased concentrations of organic THM precursors, and filter clogging problems in water treatment plants.

Figure 3-11 presents a summary of the available chlorophyll data on the Delta and source waters. The highest concentrations are found in the San Joaquin River, most likely due to the high nutrient concentrations found in this river. The concentrations in the American River, Sacramento River at Greene's Landing and Clifton Court are quite low. High chlorophyll concentrations generally do not develop in flowing waters so the concentrations at these locations may not be indicative of the concentrations that could result in terminal storage reservoirs. Nutrient concentrations in source waters are probably more indicative of the potential chlorophyll concentrations that could result in terminal reservoirs.

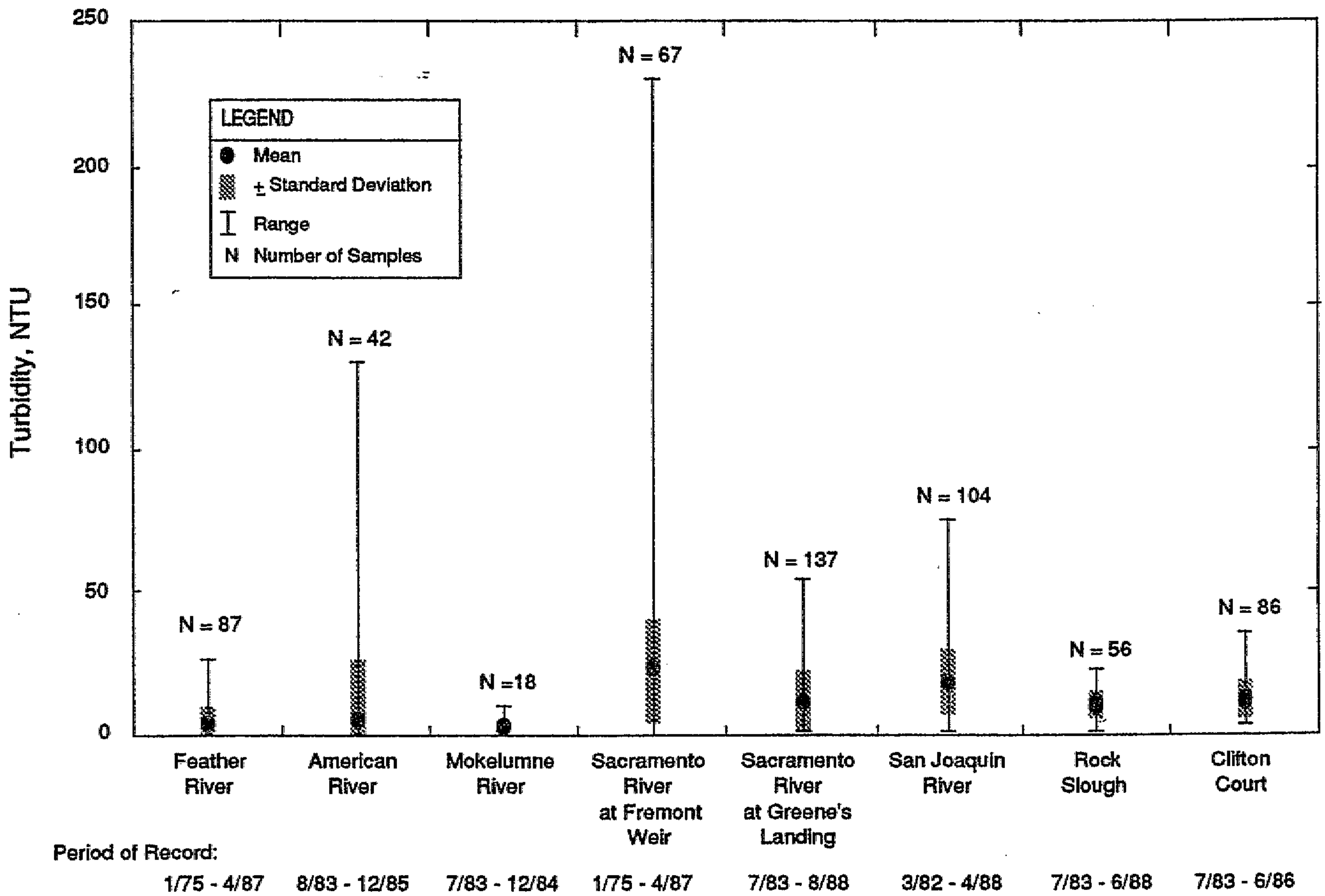


Figure 3-9. Turbidity in the Delta Source Waters

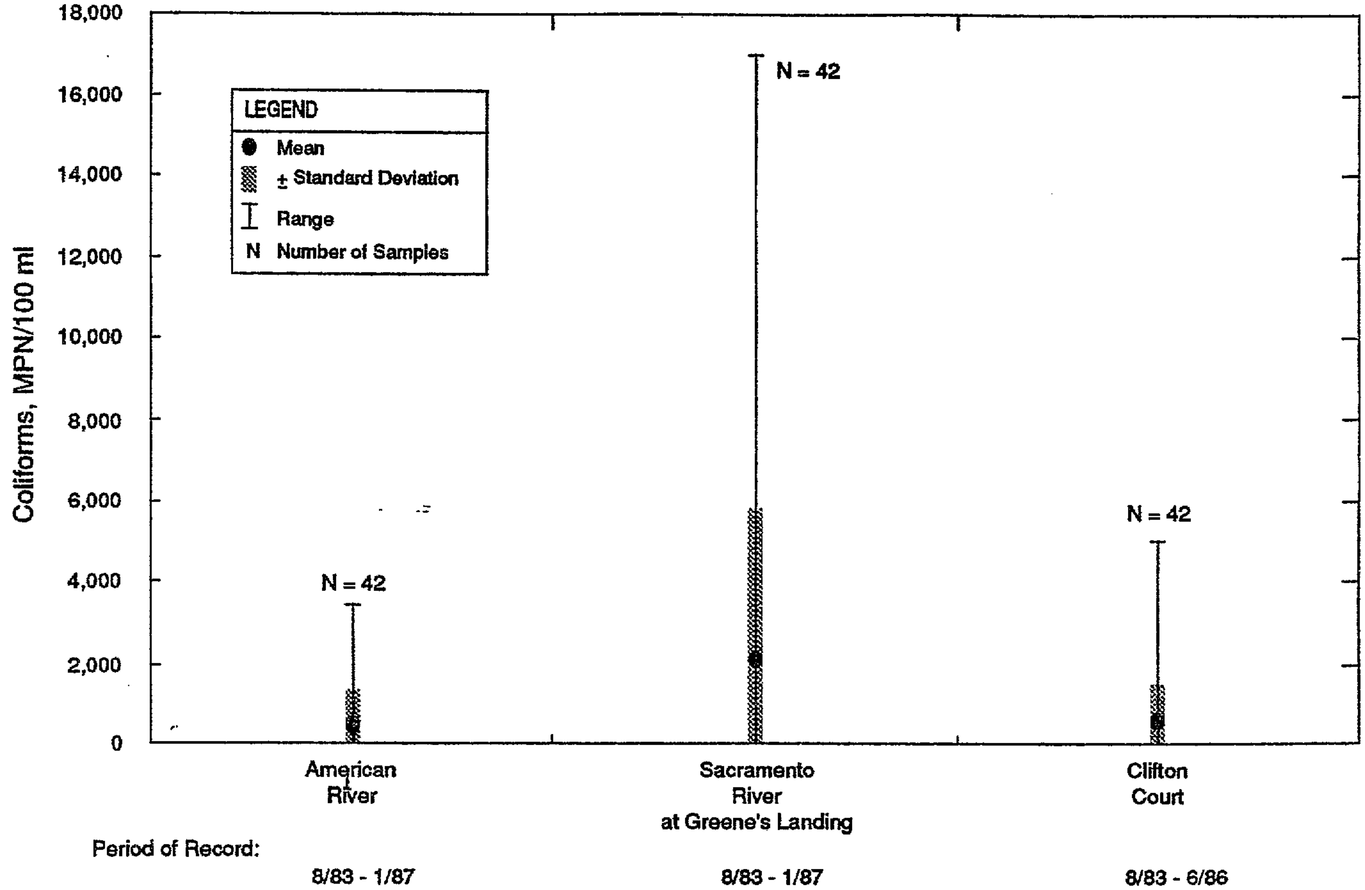


Figure 3-10. Total Coliforms in the Delta Source Waters

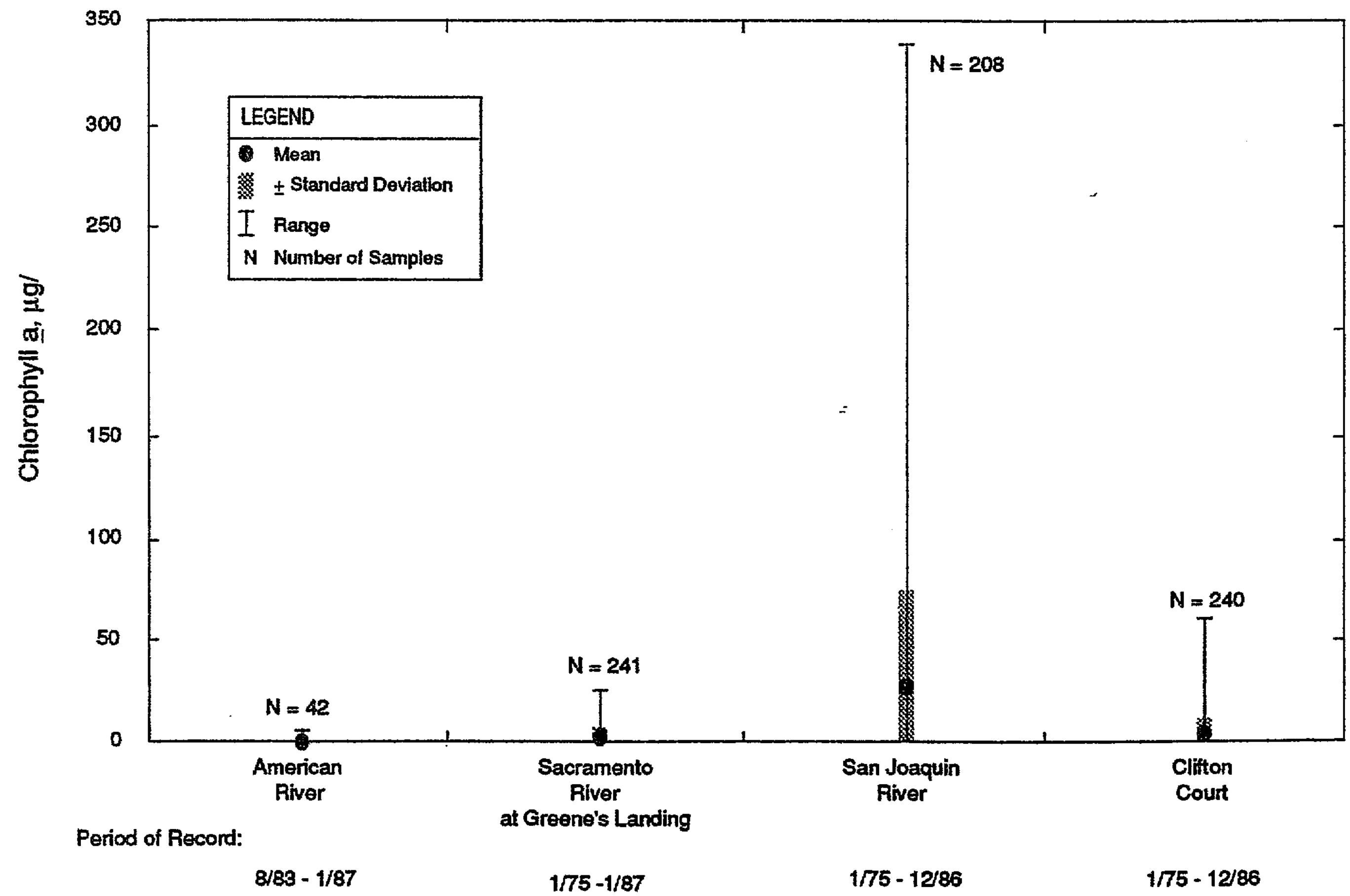


Figure 3-11. Chlorophyll a in the Delta Source Waters

Taste and Odor. Most biological taste and odor problems result from the bacterial degradation of algae, algal by-products, actinomycetes, and other microorganisms. Other sources of taste, odor, and aesthetic problems in drinking water are corrosion products and small amounts of metals, hydrogen sulfides, certain biocides, and some other organics. Consumer piping is the largest source of lead, copper, and corrosion products.

Geosmin and 2-methylisoborneol are commonly detected taste and odor compounds in Delta water supplies. Chlorophyll a is used in this study as a surrogate for predicting taste and odor problems since there are not taste and odor number data or data on the concentrations of taste- and odor-producing chemicals in the various water supply sources. The Santa Clara Valley Water District has noted a direct relationship between chlorophyll concentrations (measured by fluorescence) in Delta water and taste and odor problems in their system. Chlorophyll concentrations in the Delta move rapidly through the South Bay Aqueduct into the treatment systems in Alameda and Santa Clara counties. Drinking water treatment in these areas will be more demanding, and likely more expensive, than in the more southerly urban systems.

Nutrients. Nitrogen and phosphorus are the two nutrients which most often limit algal growth at low concentrations and trigger algal growth at elevated concentrations. Nitrogen is typically the most important in California surface waters. Generally, as nutrient concentrations increase, algal productivity increases, leading to larger algal populations and the problems associated with them. Figure 3-12 shows the total phosphorus concentrations in the source waters and the Delta. As expected, the total phosphorus concentrations in the Feather and American Rivers are low. The highest mean concentration (0.24 mg/l) occurs in the San Joaquin River. This is likely due to the large amount of agricultural drainage that flows into this river. The limited nitrate data that are available show that the American River has the lowest concentrations. The highest concentrations were found at Clifton Court. These data are shown on Figure 3-13.

Summary of Source Water Quality

The previously presented data show that the quality of source water degrades as it flows downstream into and through the Delta. The Feather, American, and Mokelumne Rivers are high quality streams with low concentrations of minerals, nutrients, metals, and organics. The THMFP of these waters is so low that additional treatment for THM or precursor removal is not needed beyond the reduction afforded by conventional treatment to meet the current MCL of 100 ug/l, or a revised MCL of 50 ug/l. With the exception of turbidity and coliform bacteria, drinking water quality standards for the constituents examined in this study, are consistently met in these waters prior to treatment.

The Sacramento River water quality is good, although the constituent concentrations are somewhat higher than in the Sierra streams. Drinking water standards for the constituents examined in this study are consistently met after conventional treatment. Additional treatment for THM removal is not needed for the Sacramento River water withdrawn from the river at Sacramento unless the finished water THM standard is reduced below 50 ug/l.

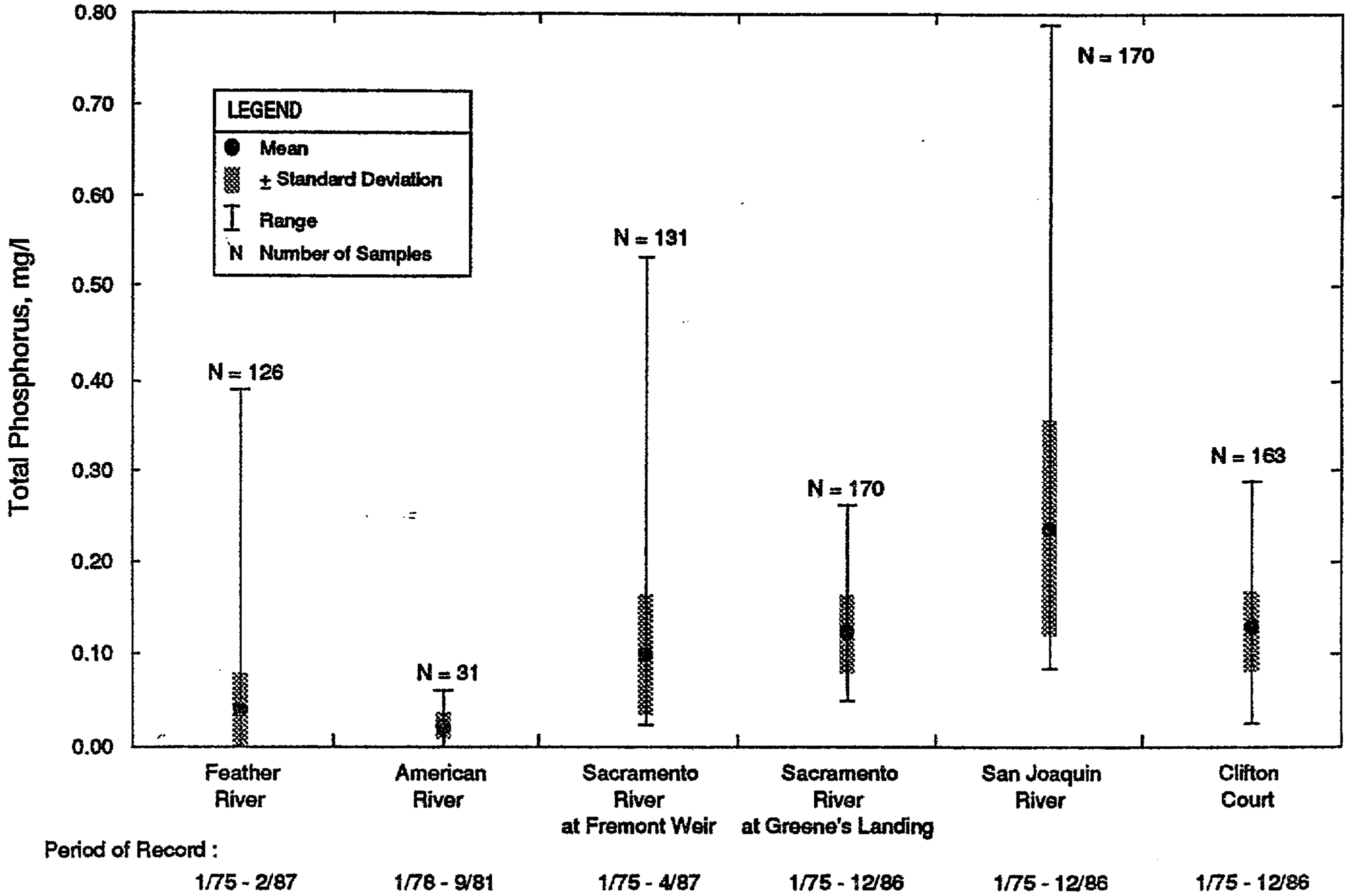


Figure 3-12. Total Phosphorus in the Delta Source Waters

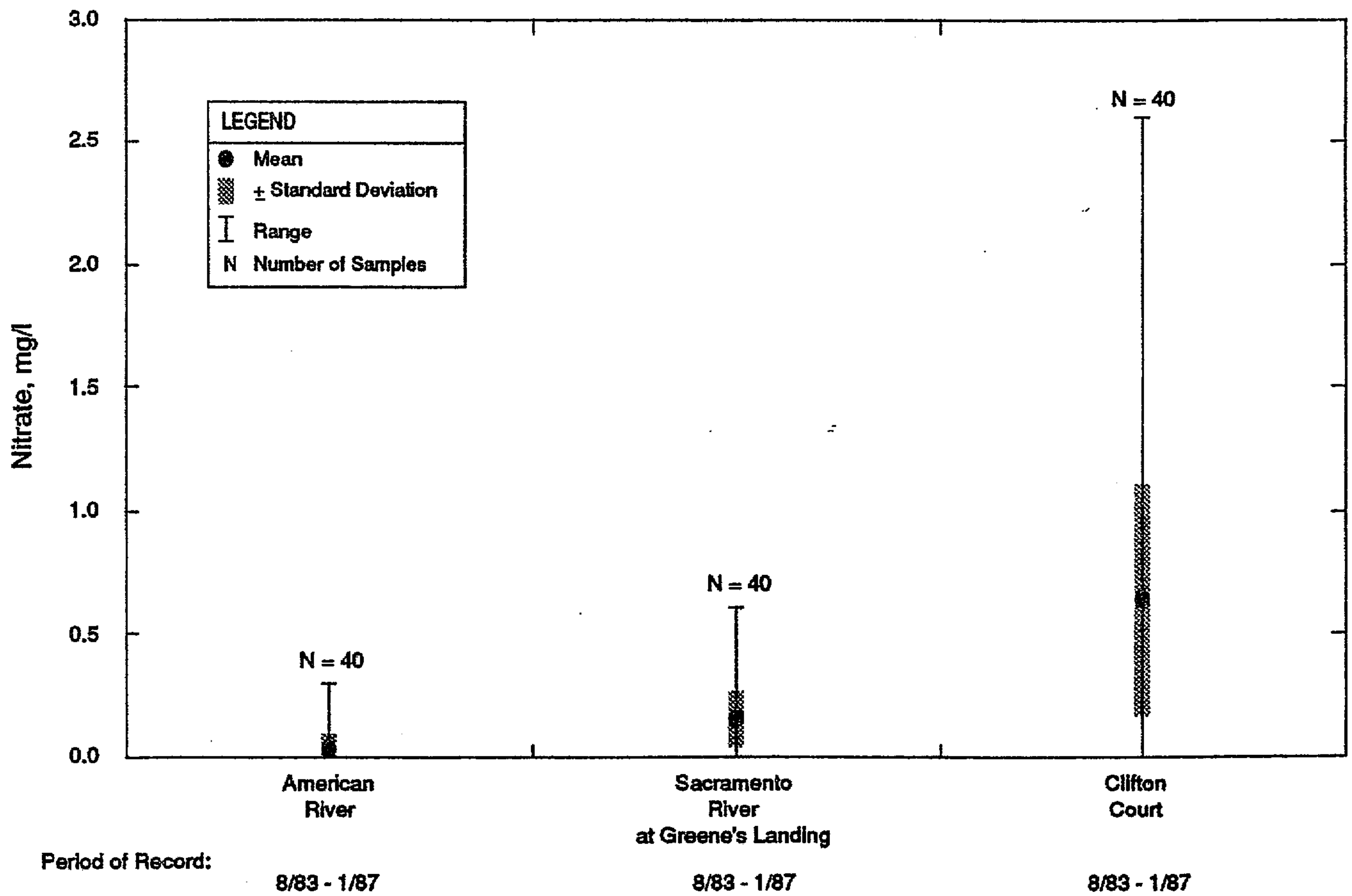


Figure 3-13. Nitrate (as N) in the Delta Source Waters

While waters from the San Joaquin River, Clifton Court, and Rock Slough can be treated to meet drinking water standards, they are of significantly poorer quality than the other waters considered in this study. The Delta water quality varies greatly in response to river flows, seawater intrusion, and agricultural drainage. Water diverted from the Delta requires additional treatment to reduce THMs in finished water to acceptable levels. The drinking water standards for turbidity and coliforms, are frequently exceeded in untreated Delta waters, although conventional treatment controls these constituents. The secondary standards for chloride (250 mg/l) and TDS (500 mg/l) are approached frequently and exceeded occasionally in the raw water supplies. The consumer acceptance levels for these constituents are sometimes exceeded. The NAS recommended criterion of 100 mg/l of sodium for people on moderately restricted sodium diets is often exceeded.

Table 3-4 summarizes the watershed characteristics of the American River, Sacramento River upstream of Hood, and the Delta. This table shows that the American River watershed is relatively small and sparsely developed. As a result, the number of municipal and industrial dischargers is small and pesticide and fertilizer usage is low. Because of these characteristics there is limited potential for contamination of the American River. The Feather and Mokelumne River watersheds are similar in characteristics to the American River watershed. Because of this, these three streams have exceptionally high quality water and relatively low risk of degradation by urban or agricultural activities.

As shown in Table 3-4, the Sacramento River watershed is large and heavily developed. There are a large number of municipal and industrial dischargers. Pesticide and fertilizer usage is two orders of magnitude greater than in the American River watershed due to the extensive amount of agriculture in the Sacramento watershed. As a result of these characteristics, there is greater potential for contamination and degradation of water quality in the Sacramento River than in the American River or other Sierra streams.

The Delta watershed encompasses the greater Sacramento River and San Joaquin River watersheds. It encompasses all of the land tributary to the Delta, and the Delta area itself. As shown in Table 3-4, it has the greatest potential for contamination and degradation of water quality due to the amount of development, number of dischargers, and pesticide and fertilizer usage. In addition, there is a tremendous amount of agricultural drainage that is discharged directly to the San Joaquin River and the Delta. DWR (1987b) has estimated that there are over 260 agricultural drainage discharges into the Delta itself.

There are currently distinct differences in the quality of the Sierra streams, Sacramento River, and the Delta. Although the differences in quality may become even greater in time as the urban and industrial areas of the Sacramento and San Joaquin watersheds continue to grow, it was assumed in this study that Delta water quality would remain substantially unchanged.

Table 3-4. Watershed Characteristics

Description[a]	American River above Nimbus	Sacramento River above Hood	Delta[b]
Watershed area, square miles	1,900	27,000	43,000
Average annual flow, million AF	2.5	21	28
Land developed and suitable for development, percent	2	35	42
Population,[c] thousands	143	1,867	3,767
Population,[c] per square mile	75	69	88
Irrigated agriculture, square miles	16	2,544	6,044
Pesticide use in 1982,			
million pounds	0.14	10.8	30.5
pounds per square mile	74	400	709
Fertilizer use in 1982,			
thousands of tons	2.9	418.9	713.9
tons per square mile	1.5	15.5	16.6
Number of municipal dischargers	1	61	94
Municipal discharges, million gallons per day	1.2	181	256
Number of industrial dischargers	3	75	120
Industrial discharges, million gallons per day	0.5	107	112
Total annual M&I discharges, percent of average annual flow	0.1	1.5	1.5
Recorded accidental spills over a 2-year period (1982-1984)	0	20	24

Source: Okun et al, 1985. Water Quality Considerations in Source Selection.

[a]All characteristics are for land tributary to the locations identified.
[b]This watershed includes the Sacramento River and San Joaquin River watersheds (total land area above Chipps Island).
[c]Population figures were adjusted to 1988 values.

WATER QUALITY CHANGES IN STORAGE AND CONVEYANCE

Water quality is dynamic and will vary with changing environments. The following discussion of water quality changes during storage and conveyance is based on a limited data collection program, a literature review, and basic limnological principles.

Storage

Impoundment of water as a means of providing water storage capacity can lead to changes, some minimal, some significant, in the quality of the stored water. The quality of water stored in reservoirs is less variable than water taken directly from the source of water to the reservoir. An important function of reservoir storage is to eliminate extremely high or low concentrations of water quality constituents in source waters by blending with water in the reservoir. There are a number of factors that affect the quality of water stored in reservoirs. Each is briefly discussed below.

Sources of Supply. The water quality of a reservoir is highly dependent on the sources of supply. Many of the problems associated with storing water in reservoirs are minimized with a high quality source water that has a low mineral, nutrient, and organic content. A high quality source water can be significantly degraded by poorer quality surface streams entering the reservoir, runoff from the watershed, and inflows of mineralized groundwater. The quality of these sources of water is greatly influenced by land use, geology, and soil types in the watershed. EBMUD has found that Mokelumne River water quality is degraded by storage in terminal reservoirs, largely due to lower quality runoff entering the reservoirs. The most important practical impact of this problem is that EBMUD uses direct filtration for its Mokelumne River supply, but must provide full conventional treatment for the supplies which include local runoff.

Thermal Stratification. Temperature-induced stratification of reservoirs commonly occurs during the spring and summer months. In spring, the surface water temperature increases and three distinct layers of water are created; the epilimnion or warm surface water, the hypolimnion or cold bottom waters, and the middle layer or metalimnion where the temperature changes rapidly with depth. During the fall, the reservoir generally mixes from surface to bottom and remains mixed throughout the winter and early spring months. Thermal stratification affects reservoir water quality because it greatly influences the content and distribution of dissolved oxygen (DO) and the distribution of algal nutrients and dissolved metals in a reservoir.

Dissolved Oxygen. The hypolimnion of a thermally stratified reservoir is often depleted of DO. It is cut off from atmospheric oxygen, there is insufficient light for photosynthesis by algae and other aquatic plants which produce DO, and there is a high DO demand from organisms, bacteria, and sediments. If the DO in the hypolimnion drops to zero, anaerobic bacteria begin producing hydrogen sulfide, methane, and ammonia. These gases and their by-products are sources of potential taste and odor problems. Under anaerobic conditions, the insoluble forms of iron and manganese are reduced to soluble forms. During the fall months, when the reservoir mixes to the bottom, the soluble iron and manganese are oxidized and form metal precipitates. These metal precipitates add to the turbidity in the reservoir. If soluble forms of iron and manganese enter a distribution system, iron and manganese deposits can form causing unsightly water and stains on laundry and plumbing fixtures.

A high quality source water is less likely to have these problems than a lower quality source water. With high quality source water there is less likelihood that the DO demand of the hypolimnion will exceed the DO content of the hypolimnion. If the hypolimnion remains aerobic during the summer months, iron and manganese are tied up as insoluble compounds in the sediment and anaerobic bacteria cannot produce the gases that lead to taste and odor problems.

Nutrient Cycling and Algal Growth. Algal growth is most often controlled by the nutrient supply, light, and temperature. In most cases, nutrient (nitrogen and phosphorus) availability is the principle growth-limiting factor. High nutrient loads to water supply reservoirs result in large algal populations. Algal blooms often occur during the late spring or early summer months when light and cold water temperatures are no longer limiting growth. Algal populations generally remain high during the summer months until the nutrient supply is depleted. There is often another algal bloom in the fall when the reservoir is fully mixed. This occurs when the nutrients that have accumulated in the hypolimnion during the summer period of thermal stratification are mixed into the surface waters and made available for algal growth.

Some of the undesirable aspects of large algal populations include increased organic THM precursors, taste and odor problems, increased turbidity levels, and depletion of the hypolimnetic DO. Chlorination of water with high algal levels causes increased concentrations of THMs in the finished water (Walker, 1983). Some of the dissolved organic carbon compounds are THM precursors and some support bacterial growth in treatment plants and distribution systems. This can result in greater chlorine usage to satisfy the chlorine demand and lead to the formation of even higher THM concentrations.

Algal-related problems are diminished with a high quality source water. High quality source waters contain low concentrations of algal nutrients, therefore, algal growth is limited by the nutrient supply.

Turbidity. Previous studies indicate that turbidity can be reduced by 30 to 60 percent by storage in reservoirs (J.M. Montgomery, 1987). Equally important, the extremes of turbidity and other constituents can be leveled out in impoundments. Reduction in turbidity is dependent upon the detention time, other sources of turbidity to the reservoir, the nutrient content/algal population of the reservoir, and thermal stratification of the reservoir. In general, as detention time increases, turbidity decreases due to the settling out of suspended solids. Inflows of highly turbid water, either surface streams or direct runoff, can increase turbidity of the stored water. As discussed previously, nutrient-rich waters can support large algal populations during the summer months, resulting in higher turbidity levels. In reservoirs that are thermally stratified during the summer months, there is less chance that wind will mix the reservoir and result in the resuspension of particulate matter.

However, when the reservoir mixes to the bottom, usually in the fall, turbidity generally increases due to the resuspension of particulate matter, the formation of iron and manganese precipitates, and the fall algal bloom, discussed previously.

Reservoir Characteristics and Operation. Reservoir water quality is a complex function of the morphological characteristics of the reservoir, the watershed characteristics, the source water quality, and the operation of the reservoir. Morphological characteristics which affect water quality include depth, volume, and surface area. In general, a deep reservoir with a small surface area will have better water quality than a shallow reservoir with a large surface area. This is due mainly to the fact that a shallow reservoir with a large surface area has a much greater percent of its total volume in the euphotic zone (zone of light penetration) and, therefore, can support a greater amount of algal biomass.

The manner in which a reservoir is operated can greatly affect the quality of the water. The detention time of the reservoir and the depth at which water is withdrawn are important operational parameters. A reservoir that has a short detention time acts more like a river than a lake. As detention time increases, the reservoir stabilizes and thermal stratification and hypolimnetic oxygen depletion can occur. As discussed previously, the water quality of the hypolimnion can be very different from the epilimnion during the summer months so the depth at which water is withdrawn greatly affects delivered water quality.

Conveyance

Water quality changes during conveyance have not been studied as extensively as water quality changes during storage. J.M. Montgomery (1982) studied changes in conveyance of Delta water in the Contra Costa Canal and South Bay Aqueduct. That study found that there were small changes in water quality in the conveyance systems. Conductivity and TDS showed a tendency to increase slightly, while alkalinity and turbidity tended to decrease during conveyance.

Conveyance in a lengthy, open channel such as the Governor Edmund G. Brown California Aqueduct (California Aqueduct) would be influenced by evaporation, surface runoff, and direct discharges into the aqueduct. Evaporation would tend to slightly increase the TDS of the water. Poor quality surface runoff and direct discharges could possibly increase TDS and nutrients. Runoff containing high concentrations of asbestos has been shown to impact portions of the California Aqueduct below San Luis Reservoir.

Alternatives Comparison

There can be major changes in water quality during conveyance and particularly storage. Numerous factors such as climate, reservoir morphology, watershed characteristics, and the initial quality of the water prior to storage and conveyance affect the final quality of water. In this study, it is not possible to determine the impact of storage and conveyance of water for each alternative. However, it is clear that in general, high quality source water will show less biological degradation during storage and conveyance than a poorer quality source water. Conversely, if higher quality waters are to retain their pristine quality, such sources require more protective facilities and care to guard against degradation by local runoff and intrusion of wastes and pollutants.

CHAPTER 4

ALTERNATIVE CONCEPTS FOR PROTECTION AND ENHANCEMENT OF DRINKING WATER QUALITY

The existing water quality of the Sacramento/San Joaquin Delta (Delta) and its tributary systems has been discussed in Chapter 3. There are a number of alternative concepts that have been considered to further the project objective of protection and/or improvement of the quality of the Delta supplies. These concepts are developed and evaluated in this chapter, and the resultant water quality and costs are presented for each.

THE ALTERNATIVE CONCEPTS

The alternatives presented and analyzed in this chapter were developed in a series of discussions with the study Advisory Committee. The alternatives are representative examples of:

1. Modification of water project operations,
2. minor modifications of water project facilities, and
3. major modifications of water project facilities.

Committee discussions early in the study recognized that an infinite number of systems could be imagined; they identified the selected alternatives based on the following types of considerations:

1. Elimination of features deemed difficult to implement because of large-scale construction impacts through urbanized areas.

2. Limitation of project scope by selecting only one of what might be a large number of similar concepts. An example is the evaluation of conjunctive use involving the New Melones Reservoir. Conjunctive use of surface and groundwaters may have potential for improving firm supply in many areas of the state, but the one representative project was selected for detailed consideration.

3. Duplication of common features was limited; the best example is protection of drinking water quality by elimination of drainage and other contaminant sources from major aqueducts. Such improvements should be made regardless of what other projects may or may not be selected. A better assessment of this issue will be available from the ongoing sanitary survey of the State Water Project (SWP). No estimate of the effectiveness of these corrective measures was made in this study.

4. Integration with independent diversion systems. Some of the alternatives that have been studied could be integrated with the Sierra supplies of the San Francisco Hetch Hetchy system and/or the East Bay Municipal Utility District (EBMUD) system. Some, but not all of the integration possibilities are discussed. Both these major utilities are assumed to have adequate supplies to meet their 2010 demands.

The six alternatives selected for further analysis are presented in an order of progression starting from the currently proposed Delta improvements, and progressing systematically to more elaborate systems to protect drinking water quality. Alternatives which are developed and evaluated are:

Alternative 1. Delta Transfer System Improvements. This alternative represents the North Delta and South Delta improvements currently proposed by the California Department of Water Resources (DWR) to improve Delta hydraulics. These improvements would increase the efficiency of Sacramento River water transfer, provide sufficient capacity to carry increased flows to the state and federal pumps, and improve water quality. This alternative is shown on page 4-19. As a subalternative, the ability of this improved Delta system to support an altered seasonal pumping pattern to yield higher quality water is considered.

Alternative 2. San Joaquin Conjunctive Use Project. In addition to completion of the proposed Delta Transfer System Improvements, large volumes of water from New Melones Reservoir would be used to supply users in the Stanislaus River and Calaveras River Basins during periods of plentiful supply. These users would switch to groundwater for a major portion of their supply during dry years, making New Melones water available for downstream release to the San Joaquin River system during these dry periods. This concept provides further water quality enhancement at the pumps because it would help to maintain water quality in the downstream portion of the San Joaquin River during dry years.

Alternative 3. Delta Agricultural Drainage Management. In this concept, the proposed Delta Transfer System Improvements (Alternative 1) would be supplemented by a system to collect all, or a major portion of, the agricultural drainage from the Delta islands. The drainage would be conveyed to a point of discharge in the San Francisco Bay estuary to eliminate this source of discharge of organic precursors into Delta waters.

Alternative 4. Peripheral Canal. This is the 42-mile-long isolated channel first proposed by the Interagency Delta Committee in 1965, adopted by DWR in 1966, and by the U.S. Bureau of Reclamation (USBR) in 1969. This channel would convey water from the Sacramento River around the Delta, releasing a portion of it for Delta channel flow improvement, and delivering the remaining water to Clifton Court Forebay (Clifton Court), and thence to the Delta pumps. It is assumed that connections would also be made to convey transferred water to the Central Valley Project (CVP) pumps and the Contra Costa Canal. Service to the Contra Costa Water District via the Los Vaqueros project facilities under this alternative and Alternative 5 would require the specific approval of the district's voters. The Peripheral Canal was rejected by California voters by their defeat of referendum Proposition 9 in 1982. Because of that rejection, the Peripheral Canal concept is no longer under consideration by DWR or USBR. This alternative is shown on page 4-48.

Alternative 5. Dual Transfer System. About half of the water being diverted from the Delta would be conveyed through existing channels, and the remainder in this new isolated channel extending from Hood on the Sacramento River to Clifton Court. The high quality Sacramento River water conveyed in this channel would be delivered to Contra Costa Canal and the South Bay Aqueduct. The high quality water conveyed south in the Governor Edmund G. Brown California Aqueduct (California Aqueduct) would be blended in varying proportions with water from the Delta in O'Neill Forebay. This blended water would be delivered to the A. D. Edmonston Pumping Plant. This alternative is shown on page 4-53. A subalternative (termed 5b), shown on page 4-55, would provide a bifurcated transmission system so that only high quality water would be delivered to the A. D. Edmondston Pumping Plant.

