Chapter 3C. Affected Environment and Environmental Consequences - Water Quality

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SUMMARY

The maintenance of beneficial uses of Delta waters depends on the levels of several key water quality variables (constituent concentrations and other water quality characteristics, such as temperature) in Delta waters. This chapter describes those key water quality variables, objectives associated with maintaining beneficial uses of Delta waters, existing Delta water quality conditions, and impacts of the DW project on levels of key variables in Delta channels and exports. Information is also presented on estimated historical Delta water quality conditions to provide a context for assessing water quality effects of the No-Project Alternative.

Diverting water onto the DW project islands would reduce Delta outflows and could increase salinity in Delta channels or exports. Discharges from the DW project islands could contribute to changes in concentrations of water quality constituents and other variables in Delta channel receiving waters and Delta exports. Variables that could be adversely affected are salinity, concentrations of dissolved organic carbon (DOC), temperature, suspended sediments (SS), dissolved oxygen (DO), and chlorophyll. Increases in DOC and salinity could indirectly increase trihalomethanes (THMs) in treated drinking water supplies that are exported from the Delta. Also of concern are pollutants that may remain in some DW island soils as a result of past agricultural and waste disposal activities; if pollutants are present, they could contaminate stored water that is later discharged into Delta channels.

Water quality impacts of salinity increases were assessed for Chipps Islands, Emmaton, Jersey Point, and Delta exports (representative of diversions at CCWD Rock Slough intake and SWP Banks and CVP Tracy Pumping Plants). Water quality impacts of increases in DOC and resulting THM concentrations were assessed for Delta exports. Impacts of other variables and potential water pollutants in island soils were assessed qualitatively because quantitative models for these variables are not presently available.

DW project diversions under Alternative 1, 2, or 3 could result in significant salinity increases at Chipps Island, Emmaton, and Jersey Point and in Delta exports during periods of low Delta outflow. These impacts would be reduced to less-than-significant levels through adjustments made to DW project diversions based on salinity estimates at these locations with and without DW project diversions. DW project discharges under Alternative 1, 2, or 3 could result in significant elevations of DOC concentrations in Delta exports and elevations of THM concentrations in treated drinking water. These impacts would be reduced to less-than-significant levels through adjustments of DW project discharges based on measurements of DOC and bromide (Br^-) in stored water during intended discharge periods and monitoring of channel receiving waters.

DW project discharges under Alternative 1, 2, or 3 could also result in significant changes in other water quality variables (temperature, SS, DO, and chlorophyll) in Delta channel receiving waters. This impact would be reduced to a less-than-significant level through adjustments of DW project discharges based on measurements of these variables in stored water during intended discharge periods and monitoring in channel receiving waters. Potential contamination of stored water by pollutant residues under Alternative 1, 2, or 3 would also be a significant impact. This impact would be reduced to a less-than-significant level through assessment and necessary remediation of soil contamination prior to project implementation to eliminate sources of potential contamination.

Water quality impacts under cumulative conditions would be similar to the direct and indirect impacts described above for Alternatives 1, 2, and 3. Additionally, use of the recreation facilities constructed on the DW project islands

would contribute to pollutant loading in the Delta from regional boating activities. The potential increase in pollutant loading from the DW project facilities and boating activities under Alternative 1, 2, or 3, in combination with other boating facilities in the Delta, is considered a significant and unavoidable cumulative impact.

Implementation of the No-Project Alternative would not result in measurable water quality effects relative to existing conditions.

INTRODUCTION

This chapter assesses the potential impacts of the DW project alternatives on:

- levels of Delta water quality variables for which Delta objectives have been established (i.e., salinity),
- levels of other water quality variables that could affect beneficial uses of the Delta, and
- Delta export concentrations of constituents associated with the quality of water treated for municipal use.

Some issues related to this water quality assessment are discussed more fully in other chapters. Chapter 3A, "Water Supply and Water Project Operations", discusses issues related to effects of DW project operations on water supply available for export by the CVP and the SWP. Chapter 3B, "Hydrodynamics", discusses potential DW project effects on local and net channel flows. Chapter 3F, "Fishery Resources", discusses potential localized and general fish habitat changes resulting from DW project operations and project-related changes in outflow and export.

The DW reservoir islands may be used for water banking or for storage and discharge of water being transferred through the Delta by other entities. The frequency and magnitude of these uses is uncertain at this time, and impacts related to these uses would have to be analyzed separately. However, the analytical tools described in this chapter could also be used to analyze the effects of these uses.