Alternative 6. Sierra Source-to-User System. New conveyance facilities would be constructed to convey water for municipal and industrial (M&I) urban water users from the Feather River/Sacramento River confluence via new conduits and an enlarged Folsom-South Canal around the Delta and directly to the Tracy Pumping Plant. The Contra Costa Canal intake would be relocated to the Tracy Pumping Plant. The Delta Mendota Canal and a new canal south of San Luis Reservoir would be used to convey this water south for M&I use, and the SWP facilities would be used for conveying water from the Delta to agricultural users. The Sierra Source-to-User System is shown on page 4-62.

Alternative Delta water improvements considered in this concept-level study are for the primary purpose of improving the quality of urban water supplies. Most of the alternatives considered in this report would benefit agriculture in various ways and degrees. For example, improvement in water mineral quality improves crop growth and reduces leaching requirements and drainage problems. Any isolated transfer facility protects the water conveyed in the event of levee failure and, further, takes some hydraulic (scour and hydrostatic) load off the Delta levees, lowering their maintenance cost and reducing risk of further levee failures.

For each of the alternatives, the following information is presented:

1. A description of the physical facilities and how they would function to improve drinking water quality.

2. The water quality that would result from its implementation and the expected level of treatment that would be required to comply with anticipated drinking water regulations.

3. Preliminary (reconnaisance-level) estimates of costs for construction, operation and maintenance (O&M), and the associated costs for treatment. Also, the economic benefits to consumers of improvements in mineral quality of water are estimated. The future cost to treat water currently diverted from the Delta is also shown.

A section describing treatment needs for each alternative precedes the discussion of the alternatives, and relies on source water quality results presented in the individual discussion of each alternative that follows. This treatment section summarizes the quality of water expected to result from each alternative, which is described in more detail in the individual alternative section, and the required treatment processes to comply with expected drinking water regulations. Treatment costs for various sizes of plants and levels of treatment are given, then using an example of a 200 million gallon per day (mgd) plant, costs per acre-foot (AF) treated are developed for each treatment option. These costs are then used to estimate the total treatment cost associated with each alternative.

METHODS OF ANALYSIS

The assumptions on which the alternatives have been based, and the basis for cost estimating and cost allocation are presented below.

Planning Assumptions

Assumptions for comparing alternatives include:

1. The future needs for water from the SWP and CVP are the same for all water conveyance alternatives. Water demands for the year 2010 (in Chapter 2) are used in these analyses.

2. All alternatives assume that all existing facilities of the SWP and CVP within the Delta are operational, and that the four planned additional pumps have been installed at the Harvey O. Banks Delta Pumping Plant (Delta Pumping Plant) and permitted to operate at the 10,300-cubic-feet-per-second (cfs) capacity of the plant.

3. All alternatives assume that the water supply is adequate to meet all entitled deliveries. Any necessary water sharing, new impoundments, or other facilities necessary for water production or storage, other than for seasonal flow equalization, are considered common to all alternatives and are therefore not included in the cost estimates for the individual alternatives.

4. The alternatives function in concert with existing facilities to form complete water storage and conveyance systems for both M&I and agricultural water. Each alternative assumes the use of existing facilities and incorporates additional features to meet demands appropriate to each alternative.

5. Layout of new facilities, system capacities, and cost estimates are all approximate (reconnaissance level) and will need to be refined in future studies.

6. No assessments have been made of environmental impacts resulting from any of the alternatives. Additionally, no costs have been included for mitigation of environmental impacts except those required for protection of water quality.

Cost Assumptions

Detailed information on the basis of cost estimates presented in this report is included in Appendix D. Cost estimates prepared using that information are tabulated in the discussion of each alternative, and summarized at the end of this chapter. The following succinct statements define the most important cost assumptions and principles used in this work.

1. Cost estimates are for new facilities required for each alternative plus necessary modifications to existing facilities. Neither the capital cost nor the cost of operating and maintaining existing supply facilities is included. These are costs already obligated, and they are common to all alternatives. However, water treatment costs represent all required treatment capacity, i.e., no adjustment is made to account for existing treatment facilities. This differing approach for treatment costs is realistic because: (a) the existing investment in treatment works represents only a small part of the total future cost of treatment; and (b) the economic life of treatment facilities is shorter than that for supply and conveyance works, so the long-term importance of existing investments in treatment works is relatively less significant.

2. All cost data have been adjusted to a common price level equivalent to current (mid-1989) prices.

3. Total cost of each alternative is the sum of the annual cost of capital and the O&M costs. Annual cost of capital is taken as the amortized cost of the project, based on an annual discount rate of 8.0 percent, and an average economic life for each type of facility (30 to 50 years). Estimated construction costs are marked up a total of 40 percent to represent total project capital costs.

4. For facilities which have been studied by the California Department of Water Resources (DWR), the cost data so developed have been used, and were indexed to current price levels. Such data are referenced in the discussions of alternatives.

5. Costs for multiple-benefit facilities have been allocated between urban and agricultural users in a simple but reasonable way. The currently proposed Delta Transfer System Improvements alternative is the least complex and least costly way to meet basic Delta hydraulic requirements and to satisfy demands on all Delta users to effect hydraulic and environmental improvements. Based on the philosophy that all users of water diverted from the Delta should share these basic costs in proportion to their annual water entitlements (in 2010), agricultural entitlement beneficiaries would pay 57 percent of the capital and O&M costs of Alternative 1. All additional costs for all alternatives are allocated to urban water users. This allocation procedure is described in more detail in Appendix D. The allocated costs for all alternatives are tabulated in Appendix D.

DRINKING WATER TREATMENT

A high quality source water is most conducive to consistently and economically producing a high quality drinking water. Alternatives are presented in this chapter to improve the source water quality for Delta diversion to urban water users. However, given the ambitious regulatory schedule for promulgating new drinking water standards, additional treatment of both existing and new source waters will be required for compliance. Treatment is thus discussed in this section in the context of bringing Delta and tributary waters into compliance with anticipated future regulations. This serves as the basis for comparison of treatment requirements and costs among the alternatives. The particular treatment processes appropriate for the water quality of each supply alternative is discussed, and costs associated with each are presented.

Standards and Source Water Quality

The existing and anticipated drinking water regulations that will be set by the Environmental Protection Agency (EPA) and the California Department of Health Services (DHS) are discussed in detail in Chapter 3. Over 100 health-based primary drinking water standards will exist by 1991, with a steady stream to follow. In addition, the list of secondary standards for aesthetic concerns is growing to help guide utilities in providing high quality drinking water to their consumers.

Only a fraction of the contaminants now regulated are found at elevated levels in the Delta and other water sources considered in this study. A somewhat larger fraction will need to be addressed when standards for the currently unregulated contaminants are promulgated. Also, certain contaminants found in these waters have been troublesome because they cause aesthetic impacts. They too must be addressed to meet secondary standards and consumer expectations. Table 4-1 lists the contaminants that are of most concern to urban users of Delta water. Although some contaminants are not currently being regulated, planning for treatment modifications will address future issues and therefore must include them.

Table 4-1. Treatment Concerns for Delta Water Users

Contaminant	Type of standard (existing or anticipated)
Trihalomethanes (THMs) and other disinfection by-products	Primary
Turbidity	Primary
Coliforms and other microbial constituents	Primary
Pesticides	Primary
Chloride	Secondary
Total dissolved solids (TDS)	Secondary
Taste and odor	Secondary
Sodium	--

The level of treatment required for a given water depends on the concentrations of key constituents. Table 4-2 shows the estimated concentrations of several constituents for each alternative and the existing concentrations at Clifton Court. This is a summary table of data which are developed in greater detail in the following sections. In determining the level of treatment required for each alternative, consideration was given to a number of other constituents. The predicted trihalomethane formation potential (THMFP) and the total organic carbon (TOC) concentrations are shown in this table. It was not possible to quantify most of the other organic constituents because there are insufficient data to properly characterize the source waters and predict the water quality as a result of implementing the alternatives. It was not possible to quantify the concentrations of nonconservative constituents such as turbidity, chlorophyll, and total coliforms for example because the concentrations will change substantially between the source and the water treatment plant.

Table 4-2. Average Water Quality Expected to be Achieved by Alternatives

Alternative	THMFP, ug/l		TDS, mg/l	TOC, mg/l
	DWR	EBMUD		
Existing condition (base case)	500	160	240	8
1. Delta Transfer System Improvements	420	130	200	7
2. San Joaquin Conjunctive Use Project	400	120	190	7
3. Delta Agricultural Drainage Management	330	100	160	7
4. Peripheral Canal	310	85	100	6
5. Dual Transfer System				
A. Nonbifurcated	370	110	150	7
B. Bifurcated	310	85	100	6
6. Sierra Source-to-User System	250	65	60	3

Note: These data are mean annual values which are expected at the diversion pumps; they do not show quality variations or account for mitigating effects of storage.

Treatment Processes

While the THM standard is the primary basis of alternative treatment comparison in this report, other drinking water quality concerns, such as taste and odor, mineralization, other disinfection by-products, and agricultural chemicals are also significant. The goal of all urban water utilities is to produce the highest feasible quality drinking water regardless of current standards, while maintaining concern regarding the cost to the users.

Several assumptions were made to select the appropriate treatment processes for alternative water sources. A certain base level of treatment is required given the existing source water and the assumed status of regulations. The utilities who currently withdraw water from the Delta use conventional filtration followed by chlorination. Some of the present users substitute chloramines as a postdisinfectant in lieu of chlorine, in order to meet the current THM standard. Also, irregular addition of powdered activated carbon (PAC) is practiced by many present users for taste and odor control, and some use granular activated carbon (GAC) filter beds for this purpose. These treatment processes are appropriate for current conditions. However, in anticipation of new standards and the possibility of some degradation of Delta water quality, additional or modified treatment processes will become necessary. For the purpose of discussion in this chapter, it is assumed that the 1991 anticipated regulations are in effect and that additional contaminants anticipated for regulation at that time are accounted for in the planning and design of all major treatment plants.

The contaminant currently of greatest concern from a treatment perspective is THMs. Treatment processes will be selected based largely on their ability to reduce THM levels. Since a new THM standard can only be speculated, two targets have been assumed. The first target, 50 micrograms per liter (ug/l), is on the high end of the range discussed earlier, but is realistic to consider. EPA is also considering setting an interim maximum contaminant level (MCL) at this or a similar level, thereby satisfying the pressure to move toward a lower level of THMs without waiting for research to be completed to enable confident further regulation of this and other disinfection by-products. Likely, a different THM standard would then become final when MCLs are promulgated for these other by-products. The second target is 20 ug/l, and is thought to be as stringent as the standard is likely to become, at least in the short range.

All of these water sources suffer at least seasonal or short-term elevation of taste- and odor-causing constituents, and can benefit from an adsorption process or other treatment techniques, such as ozone or Peroxone. Adsorption can take the form of either a simple feed of PAC or installation of GAC in the filters or following filtration. PAC is currently used in most treatment plants using water from the Delta system. It is an effective method of curbing seasonal or erratic episodes of taste and odor, and is expected to continue in this use at many plants. GAC can be more effective for controlling taste and odor, and is the process of choice where it is also needed for another purpose, such as reduction of THMs or other disinfection by-products, precursors, pesticides, volatile organic chemicals or synthetic organic chemicals. PAC also achieves some THM precursor removal, but since it is used sporadically, its net effect on average THM levels is usually small and it is not generally a good process for this purpose.

Treatment plants presented in this report for process and cost planning are assumed to be constructed downstream of the San Luis Reservoir, thereby dampening the peaks in turbidity, bacteria, and other constituents that may occur at the Delta pumps. The degree to which this quality improvement occurs varies seasonally and with location on the various transmission systems. Water quality variations should be studied by each urban user, and on a site-specific basis. Storage to be provided by Contra Costa Water District and for the San Felipe portion of Santa Clara Valley Water District will also dampen the peaks. In some cases, treatment processes might be required for plants close to the Delta that would not be needed at treatment plants further downstream.

This discussion and presentation of treatment processes is ordered from higher to lower water quality and therefore from more basic to more elaborate treatment. Figures 4-1 and 4-2 schematically illustrate six treatment options that are appropriate for the water qualities that would be produced by the alternatives. Table 4-3 describes these treatment options and lists the contaminants each is designed to remove or control. THM precursors, other disinfection by-products, and taste and odor constituents are removed by all options, but to different levels. Table 4-4 shows which of the six treatment options is appropriate for each alternative water source, and will meet the hypothetical future THM standards of 50 ug/l and 20 ug/l.

The wide range of drinking water treatment requirements shown in Table 4-4, provides the basis for comparing the approximate treatment costs for different source waters. Some of the information conveyed by Table 4-4 is obvious; for example, the existing conditions produce water supplies which require the highest level of treatment and will require extensive upgrading of most existing treatment plants as expected drinking water standards are enforced. If the THM standard is reduced to, or below, 20 ug/l, GAC treatment will likely be necessary, in addition to other treatment processes. The proposed Delta Transfer System Improvements will provide only a minor improvement of urban water quality, and this water will, in general, require the same treatment as the existing Delta supplies. Only the alternatives which isolate urban supplies from the Delta (Alternatives 4, 5B, and 6) achieve major quality improvement and reduced treatment. The Sierra Source-to-User System (Alternative 6) would provide the best quality water. All existing conventional drinking water treatment facilities of the major urban water agencies would be suitable for this supply. If the THM standard were lowered to 20 ug/l, addition of ozonation and chloramination to the existing plants would suffice together with PAC (or GAC), as discussed for taste and odor control.

Certain parameters listed in Table 4-1 as being of concern are not addressed by treatment options in this discussion. These include TDS, chloride, and sodium. They are not universally a problem, do not pose a health threat (except for very high or widely varying sodium, as discussed in Chapter 3) and, except for infrequent excursions, are found at levels less than limits of aesthetic acceptability (consumer complaint levels). Further, treatment options for removing them involve expensive and complex demineralization processes such as reverse osmosis and ion exchange. These are not practical given the degree of the problem and the quantities of water involved. The only practical approach to improvement of mineral quality is to pursue a better source water. Several of the alternatives discussed in this chapter could provide such improvement. Even though demineralization is deemed impractical, the cost consequences of providing a highly

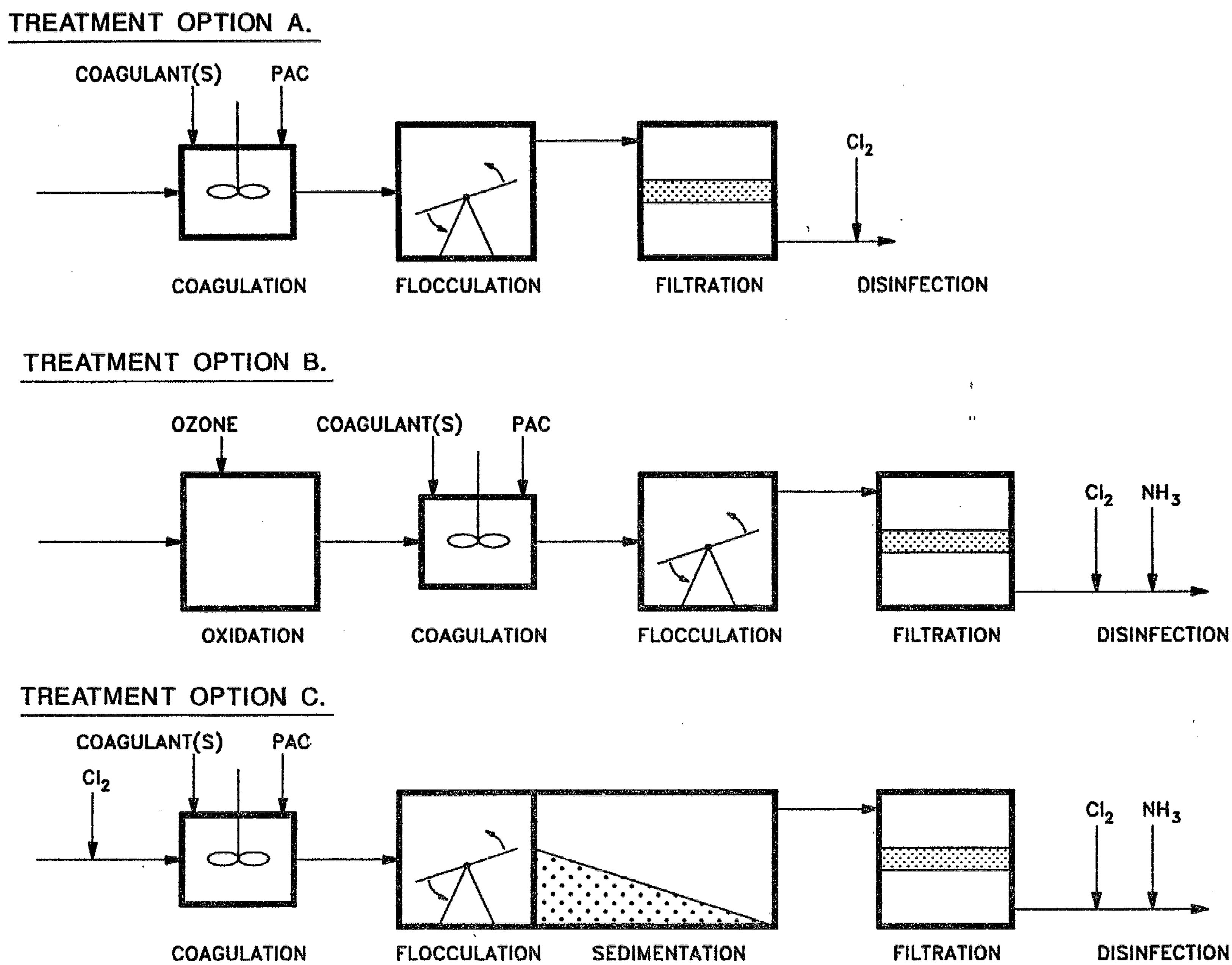


Figure 4-1. Schematic Flow Diagrams for Treatment Options A, B, and C

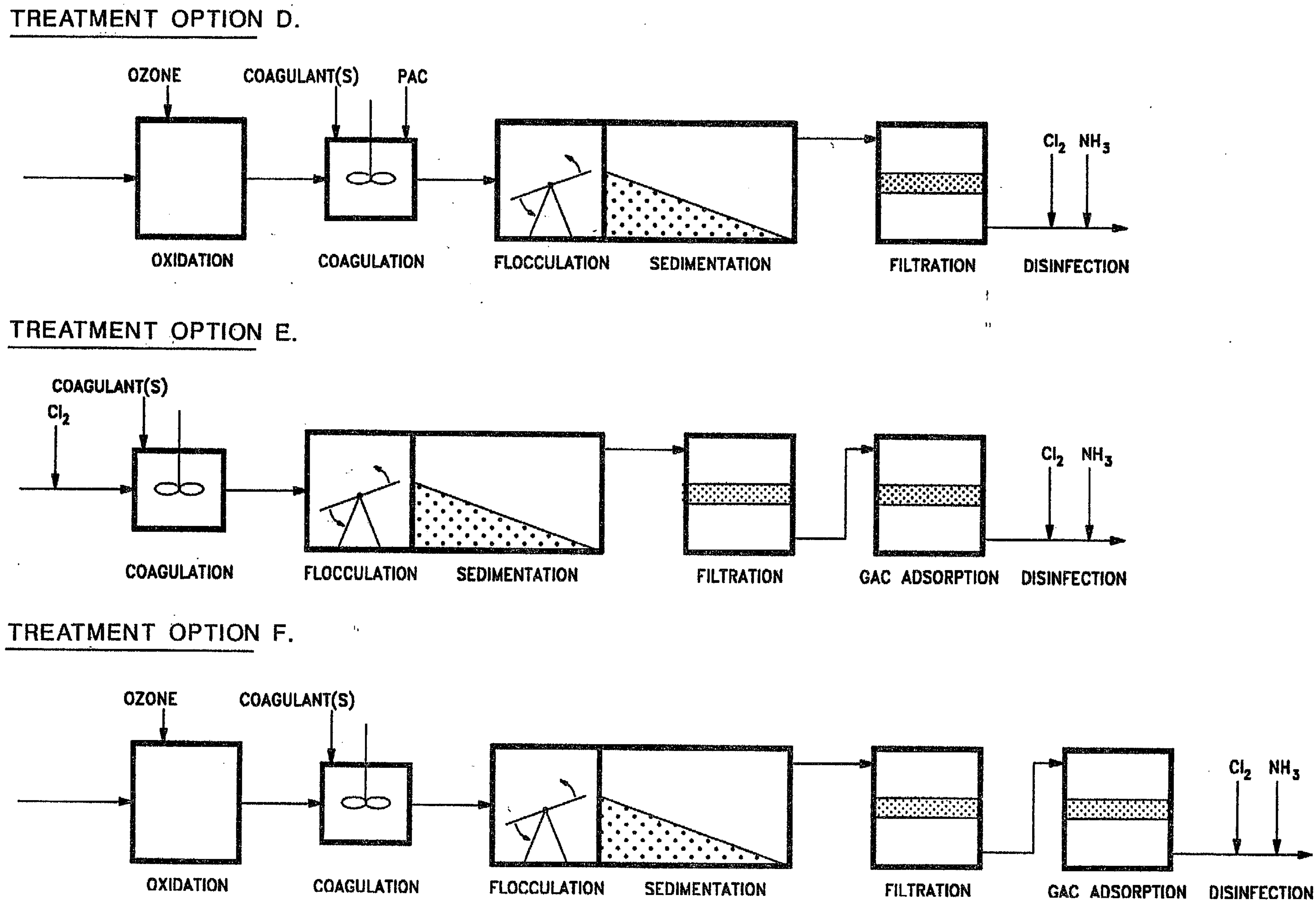


Figure 4-2. Schematic Flow Diagrams for Treatment Options D, E, and F

Table 4-3. Treatment Options

Option	Description	Contaminants removed or controlled
A	Modified direct filtration, seasonal PAC addition, chlorination	Turbidity Microbial constituents Taste and odor
B	Modified direct filtration, ozonation, seasonal PAC addition, chloramination	Turbidity Microbial constituents Taste and odor THM Pesticides
C	Conventional filtration, prechlorination, seasonal PAC addition, chloramination	Turbidity Microbial constituents Taste and odor THM
D	Conventional filtration, ozonation, seasonal PAC addition, chloramination	Turbidity Microbial constituents Taste and odor THM Pesticides
E	Conventional filtration, prechlorination, GAC adsorption, chloramination[a]	Turbidity Microbial constituents Taste and odor THM Pesticides
F	Conventional filtration, ozonation, GAC adsorption, chloramination[a]	Turbidity Microbial constituents Taste and odor THM Pesticides

[a]Regulatory agencies may require chlorination following GAC adsorption.

mineralized urban water supply should be accounted for. This matter is discussed in Chapter 3 where consumer costs are related to TDS concentrations. Such costs are considered in the alternatives comparison given later in this chapter.

Table 4-4. Treatment Options Appropriate for Meeting Hypothetical THM Standards

Alternative	Treatment option[a] THM standard of 50 ug/l	Treatment option[a] THM standard of 20 ug/l
Existing conditions	D	F
1. Delta Transfer System Improvements	D	F
2. San Joaquin Conjunctive Use Project	D	F
3. Delta Agricultural Drainage Management	C	E
4. Peripheral Canal	C	D
5. Dual Transfer System		
A. Nonbifurcated	D	E
B. Bifurcated	C	D
6. Sierra Source-To-User System	A	B

[a]A = Modified direct filtration, seasonal PAC addition, chlorination.
B = Modified direct filtration, ozonation, seasonal PAC addition, chloramination.
C = Conventional filtration, prechlorination, seasonal PAC addition, chloramination.
D = Conventional filtration, ozonation, seasonal PAC addition, chloramination.
E = Conventional filtration, prechlorination, GAC adsorption, chloramination.
F = Conventional filtration, ozonation, GAC adsorption, chloramination.

The following sections discuss the treatment requirements for each alternative. In each case, treatment is selected to meet anticipated drinking water standards. This logical process does not recognize the potential aesthetic, public health, and reliability benefits of using a higher quality source of supply. These benefits are difficult to quantify, but nonetheless valuable.

Alternatives 1 and 2. These alternatives would improve water quality by modifying the existing Delta transfer system. Alternative 1, Delta Transfer System Improvements, would potentially reduce THMFP levels by 15 percent. Alternative 2, San Joaquin Conjunctive Use Project, would not appreciably improve the average Delta water quality over that achieved by the Delta Transfer System Improvements. These Delta modifications would not improve the water quality to the extent that a lesser treatment level would be required than that which is necessary for treating the existing Delta water. Treatment of the existing Delta water is the base case and will have to be done after 1991 when anticipated regulations are promulgated and until such time as an alternative water source can be secured. Treatment Option D, consisting of ozone, conventional filtration, intermittent PAC addition, and chloramination, would be sufficient for treating even the worst Delta water if the THM standard is set at 50 ug/l.

The highest level of treatment would be required for achieving 20 ug/l with existing Delta water. This is Treatment Option F, which replaces PAC with GAC to provide maximum adsorption, and adds oxidation by ozone for THM control. The oxidation process using ozone can potentially be enhanced while reducing the cost by dosing hydrogen peroxide with the ozone. This advanced oxidation process, termed "Peroxone," is currently being researched by the Metropolitan Water District of Southern California (MWD) and others. The results of such research is needed before the process can be confidently assessed and advocated for a large-scale facility.

The treatment options appropriate for meeting 20- and 50-ug/l-THM standards shown in Table 4-4 have been subject to detailed review by the project Advisory Committee. Some of the water agencies may be able to meet a 20-ug/l-THM standard using Treatment Option D (ozone, conventional treatment, chloramine) for existing conditions, as well as Alternatives 1, 2, and 3. GAC treatment (Options E and F) may not be necessary in all cases to meet a 20-ug/l standard unless chloramines are not available as an optional distribution system disinfectant residual. MWD is currently planning to meet a 20-ug/l-THM standard by adding ozonation to its conventional treatment facilities that use chloramines.

Alternative 3. Alternative 3, Delta Agricultural Drainage Management would improve water quality by supplementing the Delta Transfer System Improvements with a system to collect all, or a major portion of, the agricultural drainage from the Delta islands. Treatment Option C would be required for this water quality to meet a target 50-ug/l-THM standard. This includes prechlorination for disinfection, postchlorination, and seasonal PAC addition, in association with conventional filtration. With a 20-ug/l MCL, Treatment Option E, which substitutes GAC adsorption for seasonal PAC addition would be needed.

Alternatives 4 and 5. The Peripheral Canal (Alternative 4) and Bifurcated Dual Transfer System (Alternative 5B) would produce the same quality water. The quality would be lower than the quality produced by Alternative 6. These alternatives, using different methods, bypass the Delta with Sacramento River water, without remixing it with Delta waters. Therefore, the quality concerns arising within the Delta itself are not present. However, the quality of the Sacramento River water at the point of diversion has been reduced from upstream influences causing turbidity, coliform bacteria, THMs, and taste and odor constituents to be found at somewhat greater levels than in Alternative 6. This water would require conventional treatment to remove turbidity and microbial constituents. With conventional treatment, THM precursor removal would occur at a slightly higher efficiency than with a direct filtration system.

Treatment Option C would be required for this water quality to meet a target 50-ug/l-THM standard. This includes prechlorination for disinfection, postchlorination, and seasonal PAC addition, in association with conventional filtration. With a 20-ug/l MCL, however, Treatment Option D, which substitutes ozone for prechlorination, would be needed.

The Dual Transfer System Alternative is also examined without bifurcation of the downstream conveyance system (Alternative 5A). This means that the portion of water routed around the Delta from the Sacramento River would be remixed with some Delta water at O'Neill Forebay. The Delta water quality would be improved over the existing quality because this alternative includes the Delta Transfer System Improvements. This basically yields a diluted Delta water. The constituents in the Delta highlighted in Table 4-1 for treatment will all be present in a diluted state. Additional treatment beyond that required for the bifurcated Dual Transfer System Alternative would be needed.

The water quality of this nonbifurcated alternative would require the same treatment, Treatment Option D, to meet a 50-ug/l-THM MCL as the bifurcated approach required for reaching 20 ug/l. A further modification in treatment would be necessary to meet a 20-ug/l MCL with this water; Treatment Option E substitutes GAC adsorption and prechlorination for ozonation.

Alternative 6. The Sierra Source-to-User alternative would provide the best source water quality. Treatment Option A would be appropriate for this water. Typically, high quality water sources lend themselves to treatment by direct filtration. Direct filtration is appropriate when turbidities are consistently less than about 15 nephelometric turbidity units (NTU) such that a settleable floc cannot readily be formed or when the filters will not be overloaded with coagulated suspended solids. Relatively low color and bacteriological levels are also required for direct filtration. When turbidity excursions occur during runoff periods, as in the case with the source used for this alternative, modifications to the direct filtration mode are necessary. This can be accomplished by including sedimentation basins and operating in the conventional filtration mode seasonally (seasonal direct filtration). The capital cost of such an alterative would not be as great as for a year-round conventional facility because the sedimentation basin would be sized for the lower demand flow of the winter. Alternatively, including other pretreatment steps such as absorption clarifiers or roughing filters could accomplish the same seasonal benefits without incurring the full cost of a conventional plant.

The seasonal direct filtration option is geared to turbidity removal; however, removal of other constituents must be considered. Direct filtration is an acceptable technology for compliance with the DHS surface water treatment rule which is expected to be in effect by the end of 1989. Treatment Option A will effectively remove coliform bacteria and other microbial constituents such as Giardia and viruses.

Postchlorination would be required for disinfection of this water if the THM standard is 50 ug/l. The combination of modified direct filtration and postchlorination with seasonal PAC addition is Treatment Option A. If the THM standard is lowered to 20 ug/l, additional treatment as illustrated by Treatment Option B, would become necessary. THM control would be accomplished by both switching to chloramination to reduce formation of THMs and by ozonation to avoid prechlorination. Ozone has the additional benefits of enhancing flocculation, reducing taste and color, and destroying some other undesirable organics.

Cost Estimates for Treatment

Ranges of construction costs for direct and conventional filtration, ozone, and GAC adsorption are presented in Appendix D on Figures D-3 and D-4. Costs for the treatment options previously presented can be calculated by summing the costs of the individual processes which comprise each option. Costs of chemical feed facilities are relatively small in comparison to these other physical structures and are included in the curves.

For ease of comparison of treatment options, Table 4-5 shows capital and annualized costs for a nominal 200-mgd treatment facility designed to provide each of the treatment options defined here. This size plant was selected to represent a typical regional treatment plant for planning purposes. The trend is toward building larger regional facilities and in the context of showing relative costs of implementing different source water alternatives, this size is appropriate. Unit costs have also been calculated as cost per year per unit of treatment plant capacity, and cost per volume of water treated. Costs for implementing treatment options for different size plants can be estimated using these figures and the cost curves on Figures D-3 and D-4. Treatment costs presented here and in the later analysis of alternatives are total costs; that is, no cost credit is given for existing treatment facilities.

ALTERNATIVE 1. DELTA TRANSFER SYSTEM IMPROVEMENTS

This group of improvements is based on the Delta Transfer System Improvements being considered by DWR as described in the report California Water: Looking to the Future (DWR, 1987c), and previously in the report Alternatives for Delta Water Transfer (DWR 1983). These proposed improvements include North Delta facilities to increase the efficiency of Sacramento River water transfer and South Delta facilities to provide enough capacity to carry increased flows to the pumps.

The Delta Transfer System Improvements would improve Delta water quality by reducing the reverse flow that carries western Delta water to the pumps. This reduction of reverse flow would improve water quality by reducing the ocean-derived salts, including bromide which contributes to THM formation. Drinking water quality related to THMFP and other constituents that are impacted by agricultural drainage originating within the Delta would depend on the extent to which the transfer improvements reduce the exposure of transferred water to the effects of Delta agricultural drainage.

Table 4-5. Treatment Costs for a 200-mgd Plant

Treatment option	Treatment process	Cost, million dollars				Total unit cost	
		Capital[a]	Annualized capital[b]	Annual O&M	Total annual	Dollars/year/mgd[c]	Dollars/AF[d]
A	Modified direct filtration, PAC addition, chlorination	77	6.8	6.1	12.9	65,000	96
B	Modified direct filtration, ozonation, PAC addition, chloramination	99	8.8	9.6	18.4	92,000	137
C	Conventional filtration, prechlorination, PAC addition, chloramination	84	7.5	6.5	14.0	70,000	104
D	Conventional filtration, ozonation, PAC addition, chloramination	106	9.4	10.0	19.4	97,000	144
E	Conventional filtration, prechlorination, GAC adsorption, chloramination	168	15.0	16.5	31.5	158,000	234
F	Conventional filtration, ozonation, GAC adsorption, chloramination	190	16.9	20.0	36.9	185,000	275

[a]Capital costs include a 40 percent markup for contingencies, engineering, and administrative costs.
[b]Annualized capital costs are based on 8 percent annual interest rate and 30-year economic life.
[c]Total annual cost per unit of treatment plant capacity.
[d]Based on annual production of 60 percent of plant capacity.

Note: All costs are based on a USBR Composite Trend Index of 160, representing projected construction costs for mid-1989.

Physical Improvements

The North Delta alternatives upon which this analysis is based include: (1) enlarged North Delta Channels, including the South Fork of the Mokelumne River channel, and (2) New Hope Cross Channel (or alternative), including enlarged channels. The North Delta alternatives have optional features to increase flow capacity (a pumping plant, tidal flow controllers, weirs, and control structures). Some alternatives to these North Delta improvements are being considered by DWR, as described below.

The South Delta alternatives include: (1) dredged and enlarged South Delta Channels, (2) channel flow control structures, (3) relocation of the Contra Costa Canal intake; (4) changes to Clifton Court, including a new intake gate or relocation of the intake and enlargement of the forebay; and (5) interconnection of the CVP with Clifton Court. The North and South Delta alternatives are described in more detail below. Figure 4-3 shows the facilities included in this alternative.

North Delta Alternatives. To reduce reverse flows in the Delta, transfer efficiency must be increased in the northern Delta. Water is presently transferred from the Sacramento River to the central Delta through the Delta Cross Channel and Georgiana Slough. The capacity of these two channels is limited. During low-flow periods, additional water must continue on down the Sacramento River into the western Delta and then back upstream in the lower San Joaquin River (reverse flow), where it blends with the cross-Delta flow on the way to the SWP and CVP pumps.

Reverse flows in the lower San Joaquin River require additional Delta outflow to maintain the same level of water quality. This additional Delta outflow is called carriage water. Carriage water is provided by releases from upstream CVP and SWP reservoirs that would otherwise not be needed to maintain the California State Water Resources Control Board's (SWRCB) mandated Bay/Delta quality standards. The need to provide carriage water reduces project yield. An improved transfer capacity would conserve a considerable amount of water by reducing carriage water needed to maintain quality in the western Delta and at the pumps. Enlargement of Georgiana Slough or the South Fork of the Mokelumne River would increase North Delta transfer capacity.

Enlarging the South Fork of the Mokelumne River was selected for first-stage improvements by DWR because it requires fewer levee setbacks and would be less costly than enlarging the other two channels. The cross section of the South Fork of the Mokelumne River would be increased to about 8,000 square feet by levee setbacks (up to 200 feet) from Dead Horse Cut to Hog Slough, and channel dredging from Dead Horse Cut to Terminous. Following improvements to deepen and widen the South Fork of the Mokelumne River, the expanded channel would be operated to determine to what extent channel improvements alone are effective in eliminating the reverse flows. After evaluating that operation, the need for any other improvements would be determined, including a new channel connecting the Sacramento and Mokelumne River systems or some other alternative.

If, after evaluating the operation of first-stage improvements, it is determined that the reverse flows are not eliminated, the New Hope Cross Channel would be the most

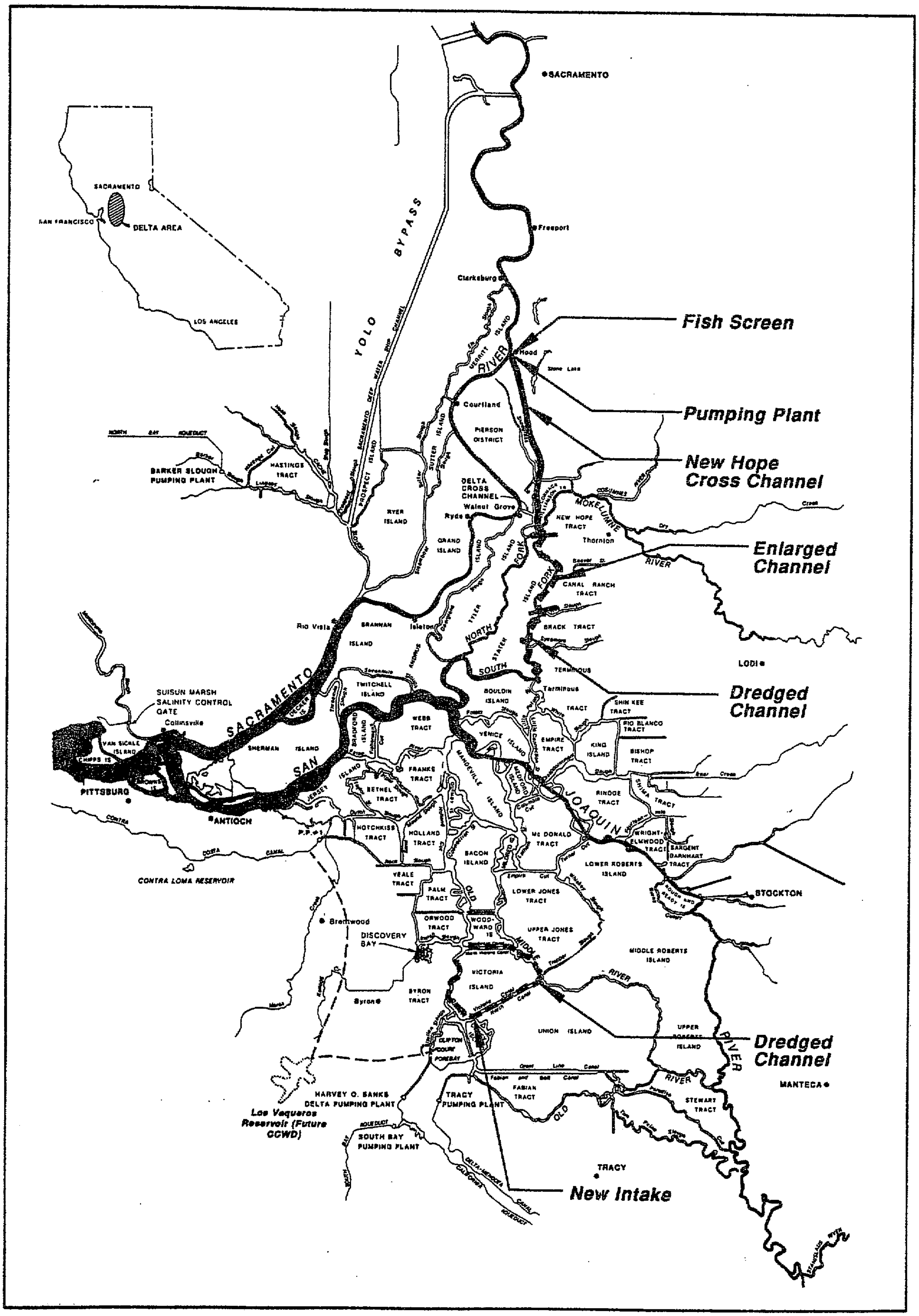


Figure 4–3. Delta Transfer System Improvements

likely alternative means of completely eliminating reverse flows. The New Hope Cross Channel consists of a new channel from the Sacramento River at Hood to Dead Horse Cut. Water would be discharged into the South Fork of the Mokelumne River below Dead Horse Cut. Another possible option is construction of flow control structures on the Sacramento River system near the Delta Cross channel.

It has been assumed that the New Hope Cross Channel would be constructed and would have a cross section of about 8,000 square feet. An 8 to 1 slope between high and low water levels would control wave wash, provide beaches, and save the cost of riprap or other slope protection. Automated controls would be added to the Delta Cross Channel to prevent transferred flows from returning to the Sacramento River during certain phases of the tide. A fish screen would also be built at the new intake at the Sacramento River, if needed.

The DWR (1988a) report, North Delta Water Management Program updates earlier planning work and describes a North Delta Transfer System that varies from the system described in previous documents (and used in this report). The new alternatives would be constructed in three phases. The first phase would include channel improvements to the South Fork of the Mokelumne River. The second phase, if determined to be necessary, would include tidal control structures on the Sacramento River downstream of the Delta Cross Channel and on Steamboat Slough. The planning indicates that these structures would eliminate the need for a new pumping plant. The third phase, if needed, would include construction of a Sacramento River Connecting Channel, which would have an alignment similar to the New Hope Cross Channel, but be closer to Snodgrass Slough, and would terminate at the Delta Cross Channel. No construction cost estimates were included in the DWR planning report for these improvements; total costs are not expected to differ markedly from the cost data used in this report.

South Delta Alternatives. South Delta channels have historically been sized to contain only flood and tidal flows, so the amount of water than can be pumped from the South Delta without eroding the channels and levees is limited. Clifton Court was built to allow water to be drawn into the forebay during periods of the tidal cycle when channels would not be scoured and drawdown of water levels in the channels would be minimized. Pumping can then be accomplished during both off-peak, and on-peak power periods.

The existing combined CVP/SWP pumping capacity is about 11,000 cfs (6,400 cfs SWP and 4,600 cfs CVP). Channel scouring occurs near the intake to Clifton Court during low San Joaquin River inflows at pumping rates above 11,000 cfs. This is a capacity constraint which prevents the SWP from using its full delivery capability of 10,300 cfs for capturing surplus winter and wet-year flows for surface and groundwater storage south of the Delta. Additional storage south of the Delta (e.g., Kern Water Bank, Los Banos Grandes Reservoir, and, prospectively, the Los Vaqueros Reservoir of the Contra Costa Water District) would also provide added SWP operational flexibility that could be used to improve project yield and help protect the Delta fishery.

A wide variety of alternatives has been considered to increase South Delta diversion capacity. Dredging existing South Delta channels is presently the preferred option. Channel improvements in Old River, Middle River, and Victoria Canal near Clifton Court Forebay, and increased inlet capacity from these channels into the forebay, would be required. These improvements would be constructed in conjunction with the first stage of the North Delta facilities.

A new intake structure with a peak capacity of 8,000 cfs would be built on the northeast corner of Clifton Court. The new intake would increase the average daily diversion capacity of the SWP by 4,000 cfs. The existing intake to Clifton Court would still be used. Four additional pumps are assumed in this analysis to have been installed at the SWP's pumping plant.

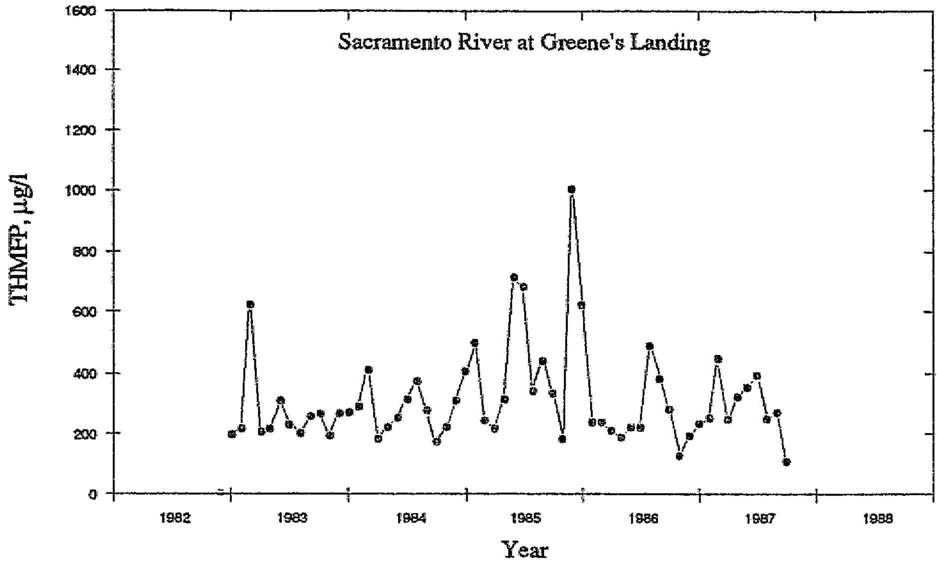
Seasonal Pumping Subalternative

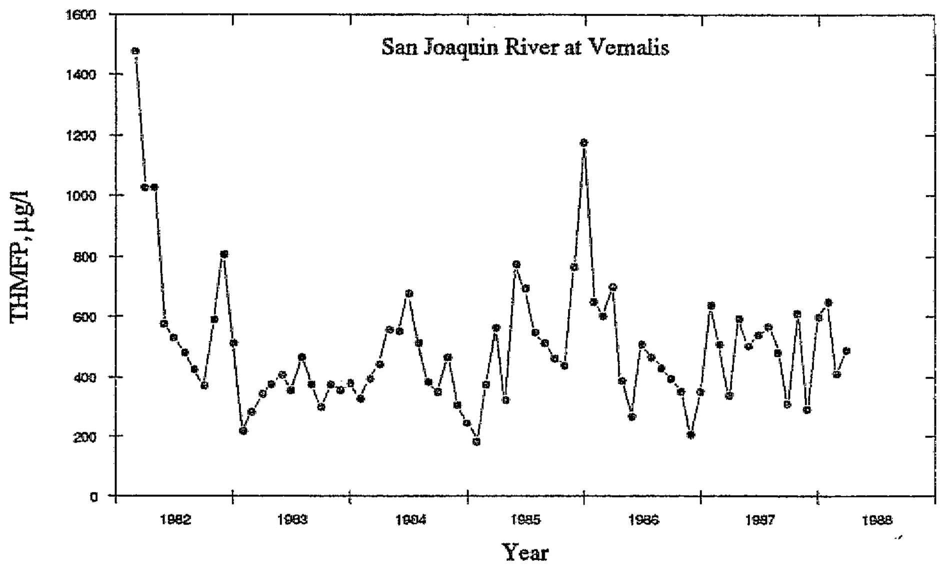
Modification of the seasonal diversion schedule to maximize water quality was examined as a possible subalternative in conjunction with the Delta channel improvements described previously. The current operation of the SWP maximizes diversions of unregulated Delta flows for storage south of the Delta in San Luis Reservoir. Unregulated flows are those flows in excess of Water Rights Decision 1485 (D-1485) outflow requirements. They generally occur from October to June and are greatest from December through March. Maximum diversion of unregulated flows minimizes carriage water requirements during regulated summer and drought flow periods. This allows conservation of water in storage in CVP and SWP reservoirs for later release during dry and critical years (DWR, 1986b).

The objectives of this analysis were to determine (1) if there are seasonal differences in water quality in the source waters and (2) if operational modifications could be made to take advantage of the seasonal differences and enhance the drinking water quality of the supplies. The water quality data on the Sacramento River at Greene's Landing, the San Joaquin River at Vernalis, and Clifton Court were examined to determine if there are distinct seasonal differences in quality. Figures 4-4 and 4-5 present the THMFP (DWR) and TDS data for the three locations. As shown on these figures, there are tremendous variations in both of these constituents. The effect of the 1976-77 drought can clearly be seen in the TDS data from the San Joaquin River and Clifton Court. The TDS variations in the Sacramento River are minimal compared to the other two locations. A distinct seasonal pattern does not occur for either of these constituents at any of the three locations.

For the purpose of this analysis, the wet season was defined as October through March and the dry season was defined as April through September. The source water quality data described in Chapter 3 were analyzed to determine if there are differences between the wet-season and dry-season mean concentrations. Appendix C contains tables summarizing these data. For many constituents there were no significant differences between the wet-season and dry-season mean concentrations. For several constituents the wet-season mean concentrations were higher and for some constituents the dry-season mean concentrations were higher.

The data for a number of constituents were then examined on a monthly basis to determine if there were months when the water quality conditions were better than others. As shown on Figures 4-6 and 4-7, monthly analysis of THMFP (DWR) and TDS data





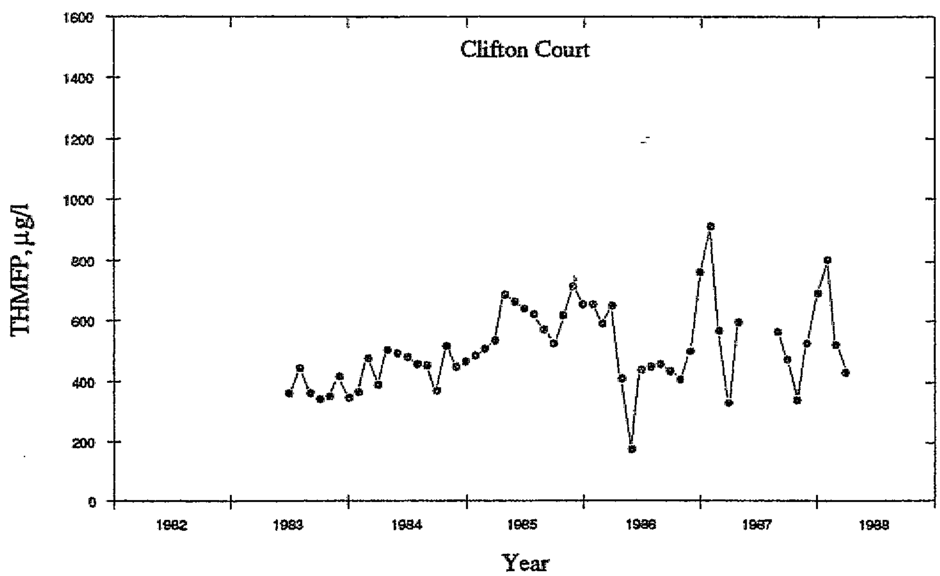


Figure 4-4. THMFP (DWR) in Delta and Source Waters

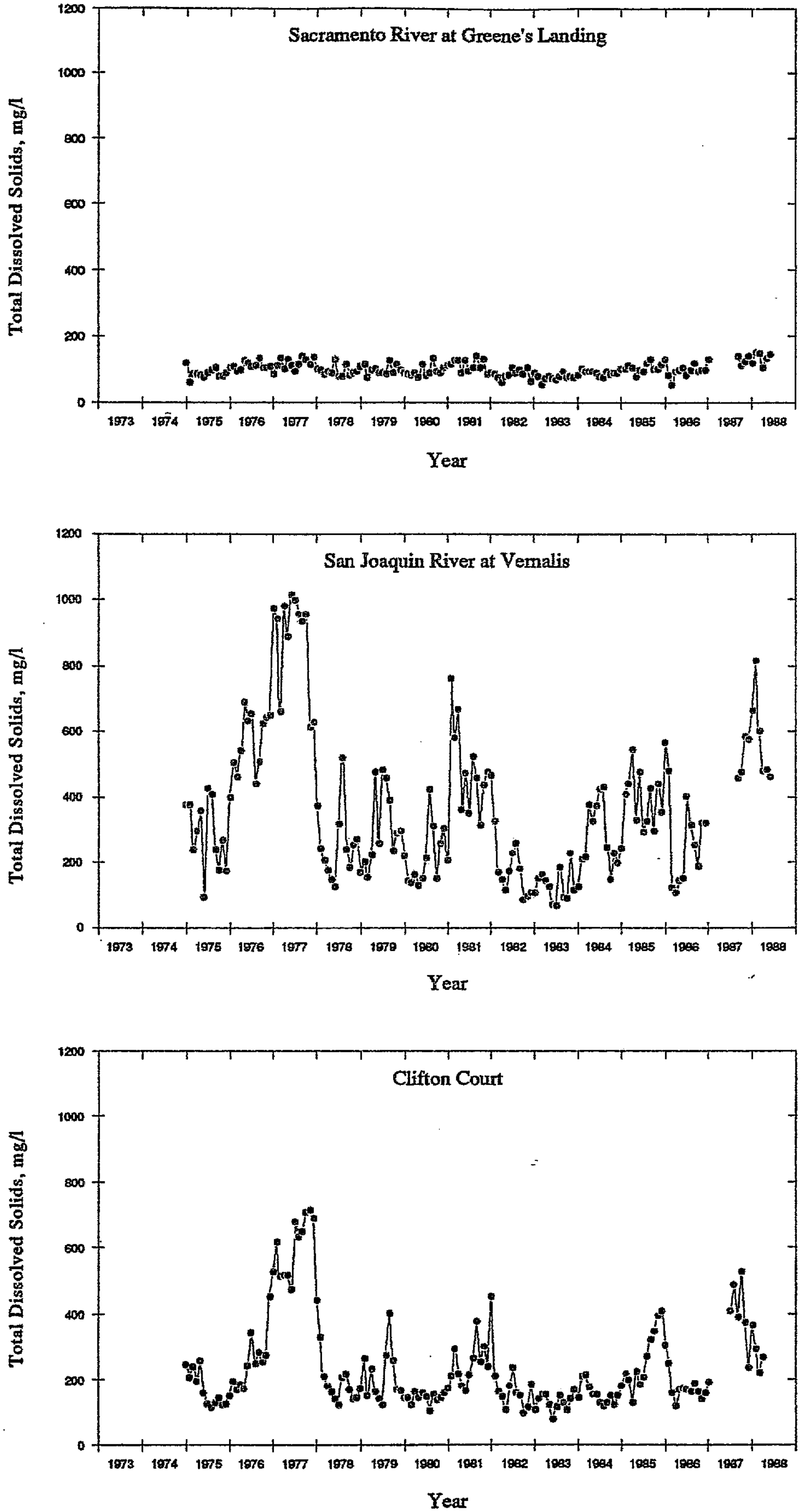
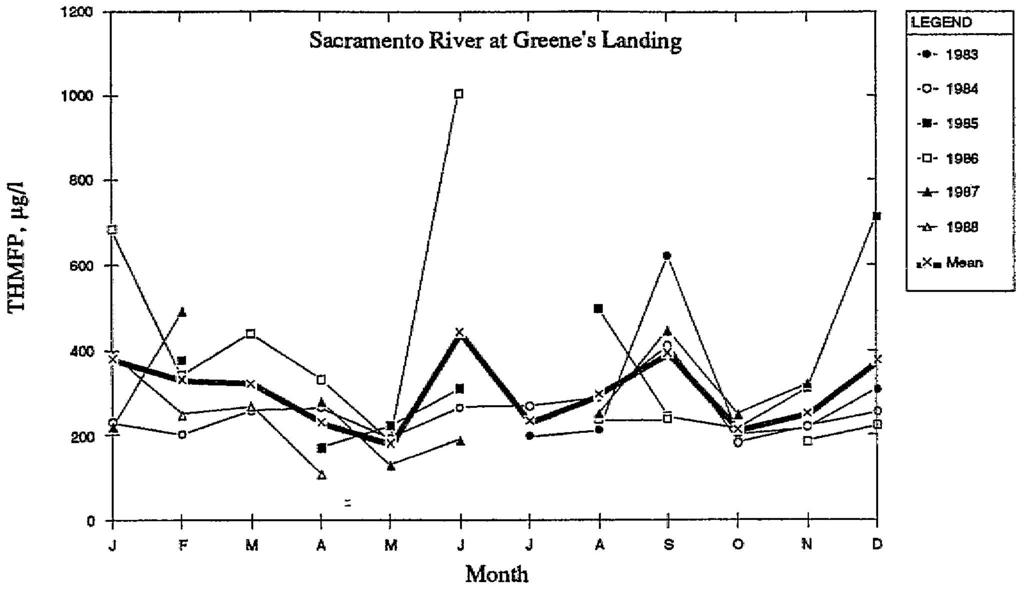
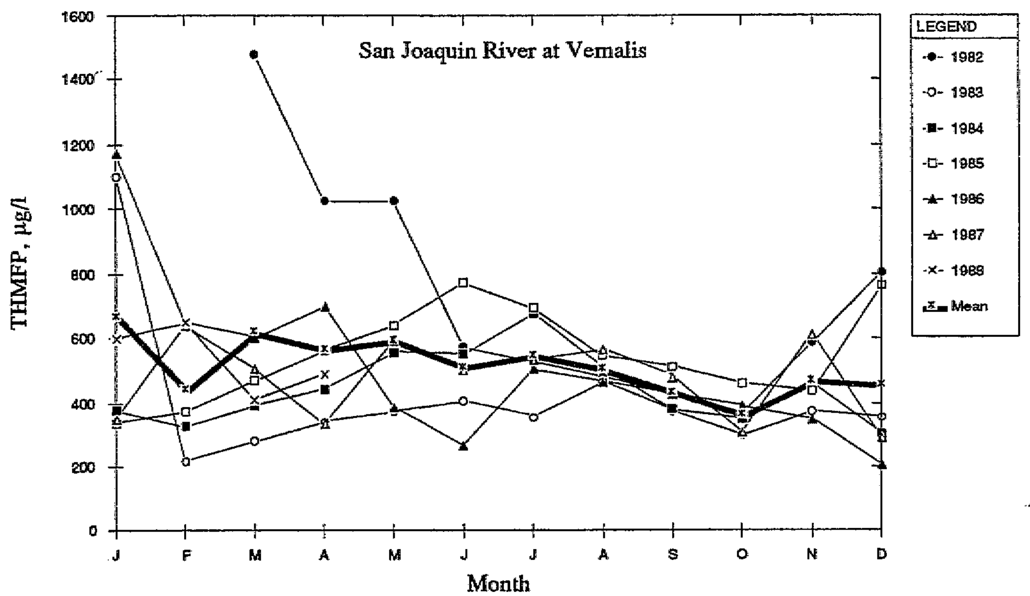


Figure 4-5. Total Dissolved Solids in Delta and Source Waters





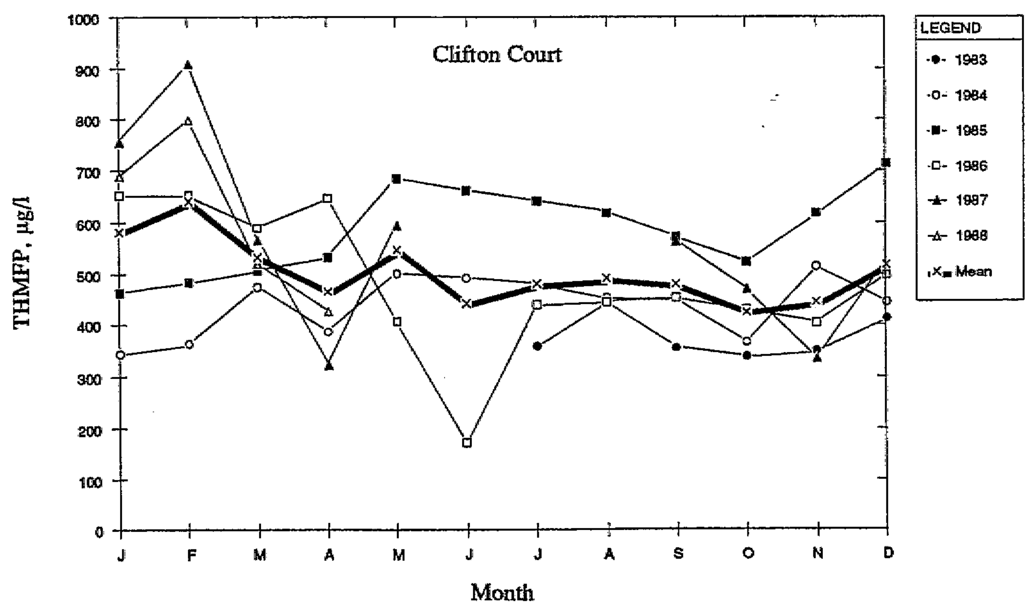


Figure 4-6. Seasonal Analysis of THMFP (DWR) Data

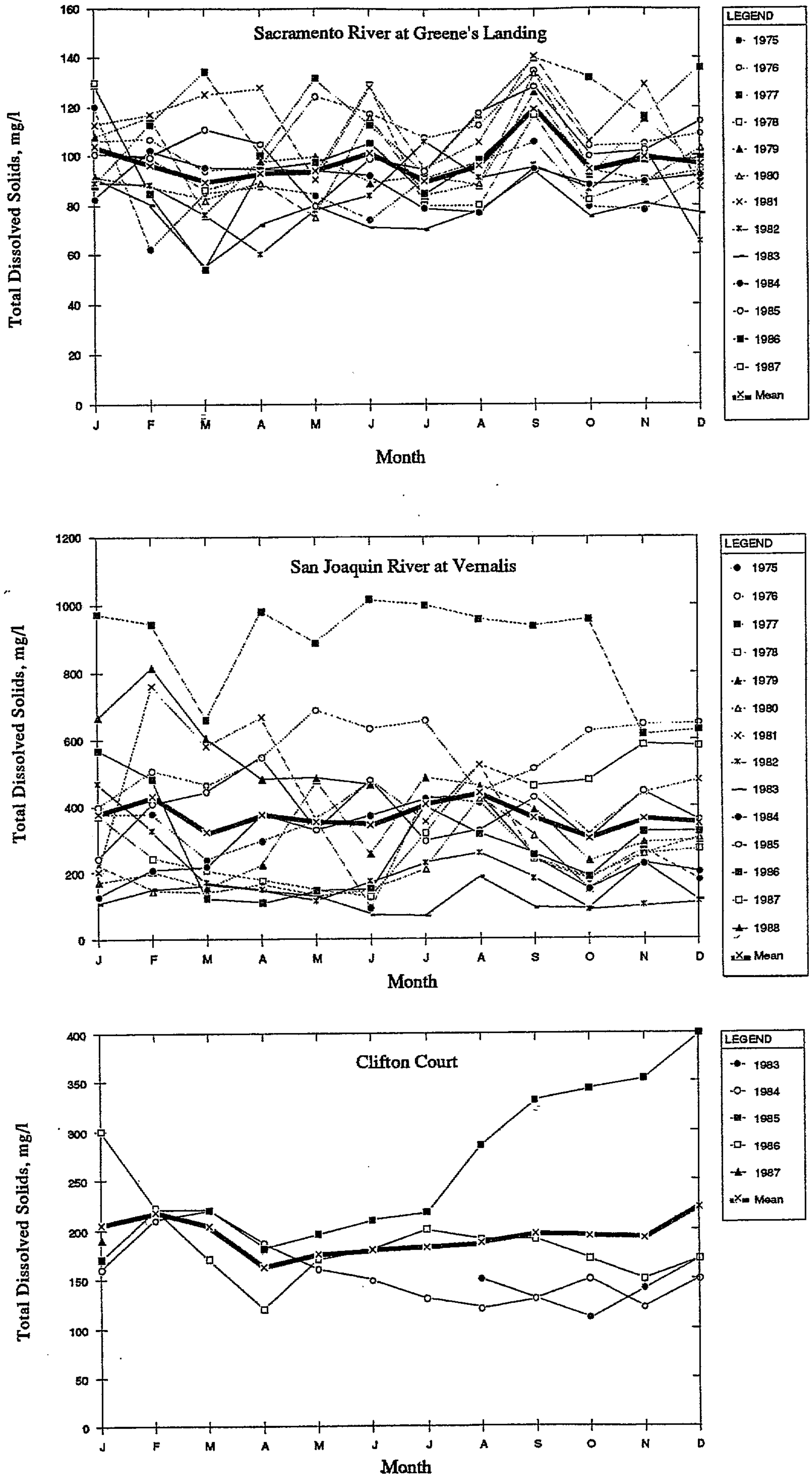


Figure 4-7. Seasonal Analysis of Total Dissolved Solids Data

showed there were no distinct periods of high quality water that occurred routinely or frequently.

The TDS and daily flow data on the Sacramento River at Greene's Landing are shown on Figure 4-8. These data were analyzed to determine if there is a relationship between flow and water quality that would be amenable to operational modifications. These data show that at extremely high flows, the TDS concentration decreases dramatically and at very low flows, such as occurred during the 1976-77 drought, the TDS concentration increases greatly. From a practical standpoint, there are no periods of high quality water that would be conducive to operational modifications. This subalternative was therefore not analyzed further.

Water Quality Improvement

To estimate the drinking water quality improvement that would result from this alternative, the following assumptions were made:

1. The TDS and chloride concentrations estimated to result from this alterative by DWR (1983) are reasonable.

2. The percent reduction in THMFP (DWR), THMFP (EBMUD), and TOC would be roughly equal to the percent reduction in TDS.

Table 4-6 presents the estimated concentrations of several key water quality constituents. These concentrations are compared to the existing quality at Clifton Court and Rock Slough to show the expected improvement in water quality that could be achieved with this alterative. These data show that on an average annual basis there would be some improvement in water quality. The mean THMFP (DWR) concentration would be reduced to 420 ug/l and the THMFP (EBMUD) concentration would be reduced to 130 ug/l. Based on the experience of EBMUD, the distribution system THM concentration would be equal to 50 to 70 percent of the THMFP (EBMUD). Using this assumption, the average distribution system THM concentration would be reduced to 65 to 90 ug/l with this alternative. At these concentrations, the current standard of 100 ug/l could be met without further treatment but the more stringent anticipated standard probably could not be met without additional treatment.

The 85 percentile values shown in Table 4-6 represent the mean concentrations plus one standard deviation (approximate). These concentrations provide a practical estimate of the upper range of concentrations that would occur with this alternative that would impact facilities design. The 85 percentile values show that the variations in concentrations of the key constituents would be less than the current variations in quality. With this alternative, the predicted 85 percentile value of THMFP (DWR) is approximately equal to the existing mean concentration. The 85 percentile values for the other constituents shown in the table fall between the existing mean and 85 percentile values.

The Delta Transfer System Improvements would improve water quality conditions at the pumps because, due to current channel capacity constraints, some water must flow down the Sacramento River into the western Delta. It then flows back upstream in the San

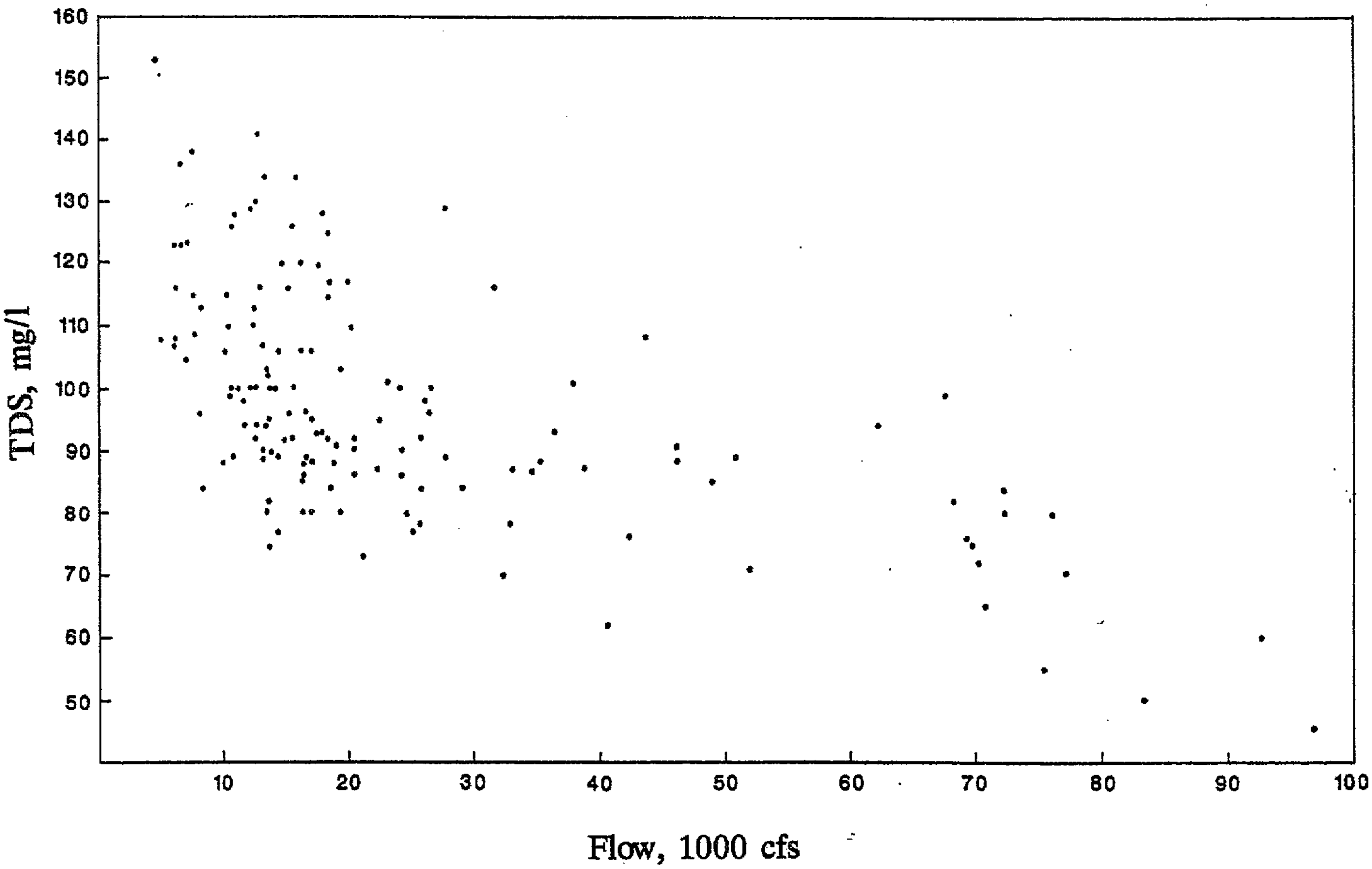


Figure 4-8. Relationship Between TDS and Flow in the Sacramento River at Greene's Landing

Joaquin River where it blends with the cross Delta flow on the way to the pumps. The TDS content of the water increases as it flows through the western Delta due to seawater intrusion. With the channel improvements, all of the water would flow directly to the pumps without flowing through the western Delta. This would result in lower concentrations of chloride and bromide in addition to TDS and THMFP. The reduction in bromide would result in the formation of fewer brominated THMs in the distribution system. Treatment Options D or F would be required to bring water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 or 20 ug/l.

Table 4-6. Comparison of Water Quality With Delta Transfer System Improvements to Existing Water Quality

Constituents, units	Estimated water quality		Existing conditions: Clifton Court		Existing conditions: Rock Slough	
	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	420	540	500	640	480	610
THMFP (EBMUD), ug/l	130	170	160	200	-	-
TDS, mg/l	200	320	240	380	240	390
TOC, mg/l	7	11	8	12	-	-
Chloride, mg/l	50	100	65	130	60	130

[a]85 percentile value is the mean plus one standard deviation.

Cost Estimates

Capital costs for improvements associated with the Delta Transfer System were estimated by DWR in the report Alternatives for Delta Water Transfer (DWR, 1983). Adjusted to mid-1989 dollars, an estimated $380 million would be required to construct North Delta improvements, and $45 million to construct South Delta improvements, for a total of $425 million (capital cost) at the current (1989) price level. M&I water users would be responsible for $183 million of the total cost. These estimates include costs associated with levee and channel improvements, but do not include any costs for O&M of new facilities. For the purposes of this study, annual O&M costs were assumed to be equal to approximately 1.5 percent of the construction cost (approximately 1.1 percent of total capital cost). Therefore, the annual O&M cost for these new facilities is estimated to be $4.6 million. The M&I portion of this annual O&M cost would be $2.0 million. The energy costs of the Delta improvements are estimated to be $0.45 million per year. The M&I portion would be about $0.19 million per year. Table 4-7 presents a summary of the major cost items for this alternative.

The estimated treatment cost to comply with anticipated drinking water regulations is $144/AF or $464 million/year (Treatment Option D), if the THM standard is set at 50 ug/l, or $275/AF or $882 million/year (Treatment Option F), if the THM standard is set at 20 ug/l. The treatment costs presented in Table 4-7 were calculated by multiplying treatment costs for a 200-mgd plant, presented previously in Table 4-5, by 3.2 million acre-feet/year (AF/yr), the total amount of water to be treated in 2010. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 200 mg/l. This would result in a reduction in TDS of 40 mg/l and an estimated savings in consumer costs of $87 million/year.

Table 4-7. Summary of Costs for Alternative 1

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	183	2.2	17	5[c]
Agricultural portion	242	2.9	23	5[d]
Total	425	5.1	40	5[e]
Treatment[f]				
50 ug/l THM	2,533	239	464	144
20 ug/l THM	4,541	478	882	275

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

ALTERNATIVE 2. SAN JOAQUIN CONJUNCTIVE USE PROJECT

Conjunctive use of water is, in the broadest sense, any managed joint beneficial use of groundwater and surface water. In water resources planning, a more useful definition of conjunctive use includes optimization of use of the resources through artificial groundwater recharge of surplus surface water followed by managed groundwater extraction or, alternatively, by regional scheduling of groundwater extraction (in-lieu recharge) and surface deliveries. The objectives of conjunctive use are generally to (1) enhance firm water supplies at an attractive price, and (2) stabilize or manage groundwater levels at a desirable condition.

Conjunctive use of water resources is an old concept and has long been practiced to some degree in many California groundwater basins, particularly in Southern California. Interest in large-scale conjunctive use projects has been growing rapidly in California, and it is now widely recognized that the firm supply from the major diversion systems could be substantially increased through large conjunctive use projects.

The largest potential conjunctive use project in the San Joaquin Valley is the Kern Water Bank being developed by DWR in cooperation with the Kern County Water Agency and other cooperators. The first phase of the Kern Water Bank, called the Kern River Fan Element, will be located on some 24,000 acres southwest of Bakersfield and will augment SWP firm yield by about 140,000 AF/yr at an estimated unit cost of about $80 per AF (DWR, 1987d). DWR recently completed the initial land purchase for the Kern Fan Element (19,900 acres) from Tenneco West, Inc. An expanded Kern Water Bank would utilize both direct recharge and in-lieu recharge features and could yield over 400,000 AF/yr. Some of this additional firm yield would be used by SWP contract users in the local area, mainly within the Kern County Water Agency, and the excess yield could be pumped into the California Aqueduct near State Highway 119, or used elsewhere in the service area through transfer agreements.

Extensive additional water quality studies for the Kern Water Bank project are scheduled. Preliminary work indicates that water from the project will be of similar mineral quality to the range now seen in SWP water. If the water delivery system were bifurcated (separate M&I and agricultural supply conduits) in the Kern County area, water of lesser drinking water quality could easily be kept out of the urban supply. The Kern Water Bank implementation plan includes additional water quality studies of boron, pesticides and other toxic organics, radionuclides, and contamination by oil field brine.

Potential conjunctive use projects within the San Joaquin River basin are of interest to this drinking water quality investigation because they could be designed and operated to enhance flow and quality in the lower San Joaquin River and thus at the diversion pumps. The San Joaquin River contributes a widely varying proportion of the Delta diversion supplies depending upon seasonal hydrology and carry-over storage in the San Joaquin and Sacramento River systems. The San Joaquin River's contribution varies from less than 10 percent to about 90 percent of the total diversions. DWR has estimated that an average of 15 percent of the water diverted is obtained from the San Joaquin River. Increasing the flow in the downstream portion of the San Joaquin River during dry years would (1) increase the minimum proportion of San Joaquin River water, and (2) more importantly, would improve the quality of diverted water by a proportion weighted to the water quality of the additional supplies.

San Joaquin Conjunctive Use Project

An important conjunctive use opportunity is being planned in the Stanislaus River-Calaveras River basins. This project would use large volumes of water from New Melones Reservoir to supply customers in the Stanislaus and Calaveras basins during periods of plentiful supply. Groundwater extractions would be markedly reduced during these periods, then would be sharply increased during dry years. This conjunctive operation would make up to 150,000 AF/yr (and potentially more) of New Melones water available for downstream releases and still meet all contractual demands.

Obviously, implementation of a water resource management project of this magnitude will require extensive work on all technical, economic, legal, and institutional aspects before it can move to completion. San Joaquin County began consideration of a New Melones conjunctive use project almost a decade ago, and made initial assessments of feasibility and economics (Brown and Caldwell, 1985). This early work showed that a conjunctive use program utilizing New Melones water is feasible and attractive, and that firm supplies can be developed for about $80/AF (actually, $80/year per AF/yr of new firm yield) at current price levels; about the same unit cost as the Kern Water Bank.

Interest in the New Melones conjunctive use project has grown, and DWR and USBR have formally expressed interest in conducting additional needed studies to develop project details. Additional work is underway and is being formalized by a memorandum of understanding among the SWP and CVP and more than 20 other interested agencies. As contract recipients of New Melones water, Stockton East Water District and Central San Joaquin Water Conservation District would be the main local participants. Some $100 million in new conveyance facilities would be needed within the two districts to effect the conjunctive use plan. Most of that cost would be paid by the downstream project beneficiaries to make the project attractive to the local water users, whose full participation is essential to its success. In late 1987, Stockton East Water District proceeded with design of Goodwin Tunnel and Farmington Canal as compatible components of the conjunctive use program. Construction of the tunnel will begin soon. The District is a strong proponent of the program and, further, believes that the same concept can be extended to nearby groundwater-using areas, possibly doubling the total firm supply available through conjunctive use.

Benefits of the Stanislaus-Calaveras conjunctive use project to downstream users, including the urban water agencies, would come from two related considerations; (1) enhancing operation and firm yield of the SWP and CVP systems, and (2) improving drinking water quality. In 1982, the South Delta Water Agency filed a lawsuit against USBR and DWR alleging that operation of the CVP (mainly) and the SWP pumps damage the agency's Delta water users by reducing the availability, water levels, and quality of Delta water. A variety of South Delta improvements is being considered by USBR and DWR (DWR, 1988b) to alleviate these effects. Additional sustained flow in the lower San Joaquin River is one of the alternatives. The San Joaquin conjunctive use project is thought to be the most practical and economical way to obtain such dry-year flow. Alternative 2 consists of the North Delta and South Delta improvements described in Alternative 1 in addition to the Stanislaus-Calaveras conjunctive use project.