The discussion of water quality in this chapter includes several terms that may not be familiar to all readers. The following are definitions of key terms as they are used in this EIR/EIS:

- **Delta standards.** A general term referring to all applicable water quality objectives; flow requirements; and other restrictions on diversions, exports, channel flows, or gate operations.
- **Historical conditions.** The combination of measured inflows and exports, estimated channel depletion and Delta outflow, simulated channel flows, and measured or simulated EC and other water quality variables.
- **Mixing zone.** A localized region surrounding a discharge pipe (or diffuser) that is used for initial mixing and dilution of a discharge with the channel water.
- **Entrapment zone.** An area or zone of the Bay-Delta estuary where riverine current meets upstream-flowing estuarine currents and variations in flow interact with particle settling to trap particles. The entrapment zone generally corresponds to a surface salinity (EC) range of 2-10 mS/cm specific conductance (Kimmerer 1992).

AFFECTED ENVIRONMENT

Delta waters serve several beneficial uses, each of which has water quality requirements and concerns associated with it. The Delta is a major habitat area for important species of fish and aquatic organisms, as well as a source of water for municipal, agricultural, recreational, and industrial uses. Dominant water quality variables that influence habitat and food-web relationships in the Delta are temperature, salinity, SS (and associated light levels), DO, pH, nutrients (nitrogen and phosphorus), DOC, and chlorophyll. Other key constituents that are monitored in water for municipal use are Br^- concentrations (measured in raw water) and concentrations of THMs formed in the disinfection of water (measured in treated water). Also of concern in this water quality assessment are pollutants that may remain in some DW island soils as a result of past agricultural and waste disposal activities. If such pollutants are present, they may contaminate stored water that is later released into Delta channels.

Sources of Information

Water Quality Appendices

This chapter is supported by a series of technical appendices that provide evaluation of available Delta water quality data and document methods and results of impact assessment models used in this EIR/EIS. Following are descriptions of the information presented in these water quality appendices:

- Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project", describes the available Delta salinity (EC) data and the results of the RMA Delta hydrodynamic and water quality modeling of Delta salinity conditions.
- Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data", describes the available water quality data for Delta inflows and exports (from DWR's Municipal Water Quality Investigations [MWQI] program) and discusses the likely loading (sources) of salt and DOC in the Delta. (The MWQI program is described below.)
- Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data", describes the available water quality data for Delta agricultural drainage (MWQI), and discusses the likely loading (sources) of salt and DOC from agricultural practices in the Delta.
- Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project", describes several water quality experiments that were conducted to identify the likely loading (sources) of salt and DOC from wetlands in the Delta, including contributions from vegetative decay and peat soil oxidation.
- Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model", describes the DeltaDWQ water quality assessment model, which was used to evaluate possible effects of DW project operations on DOC and salinity in Delta exports.
- Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water", describes the WTP model, which was used to evaluate possible effects of DW project operations on THM concentrations in treated drinking water from a typical water treatment plant.
- Appendix C6, "Assessment of Potential Water Contaminants on the Delta Wetlands Project Islands", describes the sampling of DW islands soils to identify possible sources of contamination from previous agricultural activities on the DW islands and discusses potential sources of water quality degradation related to recreational boating and facilities.

The results and conclusions from these technical water quality appendices are described below under "Impact Assessment Methodology". Details and additional information about these water quality issues can be found in the appendices. All data and model results in this chapter and the appendices are presented for water years rather than calendar years (i.e., beginning in October of the previous calendar year and ending in September of the specified year).

Agency Water Quality Sampling Programs in the Delta

State and federal agencies conduct ongoing water quality sampling programs in the Delta. The following sections review previous and ongoing studies that provided data on key water quality variables used for impact assessment of the DW project alternatives.

Interagency Ecological Program of the Sacramento-San Joaquin Estuary. The Interagency Ecological Program (IEP), previously the Interagency Ecological Study Program (IESP), was initiated in 1970 by DWR, DFG, Reclamation, and USFWS to provide information about the effects of CVP and SWP exports on fish and wildlife in the Bay-Delta estuary. Other agencies (e.g., SWRCB, EPA, the Corps, and USGS) have joined IEP and provide staff members and funding to assist in obtaining biological, chemical, and hydrodynamic information about the Bay and Delta.

The fishery and water quality components of IEP were combined in 1985 to better coordinate investigations of the Delta food web (Brown 1987). Further reorganization of IEP occurred in 1993. Fishery components of IEP were initially designed to document habitat requirements and general food-web relationships of estuarine and migratory species. Water quality components were focused on salinity and algal productivity (nutrient) effects.