Water Quality Improvement

A proposed program objective of the New Melones conjunctive use project is to maintain a TDS level in the San Joaquin River at Vernalis of less than 500 milligrams per liter (mg/l). During dry months of critically dry years (like 1987 and 1988), TDS at Vernalis now rises to over 900 mg/l. An earlier study estimated that to maintain critical year TDS at Vernalis at about 750 mg/l (the then-suggested optimum "net benefit" level of control) would require additional eastside releases of about 40,000 AF/yr with a completed San Joaquin Valley agricultural drain, and 145,000 AF/yr without the agricultural drain (DWR, 1969). It is assumed here that there will be no drain, but that a large portion of the agricultural drainage which would have been conveyed by the drain will be managed in some sound alternative way. Thus, the future (2010) condition will probably lie between the above two assumptions. Further, there is no confident technical basis to relate releases with other TDS levels. Nonetheless, for purposes of this study, it was assumed that a 500 mg/l maximum TDS concentration at Vernalis could be maintained with managed dry-year release of an additional supply of 200,000 AF/yr from New Melones into the lower San Joaquin River.

During dry years, only about 10 percent of the water diverted from the Delta by the CVP/SWP is derived from the San Joaquin River. Based on this ratio and the other assumptions used in this analysis, the San Joaquin conjunctive use project would reduce TDS in the diverted supplies about 40 mg/l during dry years and 10 mg/l on the average. Reduction of organic load would be in roughly the same proportion. It is questionable whether Delta drinking water quality improvement alone would justify the San Joaquin conjunctive use project, but it is almost certain that all benefits together make a San Joaquin conjunctive use program attractive. The appropriate scope and capacity of the project is not clear from the work done to date. Timing of the project is also a key question. Currently, much of the water quality benefit of New Melones releases occurs without a formal project. Projection of demand buildup and project scheduling is beyond the scope of this conceptual study.

Table 4-8 summarizes the estimated water quality conditions at Clifton Court resulting from the San Joaquin Conjunctive Use Project combined with the Delta Transfer System Improvements described under Aternative 1. These concentrations are compared to the existing concentrations at Clifton Court and Rock Slough. It was assumed that the improvements in quality would be additive because the Delta Transfer System Improvements would affect water quality by reducing the impacts of seawater intrusion, whereas the San Joaquin Conjunctive Use Project would improve Delta water quality by improving the quality of the San Joaquin River. Treatment Options D or F would be required to bring water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 or 20 ug/l.

Table 4-8. Comparison of Water Quality With the San Joaquin Conjunctive Use Alternative to Existing Water Quality

Constituents, units	Estimated water quality		Existing conditions			
			Clifton Court		Rock Slough	
	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	400	500	500	640	480	610
THMFP (EBMUD), ug/l	120	170	160	200	240	-
TDS, mg/l	190	280	240	380	-	390

[a]85 percentile value is the mean plus one standard deviation.

Cost Estimates

A confident capital cost estimate for the Stanislaus-Calaveras conjunctive use project is not available. It has been estimated that about $100 million in new conveyance facilities would be needed. Due to the uncertain capital cost of the conjunctive use project, it has not been included in the capital cost of this alternative. The capital and operating costs of the Delta Transfer System Improvements, presented previously in Table 4-7, are included in this alternative.

For water quality improvement through an expanded San Joaquin conjunctive use program, the augmented dry-year flow into the lower San Joaquin River of 200,000 AF/yr, would cost about $16 million annually. All Delta water diverters would benefit from this conjunctive use program, however; it was assumed that M&I users would pay this entire annual cost. Cost negotiations might result in allocating some amount of the project cost to the agricultural users. Table 4-9 presents a summary of the major cost items for this alternative.

The estimated treatment cost to comply with anticipated drinking water regulations is $144/AF or $464 million/year (Treatment Option D), if the THM standard is set at 50 ug/l or $275/AF or $882 million/year (Treatment Option F) if the THM standard is set at 20 ug/l. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 190 mg/l. This would result in a reduction in TDS of 50 mg/l and an estimated savings in consumer costs of $109 million/year.

Table 4-9. Summary of Costs for Alternative 2

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital[b]	Annual operating	Total annual	
Delivery system[c]				
M&I portion	183	18	33	10[d]
Agricultural portion	242	3	23	5[e]
Total	425	21	56	8[f]
Treatment[g]				
50 ug/l THM	2,533	239	464	144
20 ug/l THM	4,541	478	882	275

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Capital costs are for the Delta Transfer System Improvements only; the capital cost of the conjunctive use project is not available.
[c]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[d]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[e]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[f]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[g]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

ALTERNATIVE 3. DELTA AGRICULTURAL DRAINAGE MANAGEMENT

Data collected by DWR as part of the Interagency Delta Health Aspects Monitoring Program and the Delta Agricultural Drainage Investigation indicate that agricultural drains discharging into Delta waters are a major source of the organic precursors that contribute to THM formation upon chlorination of Delta water supplies. DWR has identified over 260 agricultural drains that discharge into Delta waterways. Drains on Empire Tract, Tyler Island, and Grand Island have been sampled monthly by DWR since February 1985. In March 1987, DWR began an extensive study of the water quality of agricultural drainage discharged to the Delta. To date, DWR has collected three to six samples from about 50 drains. The samples are analyzed for minerals, turbidity, TOC, selenium and several other constituents in addition to THMFP.

Figure 4-9 compares the mean THMFP concentrations in several drains to the concentrations in Delta waterways at several locations. The drains on Empire, Tyler, and Grand Islands were selected because there are three years of data on these drains. The mean THMFP concentrations range from 1,500 ug/l on Grand Island to 3,000 ug/l on Empire Tract. The mean concentration of THMFP in all of the drains sampled is 1,300 ug/l. In contrast, the mean THMFP concentrations in the Delta waterways range from 310 ug/l in the Sacramento River at Greene's Landing to 520 ug/l in the Middle River.

The THMs formed in the THMFP tests of the drainage consists of both chlorinated and brominated methanes. The brominated THMFP is 350 ug/l in Grand Island drainage, and 450 ug/l in Empire Tract drainage. The average for all drains is about 100 ug/l. The principal source of bromide is seawater intrusion which occurs during periods of low freshwater outflow. Recent studies have shown that the presence of bromide greatly affects the species of THMs that are formed and also increases the total amount of THMFP (Luong et al., Amy et al.). The presence of bromide is significant because a fully brominated THM (bromoform) weighs twice as much as a fully chlorinated THM (chloroform), and makes it more difficult for a water utility to meet the 100 ug/l THM standard. As discussed in Chapter 3, it is not clear if the bromides in the agricultural drainage originate from Delta water applied for irrigation, or whether there are local bromide sources, such as residual bromide in the soils from an era of saline water flooding. Some bromide is recycled from the drains through the channels and levees back onto the islands.

Several possible solutions exist for reducing or eliminating the drinking water contamination resulting from this agricultural drainage. Four possible solutions are:

1. Conveyance of drinking water around the Delta to prevent contamination by agricultural drainage.
2. Treatment of the agricultural drainage prior to discharge into the Delta channels.
3. Collection and transport of the drainage to a discharge location west of the Delta.
4. Reduction or elimination of agricultural drainage in selected portions of the Delta.

Conveyance of drinking water around the Delta is discussed in later sections of this chapter on Alternatives 4, 5, and 6. Treatment of agricultural drainage prior to discharge to the Delta channels would be prohibitively expensive and would only solve part of the problem. This section describes a system that would collect all, or a major portion of, the agricultural drainage from the Delta and would convey it westerly for discharge to a point in the estuary where the drainage would be diluted and transported to San Francisco Bay. This would reduce the water quality degradation resulting from discharge of agricultural drainage into the interior Delta channels.

Physical Improvements

The North Delta and South Delta improvements discussed previously in Alternative 1 are included in this alternative to improve the hydraulics of the Delta. Physical

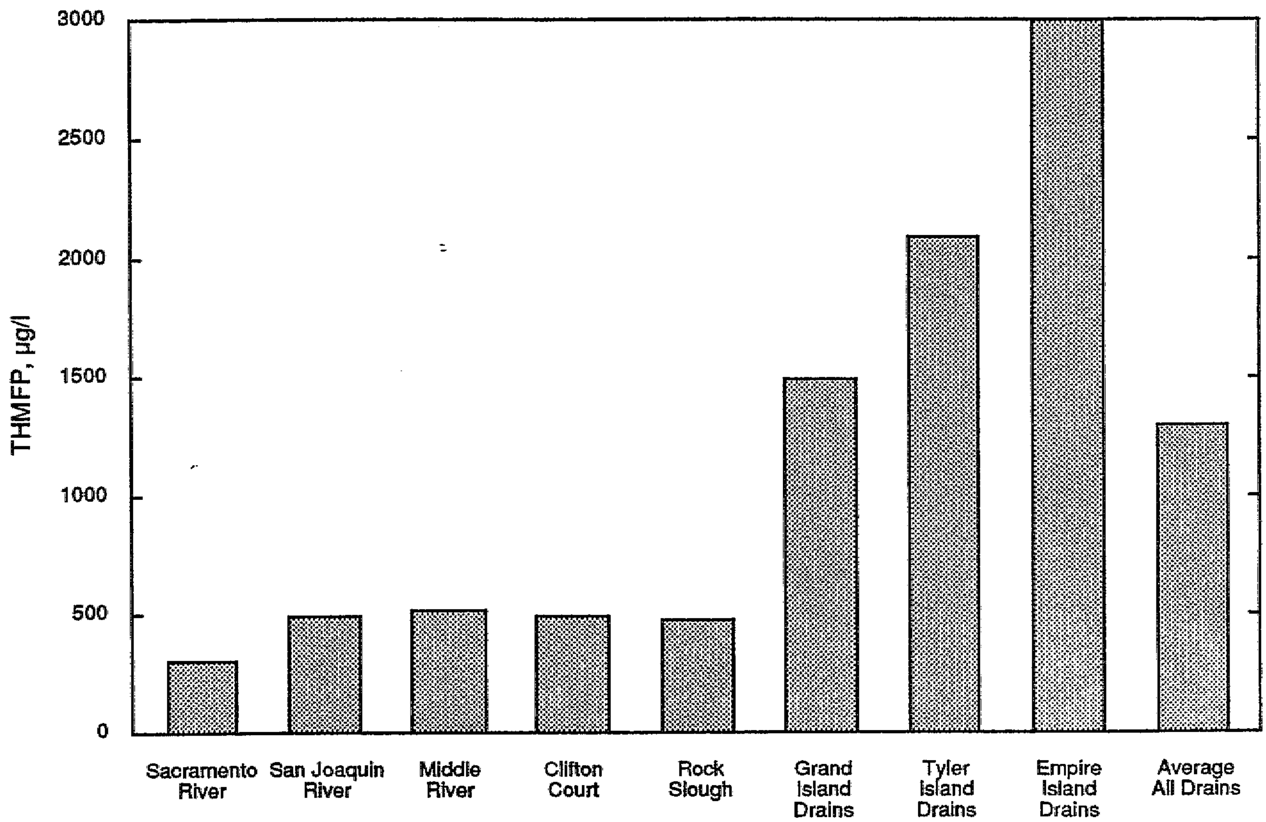


Figure 4-9. Comparison of THMFP Concentrations in Agricultural Drains and Delta Waterways

improvements to reduce or eliminate discharge of agricultural drainage into the interior Delta islands could take two approaches; (1) a complete drainage system that collects essentially all agricultural drainage from the Delta islands, and (2) collection of only the worst quality agricultural drainage. The two approaches are described below.

Collection of All Drainage. This system would collect all agricultural drainage, transport it out of the Delta, and discharge it in the estuary where it would be transported to San Francisco Bay. It would consist of a system of collection pipes on each island, or major division of land, that would convey drainage to a main pumping plant on that island. Drainage would then be pumped to an adjacent downstream island, combined with drainage from that island and pumped by a main pumping plant to an adjacent downstream island. This would continue downstream through the system until all the drainage was conveyed to one main pumping plant that would pump the drainage downstream for discharge. No assessment has been made of the water quality effects, or the acceptability, of such a discharge. A demonstration would have to be made that the discharge would not adversely impact any beneficial use of the estuary, and would fully protect water quality at the Mallard Slough intake of Contra Costa Water District.

The collection system piping would range in size from 12-inch-diameter collectors to three 120-inch-diameter transmission lines to San Francisco Bay. Over 380 miles of collection lines and 73 pumping plants would be required to collect the drainage from the islands to convey it from island to island, and then transport it west past Chipps Island for discharge.

The amount of drainage from the Delta islands was estimated using information presented in Report No. 4, Quantity and Quality of Waters Applied to and Drained From the Delta Lowlands, (DWR, 1956). Although this report contains data that are about 30 years old, it is the best available information on the quantity of agricultural drainage in the Delta. Considering that the Delta region has continued to be used for agricultural purposes for the past 30 years, the 1956 data are believed to still provide a rough but reasonable estimate of the quantity of agricultural drainage.

The unit drainage occurring during the peak month of the year is approximately 2.7 acre-feet per year per acre (AF/yr/acre). The total area from which agricultural drainage would be collected is about 420,000 acres, resulting in a peak drainage flow of 1,600 cfs. The total annual agricultural drainage is estimated to be 703,000 AF.

Collection of a Portion of the Drainage. The second approach is to only collect drainage from interior Delta islands that contain larger amounts of deep organic (peat) soils. The collection system would be configured in much the same way as for the first option. Collection pipes would carry drainage from island to island, using pumping plants where necessary, and then discharge the drainage to San Francisco Bay.

The individual drain data were analyzed to determine if there was an area of the Delta that contributed a relatively large proportion of the total THMFP load from agricultural drainage. Based on the limited data collected thus far, there are no apparent "hot spot" areas from which the drainage could be collected to achieve a disproportionately large reduction of the THMFP load. Accordingly, this subalternative was not considered further in this study. This matter warrants additional monitoring and research in the near future.

Water Quality Improvement

The primary objective of the analysis of this alternative was to determine the reduction in THMFP that would occur at the Delta pumps as a result of removing agricultural drainage from the Delta. A semiquantitative approach using mass balances was used to estimate the reduction in THMFP and in TDS. It was not possible to quantify the impact on other water quality constituents as a result of this alternative. All THMFP values used in this analysis are from the DWR database. The DWR data are used because it is necessary to use a single set of data in this analysis, and DWR monitoring provides the only set of data adequate for this work.

As discussed previously, the analytical method used by DWR involves much higher chlorine dosages than the method used by most water utilities. The DWR method results in THMFP concentrations that are indicative of the maximum amount of THMs that could be produced in a given source water. The DWR method may result in different THM yields (micrograms THM per milligram of dissolved organic carbon) with different source waters, as explained in Chapter 3. DWR is currently conducting an analytical study of the DWR and water utility methods to determine if it is possible to correlate results from the two methods. Several refinements could be made to this THMFP balance if more extensive data were available. This should be considered in the design and funding of future Delta monitoring programs.

As discussed previously in Chapter 3, there is an increase in the THMFP concentrations between the source waters to the Delta and Clifton Court. A THMFP balance was prepared to estimate the impact on the diverted water quality of removing all agricultural drainage from the Delta. Figure 4-10 shows that there is an increase of 130 ug/l in the total THMFP (TTHMFP) as the water passes through the Delta. The brominated THMFP forms increase by 30 ug/l.

The balance was calculated with the average THMFP concentrations from the DWR monitoring program on the Sacramento River at Greene's Landing, the San Joaquin River at Vernalis, and Clifton Court. It was assumed that on an average annual basis the water diverted at Clifton Court consists of 70 percent Sacramento River water and 30 percent San Joaquin River water. Overall, the Sacramento River contributes 80 percent of the total inflow to the Delta and the San Joaquin River contributes 15 percent, with the east side streams accounting for the remaining 5 percent (DWR, 1974). Based on discussions with DWR staff, it seems that the 70/30 split is a reasonable estimate of the average mix of waters at the pumps. These proportions were also used in a similar analysis by the State Water Contractors for the Bay/Delta Hearings.

The THMFP increase in the Delta is due to the discharge of organic precursors in agricultural drainage and to natural biological activity in the channels and contact with the peat soils in the levees and channels which increase the organic content of the water. Seawater intrusion results in the formation of brominated THMFP and also increases the total amount of THMFP to an extent that is not readily quantifiable. The agricultural drainage contribution to the total increase of 130 ug/l in the Delta was estimated by using the overall average THMFP concentration in the drains of 1,300 ug/l and the drainage flow data from 1954-1955. The flow data show that the discharge from agricultural drains

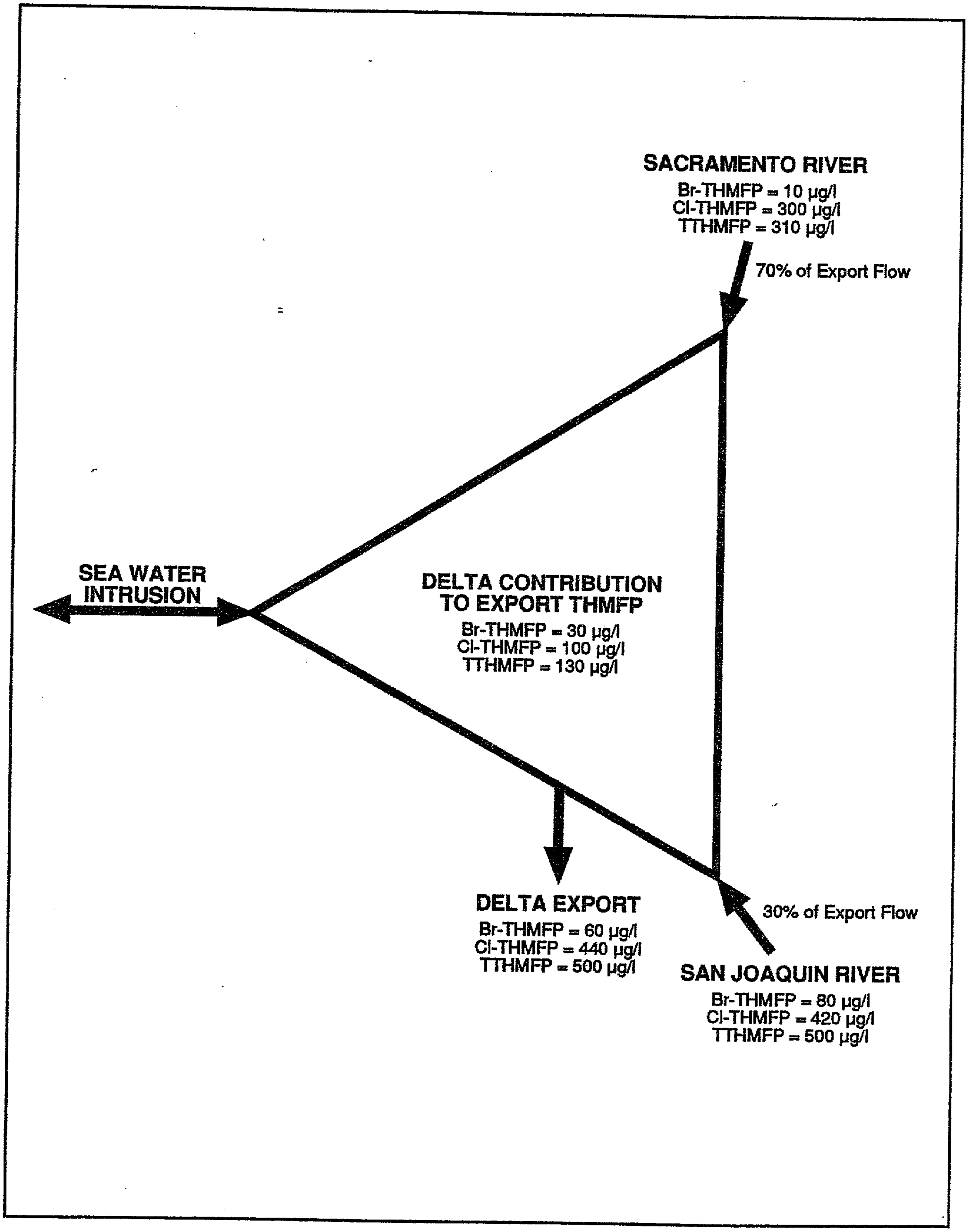


Figure 4-10. Annual THMFP Balance for the Delta

represented 7.1 percent of the total inflow to the Delta during the study period (DWR, 1956). Based on the average concentration and flow data for the agricultural drains, the drains contribute about 90 ug/l of THMFP to the diverted water. Using the average concentration of brominated THMFP, and the average flow data, the agricultural drains contribute 10 ug/l to the brominated THMFP of the diverted water.

Figure 4-11 presents a schematic of the impact of removing the agricultural drainage from the Delta. This figure shows that the diverted water THMFP could be reduced by 90 ug/l at the SWP pumps. Based on the experience of the water utilities using Delta water, the distribution system THM concentration is about 20 to 30 percent of the THMFP (DWR) at the pumps. This means that reducing the THMFP at the pumps by 90 ug/l by removing the agricultural drainage, would result in reductions of 20 to 30 ug/l in distribution system THM concentrations. The estimates shown on Figure 4-11 also indicate that, of the total weight of THMFP added in the Delta, the split among the sources is about 70 percent drains, 15 percent channels, and 15 percent seawater intrusion.

THMFP balances were also prepared for a wet-year condition and a dry-year condition to determine the impact of agricultural drainage under different hydrologic regimes. The wet-year balance was calculated with the average wet season (October to March) THMFP concentrations from the DWR monitoring program on the Sacramento River, San Joaquin River, and Clifton Court. The average wet-season THMFP concentrations of the Sacramento and San Joaquin Rivers are the same as the annual average concentrations of the rivers. Based on discussions with DWR staff, it was assumed that during wet years the water diverted at Clifton Court consists roughly of 10 percent Sacramento River water and 90 percent San Joaquin River water. The dry-year balance was calculated with the average dry season (April to September) THMFP concentrations from the three monitoring locations. The average dry-season THMFP concentrations of the Sacramento and San Joaquin Rivers are the same as the annual average concentrations of these rivers. It was assumed that during dry years the water diverted at Clifton Court consists of 90 percent Sacramento River water and 10 percent San Joaquin River water.

As shown on Figure 4-12, the THMFP increases by 40 ug/l in the Delta during a wet year. This is substantially lower than the average annual increase of 130 ug/l. This indicates that during wet years some portion of the agricultural drainage is flushed out of the Delta by the high freshwater outflows. There is no increase in the Delta in the brominated THMs during a wet year, probably due to the minimal amount of seawater intrusion during high freshwater outflows.

Removing agricultural drainage from the Delta would not markedly improve water distribution system THM concentrations during a wet year. The DWR data indicate that the water quality of the diversions during wet years is heavily influenced by the quality of the San Joaquin River. It appears that some portion of the agricultural drainage is flushed out of the system and never reaches the pumps. Using the mass balance procedures described previously and even assuming that agricultural drainage contributes 100 percent of the increase in THMFP in the Delta during wet years, the distribution system THM concentrations could only be reduced by about 10 ug/l.

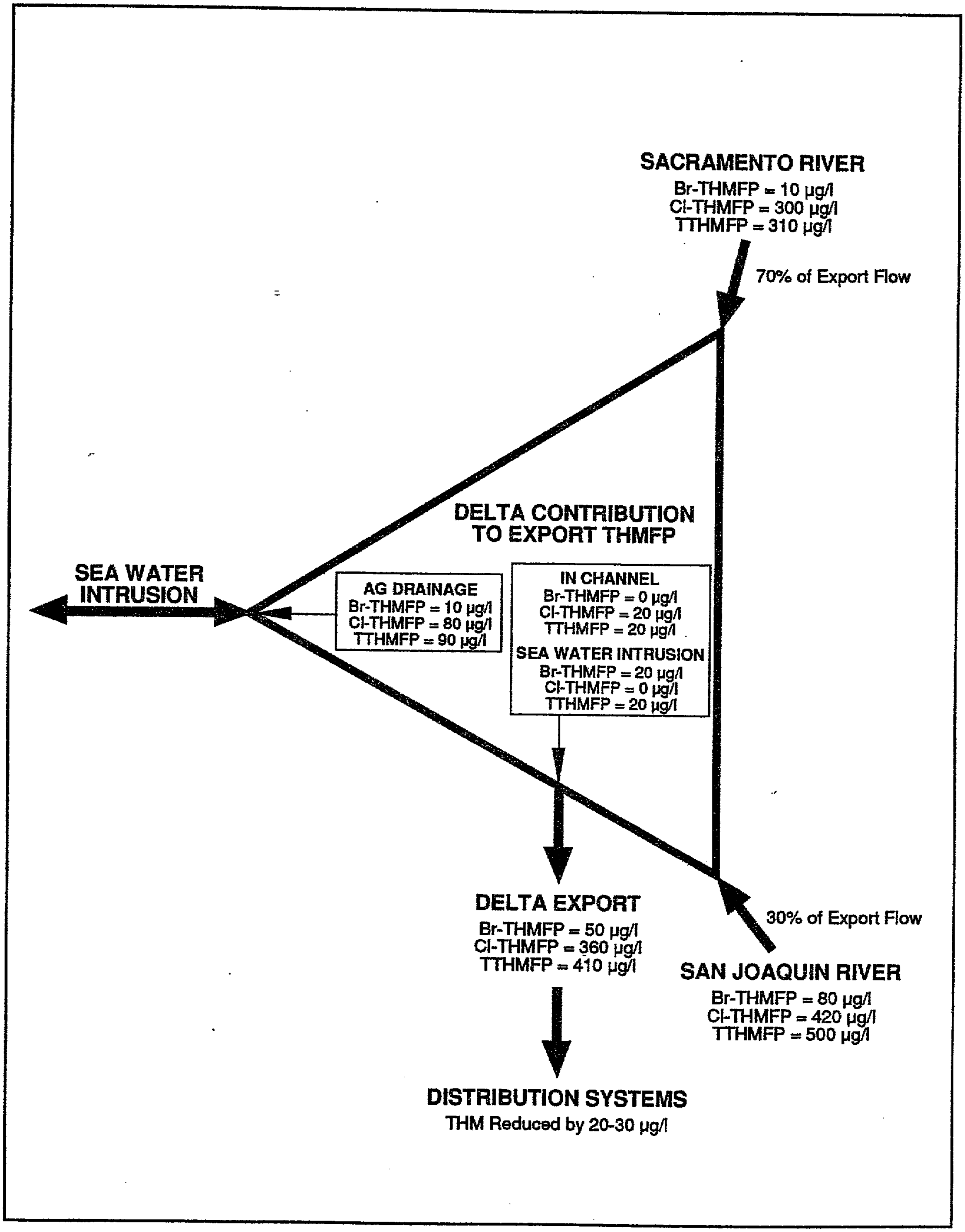


Figure 4-11. Impact of Exporting Agricultural Drainage on THMFP Concentrations

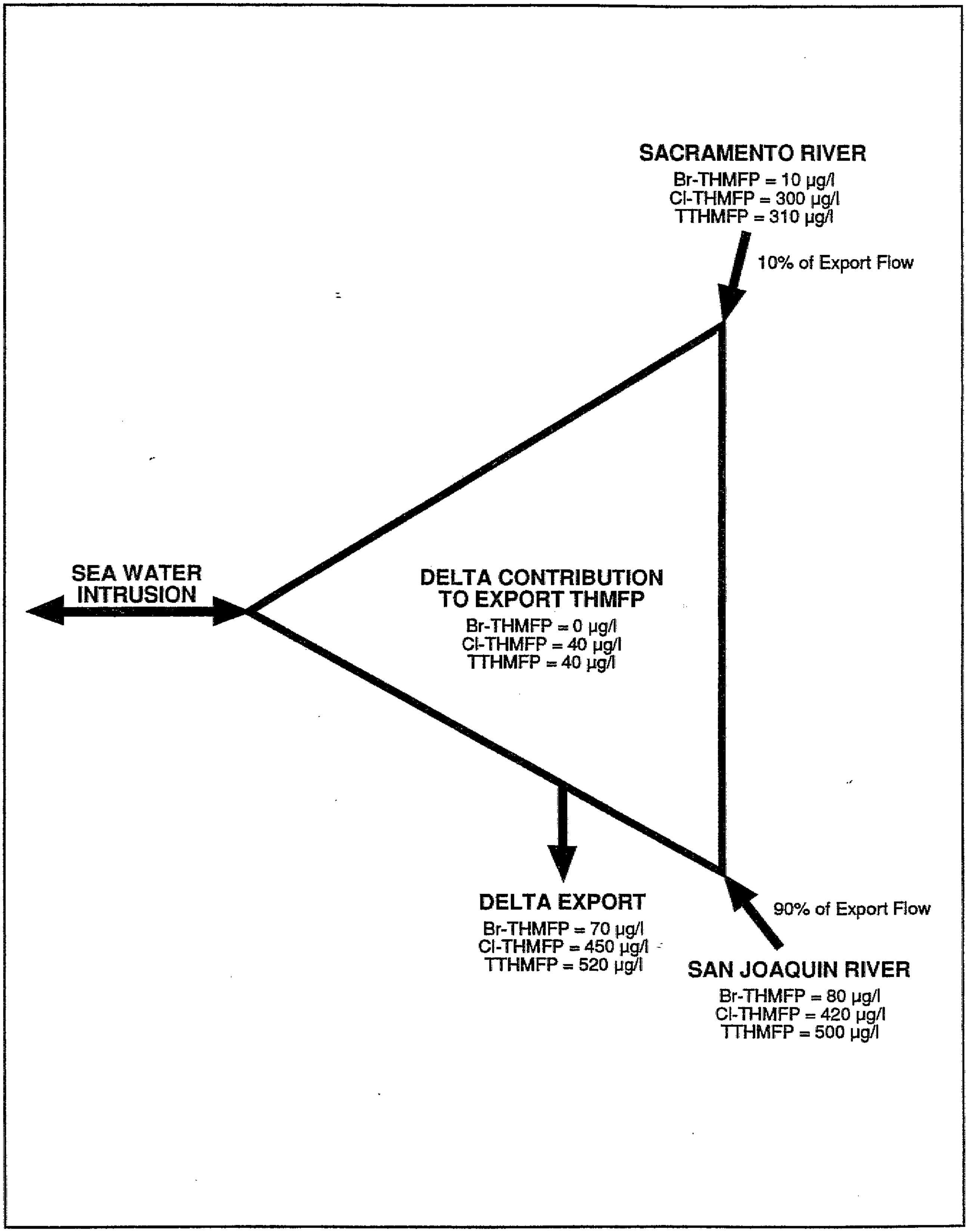


Figure 4-12. Wet Year THMFP Balance for the Delta

As shown on Figure 4-13, the THMFP increases by 150 ug/l in the Delta during a dry year. This is higher than the average annual increase of 130 ug/l. This indicates that during dry years the Sacramento River flows through the Delta channels toward the pumps. As the water flows through the channels, the drainage discharges, the natural biological productivity, and contact with the peat soils all increase the THMFP concentration. The brominated THMFP increases by 30 ug/l, which is equal to the increase during an average year. The increase in brominated THMFP is due mostly to the increased influence of seawater in the Delta during periods of low freshwater outflows.

Removing agricultural drainage from the Delta would improve the distribution system THM concentrations during dry periods. Using the mass balance procedures described previously and assuming that agricultural drainage contributes 70 percent of the increase in THMFP in the Delta during dry years, the distribution system THMs could be reduced by about 20 to 30 ug/l.

The same mass balance procedure was used to estimate the improvement in TDS due to removing agricultural drainage from the Delta for an average, wet, and dry year. The results are similar to the THMFP results. During an average year, TDS of the diverted water would be reduced from 240 mg/l to 200 mg/l by removing agricultural drainage. There would be no impact on TDS during a wet period because the Delta water quality is heavily influenced by the high TDS San Joaquin River water. During a dry period, TDS would be reduced from 220 mg/l to 160 mg/l by removing agricultural drainage.

The impacts on water quality of removing agricultural drainage from the Delta were combined with the impacts of the Delta Transfer System Improvements, described under Alternative 1. It was assumed that the improvements in quality were additive because the Delta Transfer System Improvements affect water quality by reducing the impacts of seawater intrusion, whereas the removal of agricultural drainage improves water quality by reducing the loads of contaminants discharged to the Delta.

Table 4-10 summarizes the estimated concentrations of THMFP and TDS in the diverted water as a result of transporting all agricultural drainage out of the Delta and completing the Delta Transfer System Improvements described in Alternative 1. These concentrations are compared to the existing concentrations at Clifton Court and Rock Slough. The mean values presented in the table were developed in the mass balances for average-year conditions. The 85 percentile values indicate that the improvement in water quality extremes is due solely to the Delta Transfer System Improvements. This is based on the mass balances developed for wet years which show that there would be no improvement in water quality as a result of exporting all of the agricultural drainage out of the Delta. A more sophisticated analysis of these data is needed to verify or disprove the mass balance results. The scatter of the data resulting in high 85 percentile values could be reduced with more data. The mean THMFP estimated diversion quality (330 ug/l) is lower than the existing mean values at Clifton Court (500 ug/l). Of particular interest is the steady-state influence of a reduction of agricultural drainage on the San Joaquin River concentrations of THMFP and bromide.

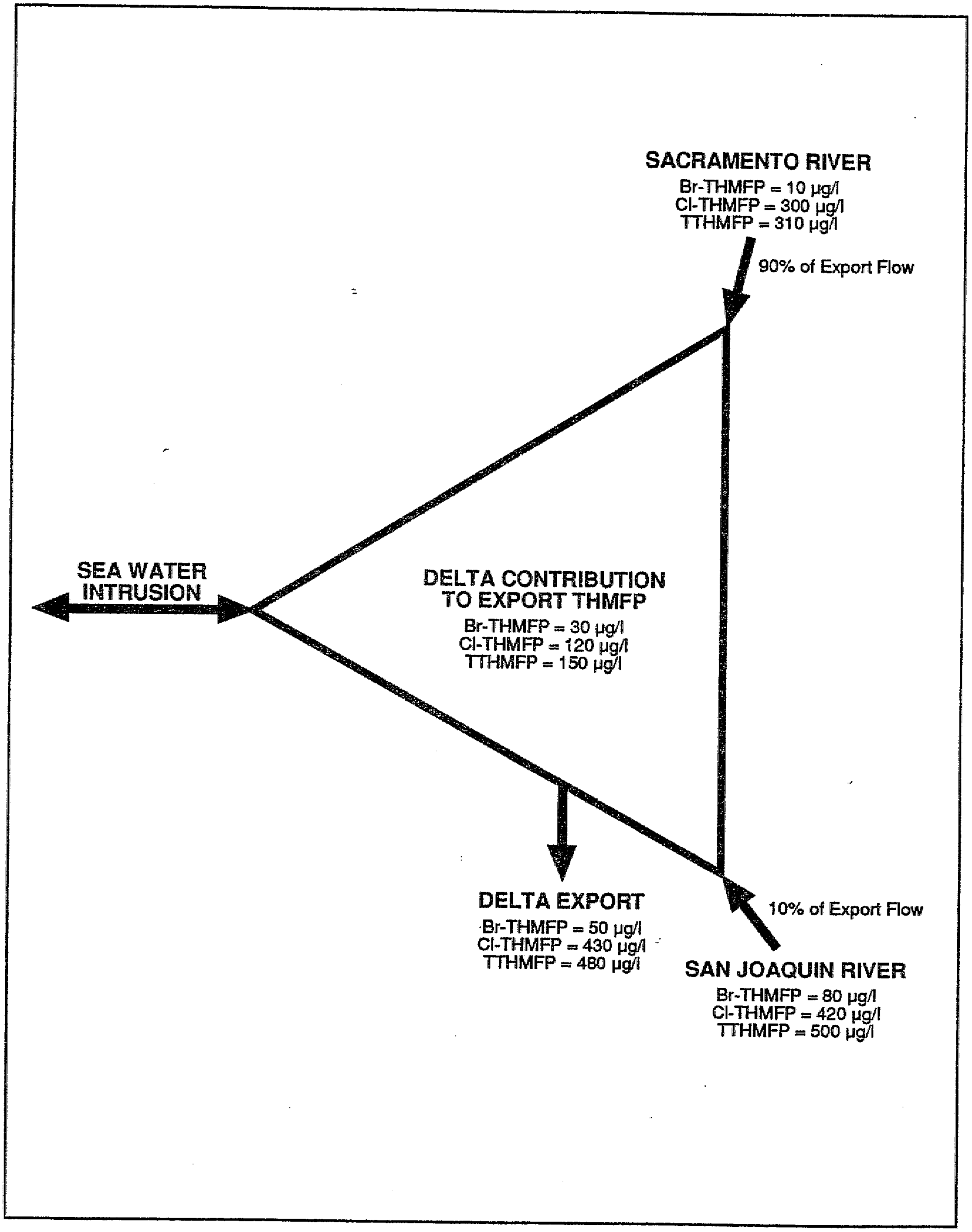


Figure 4-13. Dry Year THMFP Balance for the Delta

Table 4-10. Comparison of Water Quality With Agricultural Drainage Alternative to Existing Water Quality

Constituents, units	Estimated water quality		Existing conditions			
			Clifton Court		Rock Slough	
	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	330	540	500	640	480	610
THMFP (EBMUD), ug/l	100	170	160	200	-	-
TDS, mg/l	160	320	240	380	250	390

[a]85 percentile value is the mean plus one standard deviation.

It was not possible to quantify the expected improvement in other water quality constituents as a result of exporting the agricultural drainage out of the Delta. The pesticides and nutrients that are currently discharged in drainage waters to the Delta would be removed with this alternative. Although pesticides are currently not often detected in Delta waters, there is evidence from the accumulation of organics in fish tissues that pesticides are present and may pose a drinking water quality problem in the future (DWR, 1987a). Reducing the nutrient content of Delta waters would likely lead to lower algal concentrations, with a reduction in taste and odor and filter clogging problems. Treatment Options C or E would be required to bring diverted water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 ug/l or 20 ug/l.

Cost Estimates

The capital cost for the complete agricultural drainage system and the Delta Transfer System Improvements is estimated to be $1.75 billion. M&I water users would be responsible for $1.50 billion of the total cost. The annual O&M cost for the system would be about $28 million above existing costs. The M&I portion would be about $26 million. The energy costs are estimated to be $2.9 million per year. The M&I portion would be $2.6 million per year. Table 4-11 presents a summary of the major cost items for this alternative.

Table 4-11. Summary of Costs for Alternative 3

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	1,503	28	151	47[c]
Agricultural portion	242	3	23	5[d]
Total	1,745	31	174	23[e]
Treatment[f]				
50 ug/l THM	2,008	155	334	104
20 ug/l THM	4,015	394	751	234

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

The estimated treatment cost to comply with anticipated drinking water regulations is $104/AF or $334 million/year (Treatment Option C), if the THM standard is set at 50 ug/l, or $234/AF or $751 million/year (Treatment Option E), if the THM standard is set at 20 ug/l. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 160 mg/l. This would result in a reduction in TDS of 80 mg/l and an estimated savings in consumer costs of $174 million/year.

Similar cost comparisons for the option of partial removal of drainage were not prepared. As discussed in the water quality section, it was judged not be to a viable alternative because it was not possible to identify hot spot areas with the available data.

ALTERNATIVE 4. PERIPHERAL CANAL

In 1966, DWR officially adopted the Peripheral Canal as a feature of the SWP and in 1969 USBR issued a feasibility report recommending the Peripheral Canal as an additional unit of the CVP to serve the joint needs of the federal and state projects. Both DWR and USBR studies indicated that the Peripheral Canal was the best alternative for supplying good quality water to the SWP and CVP pumps while at the same time protecting the water quality of the Delta and improving the habitat for fish and wildlife.

In 1978, DWR formally proposed a number of joint state and federal programs and facilities, including the Peripheral Canal, Suisun Marsh protection facilities, water storage reservoirs in the Sacramento and San Joaquin valleys, groundwater recharge and storage facilities in Southern California, wastewater reclamation facilities, and water conservation. This proposed program later became embodied in Senate Bill (SB) 200. Subsequently, opponents of the Peripheral Canal and SB 200 obtained enough signatures to place a referendum on the ballot. The measure, Proposition 9, was rejected by California's voters in 1982. As a result, DWR has proposed other facilities (the Delta Transfer System Improvements discussed previously in this chapter as Alternative 1) to improve water quality of the diversions and South Delta flows. In spite of the turbulent history surrounding the Peripheral Canal, the facility is included as one of the alternatives in this conceptual study because of its ability to significantly improve drinking water quality at a favorable cost, and because extensive available information from earlier studies makes the Peripheral Canal a useful point of comparison with other alternative concepts. As stated earlier, no endorsement of this or other concepts is implied by inclusion in this water quality analysis.

Physical Improvements

The major features of the Peripheral Canal are described in this section. This facility has been described in detail in numerous DWR publications. The information presented in this section was taken mainly from the draft Environmental Impact Report (DWR, 1974).

The Peripheral Canal, as shown on Figure 4-14, was to be located along the eastern perimeter of the Delta. It would start at the Sacramento River, about 18 miles south of the City of Sacramento, near the community of Hood. It would progress in a southeasterly direction toward the City of Stockton, cross the San Joaquin River about 5 miles west of Stockton, then continue in a southwesterly direction to its terminus at Clifton Court. Outlets along the canal would provide for releases of freshwater into the Delta. The canal would be siphoned under the four major river and slough crossings to allow for passage of flood flows, boats, and migrating fish.

The 42-mile long Peripheral Canal would resemble a Delta channel but with flatter levee slopes. It would have a bottom width of 200 feet, a top width of 400 to 500 feet, and its depth would range from 20 to 30 feet. The conveyance capacity of the canal would be about 23,000 cfs at the intake. The intake structure near Hood would include a fish screen and pumping plant.

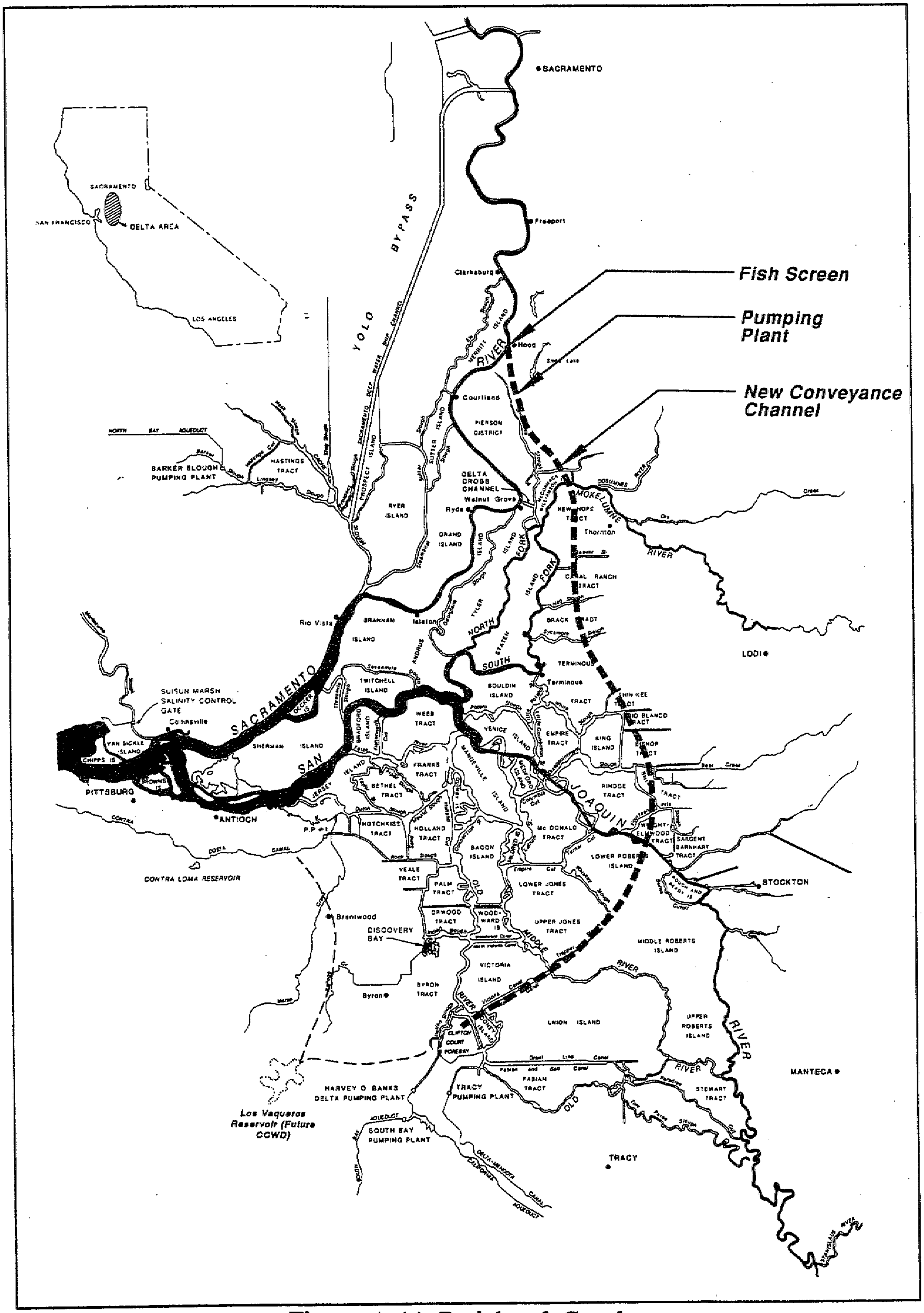


Figure 4-14. Peripheral Canal

The intakes for the Delta Mendota and Contra Costa Canals were assumed to be relocated to Clifton Court. Service to Contra Costa Water District via the Los Vaqueros project facilities under this alternative would require the specific approval of the district's voters. South of the Delta, the conveyance system would require no additional improvements beyond those planned by DWR presently. However, to maintain the quality of water diverted from this project, drainage control and other quality safeguards would be provided on the California Aqueduct in critical areas, mainly south of San Luis Reservoir. A survey of the entire SWP system for its vulnerability to contamination is presently being conducted by the SWP water users.

Water Quality Improvement

To estimate the drinking water quality improvement that would result from this alternative, the following assumptions were made.

1. Water quality in the Sacramento River at Hood, the point of diversion for the Peripheral Canal, would be equal to the water quality in the river at Greene's Landing.

2. There would be no changes in quality during conveyance to the pumps in the Delta. The effect of Middle River flows into the canal, or the feasibility of eliminating them, have not been determined.

Table 4-12 presents the estimated concentrations of several key water quality constituents. These concentrations are compared to the existing quality of Clifton Court and Rock Slough to show the expected improvement in water quality that could be achieved with this alternative. These data show that on an average annual basis there would be a significant improvement in water quality with the Peripheral Canal. The mean THMFP (DWR) would be reduced by about 40 percent to 310 ug/l and the THMFP (EBMUD) concentration would be reduced to 85 ug/l. Based on the experience of EBMUD, the distribution system THM concentration would be equal to 50 to 70 percent of the THMFP (EBMUD). Using this assumption, the average distribution system THM concentration would be reduced to 45 to 75 ug/l with the Peripheral Canal. At these concentrations, the current standard of 100 ug/l could be met without further treatment, but the more stringent anticipated standard could not be met without additional treatment. There would be significant improvements in TDS, bromide, chloride, and sodium concentrations with this alternative. The water would also be lower in algal nutrients and total organic halogens (TOX).

The 85 percentile values show that the variations in concentrations of the key constituents would be less than the current variations in quality. With the Peripheral Canal alternative, the predicted 85 percentile values are lower than the existing mean concentrations in most cases. This indicates that even during the periods of poorest water quality, the quality would be better than it currently is on the average.

There would likely be improvements in water quality constituents that cannot be quantified at this time due to limited or no data. By conveying water around the Delta, this alternative avoids contact between the drinking water and agricultural and urban drainage that is discharged to the San Joaquin River or directly into Delta waterways. These discharges can contain pesticides and other synthetic organics that are by-products of industrial activities. Although many organic constituents are currently not detected or are detected in trace amounts in the diverted water, it will become increasingly more important to limit organic contamination of water supplies as EPA develops standards for additional organic contaminants.

Table 4-12. Comparison of Water Quality With the Peripheral Canal to Existing Water Quality

	Estimated water quality		Existing conditions			
			Clifton Court		Rock Slough	
Constituents, units	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	310	470	500	640	480	610
THMFP (EBMUD), ug/l	85	110	160	200	-	-
TDS, mg/l	100	120	240	380	240	390
TOC, mg/l	6	11	8	12	-	-
TOX, ug/l	75	200	95	240	-	-
Bromide, mg/l	0.02	0.05	0.14	0.25	-	-
Chloride, mg/l	7	10	65	130	60	130
Sodium, mg/l	11	14	40	65	45	80
Total phosphorus, mg/l	0.12	0.16	0.13	0.17	-	-

[a]85 percentile value is the mean plus one standard deviation.

Although the water quality in the Sacramento River at Greene's Landing is significantly better than the existing quality at the Delta pumps, it is important to note that the diversion point for the Peripheral Canal (Hood) is downstream of nearly two million inhabitants, and about 8 river miles downstream from the discharge of the secondary effluent from the Sacramento Regional Wastewater Treatment Plant. That plant is currently being expanded to handle average dry-weather flows of 163 mgd for the year 2000. It is expected that the Sacramento metropolitan area will continue to grow and the wastewater treatment plant will be expanded to accommodate the growth. In addition to the treated effluent, there are occasional discharges of untreated combined sewage from Sacramento. These are storm-related combined sewer overflows from the combined stormwater/wastewater system that serves downtown Sacramento. There are currently no routinely measured water quality problems that can be attributed to the discharge of secondary wastewater into the river, however, as analytical methods are further refined and detection limits are reduced, constituents of concern to drinking water quality may be found in the river and may be attributed to wastewater effluent discharges. It may be found appropriate to convey the major wastewater discharges to a point downstream of Hood.

A large amount of agricultural drainage enters the Sacramento River upstream of Hood; most of it upstream of the American River confluence. The feasibility of diverting a large portion of the drainage to the Yolo Bypass drainage canal and thence downstream to Cache Slough or beyond would require additional study. Such a diversion might achieve a significant and cost-effective improvement of Sacramento River water at Hood. Treatment Options C or D would be required to bring diverted water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 ug/l or 20 ug/l.

Cost Estimates

The capital cost of the Peripheral Canal reported in Letter and Formal Statements Concerning Senate Bill 200 and Related Matters, Letter 92 (DWR, 1980), is $850 million, adjusted to projected mid-1989 dollars. This includes the cost of the Peripheral Canal, relocation of Contra Costa Canal, and South Delta water quality improvements, as defined in SB 200. Using the cost allocation method described earlier, the M&I portion of the capital cost would be about $608 million. The annual O&M cost for the facility is estimated to be 2 percent of construction cost, or $12 million above existing costs. The M&I portion of the annual O&M cost would be $9.4 million. The annual energy costs are estimated to be $5.8 million above the existing costs, with the M&I portion being about $5.5 million. Table 4-13 presents a summary of the major cost items for this alternative.

Table 4-13. Summary of Costs for Alternative 4

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	608	15	65	20[c]
Agricultural portion	242	3	23	5[d]
Total	850	18	87	12[e]
Treatment[f]				
50 ug/l THM	2,008	155	334	104
20 ug/l THM	2,533	239	464	144

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water, under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

The estimated treatment cost to comply with anticipated drinking water regulations is \$104/AF or \$334 million/year (Treatment Option C), if the THM standard is set at 50 ug/l, or \$144/AF or \$464 million/year (Treatment Option D), if the THM standard is set at 20 ug/l. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 100 mg/l. This would result in a reduction in TDS of 140 mg/l and an estimated savings in consumer costs of \$305 million/year.

ALTERNATIVE 5. DUAL TRANSFER SYSTEM

The Dual Transfer System, described in the report Alternatives for Delta Water Transfer (DWR, 1983), would convey about half the water being exported by the SWP and CVP through existing channels, and half in a new isolated channel. This system was intended to be a compromise between environmental interest groups which sought to reduce the adverse impact of flow reversals on fish by construction of an isolated Delta water transfer facility, and water users in the central and southern Delta who concluded that a through-Delta water export system would be the best way to protect their local water supplies. This alternative is no longer under consideration by DWR.

Physical Improvements

Several options and combinations for the Dual Transfer System were studied by DWR. This analysis of the Dual Transfer System is based on the alternative using a gravity-flow canal and a fish screen. Another option described in the DWR report included a pumping plant and fish screen at the northern end of the system. DWR estimated that the pumping plant option would cost approximately 6 percent less to construct than the gravity-flow system assumed herein.

As shown on Figure 4-15 the new channel would extend from Hood on the Sacramento River to Clifton Court. The entire SWP agricultural and M&I demand could be carried in the new channel in all but the high-flow, high-diversion (winter and early spring) months. This facility would follow the same alignment as the Peripheral Canal, but would have only one-third the capacity. The capacity of this East Delta Conveyance Channel would be about 7,500 cfs. A possible connection to the Contra Costa Water District's Los Vaqueros project is shown on Figure 4-15. Service to Contra Costa Water District via the Los Vaqueros project under this alternative would require the specific approval of the district's voters.

An additional option would substitute a pressure pipeline for the canal. This is advocated by some proponents of isolated transfer as a way of imposing a physical limitation on the ability to convey water to the pumps, thus removing some of the opposition to an open channel peripheral transfer system. This option is physically feasible but would involve a large and expensive pipeline project. It would require a major pumping station at Hood and probably three parallel pipelines, each at least 18 feet in diameter. The capital cost of this pipeline option would be at least double the cost of the canal option, and the resulting unit cost would be similar to that for Alternative 4, the Peripheral Canal.

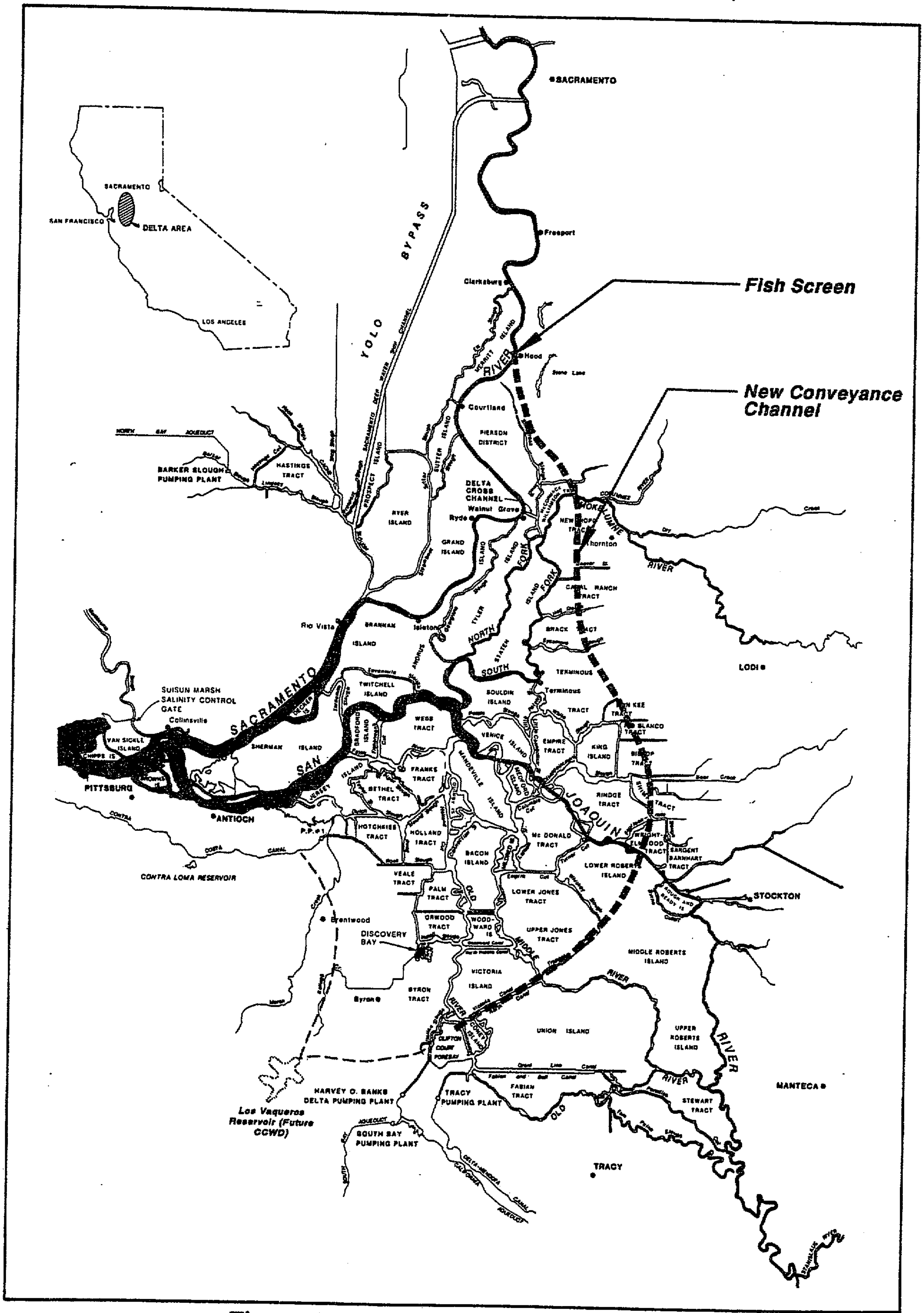


Figure 4-15. Dual Transfer System

Consideration was given to operating the SWP with high quality water only in order to eliminate the very expensive bifurcated conveyance system improvements. In this case, the Delta Mendota Canal would convey Delta water for agricultural use at flow rates required to meet the instantaneous irrigation demand; that is, with no conveyance to storage. In this mode, the Delta Mendota Canal could meet less than 20 percent of the water demands south of O'Neill Forebay. As a result, the SWP diversion system would have to operate at an 80 percent load factor (ratio of average pumpage to peak capacity) rather than the approximately 55 percent load factor currently planned. This approach was deemed infeasible and not studied further. There may be other alternative configurations or operating modes worthy of further investigation.

The East Delta Conveyance Channel would operate by gravity, with a 3-foot drop from the intake on the Sacramento River to Clifton Court, and would be about 30 feet deep and 400 feet wide at the top. An 8 to 1 slope between high and low water levels would control wave wash, provide beaches, and save the cost of riprap or other slope protection. The dimensions coincide with the size of existing pits along the proposed route, which were dug in the 1970s to supply material for highway construction. In the southern Delta, the cross section would be larger to provide enough material for the channel embankments. The channel would siphon under the Mokelumne River, Disappointment Slough, San Joaquin River, Middle River, and Old River. The siphons would be deep and long enough to allow the rivers and sloughs to carry flood flows and permit fish migration.

Except for small areas to the east which would be isolated from their existing water supply by the new channel, Delta water needs would be met from flow through existing Delta channels rather than releases from the new channel. Approximately 300 to 500 cfs of the 7,500-cfs new channel capacity would be needed to meet local water needs in the Delta. The East Delta Conveyance Channel would nearly eliminate the need for carriage water. During most of the year, the SWP would take water only through the new transfer channel. Needs of the SWP beyond the capacity of the new channel would be met by conveyance through Delta channels.

Bifurcated Dual Transfer System. To maximize drinking water quality protection, the DWR Dual Transfer System could be modified by extending the East Delta Conveyance Channel to the Tracy Pumping Plant. The majority of the flow in the new channel would be M&I-only water. Amounts in excess of the M&I demand could be released for pumping to supplement the agricultural supply diverted at the Delta Pumping Plant. This modified concept, shown on Figure 4-16, would be a bifurcated system, called Alternative 5B, providing separate conveyance facilities for M&I and agricultural water supplies all the way to the A.D. Edmonston Pumping Plant. There are a number of possible configurations for conveying water from the Delta south to downstream users. Two options appeared to be the most promising and are discussed below.

Option 1--Los Banos Grandes Reservoir Used for M&I Storage. Option 1 uses Los Banos Grandes Reservoir for M&I storage. The M&I elements of this alternative would be configured as follows:

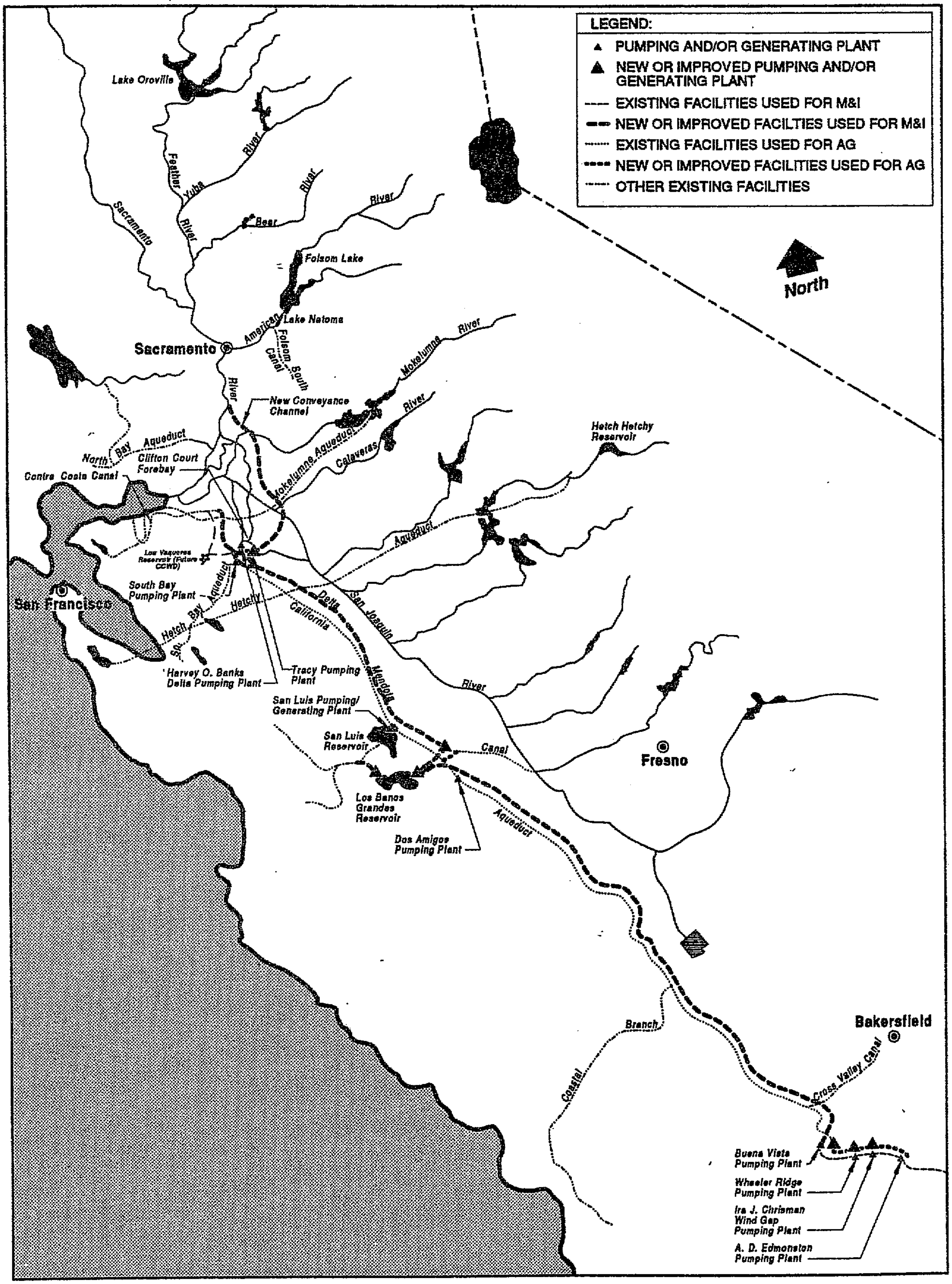


Figure 4–16. Bifurcated Dual Transfer System

1. The existing Tracy Pumping Plant would be enlarged to a capacity of 5,200 cfs, M&I water would be pumped to the Contra Costa Canal and South Bay Aqueduct through new pressure conduits, and the existing discharge pipeline would be used to convey water to the Delta Mendota Canal. The existing connection between the South Bay Pumping Plant and the Bethany Forebay would be deactivated, except for use as an emergency supply connection. Agricultural water users on the South Bay Aqueduct would also receive water from the M&I system.

2. The Delta Mendota Canal would be enlarged to a capacity of 4,500 cfs, where necessary, to carry M&I water from the Tracy Pumping Plant to the Los Banos Grandes Reservoir. All municipal and agricultural wastewater and drainage discharges would be eliminated from the Delta Mendota Canal. A survey of the Delta Mendota Canal is currently being conducted to identify sources of possible contamination.

3. The existing connection between the Delta Mendota Canal and O'Neill Forebay would be deactivated for regular use at the San Luis Reservoir, but would remain in place for emergency or drought supply purposes.

4. Los Banos Grandes Reservoir would be constructed for storage of M&I water. The estimated active storage volume needed for this alternative is 260,000 AF. Additional storage capacity would be provided in the project for other purposes.

5. A new 4,500-cfs M&I pumping plant would be constructed to convey flows from the Delta Mendota Canal to Los Banos Grandes Reservoir.

6. A new 410-cfs M&I pumping plant would be constructed at the Los Banos Grandes Reservoir to convey water to the Pacheco Tunnel. Agricultural users receiving water from the Pacheco Pipeline would also be supplied by the M&I system.

7. A new M&I canal, ranging in capacity from 4,200 cfs to 3,900 cfs, would be constructed from the Los Banos Grandes Reservoir to the Buena Vista Pumping Plant. The alignment of this new canal would run parallel to the existing California Aqueduct.

8. At the Buena Vista Pumping Plant, the new M&I canal would be connected to the California Aqueduct for conveyance south, over the Tehachapi Mountains. The existing Buena Vista, Wheeler Ridge, Wind Gap, and A.D. Edmonston Pumping Plants would be used for conveying M&I water only, except for some small agricultural water uses which will diminish with time.

   South of the A.D. Edmonston Pumping Plant, almost all water demands are M&I. Both agricultural and M&I demands located south of A.D. Edmonston Pumping Plant would be met with the water brought to the pumping plant in the M&I conveyance system. Any deficit in this supply could be met from the agricultural supply brought from the Delta. The agricultural supply could be used to meet emergency or drought needs of users located south of A. D. Edmonston Pumping Plant.

Option 1 agricultural system components would be configured as follows:

1. Clifton Court and the Delta Pumping Plant would be used to divert water from the Delta to meet agricultural demands.

2. From the Delta Pumping Plant, agricultural water would be carried south in the existing California Aqueduct to San Luis Reservoir. New agricultural diversion points would be constructed along the aqueduct in this region to supply agricultural users that previously received water from the Delta Mendota Canal.

3. San Luis Reservoir would be used for agricultural water storage.

4. Agricultural water would be carried in the existing California Aqueduct from San Luis Reservoir, south to the vicinity of the existing Buena Vista Pumping Plant.

5. At Los Banos Grandes Reservoir and immediately downstream of the new M&I canal, a new connection between the California Aqueduct and the Delta Mendota Canal would be constructed to transfer agricultural water to the Delta Mendota Canal.

6. New conveyance facilities would be constructed for carrying agricultural water from the vicinity of the Buena Vista Pumping Plant to the vicinity of the A. D. Edmonston Pumping Plant, including new agricultural-only pumping plants near the existing Buena Vista, Wheeler Ridge, and Wind Gap Pumping Plants, as well as a new agricultural-only canal between these plants.

Option 2--Los Vaqueros Reservoir Used for M&I Storage. The configuration of the conveyance system under Option 2 only differs from Option 1 with respect to the M&I storage reservoir location, and the associated changes in the conveyance system required to make the system functional. Option 2 would use an enlarged Los Vaqueros Reservoir for M&I storage.

M&I water would be pumped from the Tracy Pumping Plant to a new canal that would carry water to a new pumping/generating plant at Los Vaqueros Reservoir. Use of the Los Vaqueros project facilities in this manner would require an agreement with the Contra Costa Water District and express approval by the district's voters. Water from the reservoir would be carried by this canal to the Contra Costa Canal, South Bay Aqueduct, and Delta Mendota Canal. Just north of San Luis Reservoir, a new pumping plant would convey water to the Pacheco Tunnel.

Based on the rough cost estimates made in this study, the construction cost for Option 2 would be almost $1 billion more than the Option 1 bifurcated system. Also, the cost to supply water to users from the Pacheco Pipeline from the Delta Mendota Canal would be substantially more than using the Option 1 system. Due to the large cost difference between the options, Option 1 costs are used in this report.

Water Quality Improvement

To estimate the drinking water quality improvement that would result from the nonbifurcated Dual Transfer System, the following assumptions were made.

1. The Sacramento River water, diverted near Hood and conveyed in the channel, would mix completely with Delta water in O'Neill Forebay roughly in equal portions.

2. The Delta water quality would be improved over the existing quality because this alternative includes the Delta Transfer System Improvements. The water quality resulting from the Delta Transfer System Improvements was presented previously in this chapter.

There are significant drinking water quality impacts on this alternative from the Sacramento metropolitan area and from upstream agricultural drainage. These pollutants, and possible mitigation measures, are discussed more fully under Alternative 4.

The estimated concentrations of several key water quality constituents at O'Neill Forebay are summarized in Table 4-14. These concentrations are compared to the existing quality at Clifton Court and Rock Slough to show the expected improvement in water quality that could be achieved with this alternative. These data show that on an average annual basis there would be a considerable improvement in water quality with this alternative. The mean THMFP (DWR) would be reduced by about 25 percent to 370 ug/l and the THMFP (EBMUD) concentration would be reduced to 110 ug/l. Using the EBMUD data, the average distribution system THM concentration would be reduced to 55 to 75 ug/l with the nonbifurcated Dual Transfer System. At these concentrations, the current standard of 100 ug/l could be met without further treatment but the more stringent anticipated standards probably could not be met without additional treatment. There would be some improvement in TDS, bromide, chloride, and sodium concentrations with this alternative.

The 85 percentile values were calculated by blending Sacramento River water with improved Clifton Court water on a 40 percent/60 percent basis. This is the mix of waters expected to occur during the peak pumping periods. The existing 85 percentile concentrations in the Sacramento River and the predicted 85 percentile values for Clifton Court were used in the blending of the two waters. The data show that the variations in concentrations of the key constituents would be less than the current variations in quality. With the nonbifurcated Dual Transfer System alternative, the predicted 85 percentile values are lower than the existing mean values. This indicates that during the periods of poorest water quality, the quality would be improved over the existing average quality. Treatment Options D or E would be required to bring diverted water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 ug/l or 20 ug/l.

The bifurcated Dual Transfer System alternative would achieve the same improvements in water quality as the Peripheral Canal alternative. The expected water quality at the pumps was presented previously in Table 4-12. The level of treatment necessary to meet drinking water regulations would thus be the same as the Peripheral Canal (Options C or D). The major difference between these two alternatives is that the Peripheral Canal Alternative would supply high quality M&I and agricultural water, and the Dual Transfer System would only supply high quality M&I water.

Table 4-14. Comparison of Water Quality With the Nonbifurcated Dual Transfer System and Existing Water Quality

	Estimated water quality		Existing conditions			
			Clifton Court		Rock Slough	
Constituents, units	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	370	460	500	640	480	610
THMFP (EBMUD), ug/l	110	150	160	200	-	-
TDS, mg/l	150	240	240	380	240	390
TOC, mg/l	7	11	8	12	-	-

[a]85 percentile value is the mean plus one standard deviation.

Cost Estimates

The capital cost of the Dual Transfer System improvements has been estimated in the DWR (1983) publication Alternatives for Delta Water Transfer. Based on a USBR cost index of 160, representing mid-1989 dollars, the capital cost for a gravity flow East Delta Conveyance Channel, including new fish screens at the intake structure near Hood, would be approximately $525 million. The M&I water users would be responsible for about $283 million of the total capital cost. The DWR cost estimate did not include O&M costs. For the purpose of this study, annual O&M costs for the Dual Transfer System were assumed to be equal to 1.5 percent of the construction cost, or about $5.6 million per year above existing costs. The M&I portion of the annual O&M cost would be $3.0 million. There would not be a significant increase in energy costs per AF of water over the existing system. Table 4-15 presents a summary of the major cost items for this alternative.

The estimated treatment cost to comply with anticipated drinking water regulations is $144/AF or $464 million/year (Treatment Option D), if the THM standard is set at 50 ug/l, or $234/AF or $751 million/year (Treatment Option E), if the THM standard is set at 20 ug/l. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 150 mg/l. This would result in a reduction in TDS of 90 mg/l and an estimated savings in consumer costs of $196 million/year.

Table 4-15. Summary of Costs for Alternative 5A (Nonbifurcated)

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	283	3.0	26	8[c]
Agricultural portion	242	2.6	23	5[d]
Total	525	5.6	49	7[e]
Treatment[f]				
50 ug/l THM	2,533	239	464	144
20 ug/l THM	3,015	394	751	234

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water, under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

Cost for additional improvements, south of the Delta, needed to provide a bifurcated system is estimated to be approximately $2.31 billion. The total cost for a bifurcated Dual Transfer System would be about $2.84 billion. The M&I portion of the capital cost would be $2.60 billion. The annual O&M cost for a bifurcated system would be about $24 million above existing costs. The M&I portion of the annual O&M cost would be $21 million. There would not be a significant increase in energy costs per AF of water over the existing system. Table 4-16 presents a summary of the major cost items for this alternative. The estimated cost for treatment of water diverted from the Delta with a bifurcated conveyance system south of the Delta, would be the same as with the Peripheral Canal, $104/AF or $334 million/year if the THM standard is set at 50 ug/l, and $144/AF or $464 million/year if the THM standard is set at 20 ug/l. The consumer cost reduction would also be the same as Alternative 4, $305 million/year.

Table 4-16. Summary of Costs for Alternative 5B (Bifurcated)

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	2,598	21	233	73[c]
Agricultural portion	242	3	23	5[d]
Total	2,840	24	256	34[e]
Treatment[f]				
50 ug/l THM	2,008	155	334	104
20 ug/l THM	2,533	239	464	144

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

ALTERNATIVE 6. SIERRA SOURCE-TO-USER SYSTEM

The Sierra Source-to-User System would be a completely bifurcated conveyance system, conveying water from the Feather and Sacramento Rivers to supply M&I users and conveying water from the Delta to supply agricultural users. Under this system, new conveyance facilities would be constructed for conveying M&I water from the Feather River/Sacramento River confluence to the south, bypassing the Delta, to the Tracy Pumping Plant, and then through the Delta Mendota Canal to M&I users located in the San Francisco Bay, central coastal, and Southern California regions. The existing SWP facilities plus an expanded Delta Pumping Plant and Delta channel improvements would be used for conveying water from the Delta to agricultural water users. This alternative is shown on Figure 4-17.

The Sierra Source-to-User System could bring high quality water to all urban water users who are now served, or expect to be served, through the California Aqueduct and Delta Mendota Canal systems. Additional connections and exchanges with this system could readily bring the total population served (wholly, or in part) by it to 80 percent of the state's population. An additional 10 percent of the population have present or planned supplies of high quality water from other Sierra or Coast Range sources.