Agencies participating in IEP conduct extensive programs of routine sampling, as well as more intensive special studies, in the Delta. IEP maintains its data in EPA's centralized database (STORET) and other database systems to allow access to and analysis of collected data. Annual IEP reports are issued, and newsletters and annual meetings provide participants and the interested public with timely information about study results.

SWRCB Biennial Reports for Clean Water Act Section 305(b). SWRCB, in fulfilling requirements of Section 305(b) of the Clean Water Act, prepares biennial reports on water quality conditions in California. SWRCB's 1986 report identified approximately 40 miles of the lower San Joaquin River from Vernalis to Stockton as a segment that did not fully support fishery-related designated uses because of water quality limitations. The 1988 report did not list the lower San Joaquin River, but water quality remains a concern for this river. In contrast, the Sacramento River, the largest tributary to the Delta, has relatively good water quality because of the large amount of dilution provided by runoff from the watershed and releases from storage reservoirs.

Municipal Water Quality Investigations Program. DWR's MWQI program encompasses the previous Interagency Delta Health Aspects Monitoring Program (IDHAMP) and Delta Island Drainage Investigations (DIDI). IDHAMP was initiated by DWR in 1983 to provide a reliable and comprehensive source of water quality information for judging the suitability of the Delta as a source of drinking water (DWR 1989). Issues of concern included sodium, asbestos, and the potential formation of disinfection byproducts (DBP) such as THMs in treated drinking water from the Delta.

As the MWQI program has proceeded, assessment of more water quality constituents has been added. These constituents include pesticide residues and concentrations of organic materials and THM precursors that are contributed to Delta waters from agriculture drains and from algal biomass in the Delta. The ionic compositions of inflowing rivers and exported water have been compared to provide a means of chemically tracking the movement of water through the Delta.

MWQI studies have documented that Delta exports contain relatively high concentrations of DOC, a THM precursor. Agricultural drainage discharges containing natural decomposition products of peat soil and crop residues are considered dominant sources of DOC in Delta waters (DWR 1994). Additionally, DOC is contributed to Delta waters by Delta inflows.

The MWQI program recently determined that Br^- in Delta water contributes significantly to formation of the THMs observed in treated drinking water from the Delta. Sources of Br^- in Delta water are seawater intrusion, San Joaquin River inflow containing agricultural drainage, and possible connate groundwater. Br^- measurements are relatively difficult to make but have been included in the MWQI study since January 1990.

The Delta agricultural drainage component of the MWQI program has located and sampled discharge points of irrigation drainage water in the Delta since 1985. The program initially focused on Empire Tract, Grand Island, and Tyler Island, collecting monthly samples from agricultural drains on these islands. Several new monitoring stations were added to the program in 1987, allowing a much broader interpretation of patterns among islands with different soil and farming practices (DWR 1990). Drainage discharges from Bouldin and Bacon Islands and Webb and Holland Tracts are currently sampled under this program. Figure 3C-1 shows the location of Delta agricultural drainage pumps and MWQI sampling locations (not all drains are sampled).

In general, intensive surveys of agricultural drains on Delta islands have shown high DOC concentrations that may represent a significant contribution to DOC concentrations in Delta waters (DWR 1990). The salt content of the drainage water is found to be greatest during October-March as a result of the leaching of salts from Delta island soils between growing seasons.

In 1988, the DWR MWQI program analyzed agricultural drainage from approximately 30 Delta drains for a wide spectrum of agricultural pesticides. The drains were sampled during periods of heavy pesticide use or high drainage discharge to document concentrations during worst-case events. Pesticides were generally not detected in drainage water, except for small amounts of atrazine, simazine, and 2,4-D (DWR 1989).

Toxic Substances Monitoring Program. Initiated in 1976, the Toxic Substances Monitoring Program (TSMP) is a statewide program for assessing water quality based on sampling of resident aquatic organisms (e.g., freshwater clams, carp, bass, and trout) to determine the extent of synthetic organic chemicals and heavy metals in California rivers and major waterways. This approach to water quality monitoring is based on the assumption that an organism integrates toxicant exposure over time and concentrates pollutants to measurable levels (SWRCB 1985).

Although pesticides are rarely detected in Delta waters, data from various monitoring programs conducted by DWR and SWRCB have shown that contamination by synthetic organic chemicals is prevalent in sediment and organisms collected throughout the Delta. DDT, toxaphene, Aldrin, and other agricultural pesticides are consistently detected in fish collected from the Sacramento and San Joaquin Rivers and the Delta. Most pollutant concentrations in fish do not exceed standards established by the U.S. Food and Drug Administration or the National Academy of Sciences for the consumption of fish tissues. However, the presence of pollutants in fish demonstrates that organic chemicals are being bioaccumulated through the Delta food chain.