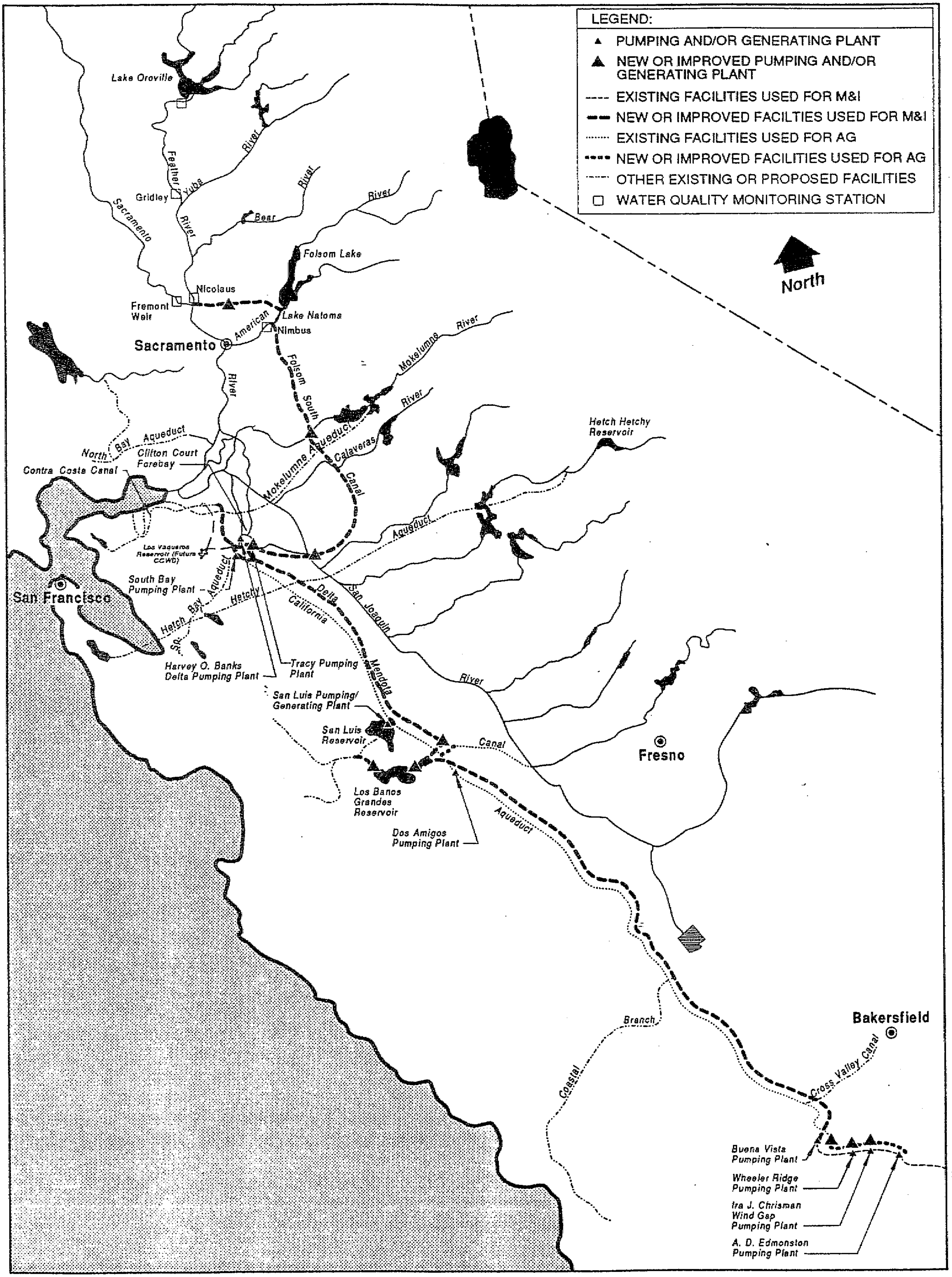


Figure 4-17. Sierra Source-to-User System

Physical Improvements

The elements of the Sierra Source-to-User System are described in this section. The projected water demands which the system is developed to meet were described in Chapter 2.

Diversion. Several diversion points were considered for supplying M&I water from the Feather and Sacramento Rivers. Flows in the Sacramento River are capable of supplying the entire water demand in the critical period (years 1928 to 1934); whereas, water diverted solely from the Feather River would not be sufficient to meet all M&I demands during dry years.

Water quality data were evaluated on the Sacramento River and the Feather River to assess the water quality advantage of diverting water from the Feather River rather than taking the necessary quantity directly from the Sacramento River. In addition, data were evaluated at three locations on the Feather River to determine if upstream water was of better quality than downstream water. Data were analyzed from the following locations:

1. Sacramento River at Fremont Weir--immediately upstream of the confluence with the Feather River.

2. Feather River at Oroville--5 miles below Oroville Dam.

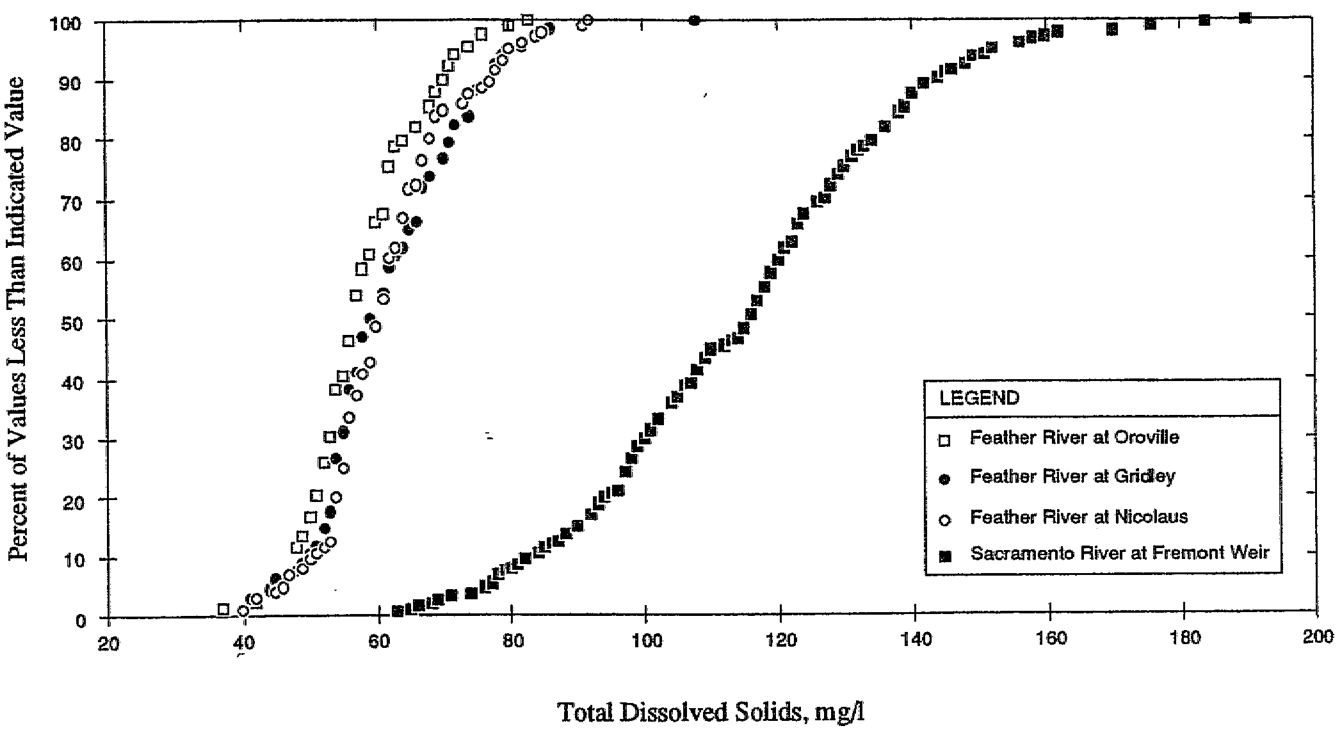
3. Feather River at Gridley--upstream of the Yuba River confluence.

4. Feather River at Nicolaus--downstream of the Yuba and Bear Rivers near the confluence with the Sacramento River.

The available data on several water quality constituents, including TDS, TOC, total Kjeldahl nitrogen, and total phosphorus were evaluated at the four locations. The results are presented on Figures 4-18 and 4-19. There were limited data available on the concentrations of organics and metals and no data on THMFP in the Feather River and upper Sacramento River. Based on the limited data available, the raw water quality of the Feather River is clearly superior to the Sacramento River. Therefore, the Feather River was selected as the major source of water for this alternative. The three locations on the Feather River have essentially the same quality of water so there would be no significant water quality advantage to diverting further upstream. The selected diversion point for this alternative is the Feather River immediately upstream of the confluence with the Sacramento River.

The required diversion capacity could be obtained at the confluence of the Feather and Sacramento Rivers. To supply the highest quality water, as much water as possible would be obtained from the Feather River, which has superior quality compared to the Sacramento River. The Sacramento River would supplement the diversion from the Feather River to meet peak water demands.

The firm yield from the Feather and Sacramento Rivers near the mouth of the Feather River was estimated using results from the DWR Planning Simulation Model used for



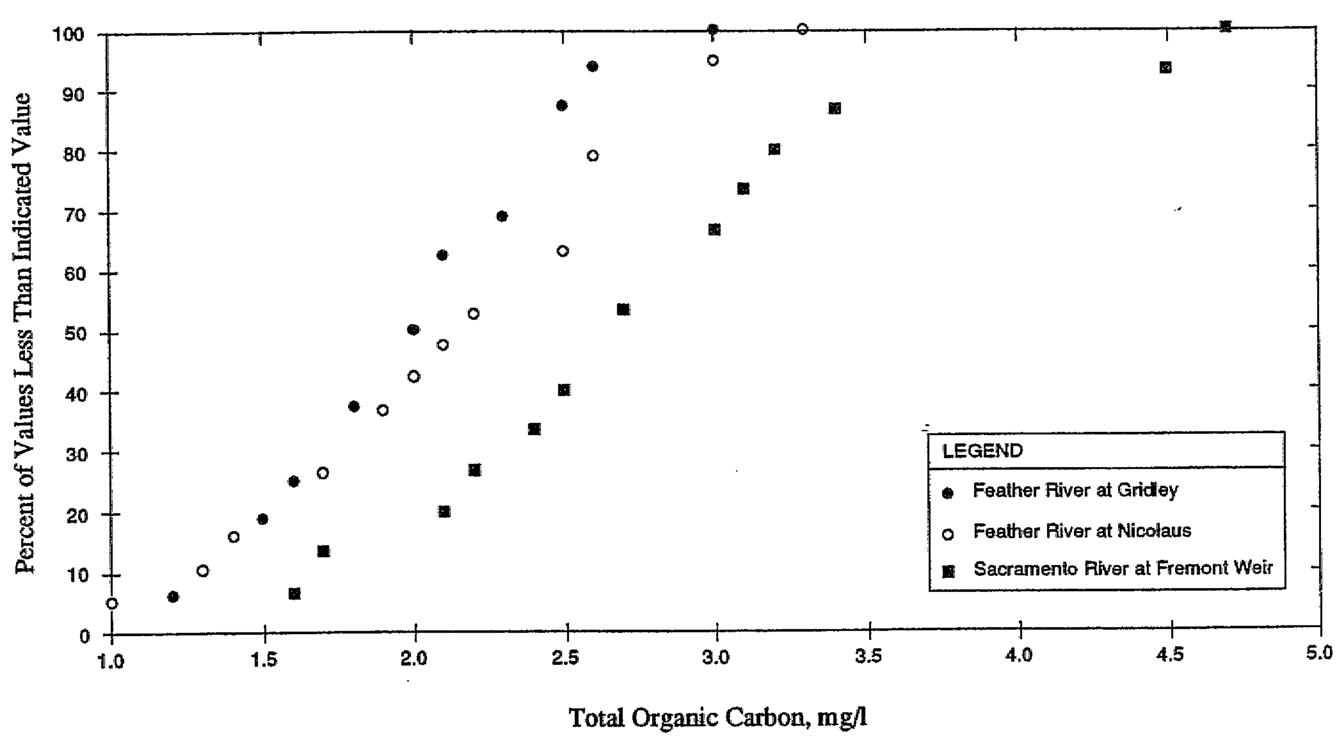
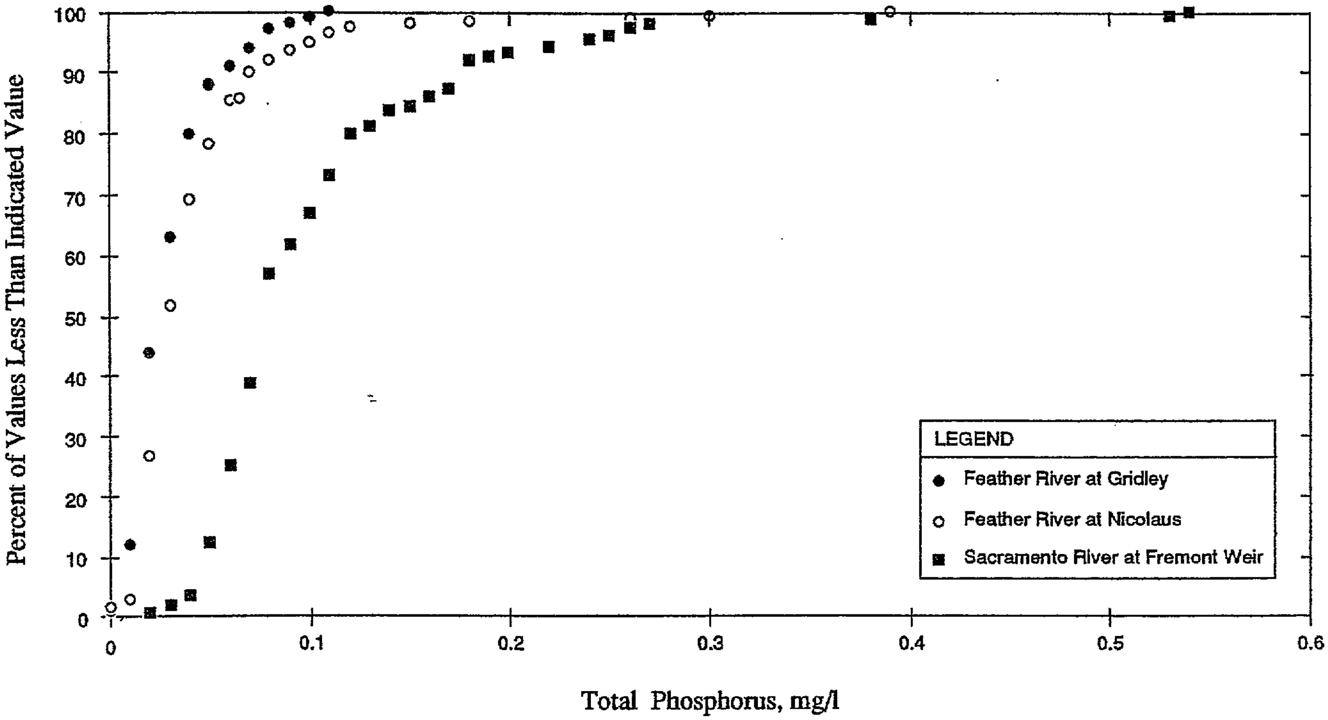


Figure 4-18. Occurrence of Total Dissolved Solids and Total Organic Carbon at Alternative Diversion Sites



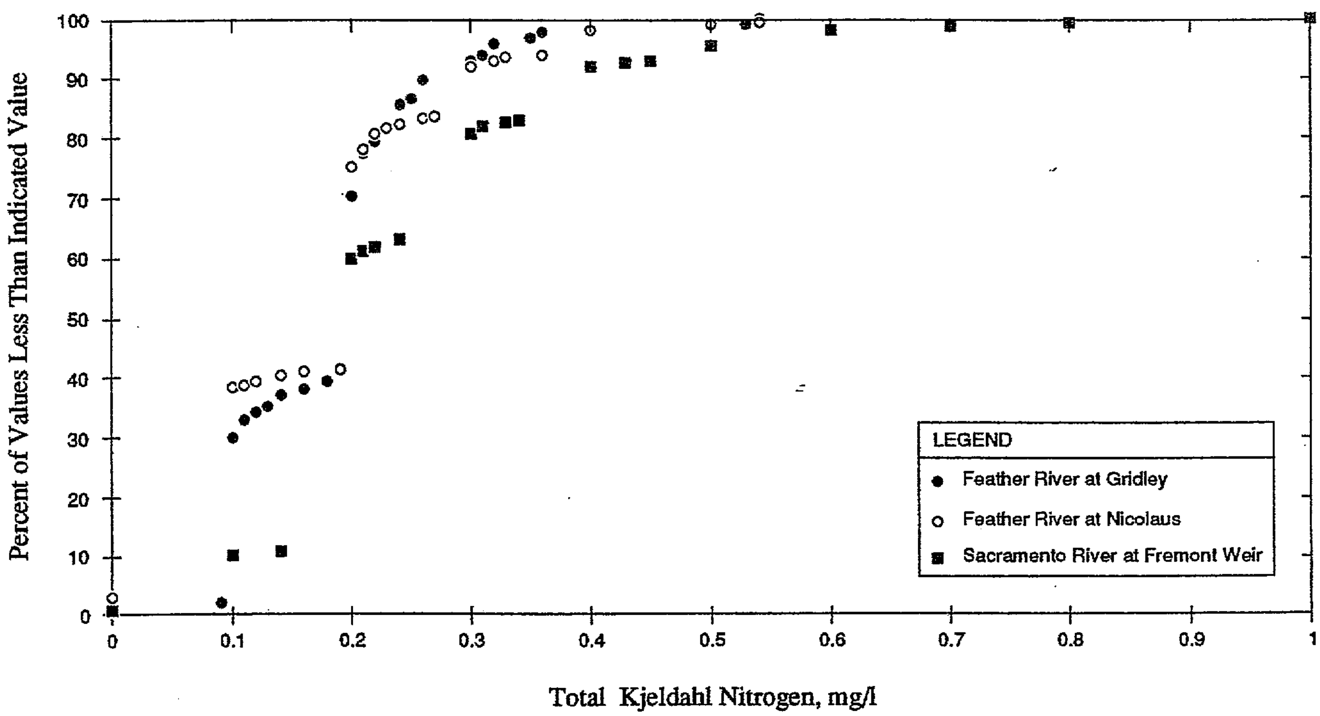


Figure 4-19. Occurrence of Nutrients at Alternative Diversion Sites

operations and new project facilities planning studies. Figure 4-20 shows the average monthly water supply available during the critical period (years 1928 to 1934) from the Feather River and the combined supply from the Feather and Sacramento Rivers necessary to meet the M&I water demand. The M&I water demand is also shown on the figure. On an average basis during this critical hydrologic period, 2.3 million AF/yr would be diverted from the Feather River, and 1.2 million AF/yr would be diverted from the Sacramento River. A possible source to supplement Feather River water during low-flow periods would be development of a large conjunctive use project in the valley aquifers in the area between the Feather and American Rivers.

Conveyance. The conveyance facilities south of the Delta for the Sierra Source-to-User System are identical to the Bifurcated Dual Transfer System described previously (Alternative 5B). The Sierra Source-to-User System from the source of supply for M&I water at the Feather/Sacramento River confluence, to the Tracy Pumping Plant, would be configured as follows:

1. A new canal would convey M&I water from the diversion near the confluence of the Feather and Sacramento Rivers to a 5,300-cfs pumping plant, through a pressure pipeline and tunnel to Lake Natoma, and finally into the Folsom South Canal. To reduce the total lift, a 27-foot-diameter tunnel would be constructed from just north of Roseville south to Lake Natoma (approximately 50,000 feet). This would be a major tunnelling project and would require extensive planning and geotechnical exploration to establish the best route and construction materials.

   In this preliminary study, a number of possible routes were investigated to get water from the river to the Folsom South Canal. One possible route was to pump water up to Folsom Lake and thence down to the Folsom South Canal through the American River, generating power through the drop into Lake Natoma. Based on preliminary cost analyses, this route proved not to be as cost-effective as using a tunnel to minimize the total lift for the pumps. Another possible route investigated was to construct a pressure pipeline from Roseville to Lake Natoma. This route was also determined to be less cost-effective than the tunnel.

2. South from Lake Natoma, the existing Folsom South Canal would be enlarged to a capacity of 5,300 cfs and extended to the Mokelumne Aqueduct, where a connection between the two facilities would be constructed to provide delivery of M&I water to EBMUD to meet the CVP contract entitlements of that district. From the Mokelumne Aqueduct, the Folsom South Canal would be extended to the Tracy Pumping Plant, with a carrying capacity of 5,200 cfs. There are a number of other possible alignments for the Folsom South Canal, one of which would be to use an alignment parallel to the Mokelumne Aqueduct. At the intersection of the Folsom South Canal and the Mokelumne Aqueduct, the Folsom South Canal could connect to a new pipeline that would convey water to the Tracy Pumping Plant using an alignment that is parallel to the Mokelumne Aqueduct. Near the confluence of Whiskey and Trapper Sloughs, on Roberts Island in the Delta, the new pipeline could continue southwesterly to the Tracy Pumping Plant.

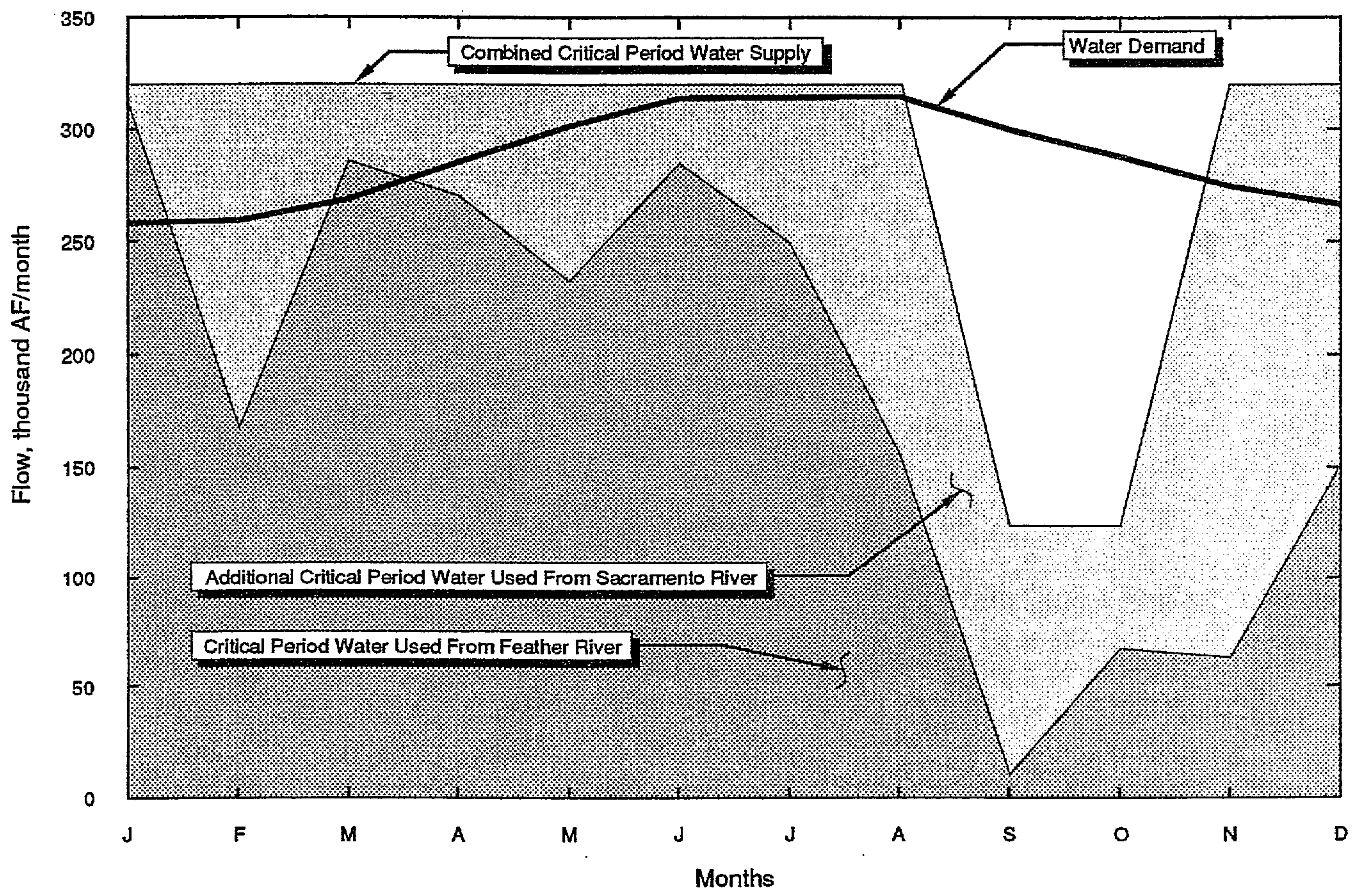


Figure 4-20. Demand and Critical Period Supply at Diversion Point

The disadvantage of using an alignment parallel to the Mokelumne Aqueduct is that the new pipeline would be constructed on poor foundation soil. Most of the interior Delta region contains peat soils that do not provide a good foundation for structures. This would make the new pipeline less reliable, increasing the risk of foundation failure, earthquake damage, and flooding damage. The interior Delta island levees have a history of failure, and resultant island flooding. This alignment was eliminated from further consideration because of the poor reliability that it provides for the system. Essentially all of the M&I water supplied by SWP would be carried in this new pipeline. Reliability is judged more important than the potential cost savings of this alignment.

Water Quality Improvement

To estimate the drinking water quality improvement that would result from this alternative, the following assumptions were made.

1. There would be complete mixing of the Feather River and Sacramento River water during conveyance to Lake Natoma.

2. The combined Feather/Sacramento River water would mix completely with the American River water in Lake Natoma.

3. There would be no changes in quality during storage in Lake Natoma or conveyance to the Tracy Pumping Plant.

4. The mean THMFP concentrations in the Feather River and the Sacramento River at Fremont Weir were assumed to be equal to the mean concentrations in the American River at Nimbus and the Sacramento River at Greene's Landing, respectively. This assumption was made because there were no THMFP data on the Feather River or the upper Sacramento River. This assumption is slightly conservative; that is, the actual water quality would likely be more favorable.

Table 4-17 presents the estimated concentrations of several key water quality constituents. These concentrations are compared to the existing quality at Clifton Court and Rock Slough to show the expected improvement in water quality that could be achieved with this alternative. These data show that on an average annual basis there would be a significant improvement in water quality with the Sierra Source-to-User System. The THMFP (DWR) would be reduced by at least 50 percent to 250 ug/l and the THMFP (EBMUD) concentration would be reduced to 65 ug/l. Using the EBMUD data, the average distribution system THM concentration would be reduced to 35 to 45 ug/l with the Sierra Source-to-User System. At these concentrations, the current standard of 100 ug/l could be met with existing treatment. Depending on how stringent the revised standard will be, it might be possible to meet the revised standard without additional treatment with this alternative. There would be significant improvements in TDS, chloride, and sodium concentrations with this alternative. The water would also be lower in algal nutrients.

Table 4-17. Comparison of Water Quality With the Sierra Source-to-User System Alternative and Existing Water Quality

	Estimated water quality		Existing conditions			
			Clifton Court		Rock Slough	
Constituents, units	Mean	85 percent[a]	Mean	85 percent[a]	Mean	85 percent[a]
THMFP (DWR), ug/l	250	330	500	640	480	610
THMFP (EBMUD), ug/l	65	80	160	200	-	-
TDS, mg/l	60	70	240	380	240	390
TOC, mg/l	3	6	8	12	-	-
Chloride, mg/l	3	4	65	130	60	130
Sodium, mg/l	5	6	40	65	45	80
Total phosphorus, mg/l	0.04	0.07	0.13	0.17	-	-

[a]85 percentile value is the mean plus one standard deviation.

The 85 percentile values show that the variations in concentrations of the key constituents would be less than the current variations in quality. With this alternative, the predicted 85 percentile values are lower than the existing mean concentrations. This indicates that even during the periods of poorest water quality, the quality would be better than it currently is on the average.

There would also be improvements in water quality constituents that cannot be quantified at this time due to limited or no data. This alternative avoids contact between the drinking water and agricultural and urban drainage that is discharged to the Sacramento River below Fremont Weir, the San Joaquin River, or directly into Delta waterways. These discharges can contain pesticides and other synthetic organics that are by-products of industrial activities. A significant amount of agricultural drainage enters the rivers upstream of the diversion point for this alternative. Further investigation might show that a portion of this drainage could be cost-effectively conveyed below the diversion point. Although many organic constituents are currently not detected or are detected in trace amounts in the Delta water, it will become increasingly more important to limit organic contamination of water supplies as EPA develops standards for additional organic contaminants. Treatment Options A or B would be required to bring the water from this alternative into compliance with existing and expected drinking water regulations, depending on whether the THM standard is set at 50 ug/l or 20 ug/l.

Cost Estimates

The capital cost for the Sierra Source-to-User System is estimated to be $4.95 billion. M&I water users would be responsible for $4.70 billion of the total cost of this system.

The O&M cost (excluding energy) for this alternative is estimated to be $41 million per year above existing costs. M&I water users would be responsible for $38 million of the O&M costs. The additional energy costs are estimated to be $60 million per year. M&I water users would be responsible for this entire amount. Table 4-18 presents a summary of the major cost items for this alternative.

Table 4-18. Summary of Costs for Alternative 6

Component	Cost,[a] million dollars			Total unit cost, dollars/AF
	Capital	Annual operating	Total annual	
Delivery system[b]				
M&I portion	4,704	98	482	150[c]
Agricultural portion	242	3	23	5[d]
Total	4,946	101	505	68[e]
Treatment[f]				
50 ug/l THM	1,840	146	310	96
20 ug/l THM	2,366	229	440	137

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]M&I unit cost based on M&I projected 2010 demand of 3,211,000 AF/yr.
[d]Agricultural unit cost based on agricultural projected 2010 demand of 4,216,000 AF/yr.
[e]Total unit cost based on total projected 2010 demand of 7,427,000 AF/yr.
[f]Treatment costs based on anticipated standards and requirements after 1991 for alternative levels of THM standards. See other treatment assumptions in Chapters 3 and 4.

To maintain the overall water quality improvements within the Delta that would be obtained with the proposed Delta Transfer System Improvements, some improvements would be required in the Delta under the Sierra Source-to-User System. Specifically, channel improvements/enlargements in the North and South Delta and the enlarged Delta Pumping Plant would be needed. The cost for these improvements was estimated using information contained in the report Alternatives for Delta Water Transfer (DWR, 1983) and the cost curves developed for this study. The total cost for Delta improvements needed, as part of the Sierra Source-to-User System, is estimated to be $340 million. It was assumed that agricultural users would be responsible for the same dollar-value of Delta improvements as for the Delta Transfer System Improvements alternative ($242 million).

M&I users would be responsible for the remainder of the improvement costs, or approximately $98 million. This cost for Delta improvements has been included in the Sierra Source-to-User System cost estimate.

The estimated treatment cost to comply with anticipated drinking water regulations is $96/AF or $310 million/year (Treatment Option A), if the THM standard is set at 50 ug/l, or $137/AF or $440 million/year (Treatment Option B), if the THM standard is set at 20 ug/l. This alternative would reduce the average TDS of the diverted water from the present level of 240 mg/l to about 60 mg/l. This would result in a reduction in TDS of 180 mg/l and an estimated savings in consumer costs of $392 million/year.

SUMMARY OF ALTERNATIVES

The results of the analysis of the six alternatives are arrayed in the following three summary tables and discussed below. The following chapter discusses further evaluations which would be needed to rank the alternative concepts or to make water development program recommendations.

Water Quality Improvement

The mean values of resultant quality of diverted Delta water for the six alternatives are compared in Table 4-19 to the existing conditions for THMFP and TDS. It is clear from this comparison that significant drinking water quality improvement would result from alternatives that protect source water quality.

The existing Delta water conveyance and supply system is inadequate from several viewpoints, including drinking water quality protection, South Delta agriculture, and fishery protection.

Alternative 1, Proposed Delta Transfer System Improvements, would provide important Delta hydraulics improvements, but would not achieve major drinking water quality improvement. Delta channel transfer could not achieve water quality that would be considered fully adequate by the drinking water suppliers.

Alternative 2, San Joaquin Conjunctive Use Project, is an excellent concept for several reasons, but its impact on drinking water improvement in the major export systems is so small that it is simply not a major factor within the focus of this study.

Alternative 3, Delta Agricultural Drainage Management, is also a concept with merit, but without a large enough potential impact on drinking water quality to justify its high cost or to be a high priority concept.

Alternative 4, Peripheral Canal, would provide significant drinking water quality improvement at relatively low cost, and would reduce the level and cost of treatment compared to alternatives which would not provide isolation of urban supplies from the Delta.

Table 4-19. Summary of Water Quality

Alternative	THMFP, ug/l DWR	THMFP, ug/l EBMUD	TDS, mg/l	TOC, mg/l
Existing condition (base case)	500	160	240	8
1. Delta Transfer System Improvements	420	130	200	7
2. San Joaquin Conjunctive Use Project	400	120	190	7
3. Delta Agricultural Drainage Management	330	100	160	7
4. Peripheral Canal	310	85	100	6
5. Dual Transfer System				
A. Nonbifurcated	370	110	150	7
B. Bifurcated	310	85	100	6
6. Sierra Source-to-User System	250	65	60	3

Note: These data are mean annual values which are expected at the diversion pumps; they do not show quality variations or account for mitigating effects of storage.

Alternative 5, Dual Transfer System, could also achieve significant drinking water quality improvement, but mingling of the transferred water with Delta water, limits the resulting drinking water protection. A fully bifurcated option (Alternative 5B) would avoid mixing the protected supply, but would have a much higher cost.

Alternative 6, the Sierra Source-to-User System, would provide the highest quality drinking water and a high level of protection against future water quality degradation and natural disasters in the Delta. On the other hand, it is an expensive and complex project which would create many construction and community impacts in its implementation.

All of these concepts, and all feasible variations of them should be further studied. These investigations should proceed concurrently with further studies of water quality in the tributaries, the Delta, and in the estuary, including San Francisco Bay.

Costs for Supply Alternatives

A summary of total costs for the alternative delivery systems is given in Table 4-20. The M&I costs for delivery systems associated with the alternative concepts analyzed in this study are shown in Table 4-21. Treatment costs are not included in this table. Project costs shown in the summary tables are portions of the costs of new facilities allocable to water users, expressed as total annual cost, including all incremental (additional) operating costs in addition to the annual (amortized) cost of capital. The capital value and future operating costs of existing facilities are not included. Annual cost of some of the capital-intensive alternatives is very high compared to the currently planned Delta Transfer System Improvements. Costs shown include capital, the equivalent annualized value of this capital, and operating costs (including O&M and energy). It is important to note in reviewing and comparing these costs that the sharing of costs by M&I and agricultural users varies for each alternative. These costs are only those additional costs imposed by the alternative (in addition to continuing costs for existing facilities).

Treatment Costs and Consumer Cost Savings

The costs to treat the water resulting from each alternative to comply with existing and anticipated drinking water regulations are compared in Table 4-22, on the basis of both total annual cost and dollars/AF. Two treatment costs are given for each alternative based on the treatment necessary if the THM standard is set at 50 ug/l or 20 ug/l.

Figure 4-21 is a graphic summary of the estimated total savings to urban water consumers available through better mineral water quality (see discussion in Chapter 3). For all but Alternative 6, the estimated consumer cost benefits would exceed the entire cost of the alternative delivery system. Much nonutility consumer water cost is not accounted for by this approach. For example, if bottled water purchases could be significantly reduced by providing better drinking water and improving consumer confidence, the total economic benefit could be considerably greater than the amounts calculated in this analysis.

Table 4-20. Summary of Total Delivery Costs

Alternative	Delivery cost,[a,b] million dollars				Total unit cost,[c] dollars/AF
	Capital	Annualized capital	Annual operating	Total annual	
1. Delta Transfer System Improvements	425	35	5.1	40	5
2. San Joaquin Conjunctive Use Project[d]	425	35	21	56	8
3. Delta Agricultural Drainage Management	1,745	143	31	174	23
4. Peripheral Canal	850	69	18	87	12
5. Dual Transfer System					
A. Nonbifurcated	525	43	5.6	49	7
B. Bifurcated	2,840	232	24	256	34
6. Sierra Source-To-User System	4,946	404	101	505	68

[a]Costs based on mid-1989 price levels and projected 2010 water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]Total unit cost was based on the total (agricultural and M&I) 2010 demand of 7,427,000 AF/yr. Total unit cost for agricultural use would be $5/AF for all alternatives.
[d]Capital costs are for the Delta Transfer System Improvements only; the capital cost of the conjunctive use project is not available.

Table 4-21. Summary of M&I Portion of Delivery Costs

Alternative	Delivery cost,[a,b] million dollars				Total unit cost,[c] dollars/AF
	Capital	Annualized capital	Annual operating	Total annual	
1. Delta Transfer System Improvements	183	15	2.2	17	5
2. San Joaquin Conjunctive Use Project[d]	183	15	18	33	10
3. Delta Agricultural Drainage Management	1,503	123	28	151	47
4. Peripheral Canal	608	50	15	65	20
5. Dual Transfer System					
A. Nonbifurcated	283	23	3.0	26	8
B. Bifurcated	2,598	212	21	233	73
6. Sierra Source-To-User System	4,704	384	98	482	150

[a]Costs based on mid-1989 price levels and projected 2010 M&I water deliveries. Annual operating cost includes energy cost.
[b]Delivery system includes all necessary modifications to existing systems, and new facilities required to deliver untreated water under this alternative. New supply facilities needed to augment system yield are not included.
[c]Total unit cost was based on the M&I 2010 demand of 3,211,000 AF/yr.
[d]Capital costs are for the Delta Transfer System Improvements only; the capital cost of the conjunctive use project is not available.

Table 4-22. Summary of Treatment Costs

Alternative	Total annual cost, million dollars		Unit cost, dollars/AF	
	50 ug/l[a]	20 ug/l[b]	50 ug/l[a]	20 ug/l[b]
Existing conditions[c]	464	882	144	275
1. Delta Transfer System Improvements	464	882	144	275
2. San Joaquin Conjunctive Use Project	464	882	144	275
3. Delta Agricultural Drainage Management	334	751	104	234
4. Peripheral Canal	334	464	104	144
5. Dual Transfer System				
A. Nonbifurcated	464	751	144	234
B. Bifurcated	334	464	104	144
6. Sierra Source-to-User System	310	440	96	137

[a]Costs based on a hypothetical THM standard of 50 ug/l.
[b]Costs based on a hypothetical THM standard of 20 ug/l.
[c]Treatment costs for existing conditions are based on needing Treatment Option D, if the THM standard is set at 50 ug/l, and Treatment Option F, if the THM standard is set at 20 ug/l.