Monitoring Program for D-1485 Standards. D-1485 (SWRCB 1978), issued by SWRCB in August 1978, amended previous water right permits of DWR and Reclamation for the SWP and CVP facilities, respectively. D-1485 also set numerical water quality objectives and requirements for Delta outflow, export pumping rates, salinity as measured by electrical conductivity (EC), and chloride (Cl^-) to protect three broad categories of beneficial uses: fish and wildlife, agriculture, and municipal and industrial water supply. The standards included adjustments to reflect hydrologic conditions under different water-year types.

D-1485 has required DWR and Reclamation to conduct comprehensive water quality monitoring of the Delta. Annual reports have been prepared on observed water quality conditions in the Delta and compliance with limits set in D-1485 (DWR 1978). Similar monitoring requirements are included in the 1995 WQCP. DWR and Reclamation are responsible for adjusting their operations to satisfy the applicable objectives. Figure 3C-2 shows a map of the D-1485 water quality monitoring stations in the Delta. Some of these stations have continuous EC monitors; others are sampled routinely for chemical and biological measurements.

EC monitors at Jersey Point and Emmaton are especially important for managing the linkage between upstream reservoir releases and export pumping limits needed to satisfy Delta water quality objectives. The CVP and SWP operations staffs have access to telemetered data from these and several other EC monitors. The DWR Delta Operations Water Quality Section prepares and distributes a daily report of data on flows and EC to assist in decision making on Delta water project operations.

Delta Water Quality Issues

Water quality requirements and concerns are associated with each beneficial use of Delta water. Beneficial uses include agriculture, municipal and industrial water supply, fish and wildlife, and recreation (SWRCB 1975). Water is diverted for agricultural crop and livestock production at more than 1,800 siphons. Drainage water is returned to the Delta through pumping stations operated independently by reclamation districts (Figure 3C-1).

The Delta export pumping plants (SWP Banks, CVP Tracy, and SWP North Bay Aqueduct) and CCWD diversions at Rock Slough intake supply a combination of agricultural, industrial, and municipal users and also some wildlife uses (water supply for refuges). Industrial intakes and discharges occur near Sacramento, Stockton, and Antioch. A wide variety of fish and wildlife inhabit or migrate through the Delta. Many public and private recreational facilities are located in the Delta.

Recognized Delta water quality issues include the following:

- High-salinity water from Suisun Bay intrudes into the Delta during periods of low Delta outflow. Salinity adversely affects agricultural, municipal, recreational, and industrial uses.
- Delta exports have elevated concentrations of DBP precursors (e.g., DOC), and the presence of Br^- increases the potential for formation of brominated DBP.
- Agricultural drainage in the Delta contains high levels of nutrients, SS, DBP precursors (DOC), and minerals (salinity), as well as traces of agricultural chemicals (pesticides).
- Synthetic and natural contaminants have bioaccumulated in Delta fish and other aquatic organisms. Synthetic organic chemicals and heavy metals are found in Delta fish in quantities occasionally exceeding acceptable standards for food consumption.
- The San Joaquin River delivers water of relatively poor quality to the Delta, with agricultural drainage to the river being a major source of salts and pollutants. The Sacramento River also contains agricultural drainage, but in lower concentrations because river flows are higher.

- Populations of striped bass and other species have declined significantly from recent historical levels. Causes of the declines are uncertain, although water quality conditions in the Bay and Delta, decreases in Delta inflow and outflow rates, and increases in Delta exports are suspected of contributing to the declines.

- The location of the estuarine salinity gradient and its associated "entrapment zone", with relatively high biological productivity, is controlled by Delta outflow. The location of the entrapment zone relative to the available estuarine habitat area must be appropriate to protect estuarine species.

Delta Water Quality Variables

Water quality conditions in the Delta are influenced by natural environmental processes, water management operations, and waste discharge practices. The DW project would provide an additional method of water management in the Delta and thus would influence Delta water quality. This section describes water quality variables that might be affected by DW operations and identifies several key variables selected for impact assessment purposes. Some of the selected variables are assessed with impact assessment models and are discussed quantitatively in the impact assessment. Others cannot be assessed with impact assessment models and are therefore discussed qualitatively. Variables that have not been identified as current problems in the Delta and those that are not likely to be affected by DW operations were not selected as impact assessment variables.

Table 3C-1 lists the major water quality variables considered for use in this impact assessment.