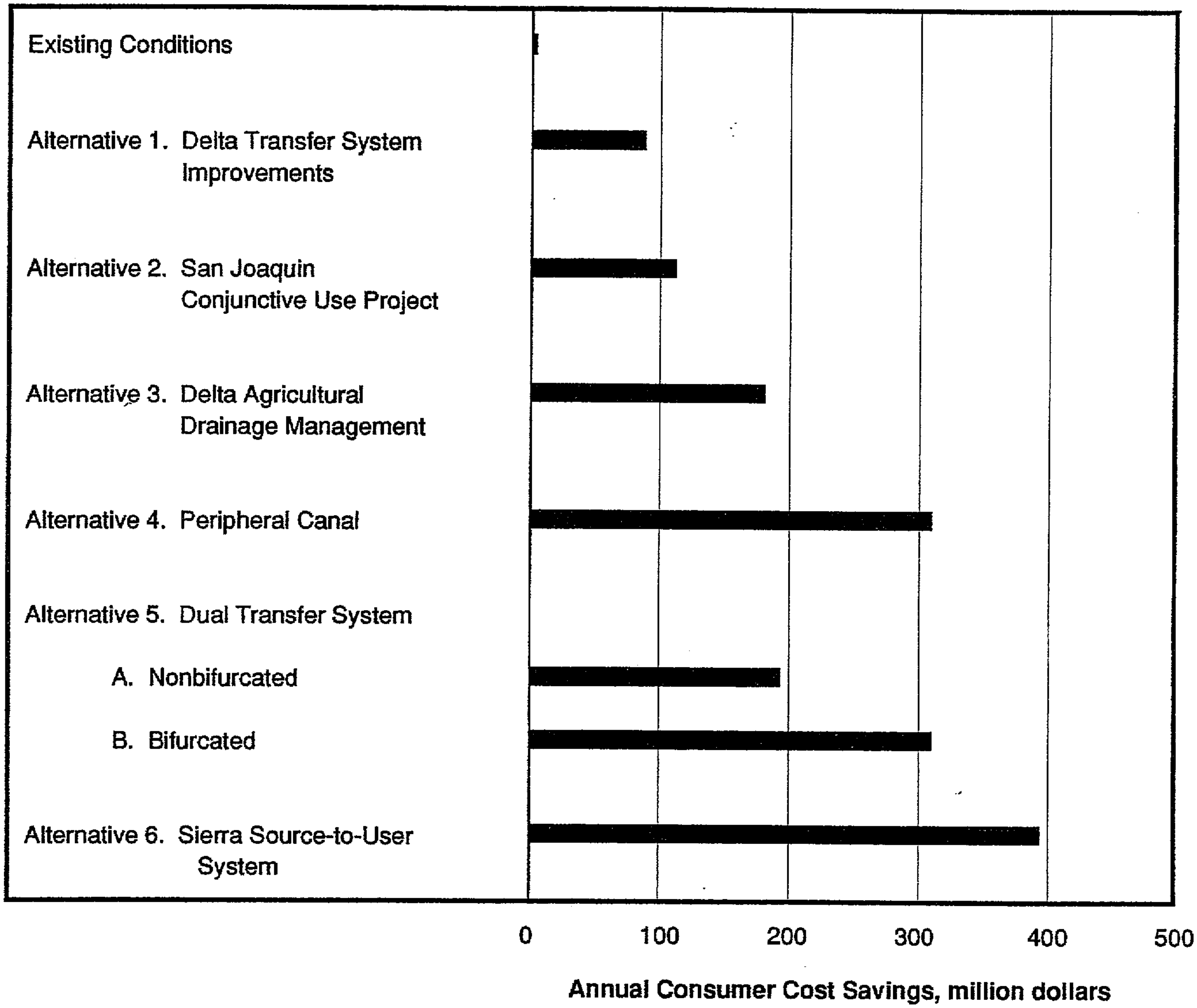


Figure 4-21. Summary of Estimated Consumer Cost Savings

CHAPTER 5

FUTURE EVALUATIONS AND INVESTIGATIONS

This report develops some alternative concepts for protection and improvement of drinking water quality to the reconnaissance, or "first-cut," level of detail. This work provides an initial evaluation of the water quality and water engineering aspects of the various management concepts. It does not provide an evaluation of the many other important features and impacts of these possible approaches. It is recognized that, in the final analysis, the nonengineering factors will likely be more important in the success or failure of a major water project than those factors which we have analyzed in this study.

The project Advisory Committee decided that a list of important evaluation criteria should be presented for review and discussion, and to provide a starting point for planning further work. That list is provided in the following sections.

The last part of this concluding chapter focuses on the specific work items that should be considered in planning and budgeting further work on the Sacramento-San Joaquin Delta (Delta) drinking water quality issues. These latter sections provide, again at a preliminary level, recommendations for high priority follow-on work.

Evaluation Criteria

Many criteria must be considered in the evaluation of alternative water management concepts. These criteria address different categories of concern and several items within each category. The various items are of differing levels of concern or priority to the many people and agencies that have a stake in Delta water issues. The evaluation items identified below address the broad range of concerns that was deemed relevant to this project. The evaluation items are defined in four categories or groups. They are listed and explained below, not in order of priority or level of concern.

Drinking Water Quality Protection and Improvement. The three evaluation criteria in this category are listed here. The water quality analyses in this report are first steps in answering these questions.

1. Meeting water quality objectives. How well does the alternative accomplish the drinking water quality objectives defined for this study? This includes assessment of the ability of the alternative to meet quality objectives during dry years.

2. Benefit or detriment to upstream users. These are drinking water quality benefits or detriments to urban water users who divert water from rivers upstream of the Delta.

3. Reliability in meeting objectives. How reliably can the alternative meet the drinking water quality objectives in light of exposure to risk of physical failure, contamination, or natural disaster in the supply and transmission system?

Legal and Institutional Feasibility. These key considerations involve not only the definable legal contractual and institutional questions, but also must integrate the politics and psychology rooted in the long history of debates over all Delta water issues.

1. Public acceptance. What is the relative compatibility with public attitudes as expressed through the legislature, past referenda, and positions of major special interest groups? This is a highly subjective matter because there are many "publics", and their attitudes vary widely.

2. Political feasibility. Is the State Legislature likely to support this project?

3. Legal feasibility. Feasibility considering all relevant provisions and constraints of current state and federal law, including water rights laws.

4. Institutional arrangements. This item considers the reliability and probable longevity of new institutional arrangements which would be necessary to implement the project.

5. Contractual feasibility. How feasible is the project under the current provisions of state and federal agreements (e.g., Coordinated Operation Agreement (COA)) and water supply contracts?

Costs and Engineering Factors. The five evaluation criteria in this category address both physical/engineering aspects and economic considerations.

1. Energy requirements. This considers mainly pumping and treatment energy requirements and their associated costs. The differing impacts and costs of off-peak and on-peak energy is a consideration that has not been analyzed in this work.

2. Physical feasibility. Are all physical and engineering features and requirements feasible using currently accepted methods and technologies?

3. Time to implement. What total project implementation time can be expected, and how vulnerable is the project to major unforeseen delays?

4. Economic feasibility. This item considers the balance between costs and economic benefits; it is analogous to a relative cost/benefit evaluation.

5. Financial feasibility. Can the project be financed with support by the financial institutions and the beneficiaries to whom project costs will be allocated?

Environmental and Other Impacts. These criteria assess impacts, both beneficial and detrimental, on the environment, on other projects, and on other beneficial uses of the water resources.

1. Delta impacts. This is the impact of the project on the ability of the major Delta water operators to meet established water quality and flow standards.

2. Fishery impacts. This includes both impacts of the project on adjacent habitat, and impacts on ability to meet desirable estuarine flow regimes.

3. In-stream flow impacts. Does the project impact the ability of system operators to comply with in-stream flow requirements below foothill reservoirs as determined by existing regulations, legal mandates, or agreements?

4. Water yield impacts. Does the alternative affect the water supply yield of the State Water Project (SWP), Central Valley Project (CVP), and other major projects?

5. Other beneficial uses. How does the project impact, beneficially or detrimentally, other designated beneficial uses of water beside those addressed above?

6. Need for discharge regulations. Is the project performance heavily dependent on new regulation (limitation) of urban and agricultural discharges?

7. Agricultural water impacts. What impacts does the project have on agricultural water reliability and quality?

Additional Investigations

It is not the purpose of this study to recommend a specific physical system for providing drinking water to the urban water agencies; rather, its purpose is to identify and compare alternative concepts for protection and enhancement of drinking water quality. Many of the alternative concepts evaluated in this project should be studied further to fully assess their feasibility. The following sections contain recommendations on hydrologic and operational studies, water quality studies, and additional monitoring programs that should be conducted.

The work in this study was based on available data, and was intended to put both the water quality problems and possible improvements into physical and economic perspective. No development program recommendations can be made based on this work. The most important next step in considering the Delta drinking water quality issue is for all interested agencies to review this report, to consider and discuss its findings, and to make judgments about the timing, scope, and conduct of follow-on work. That work can be considered in three categories: (1) extension and refinement of alternative drinking water quality protection measures; (2) additional monitoring, and (3) special investigations to fill important gaps in understanding of these issues. These items are briefly discussed, and some specific investigations are suggested in the following sections.

Much of the proposed future work can be done by the existing water resources planning and operating agencies within their current capabilities and missions. Some of the work will require involvement of other research and investigative resources. The California

Urban Water Agencies should promote and monitor all of this work, and join in its planning, financing, and conduct as appropriate.

Refinement of Alternatives. In this report, work on alternative concepts for protection and enhancement of drinking water quality in the Delta diversion systems is done at a reconnaissance level. The alternative concepts considered here have enough potential to justify further work. The urban water agencies and interested state and federal agencies will have to decide how rapidly and at what budget level this work is to proceed. The next phase of investigation should include significant work on the following items:

A. Hydrology and Operations Studies

1. Can the project function as intended under all relevant hydrologic conditions?

2. How would the project perform under critically dry hydrology with supply shortages and entitlement deficiencies (reduced deliveries allowed by contracts) in effect?

3. How much will the project augment total system supply capability by reducing carriage water flow?

4. How would the project affect other beneficial uses (other than its designated beneficiaries) during stressed hydrologic conditions?

5. Would the project require operations outside present limitations; including provisions of the COA?

6. How would the project be impacted by the Bay-Delta Hearings of the California State Water Resources Control Board (SWRCB)?

7. How would the project affect water system performance under various assumptions regarding long-term weather trends and natural risks (e.g., levee failures)?

B. Water Quality and Variations

1. Confirm water quality performance of the project and improve the estimates of variability of quality.

2. Consider impacts of the Bay-Delta Water Quality Control Plans of SWRCB.

3. Determine whether, and to what extent, discharges to Delta tributary waters of precursors to disinfection by-products are likely to be controlled under the federal Clean Water Act.

4. Define additional opportunities for diversion or control of agricultural drainage.

5. Confirm water treatment assumptions, given the estimated water quality variability and the status of drinking water regulations.

6. Are there any new contaminant concerns or treatment processes which might alter the judgments made in this study?

C. Costs and Economic Benefits

1. Refine estimates of economic costs and benefits to all parties affected by the project.

2. Develop more detailed cost-allocation principles and show net benefit or detriment to nonurban participants.

3. What are the impacts on cost/benefit of a variety of economic scenarios for the future; including energy cost ranges?

D. Water Rights

1. Is the project operable under existing and prospective water rights decisions?

2. Are necessary water rights amendments likely to be obtained, and without difficult concessions?

3. What are the impacts on the project of possible water rights revisions arising out of the SWRCB Bay-Delta hearings?

E. Fishery Impacts

1. Make detailed assessments of fishery impacts of the project.

2. Can negative fishery impacts be reasonably mitigated, compensated, or tolerated?

F. Institutional Issues

1. Would implementation of the project require a major revision of CVP and/or SWP supply contracts?

2. Would the project create difficult relationships with affected landowners and agencies?

3. Would the project require amendment of the COA?

G. Environmental Impacts

1. Identify and discuss environmental impacts at the level of an initial study.

2. Prioritize environmental impacts and designate those that might stop the project.

Additional and Special Monitoring. A difficult aspect of this kind of study is that many of the drinking water pollutants of current concern have become recognized only in recent years. As discussed in Chapter 3, many of these constituents do not yet have formal drinking water standards or even well established evidence of human health risk. Nonetheless, it is important to have a comprehensive data base for this work. Sampling and analyses should be conducted at a few selected stations downstream from major sources or impoundments, at least quarterly for 2 years then on a modified schedule, for an extended list of constituents, including:

1. All state/federal drinking water standards constituents (for which maximum contaminant levels or maximum contaminant level goals have been set or are prospective).

2. Environmental Protection Agency (EPA) Drinking Water Priority List.

3. EPA Unregulated Drinking Water Monitoring List.

4. Other organic constituents, or indicators, including total and dissolved organic carbon, trihalomethane formation potential, total organic halogen formation potential, and chlorophyll a or ultraviolet absorbance. (There is a strong need for agreement among cooperating agencies on exactly how to analyze for formation potentials, and to make parallel analyses and correlations when an analytical change is made).

5. Selected pesticides of local significance.

Special Investigations. Five areas of special investigation are particularly important to Delta drinking water quality concerns. The California Department of Water Resources (DWR) should be the lead agency in pursuing this work in cooperation with other interested agencies.

A. Study of Delta soils and agricultural drains. This work could be an expansion of the current Delta Agricultural Drainage Investigation. It would include:

    1. Completion of a comprehensive inventory of Delta agricultural drainage, including locations, quality characteristics, and flows from all drains.

    2. Classification of Delta trihalomethane/total organic halogen (THM/TOX) precursors by chemical groups (types of compounds, molecular weights, etc.), by source, location, soil types, and agricultural practices, as feasible.

    3. Define "hot-spot" sources of high THM/TOX precursors, leading to a better analysis of cost-effective drainage management alternatives.

4. Perform improved mass balances of THM/TOX precursors and bromide forms within the Delta waterway system to provide better estimates of how much precursor load is coming from sources other than drain discharges; e.g., from channels, levees, macrophytes, plankton, etc. This would extend the work begun by DWR in 1988, and the analyses presented in this report.

B. Improve the understanding of the effect of bromide on formation of THM and other disinfection by-products, and their species, in Delta waters at various locations, and using various combinations of the oxidants chlorine, ozone, and hydrogen peroxide.

C. Improve Delta water quality modeling and model calibrations for both salinity and organics to assess the influence of drain discharges on drinking water quality under (1) present conditions, and (2) flow conditions that would exist upon completion of any Delta transfer improvements.

D. Studies of relationships between source water quality and drinking water quality (e.g., taste and odor, THM, etc.), and the effects on these characteristics of residence in the major transmission and storage systems.

E. Investigation of the transport and fate of organic precursors and bromide species both within the SWP and in water treatment plants.

There is much additional work to be done before the alternative concepts for protection and improvement of drinking water quality identified in this study can be fully analyzed to develop a recommended alternative. These investigations should proceed concurrently with further studies of water quality in the tributaries, the Delta, and in the estuary, including San Francisco Bay. It seems clear that better information on all of these topics, coupled with statutory and regulatory environmental safeguards, will be the keys that open the way to construction of Delta facilities that can ensure protection and improvement of drinking water quality

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

Alameda County Water District. 1963. Interoffice Memorandum: Replies to Water Softener Questionnaire.

Amy, G.L., et al. 1985. "Factors Affecting Incorporation of Bromide into Brominated Trihalomethanes During Chlorination," a Chapter in Water Chlorination: Environmental Impact and Health Effects. Vol. 5, pp. 907-922.

Anonymous. 1986. "Softeners Boost Water Heater's Performance." Machine Design.

Brown and Caldwell. 1985. Eastern San Joaquin County Groundwater Study, a Report to San Joaquin County Flood Control and Water Conservation District.

California Department of Water Resources. 1956. Report No. 4, Quantity and Quality of Waters Applied to and Drained From the Delta Lowlands.

California Department of Water Resources. 1969. Lower San Joaquin River Water Quality Investigation. Bulletin No. 143-5.

California Department of Water Resources. 1978. Consumer Costs of Water Quality in Domestic Water Use, Lompoc Area.

California Department of Water Resources. 1980. Letters and Formal Statements Concerning Senate Bill 200 and Related Matters, Letter 92.

California Department of Water Resources. 1983. Alternatives for Delta Water Transfer.

California Department of Water Resources. 1986a. Interagency Delta Health Aspects Monitoring Program. Project Report.

California Department of Water Resources. 1986b. Management of the California State Water Project. Bulletin 132-86.

California Department of Water Resources. 1987a. Evaluation of Toxic Substances in Fish, Benthic Organisms, and Sediment in the State Water Project.

California Department of Water Resources. 1987b. Progress Report 7 of the Interagency Delta Health Aspects Monitoring Program.

California Department of Water Resources. 1987c. California Water: Looking to the Future. Bulletin 160-87.

California Department of Water Resources. 1987d. Kern River Fan Element of Kern Water Bank. Preliminary Technical Report.

California Department of Water Resources. 1987e. Management of the California State Water Project. Bulletin 132-87.

California Department of Water Resources. 1988a. North Delta Water Management Program.

California Department of Water Resources. 1988b. South Delta Water Management Program.

California State Water Resources Control Board. 1988a. Report of Referee, Lower American River Court Reference (EDF et. al., v. EBMUD).

California State Water Resources Control Board. 1988b. Water Quality Control Plan for Salinity, San Francisco Bay/Sacramento-San Joaquin Delta Estuary.

Contra Costa Water District. Tabulation of Annual Water Deliveries From Contra Costa Canal 1978-1986, Exhibit Number 26.

Curry, Lynn L. 1983. Illinois Department of Energy and Natural Resources. Consumer Attitudes Toward Public Water Supply Quality: Dissatisfaction and Alternative Water Sources. ISWS/CIR-158/183.

East Bay Municipal Utility District. 1987. Water Use and Water Supply Management.

James M. Montgomery, Consulting Engineers, Inc., 1982. Clifton Court Water Quality.

James M. Montgomery, Consulting Engineers, Inc., 1984. Modesto-Ceres Area Water Management Study, Final Report.

James M. Montgomery, Consulting Engineers, Inc., 1987. Effect of Impoundment on Water Quality. Contra Costa Water District Los Vaqueros/Kellogg Project.

Luong, Tieu, V., Christopher J. Peters, and Roger Perry. 1982. "Influence of Bromide and Ammonia upon the Formation of Trihalomethanes Under Water-Treatment Conditions." Environmental Science and Technology. Vol. 16, No. 8, pp. 473-479.

McFarland, W.E., 1985. "Groundwater Treatment Alternatives for Industry, Part II, Understanding and Reducing Hardness." Plant Engineering.

National Academy of Sciences, 1977. Drinking Water and Health.

Okun, Daniel A., R.H. Harris, and R. Tardiff. 1985. Water Quality Considerations in Source Selection. Prepared for East Bay Municipal Utility District.

Orange County Water District. 1972. Water Quality and Consumer Costs.

Palo Alto, City of. 1961. Report Upon Palo Alto Water Conditioning Survey and Discussion of Some Water Quality Considerations.

Public Utilities Commission, City and County of San Francisco. 1987. San Francisco Water, Phase One, Bay Delta Water Quality.

Stammer, Larry B., 1986. "4 in 10 Statewide Avoid Tapwater." Los Angeles Times, September 20, 1986.

U.S. Environmental Protection Agency. 1976. Quality Criteria for Water.

Walker, William W., Jr. 1983. "Significance of Eutrophication in Water Supply Reservoirs." Journal AWWA. pp. 38-42.

APPENDIX B

DRINKING WATER STANDARDS AND CRITERIA

Table B-1. Drinking Water Standards and Criteria

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
I. <u>83 Contaminants Required to be Regulated Under the SDWA of 1986</u>[d]				
A. <u>Inorganic Chemicals</u>				
Antimony	--	--	1.4[a]	No adverse health effects fom drinking water exposure levels.
Arsenic	50[e,f]	--	--	Liver and kidney damage.
Asbestos million long fibers/l	7[g]	7[g]	7.1[b]	Possibly causes gastrointestinal cancer.
Barium	1,000[e,f] 5,000[g]	5,000[g]	1,500[a,b]	Hypertension and cardiotoxicity in animals.
Beryllium	--	--	17.5[a]	No adverse health effects fom drinking water exposure levels.
Cadmium	10[e,f] 5[g]	5[g]	5[b]	Renal dysfunction, hypertension, anemia.
Chromium	50[e,f] 100[g]	100[g]	17.5[a], 120[b]	Liver and kidney damage, internal hemorrhage, respiratory disorders.
Copper	1,300[g]	1,300[g]	--	Gastrointestinal disturbances.
Cyanide	--	--	70[a], 154[b]	Hypoxia.
Fluoride	4,000[h] 2,000[h]	4,000[h] --	-- --	Skeletal fluorosis. Dental fluorosis.
Lead	50[e,f] 5[g]	0[g]	--	Severe neurotoxic effects irreversible brain damage.
Mercury	2[e,f,g]	2[g]	1.1[b]	Renal effects.
Nickel	--	--	150[b]	Inadequate toxicological data.
Nitrate, as N	10,000[e,f,g]	10,000[g]	10,000[a]	Reduced to nitrite in gastrointestinal system of infants.
Selenium	10[e,f] 50[g]	50[g]	--	Liver and kidney damage.
Sulfate	--	--	--	Diarrhea and dehydration due to transient exposure.
Thallium	--	--	--	No adverse health effects fom drinking water exposure levels.

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
B. Volatile Organic Chemicals				
Benzene	1[f], 5[h]	0[h]	0.7[b]	Carcinogen.
Carbon tetrachloride	0.5[f], 5[h]	0[h]	0.3[a,b]	Carcinogen.
m-Dichlorobenzene	--	--	620[b] 130[c]	--
o-Dichlorobenzene	600[g]	600[g]	620[b], 130[c]	Central nervous system depression, kidney and liver damage.
p-Dichlorobenzene	5[f], 75[h]	75[h]	75[b]	Liver and kidney damage.
1,2-Dichloroethylene	0.5[f], 5[h]	0[h]	0.4[a], 0.38[b,c]	Carcinogen.
1,1-Dichloroethylene	6[f], 7[h]	7[h]	0.06[a], 7[b], 6[c]	--
cis-1,2-Dichloroethylene	70[g]	70[g]	70[b], 6[c]	Liver and kidney effects.
trans-1,2-Dichloroethylene	100[g]	100[g]	70[b], 10[c]	Liver and kidney effects.
Methylene chloride (Dichloromethane)	--	--	420[a], 5[b], 40[c]	--
Monochlorobenzene	30[f], 100[g]	100[g]	300[b]	Possible carcinogen.
Tetrachloroethylene	5[g,i]	0[g]	140[a], 3.5[b], 5.0[c]	Carcinogen.
Trichlorobenzene	--	--	--	--
1,1,1,-Trichloroethane	200[f,h]	200[h]	630[a], 200[b]	Central nervous system depression.
Trichloroethylene	5[f,h]	0[h]	3[a], 2.8[b]	Carcinogen.
Vinyl chloride	0.5[f], 2[j]	0[h]	0.015[b]	Carcinogen.
C. Synthetic Organic Chemicals				
Acrylamide	treatment technique[g]	0[g]	0.01[b]	Carcinogen.
Adipates	--	--	--	Inadequate health effects data.
Alachlor	2[g]	0[g]	70[a], 0.15[b], 0.2[c]	Carcinogen.
Aldicarb	10[g]	10[g]	9[a,b], 10[c]	Cholinesterase inhibition.
Atrazine	3[f,g]	3[g]	3[b]	Inadequate health effects data.
Carbofuran	40[g]	40[g]	36[b]	Cholinesterase inhibition.
Chlordane	2[g]	0[g]	0.35[a], 0.022[b], 0.1[c]	Carcinogen.
Dalapon	--	--	560[b]	Inadequate health effects data.
Dibromochloropropane (DBCP)	0.2[g,i]	0[g]	0.025[b], 1.0[c]	Carcinogen.
2,4-Dichlorophenoxy acetic acid (2,4-D)	100[e,f], 70[g]	70[g]	70[a,b]	Kidney damage, skeletal muscle effects.
1,2-Dichloropropane	5[g]	0[g]	0.56[b], 5[c]	Possible carcinogen, liver damage.
Dinoseb	--	--	7[a,b]	Inadequate health effects data.
Diquat	--	--	15[a]	Inadequate health effects data.
Endothall	--	--	140[a,b]	Inadequate health effects data.
Endrin	0.2[e,f]	--	0.32[b]	Rarely detected in drinking water.
Epichlorohydrin	treatment technique[g]	0[g]	3.6[a], 3.5[b]	Carcinogen.
Ethylene dibromide (EDB)	0.02[f], 0.05[g]	0[g]	0.0005[b]	Carcinogen.

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/l	Maximum contaminant level goal, ug/l	Other drinking water criteria,[a,b,c] ug/l	Regulatory rationale
Glyphosate	—	—	700[a,b,c]	Inadequate health effects data.
Hexachlorocyclopentadiene	—	—	49[a]	Inadequate health effects data.
Lindane	4[e,f], 0.2[g]	0.2[g]	2[a,b]	Possible carcinogen.
Methoxychlor	100[e,f], 400[g]	400[g]	340[b]	Central nervous system effects.
Pentachlorophenol	200[g]	200[g]	210[a], 220[b], 30[c]	Liver and kidney effects.
Phthalatas	—	—	—	Not found at significant levels in drinking water.
Picloram	—	—	490[b]	Inadequate health effects data.
Polychlorinated biphenyls (PCBs)	0.5[g]	0[g]	—	Carcinogen.
Polynuclear aromatic hydrocarbons (PAH)s	—	—	—	Inadequate health effects data.
Simazine	10[f]	—	35[b]	Inadequate health effects data.
2,3,7,8-Tetrachlorodibenzo-p-dioxin	—	—	2.2 x10[-7b]	Not detected in drinking water.
Toluene	2,000[g]	2,000[g]	2,100[a], 2,420[b], 100[c]	Central nervous system depression.
Toxaphene	5[e,f,g]	0[g]	0.03[b]	Carcinogen.
1,1,2-Trichloroethane	32[f]	—	0.6[a]	Inadequate health effects data.
2,4,5-Trichlorophenoxy propionic acid (Silvex)	10[e,f], 50[g]	50[g]	52[b]	Variety of physiological and biochemical effects.
Vydate	—	—	175[a,b]	Inadequate health effects data.
Xylene	1,750[f], 10,000[g]	10,000[g]	400[b]	Central nervous system disturbances.
D. Microbiology and Turbidity				
Giardia lamblia	—[j]	0[g]	—	Intestinal parasite that causes giardiasis.
Legionella	—[j]	0[g]	—	Bacteria that cause legionellosis.
Standard plate count	—[j]	—	—	Detects presence of bacteria.
Total coliforms MPN/100 ml	1[e,f], —[j]	0[g]	—	Indicator of treatment effectiveness, potential presence of fecal pathogens.
Turbidity, NTU	1[e], 0.5[f], —[j]	—[j]	—	Indicator of treatment effectiveness.
Viruses	—[j]	0[g]	—	Cause numerous diseases, including hepatitus and gastrointestinal diseases.
E. Radionuclides				
Beta particle and photon radioactivity, millirems/year	4[e]	—	—	—
Gross alpha particle activity, pCi/l	15[e,f]	—	—	—
Radium 226 and 228, pCi/1	5[e,f]	—	—	—
Radon, pCi/l	—	—	—	—
Uranium, pCi/l	20[f]	—	—	—

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
II. Contaminants Substituted on 1-22-88				
Aldicarb sulfone	40[g]	40[g]	--	Cholinesterase inhibition.
Aldicarb sulfoxide	10[g]	10[g]	--	Cholinesterase inhibition.
Ethylbenzene	700[f,g]	700[g]	700[a], 680[b]	Adverse kidney and liver effects.
Heptachlor	0.4[g]	0[g]	0.076[b], 0.01[c]	Potential carcinogen.
Heptachlor epoxide	0.2[g]	0[g]	0.09[a], 0.038[b], 0.01[c]	Potential carcinogen.
Nitrite, as N	1,000[g]	1,000[g]	1,000[a]	Methemoglobinemia in infants.
Styrene	5[g]	0[g]	1,400[a], 140[b]	Neurologic and behavioral changes, chromosome aberrations and skin and respiratory tract irritations.
III. Drinking Water Priority List				
A. Substitutes from the SDWA List				
Aluminum	1,000[f]	--	--	No adverse health effects from drinking water exposure levels.
Dibromomethane	--	--	--	No adverse health effects fom drinking water exposure levels.
Molybdenum	--	--	--	No adverse health effects fom drinking water exposure levels.
Silver	50[e,f]	--	10.5[a]	No adverse health effects fom drinking water exposure levels.
Sodium	--	--	--	No relationship between sodium in drinking water and hypertension.
Vanadium	--	--	--	Rarely found in drinking water.
Zinc	--	--	--	No adverse health effects fom drinking water exposure levels.
B. Disinfectants and Disinfection By-Products				
1. Disinfectants				
Ammonia	--	--	--	--
Chloramines	--	--	581[b]	--
Chlorate	--	--	24[b]	--
Chlorine	--	--	--	--
Chlorine dioxide	--	--	210[a], 380[b]	--
Chlorite	--	--	24[b]	--
Hypochlorite ion	--	--	--	--
Ozone by-products	--	--	--	--
2. Trihalomethanes	100[e,f,k]	--	--	--
Bromodichloromethane	--	--	--	--
Bromoform	--	--	--	--
Chloroform	--	--	--	--
Dibromochloromethane	--	--	--	--
3. Halonitriles				
Bromochloroacetonitrile	--	--	--	--

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
Dibromoacetonitrile	--	--	--	--
Dichloroacetonitrile	--	--	56[b]	--
Trichloroacetonitrile	--	--	--	--
4. Halogenated Acids, Alcohols, Aldehydes, Ketones, and Other Nitriles[i]				
5. Others				
Chloropicrin	--	--	40[b], 50[c]	--
Cyanogen chloride	--	--	--	--
C. SARA priority List				
Chloroethane	--	--	--	--
2,4-Dinitrotoluene	--	--	--	--
Isophorone	--	--	1,050[a]	--
1,1,2,2-Tetrachloroethane	1[f]	--	0.2[a]	--
D. Pesticides				
Cyanazine	--	--	9[b]	Inadequate health effects date.
Dicamnba	--	--	9[b]	Probable human carcinogen.
1,3-Dichloropropene	0.5[f]	--	--	Probable human carcinogen
2-ImidazoVdethione (ETU)	--	--	--	--
Metolachlor	--	--	10[b]	Possible human carcinogen.
Metribuzin	--	--	175[b]	Inadequate health effects data.
2,4,5-Trichlorophenoxy acetic acid (2,4,5-T)	--	--	21[b]	Inadequate health effects data.
Trifluralin	--	--	2[b]	Possible human carcinogen.
E. Monitoring Contaminants				
Bromobenzene	--	--	--	--
Bromomethane	--	--	2.8[a]	--
Chloromethane	--	--	--	--
o-Chlorotoluene	--	--	--	--
p-Chlorotoluene	--	--	--	--
1,1-Dichloroethane	--	--	5[c]	--
1,3-Dichloropropane	--	--	--	--
2,2-Dichloropropane	--	--	--	--
1,1-Dichloropropene	--	--	--	--
1,1,1,2-Tebachloroethane	--	--	--	--
1,2,3-Trichloropropane	--	--	42[a]	--

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
F. Substances Frequently Reported				
Boron	--	--	--	--
Cryptosporidium	--	--	--	Protozoan that causes gastroenteritis.
Strontium	8[f]	--	--	--
G. High Risk Substances				
Methyl-tertiarybutyl ether	--	--	--	--
IV. Monitoring List				
A. List 1--All Systems				
Bromobenzene[m]	--	--	--	--
Bromodichloromethane[m]	--	--	--	--
Bromoform[m]	--	--	--	--
Bromomethane[m]	--	--	2.8[a]	--
Chlorobenzene[a]	30[f], 100[g]	100[g]	300[b]	Possible carcinogen.
Chlorodibromomethane[m]	--	--	--	--
Chloroethane[m]	--	--	--	--
Chloroform[m]	--	--	70[a]	--
Chloromethane[m]	--	--	--	--
o-Chlorotoluene[m]	--	--	--	--
p-Chlorotoluene[m]	--	--	--	--
Dibromomethane[m]	--	--	--	--
m-Dichlorobenzene[a]	--	--	620[b], 130[c]	--
o-Dichlorobenzene[a]	600[g]	600[g]	620[b], 130[c]	Central nervous system depression, kidney and liver damage.
1,1-Dichloroethane[m]	--	70[g]	5[c]	--
cis-1,2-Dichloroethylene[a]	70[g]	70[g]	70[b], 6[c]	Liver and kidney effects.
trans-1,2-Dichloroethylene[a]	70[g]	70[g]	70[b], 10[c]	Liver and kidney effects.
Dichloromethane[a]	--	--	420[a], 5[b], 40[c]	--
1,2-Dichloropropane[a]	5[g]	0[g]	0.56[b], 5[c]	Possible carcinogen, liver damage.
1,3-Dichloropropane[m]	--	--	--	--
2,2-Dichloropropane[m]	--	--	--	--
1,1-Dichloropropene[m]	--	--	--	--
1,3-Dichloropropene[m]	0.5[f]	--	--	--
Ethylbenzene[a]	700[f,g]	700[g]	700[a], 680[b]	Adverse kidney and liver effects.
Styrene[a]	5[g]	0[g]	1,400[a], 140[b]	Neurologic and behavioral changes, chromosome, aberrations, and skin and respiratory tract irritations.
1,1,1,2-Tetrachloroethane[m]	--	--	--	--
1,1,2,2-Tetrachloroethane[m]	1[f]	--	0.2[a]	--

Table B-1. Drinking Water Standards and Criteria, continued

Constituent	Maximum contaminant level, ug/1	Maximum contaminant level goal, ug/1	Other drinking water criteria,[a,b,c] ug/1	Regulatory rationale
Tetrachloroethylene[a]	30[f], 100[g]	0[g]	140[a], 3.5[b]	Carcinogen.
Toluenes[a]	2,000[g]	2,000[g]	2,100[a], 2,420[b], 100[c]	Central nervous system depression.
1,1,2-Trichloroethane[a]	32[f]	--	0.6[a]	Inadequate health effects data.
1,2,3-Trichloropropane[m]	--	--	42[a]	--
m-Xylene[a]	1,750[f], 10,000[g]	10,000[g]	--	Central nervous system disturbances.
o-Xylene[a]	1,750[f], 10,000[g]	10,000[g]	--	Central nervous system disturbances.
p-Xylene[a]	1,750[f], 10,000[g]	10,000[g]	--	Central nervous system disturbances.
B. List 2--Vulnerable Systems				
1,2-Dibromo-3-chloropropane (DBCP)[a]	0.2[f,g]	0[g]	0.025[b], 1.0[c]	Carcinogen.
Ethylene dibromide (EDB)[a]	0.02[f], 0.05[g]	0[g]	0.0005[b]	Carcinogen.
C. List 3--State's Discretion				
Bromochloromethane	--	--	--	--
n-Butylbenzene	--	--	--	--
sec-Butylbenzene	--	--	--	--
tert-Butylbenzene	--	--	--	--
Dichlorodifluoromethane	--	--	1,400[a]	--
Fluorotrichloromethane	--	--	150[c]	--
Hexachlorobutadiene	--	--	0.5[a]	Carcinogen.
Isopropylbenzene	--	--	--	--
p-Isopropyltoluene	--	--	--	--
Napthalene	--	--	--	--
n-Propylbenzene	--	--	--	--
1,2,3-Trichlorobenzene	--	--	--	--
1,2,4-Trichlorobenzene	--	--	140[a]	--
1,2,4-Trimethylbenzene	--	--	--	--
1,3,5-Trimethylbenzene	--	--	--	--
V. Additional California Constituents				
Bentazon	18[f]	--	--	--
Gross beta particle activity, pCi/l	50[f]	--	--	--
Molinate	20[f]	--	--	--
Thiobencarb	70[f]	--	--	--
Tritium, pCi/l	20,000[f]	--	--	--

[a]EPA's Integrated Risk Information System (IRIS) Drinking Water Lifetime Calculation.

[b]EPA Office of Drinking Water Chronic Health Advisories (formerly Suggested No Adverse Response Levels (SNARLS)).

[c]California Department of Health Services (DHS) action levels.

[d]The seven contaminants removed fom the list on 1-22-88 are not included in this list. They are included in the Drinking Water Priority List.

[e]Interim primary drinking water maximum contaminant levels (MCLs).

[f]Current California MCLs.

[g]Proposed MCL or maximum contaminant level goal (MCLG).

[h]Final MCL or MCLG.

[i]Proposed California MCLs.

[j]Proposals for regulating coliform bacteria through a new presence/absence compliance calculation and microbial contaminants through a treatment technique outlined in the surface water treatment rule(SWTR) were published on November 3,1987. Final regulations for these two proposals are expected about June 1989.

[k]The interim MCL of 100 ug/1 is for total trihalomethanes.

[l]EPA will determine which contaminants in this class will require individual regulations and which should be regulated as a group.

[m]These contaminants are also on the drinking water priority list (DWPL).

[n]These contaminants are also on the list of 83 contaminants required to be regulated under the SDWA of 1986.

Table B-2.

State of California
Department of Health Services

Drinking Water Action Levels Recommended
by the Department of Health Services

April 1989

Chemical	Action Level parts per billion (ppb)
Pesticides	
Chlorinated Hydrocarbon	
Aldrin	Limit of Quantification (0.05)
a-Benzene Hexachloride (a-BHC)	0.7
b-Benzene Hexachloride (b-BHC)	0.3
Chlordane	0.1
Dieldrin	Limit of Quantification (0.05)
Heptachlor	0.01
Heptachlor Epoxide	0.01
Pentachlorophenol	30.0
Organophosphate	
Dimethoate	140.0
Diazinon	14.0
Ethion	35.0
Malathion	160.0
Methyl Parathion	30.0
Parathion	30.0
Trithion	7.0
Carbamate	
Aldicarb	10.0
Baygon	90.0
Carbaryl	60.0
Phthalamide	
Captan	350.0
Amides	
Diphenamide	40.0
Fumigants	
Dibromochloropropane	1.0
1,2-Dichloropropane	5.0
Chloropicrin	50.0 (37.0)*
Miscellaneous	
Terrachlor (Pentachloronitrobenzene)	0.9

*Taste & Odor Threshold

Herbicides		
CIPC (isopropyl N (3-chlorophenyl) carbamate)	350.0	
Glyphosate	700.0	
Alachlor	Limit of Quantification (0.2)	
Purgeable Halocarbons		
Methylene Chloride	40.0	
Tetrachloroethylene	5.0	
1,1-Dichloroethane	5.0	
Trichlorofluoromethane (Freon 11)	150.0	
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	1,200.0	
Cis-1,2-Dichloroethylene	6.0	
Trans-1,2-Dichloroethylene	10.0	
Purgeable Aromatics		
1,2-Dichlorobenzene	130.0	(10)*
1,3-Dichlorobenzene	130.0	(20)*

(Action Level for 1,2-Dichlorobenzene and 1,3-Dichlorobenzene is either for a single isomer or for the sum of the 2 isomers)

Toluene	100.0

(Action Level for Xylene is either for a single isomer or the sum of the 3 isomers)

Phenols	
2,4-dimethylphenol	(400.0)*
Phenol	(1.0)* (For Chlorinated Systems)
Aldehydes	
Formaldehyde	30.0

*Taste & Odor Threshold

APPENDIX C

WATER QUALITY DATA SUMMARY TABLES

Table C-1. Feather River at Nicolaus Data Summary

	Wet Season				Dry Season				Annual			
Constituents, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
TDS, mg/l	65	40 - 92	66	10	70	45 - 91	61	9	135	40 - 92	63	10
Chloride, mg/l	38	0 - 7	2	2	34	0 - 4	2	0.7	72	0 - 7	2	1
Sodium, mg/l	38	3 - 7	4	1	34	2.7 - 6	3.7	0.8	72	2.7 - 7	4	0.9
Turbidity, NTU	42	1 - 26	8	7	45	1 - 19	5	4	87	1 - 26	6	5
Lead, mg/l	4	0	0	0	7	0 - 10	1	4	11	0 - 10	0.9	3
Selenium, mg/l	5	0 - 10	3	6	6	0 - 10	4	5	11	0 - 10	4	5
TOC,mg/l	3	1.7 - 2.5	2.1	0.4	17	1 - 3.3	1.9	0.7	20	1 - 3.3	2.2	0.6
T. Phosphorus, mg/l	64	0 - 0.3	0.04	0.04	62	0 - 0.39	0.04	0.05	126	0 - 0.39	0.04	0.04
TKN, mg/l	67	0 - 0.54	0.19	0.1	66	0 - 0.4	0.2	0.09	133	0 - 0.54	0.19	0.09

N = Number of samples
S. D. = Standard deviation

Table C-2. Sacramento River at Fremont Weir Data Summary

	Wet Season				Dry Season				Annual			
Constituent, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
TDS, mg/l	68	66 - 184	113	23	70	76 - 190	124	22	138	66 - 190	119	23
Chloride, mg/l	62	2 - 24	6	3	62	2 - 16	7	2	124	2 - 24	7	3
Sodium, mg/l	61	5 - 26	11	4	62	4.6 - 26	14	4	123	4.6 - 26	12	5
Turbidity, NTU	32	2 - 230	33	46	35	2.5 - 48.5	17	12	67	0 - 230	24	34
TOC, mg/l	0	--	--	--	14	1.7 - 4.7	2.8	0.8	14	1.7 - 4.7	2.8	0.8
Total Phosphorus, mg/l	65	0.03 - 0.54	0.11	0.09	66	0.04 - 0.24	0.09	0.04	131	0.03 - 0.54	0.1	0.07
TKN, mg/l	62	0 - 0.1	0.3	0.1	66	0.1 - 0.7	0.3	0.1	128	0.1 - 1	0.3	0.1

N = Number of samples
S. D. = Standard deviation

Table C-3. American River at Nimbus Data Summary

	Wet Season				Dry Season				Annual			
Constituents, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	20	120 - 375	229	65	24	164 - 387	244	60	44	120 - 387	237	62
THMFP (EBMUD), ug/l	22	41 - 100	60	18	20	41 - 80	55	10	42	41 - 100	58	15
TDS, mg/l	45	27 - 44	38	5	44	27 - 39	34	4	89	27 - 44	36	5
Bromide, mg/l	22	0.004 - 0.06	0.03	0.02	19	0.01 - 0.05	0.03	0.02	41	0.004 - 0.06	0.03	0.02
Chloride, mg/l	22	1 - 4	2	0.8	20	1 - 3	2	0.6	42	1 - 4	2	0.7
Sodium, mg/l	15	1.9 - 2.5	2.2	0.2	14	1.4 - 2.7	2.1	0.4	29	1.4 - 2.7	2.2	0.31
Turbidity, NTU	22	0.5 - 130	10	29	20	0.6 - 5	1.3	1	42	0.5 - 130	6	21
Asbestos, mF/l	9	70 - 2200	504	718	5	12 - 190	53	77	14	12 - 2200	343	608
Lead, mg/l	7	0.002 - 0.004	0.003	0.001	9	0.001 - 0.005	0.003	0.002	16	0.001 - 0.005	0.003	0.001
Selenium, mg/l	7	<0.002 - <0.005	<0.004	<0.001	9	<0.002 - <0.009	<0.005	<0.002	16	<0.002 - <0.009	<0.004	<0.002
TOX, ug/l	13	4 - 110	50	33	11	6 - 500	95	155	24	4 - 500	71	107
TOC, mg/l	13	1 - 5.9	3	2	11	1.6 - 8.3	4	2	24	1 - 8.3	3.4	1.9
Chlorophyll a, ug/l	22	0 - 6	2	1.6	20	0.05 - 6	1.4	1.3	42	0.05 - 6	1.6	1.4
T. Coliforms, MPN/100ml	22	49 - 3500	714	1048	20	2 - 1300	231	326	42	2 - 3500	484	819
T. Phosphorus, mg/l	12	0 - 0.06	0.02	0.01	19	0.01 - 0.03	0.01	0.007	31	0 - 0.06	0.02	0.01
TKN, mg/l	15	0.1 - 0.85	0.24	0.19	19	0.04 - 1.31	0.4	0.4	34	0.04 - 1.31	0.32	0.3

N = Number of samples
S. D. = Standard deviation

Table C-4. Sacramento River at Greene's Landing Data Summary

	Wet Season				Dry Season				Annual			
Constituent, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	25	184 - 1005	311	178	32	131 - 712	305	142	57	131 - 1005	307	158
THMFP (EBMUD), ug/l	22	57 - 230	89	35	20	55 - 110	80	14	42	55 - 230	84	27
TDS, mg/l	98	54 - 151	100	20	111	60 - 143	101	20	209	54 - 151	100	20
Bromide, mg/l	3	0 - 0.05	0.03	0.03	1	0	0	0	4	0 - 0.05	0.02	0.03
Chloride, mg/l	121	2 - 18	7	3	136	2 - 15	7	3	257	1.5 - 18	7	3
Sodium, mg/l	38	5 - 15	10	3	38	3 - 18	11	3	76	3 - 18	11	3
Turbidity, mg/l	62	3 - 54	13	12	75	5 - 36	10	7	137	3 - 53	12	10
Asbestos, mF/l	15	0 - 3200	721	882	13	0 - 680	272	166	28	0 - 3200	512	684
Selenium, mg/l	2	0 - 0.001	0.0005	0.0007	4	0 - 0.001	0.0006	0.0004	6	0 - 0.001	0.0006	0.0005
TOX, ug/l	5	0 - 310	91	128	1	0	0	0	6	0 - 310	76	121
TOC, mg/l	7	1 - 8.3	4	3	6	1.8 - 14	9.5	5	13	1 - 14	6.4	5
Chlorophyll a, ug/l	100	0 - 23	3	3	141	0 - 28	4	4	241	0 - 28	3	4
T. Coliforms, MPN/100ml	22	70 - 17000	2883	4642	20	41 - 7900	1301	1804	42	41 - 17000	2129	3631
T. Phosphorus, mg/l	77	0.06 - 0.26	0.13	0.04	93	0.05 - 0.24	0.11	0.03	170	0.05 - 0.26	0.12	0.04

N = Number of samples
S. D. = Standard deviation

Table C-5. San Joaquin River at Vernalis Data Summary

	Wet Season				Dry Season				Annual			
Constituent, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	31	207 - 1476	501	271	29	267 - 773	504	123	60	207 - 1476	502	211
TDS, mg/l	76	88 - 958	379	253	90	94 - 1014	418	237	166	88 - 1014	390	245
Chloride, mg/l	103	11 - 286	73	54	108	10 - 354	81	55	211	10 - 354	75	55
Sodium, mg/l	23	11 - 100	54	26	23	15 - 89	53	23	46	11 - 100	54	24
Turbidity, mg/l	47	3 - 34	16	4	57	9 - 75	27	11	104	3 - 75	20	8
Asbestos, mg/l	9	270 - 1800	849	456	5	900 - 3300	1700	938	14	270 - 3300	1153	760
Lead, mg/l	1	0.01	0.01	0	0	0	0	0	1	0.01	0.01	0
Selenium, mg/l	18	0 - <0.003	<0.001	<0.001	14	0 - <0.002	<0.001	<0.001	32	0 - <0.003	<0.001	<0.001
Chlorophyll a, ug/l	82	2 - 220	26	56	126	5 - 337	51	63	208	2 - 337	38	54
T. Phosphorus, mg/l	77	0.1 - 0.6	0.3	0.1	93	0.1 - 0.5	0.3	0.09	170	0.1 - 0.6	0.3	0.1

N = Number of samples
S. D. = Standard deviation

Table C-6. Clifton Court Data Summary

	Wet Season				Dry Season				Annual			
Constituents, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	24	339 - 910	517	157	22	174 - 686	476	121	46	174 - 910	497	142
THMFP (EBMUD), ug/l	22	110 - 250	168	47	20	100 - 230	158	31	42	100 - 250	163	40
TDS, mg/l	95	98 - 713	253	148	106	80 - 678	221	130	201	80 - 713	237	140
Bromide, mg/l	20	0.04 - 0.48	0.13	0.1	20	0.02 - 0.4	0.2	0.1	40	0.02 - 0.48	0.14	0.11
Chloride, mg/l	118	16 - 300	67	65	129	11 - 307	59	64	247	11 - 307	64	64
Sodium, mg/l	38	17 - 108	46	26	36	18 - 79	35	18	74	17 - 108	41	23
Turbidity, NTU	44	4.7 - 23.5	10.2	4.5	42	4.9 - 35	15.6	7.2	86	4.7 - 35	12.7	6.4
Asbestos, mF/l	9	230 - 910	519	188	5	500 - 960	720	196	14	230 - 960	591	209
Lead, mg/l	7	0.001 - 0.005	0.003	0.001	9	0.001 - 0.018	0.005	0.006	16	0.001 - 0.018	0.004	0.004
Selenium, mg/l	17	<0.001-<0.005	<0.004	<0.001	20	<0.001-<0.009	<0.004	<0.003	37	<0.001-<0.009	<0.004	<0.002
TOX, ug/l	9	10 - 750	121	195	10	12 - 180	62	51	19	10 - 750	94	148
TOC, mg/l	13	3 - 16	7	4	11	2.8 - 16	9	4	24	2.8 - 16	8	4
Chlorophyll a, ug/l	100	0 - 22	4	4	140	3 - 63	11	10	240	0 - 63	8	8
T. Coliforms, MPN/100ml	22	23 - 5000	780	1124	20	33 - 2800	518	826	42	23 - 5000	652	985
T. Phosphorus, mg/l	73	0.08 - 0.29	0.13	0.04	90	0.03 - 0.21	0.12	0.03	163	0.03 - 0.29	0.13	0.04

N = Number of samples
S. D. = Standard deviation

Table C-7. Rock Slough Data Summary

	Wet Season				Dry Season				Annual			
Constituent, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	30	256 - 775	498	145	29	225 - 638	458	102	59	225 - 775	479	126
TDS, mg/l	30	122 - 706	272	170	26	111 - 574	212	117	56	111 - 706	244	150
Chloride, mg/l	30	13 - 277	73	78	23	14 - 210	45	52	53	13 - 277	61	69
Sodium, mg/l	30	13 - 154	49	42	26	15 - 125	36	29	56	13 - 154	43	37
Turbidity, mg/l	30	3 - 18	10	4	26	5 - 22	13	5	56	3 - 22	11	5
Asbestos, mF/l	11	260 - 950	553	160	5	140 - 1100	602	357	16	140 - 1100	568	227
Selenium, mg/l	9	0 - 0.001	0.0001	0.0003	7	0	0	0	16	0 - 0.001	0	0.0003

N = Number of samples
S. D. = Standard deviation

Table C-8. Mokelumne River Data Summary

	Wet Season				Dry Season				Annual			
Constituent, units	N	Range	Mean	S. D.	N	Range	Mean	S. D.	N	Range	Mean	S. D.
THMFP (DWR), ug/l	9	115 - 295	222	53	9	204 - 425	280	73	18	115 - 425	251	69
TDS, mg/l	9	34 - 43	40	3.5	9	35 - 44	41	4	18	34 - 44	40	4
Chloride, mg/l	9	1 - 2	1	0.3	9	1	1	0	18	1 - 2	1	0.2
Sodium, mg/l	9	1 - 2	2	0.3	9	2	2	0	18	1 - 2	2	0.2
Turbidity, mg/l	9	2 - 9	5	2	9	1 - 3	2	0.7	18	1 - 9	3	2
Asbestos, mF/l	7	17 - 200	71	79	4	10 - 53	30	22	11	10 - 200	56	66

N = Number of samples
S. D. = Standard deviation

APPENDIX D

ECONOMIC ANALYSIS OF ALTERNATIVES

APPENDIX D

ECONOMIC ANALYSIS OF ALTERNATIVES

This appendix presents the detailed information and basis for the economic assessments of alternative management concepts for the protection and improvement of drinking water quality in the major urban systems using Sacramento-San Joaquin Delta (Delta) water. Sections of this appendix cover the basis of cost estimates, cost allocations to urban and agricultural Delta water users, and the method used to show the urban consumer cost benefits of water mineral quality improvements.

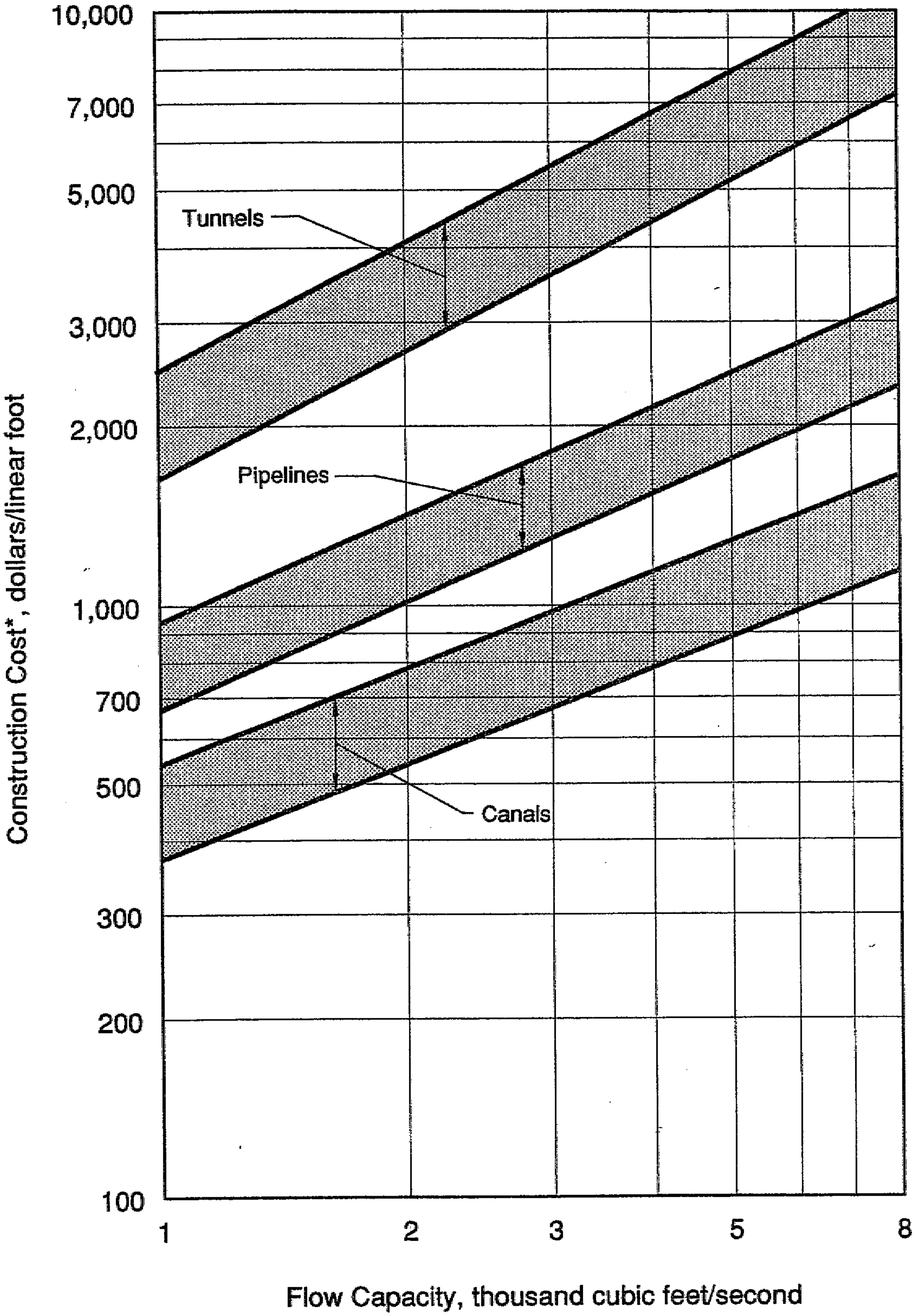
Basis of Cost Estimates

All cost estimates presented in this report have been normalized to the U.S. Bureau of Reclamation (USBR), Composite Trend Index of 160 as published in their "Construction Cost Trends". This index level represents projected costs for mid-1989, and is also equal to an ENR Construction Cost Index (CCI) of 428. Data for estimating costs for the various facilities presented in this report were obtained or developed from a number of different sources. These cost estimates are reconnaissance level estimates and should only be used for comparison of alternatives presented in this report.

New Facilities. Cost estimates for alternatives that have been newly developed in this study, including Agricultural Drainage Management, Bifurcated Dual Transfer System, and Sierra Source-to-User System were developed based on cost data from other projects containing components of similar size. These cost data were normalized and updated to a USBR, Composite Trend Index of 160, as stated previously.

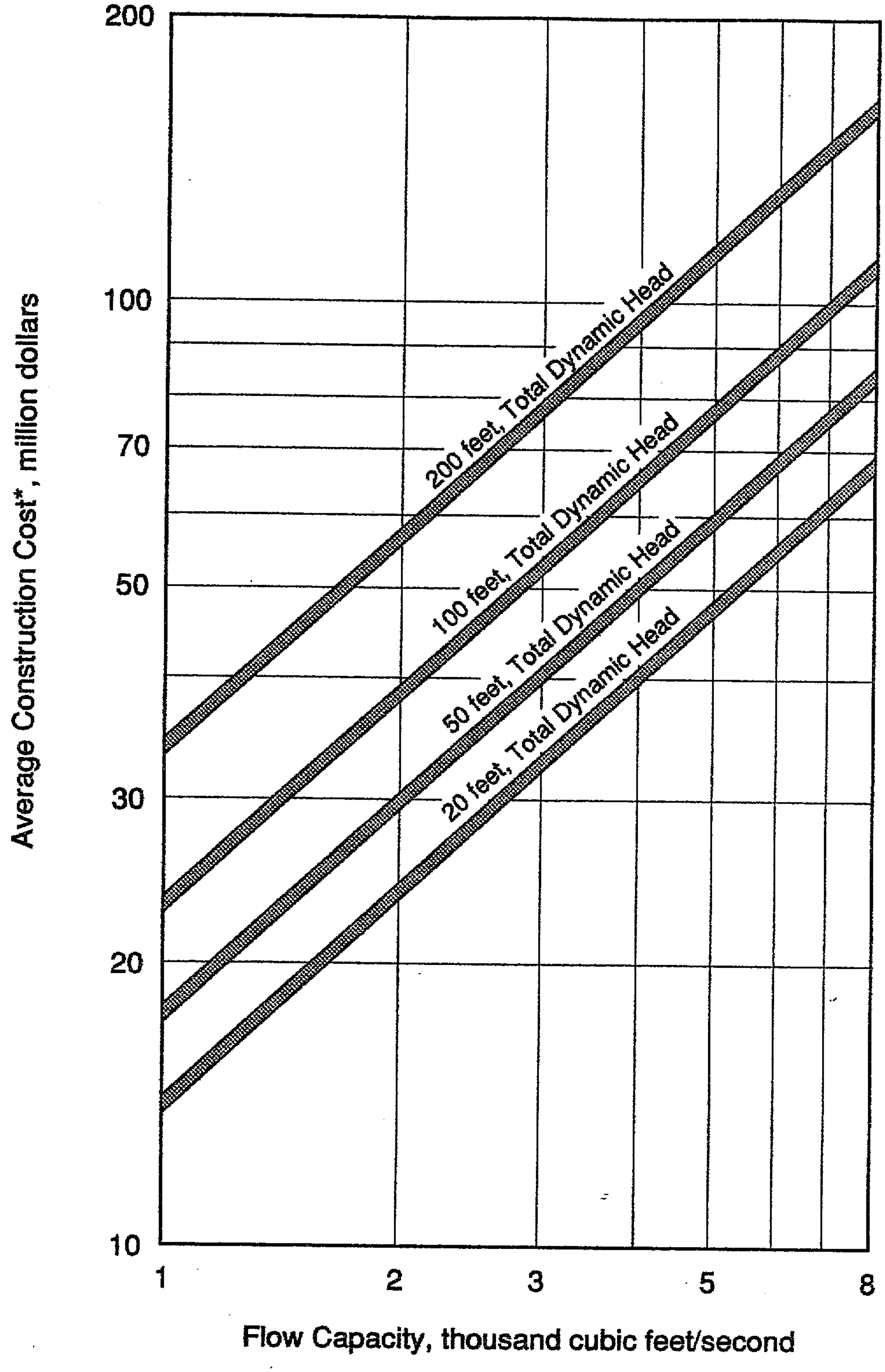
Planning estimates and actual construction bid data from USBR files were used to develop cost estimating curves which were then used to estimate construction costs for new canals, pipelines, and tunnels. As shown on Figure D-1, a cost range was defined with these cost curves to represent the cost variations which might be encountered in actual project conditions. The actual unit costs used to estimate a particular facility's construction cost were selected from within this range, based on a judgement of the relative difficulty of construction. Factors that were considered, to estimate difficulty of construction, include the terrain of the area; the complexity of cross drainage; and the number of interconnects, diversions, water course crossings, and canal check structures.

Cost estimates for pumping plants were also developed using planning estimates and actual construction bid data from USBR files. Cost curves were developed from the USBR data which were then used to estimate the costs for new pumping plants. Figure D-2 shows the cost curves used to estimate pumping plant costs based on the estimated capacity and total dynamic head for a given pumping plant.



* Based on USBR, Contruction Cost Trends, Composite Trend Index of 160, representing projected construction costs for mid-1989.

Figure D-1. Construction Cost Estimates for Canals, Pipelines, and Tunnels



* Based on USBR, Contruction Cost Trends, Composite Trend Index of 160, representing projected construction costs for mid-1989.

Figure D-2. Construction Cost Estimates for Conveyance Pumping Plants

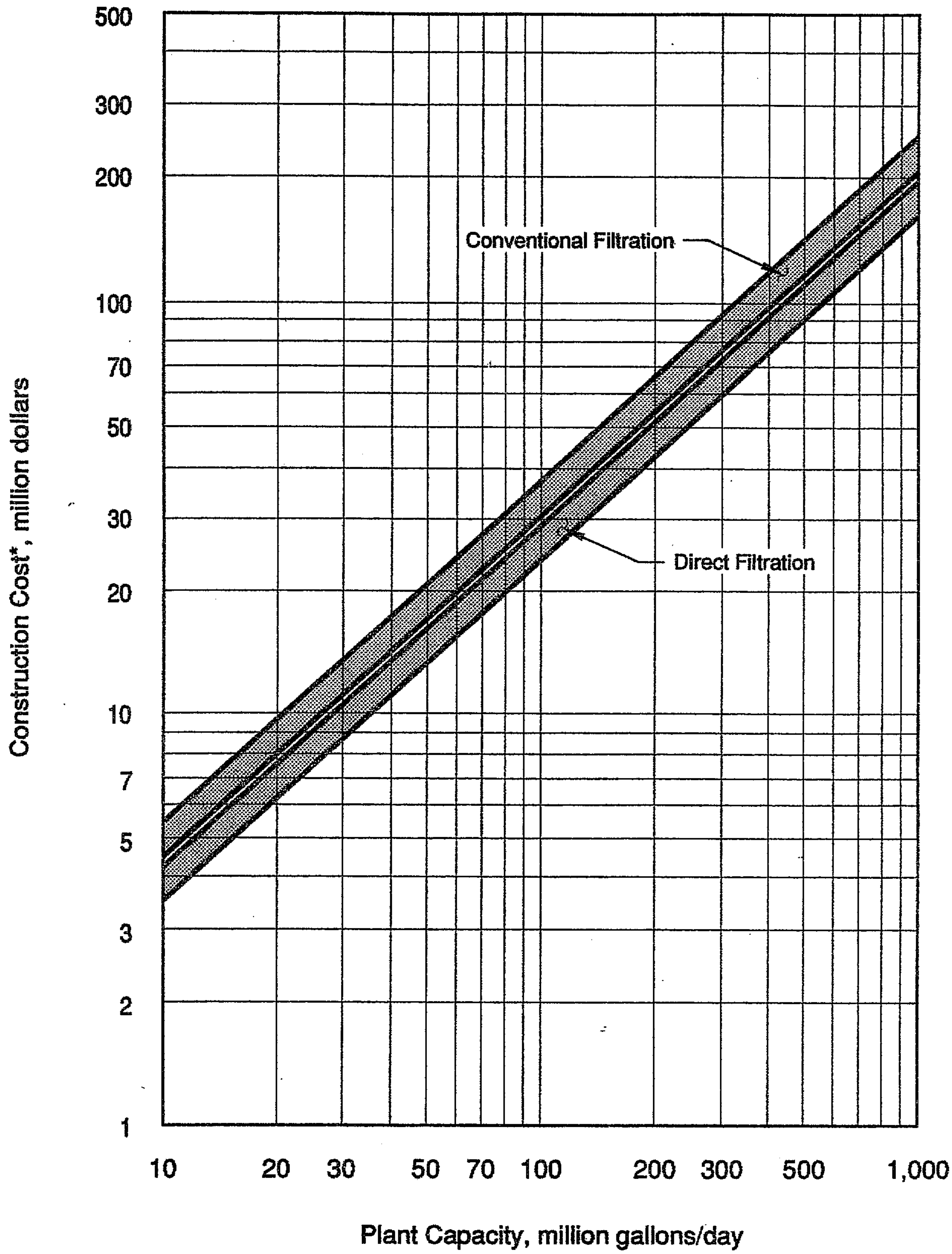
New storage reservoir costs, specifically Los Vaqueros and Los Banos Grandes reservoirs, were based on the most recent cost data for these facilities as reported in California Department of Water Resources (DWR) publications. These DWR costs were interpolated to reflect estimated costs for differing facility sizes presented in this report.

The construction costs for miscellaneous items, such as fish screens, inlet and outlet structures, forebays, small pipes, small pumping plants, drainage control, and diversion structures, were estimated using records from the publications or files of USBR, DWR, and Brown and Caldwell, and from standard cost estimating reference publications. Construction costs were marked up 40 percent for contingencies, engineering, management, and financing to develop capital cost estimates for each alternative.

Facilities Documented by Others. Costs for components which are part of facilities already studied by DWR, including the Delta Transfer System Improvements, Peripheral Canal, and Dual Transfer System, were obtained from information published by DWR. Cost estimates for the Delta Transfer System Improvements and the Dual Transfer System, were obtained from Alternatives for Delta Water Transfer, (DWR, 1983). The cost for the Peripheral Canal was obtained from the DWR document Letters and Formal Statements Concerning Senate Bill 200 and Related Matters Letter 92, September 1980. The DWR costs were updated to mid-1989 prices as described above. For the Peripheral Canal, it was assumed that since the cost was reported by DWR as capital cost, it included engineering, contingencies, management, and financing allowances and was not further increased.

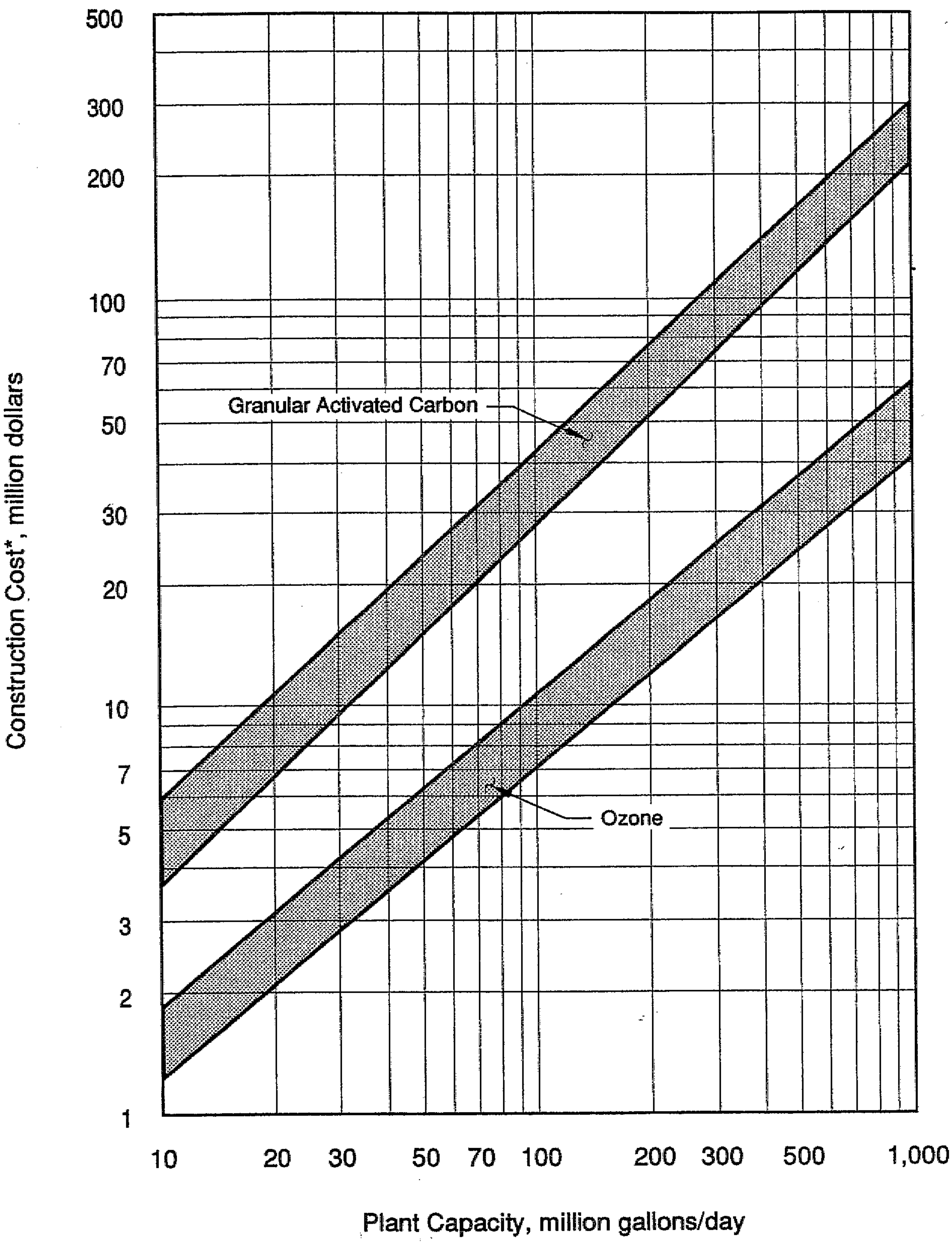
There may be some differences in the capacity of facilities shown herein compared to those described in the DWR reports, because the projected 2010 water demand developed in this report is slightly greater than that used by DWR. The DWR cost estimates were not increased to account for the higher water demand numbers used in this study. The actual capacity of any of the facilities presented in this report is dependent upon the way the system is operated. Also, the actual mode of operation and actual quantities of water delivered to users during a critically dry year could vary significantly from the projected demands presented in Chapter 2. Finally, detailed information on the actual capacities of the DWR facilities components presented in Alternatives for Delta Water Transfer were not available.

Water Treatment Plants. Figures D-3 and D-4 show cost curves for four treatment processes used in various combinations to treat water which would result from implementation of the alternative concepts. A range of costs for each process is given to account for variation in certain design and operating parameters. For example, the lower end of the ozone curve would apply to a dose of about 2 milligrams per liter (mg/l) and relatively simple designs, whereas the upper limit reflects a dose of 4 mg/l and more difficult construction. Midrange costs were used to arrive at total treatment cost for each alternative. These are construction cost estimates; they were developed from published references by the Environmental Protection Agency, estimating manuals, data from past projects, State Water Contractor Exhibits, and calculations. These cost curves cover the straightforward construction of a plant of the type identified, on a level site without any unusual or appurtenant features. All data were adjusted to mid-1989 costs, so the curves are for a USBR Composite Trend Index of 160, or an ENR CCI of 428.



* Based on USBR, Contruction Cost Trends,Composite Trend Index of 160, representing projected construction costs for mid-1989.

Figure D-3. Construction Cost Estimates for Conventional and Direct Filtration Plants



* Based on USBR, Contruction Cost Trends, Composite Trend Index of 160, representing projected construction costs for mid-1989.

Figure D-4. Construction Cost Estimates for Adding GAC and Ozone to an Existing Water Treatment Plant

Operation and Maintenance Costs. In this report, operation and maintenance (O&M) costs are estimated and presented for new or modified facilities only. They do not include costs for O&M of existing facilities because these are common to all alternatives. The O&M costs presented in this report thus do not represent the entire cost for a particular system, but only the incremental cost for modification and additions to the existing system. These costs are also only for the municipal and industrial (M&I) portion of each system. Estimates of O&M costs for facilities developed in this study were developed using data from operation of the existing State Water Project (SWP) for components of similar size and complexity, where available. Where these data were not available, 1.5 percent of construction cost was used to estimate annual O&M costs. Two exceptions were the Delta Agricultural Drainage Management and Peripheral Canal alternatives. The Peripheral Canal O&M was increased to 2 percent of construction cost to account for increased O&M associated with the large pumping station. With the Delta Agricultural Drainage Management alterative, there are a large number of comparatively small pumping stations, and estimated O&M was increased to 2.5 percent of construction cost.

Energy Costs. In this report, energy costs represent only the incremental unit energy costs, in dollars per acre-foot (AF), required to convey M&I water from a given diversion location to the A. D. Edmonston Pumping Plant forebay; that is, the energy above that required for existing facilities. The unit energy costs to convey water from the vicinity of Clifton Court Forebay to the A. D. Edmonston Pumping Plant pool are essentially the same for all alternatives. The energy costs presented in this report are thus only those associated with diversion and major conveyance configurations that differ from the existing system at or upstream of Clifton Court Forebay, plus energy required for operation of treatment systems.

Power costs were estimated using projected power costs by DWR for the SWP (DWR, 1986 and 1987). The average unit cost used to estimate energy cost for the conveyance alternatives was $0.03 per kilowatt-hour. Because of the small, scattered pumping stations in the Delta Agricultural Drainage Management alternative, the power cost was increased to $0.06 per kilowatt-hour. Energy for treatment is not separately tabulated, but is based on $0.06 per kilowatt-hour.

Total Costs. The total cost for each project is the sum of capital cost and O&M cost. To correctly combine these two cost components, total annual cost and total unit cost per AF of M&I water delivered were calculated. The annual cost of capital is taken as the amortized cost based on an annual discount rate of 8.0 percent and an economic life of facilities of 50 years for major conveyance works, and 30 years for large treatment facilities. Capital cost was taken as estimated construction cost (contractors bid price) plus 40 percent for engineering, contingencies, administrative services, and financing costs.

All cost calculations were done for year 2010 project operations (but at current price levels). Unit costs were thus calculated for the total estimated M&I water deliveries at that date; shown in Chapter 2 to be 3,211,000 acre-feet per year.

Cost Allocations

The costs for the proposed Delta Transfer System Improvements, Peripheral Canal, and Dual Transfer System were allocated between M&I and agricultural water users to compare alternatives. The simple method used for allocating costs is described below; it is not intended to represent methods which might be used in practice, but only to serve as a basis for developing costs for comparison of alternatives in this study.

For example, the Delta Transfer System Improvements alternative is found to be the least complex and least expensive improvement program for meeting basic Delta hydraulic requirements. Design conditions for these improvements include an increase of peak SWP pumping rate to 10,300 cubic feet per second, alleviating channel restrictions and low water levels in certain South Delta channels, and minimizing channel flow reversals in the lower San Joaquin River. Based on the philosophy that all users of water diverted from the Delta should share in the costs of meeting these basic hydraulic and environmental goals, costs for the Delta Transfer System Improvements were allocated to all (SWP plus Central Valley Project) M&I and agricultural water purchasers in proportion to their annual water entitlements in the year 2010 (see Table 2-1). On this basis, agricultural entitlement beneficiaries would pay 57 percent of the costs (both capital and O&M) of the Delta Transfer System Improvements. The total capital cost of the Delta Transfer System Improvements is $425 million at the current (1989) price level. The agricultural user's share of the capital costs of this plan would accordingly be $242 million.

Additional or alternative Delta water improvements considered in this concept-level study are for the primary purpose of improving the quality of urban water supplies. Most of the alternatives considered in this report would benefit agriculture and environmental values in various ways and degrees. For example, any improvement in water mineral quality improves crop growth and reduces leaching requirements and drainage problems. Any isolated transfer facility protects the water conveyed in the event of levee failure and, further, takes some hydraulic (scour and hydrostatic) load off the Delta levees, lowering their maintenance cost and reducing risk of further levee failures. Even though these multiple benefits would occur, we have used the simplistic cost-allocation approach of leaving the agricultural cost share constant at the level of the allocated agricultural cost for the Delta Transfer System (a capital cost allocation of $242 million) for all alternatives. Accordingly, urban water agencies are assumed to bear 100 percent of all project costs which are in addition to the costs for the Delta Transfer System Improvements. Table D-1 shows how the capital costs were allocated between M&I and agricultural users for each alternative. Operating costs were allocated in the same manner.

Consumer Costs

As discussed in Chapter 3, the economic impact of differing water quality on the community of water consumers is large, but is difficult to quantify in simple terms because consumer costs are affected by several water quality parameters. Treatment cost estimates account for some of the impacts on consumers (mainly public health and aesthetic acceptance) by quantifying the cost to produce a drinking water which consistently meets expected drinking water standards. On the other hand, mineral quality differences in the alternative supplies are quite large, are not amenable to correction by practical municipal-scale treatment, and are not accounted for by the treatment costs presented in Chapter 4.

Table D-1. Capital Cost Allocation Method

Alternative	Cost, million dollars		
	Agricultural	M&I	Total
1. Delta Transfer System Improvements	242	183	425
2. San Joaquin Conjunctive Use Project[a]	242	183	425
3. Delta Agricultural Drainage Management	242	1,503	1,745
4. Peripheral Canal	242	608	850
5. Dual Transfer System			
A. Nonbifurcated	242	283	525
B. Bifurcated	242	2,598	2,840
6. Sierra Source-to-User System	242	4,704	4,946

[a]No capital cost estimates made for conjunctive use project. The capital costs of the Delta Transfer System Improvements are shown. Annual costs assumed to be allocated same as Alternative 1.

A generalized consumer cost figure of $0.68 per AF per mg/l of incremental total dissolved solids (TDS) was proposed in Chapter 3, based on a review of available studies of the relationships between water quality and consumer impacts, and is used in the evaluations in this chapter. Clearly, this cost component can be quite large. For 2010 M&I demand, this unit cost burden of mineralized water translates to $2.18 million per year per mg/1 of TDS. The maximum mean TDS difference among the alternatives is about 180 mg/1, and this would equate to a consumer cost difference of approximately $400 million annually. In the alternatives evaluations the consumer benefit of higher quality water is based on the mean TDS achieved by the alternative compared to the mean TDS in the current Delta diversion systems (base case is Clifton Court mean) which is 240 mg/l.

Much nonutility consumer water cost is not accounted for by this approach. For example, if bottled water purchases could be significantly reduced by providing better drinking water and improving consumer confidence, the total economic benefit could be considerably greater than the amounts calculated in this analysis.