Flow

Delta water quality conditions can vary dramatically because of year-to-year differences in runoff and water storage releases, and seasonal fluctuations in Delta flows. Concentrations of materials in inflowing rivers are often related to streamflow volume and season.

Transport and mixing of materials in Delta channels are strongly dependent on river inflows, tidal flows, agricultural diversions, drainage flows, wastewater effluents, exports, and cooling water flows. Possible water quality effects of the DW project depend on flows in the Delta. An accurate assessment of possible Delta water quality effects therefore requires consideration of the patterns of Delta channel flows (see Chapter 3B, "Hydrodynamics"). Channel flow was not selected as a variable for impact assessment in this chapter but is considered in Chapter 3B.

Temperature

Temperature governs rates of biochemical processes and is considered a major environmental factor in determining organism preferences and behavior. Fish growth, activity, and mortality are related to temperature. The maximum (saturated) concentration of DO in water is lower at higher temperatures.

Water temperatures are determined predominantly by surface heat exchange processes, which are a function of weather. Delta temperatures are only slightly influenced by water management activities. The most common environmental impacts associated with water temperatures are localized effects of discharges of water at substantially elevated temperatures (e.g., thermal shock). DW discharges may influence temperatures in surrounding Delta channels because stored water may become warmer during storage periods. Temperature is discussed qualitatively for impact assessment, with measurements proposed as part of impact mitigation to prevent any significant impacts from occurring.

Suspended Sediments

The presence of SS (often measured as turbidity) is a general indicator of surface erosion and runoff into water bodies or resuspension of sediment materials. Following major storms, water quality is often degraded by inorganic and organic solids and associated adsorbed contaminants, such as metals, nutrients, and agricultural chemicals, that are resuspended or introduced in runoff. Such runoff and resuspension episodes are relatively infrequent, persist for only a limited time, and therefore are not often detected in regular sampling programs.

The attenuation of light in Delta waters is controlled by SS concentrations (with some effects from chlorophyll). SS concentrations are often elevated in the entrapment zone as a result of increased flocculation (i.e., aggregation of particles) in the estuarine salinity gradient. High winds and tidal currents also contribute to increased SS in the estuary.

The DW reservoir islands are expected to act as settling basins; therefore, SS concentrations are expected to be considerably lower in discharges than in Delta

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channels. Nevertheless, resuspension of SS materials from the reservoir bottoms into the water on the DW reservoir islands is possible and might have an impact on Delta channel SS concentrations. As the reservoir islands are emptied, the discharge water may have higher SS concentrations. SS is discussed qualitatively for impact assessment, with measurements proposed as part of impact mitigation.

Dissolved Oxygen

DO is often used as an indicator of the balance between sources of oxygen (e.g., aeration and photosynthesis) and the consumption of oxygen in decay and respiration processes. The DO saturation concentration changes with temperature, and DO concentration often varies diurnally. DO concentrations in Delta channels are not generally considered to be a problem, except near Stockton and in some dead-end sloughs. DO concentrations in MWQI agricultural drainage samples are sometimes slightly depressed (e.g., less than 5 milligrams per liter [mg/l]), indicating the presence of a large quantity of organic material (measured by DOC). DO is discussed qualitatively for impact assessment, with measurements proposed as part of impact mitigation.

pH

The measurement of the overall acidity or alkalinity of water is its pH. The pH of Delta water is governed by inflows, aquatic productivity, and the buffering capacity of the carbonate system (especially in estuarine water), so it is relatively constant in the Delta. DW discharges are not expected to have any measurable effect on channel pH. Therefore, pH was not selected as a variable for impact assessment.

Electrical Conductivity

EC is a general measure of dissolved minerals and is the most commonly measured variable in Delta waters. EC is generally considered a conservative parameter, not subject to sources or losses internal to a water body. Therefore, changes in EC values can be used to interpret the movement of water and the mixing of salt in the Delta (see Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project").

EC values increase with evaporation, decrease with rainfall, and may be elevated in agricultural drainage flows in the Delta. Because EC changes with temperature, Delta EC measurements are standardized to 25°C.

Seawater intrusion from the modeled downstream boundary of the estuary at Benecia has a large effect on salinity in the Suisun Bay portion of the estuary. The estuarine entrapment zone, an important aquatic habitat region associated with high levels of biological productivity is defined by the mean daily EC range of about 2-10 mS/cm (Arthur and Ball 1980).

The location of the estuarine salinity gradient and associated entrapment zone is estimated from EC monitoring data and is directly related to Delta outflow. DW project operations will have direct effects on channel EC during DW discharge periods and may indirectly influence EC by changing Delta outflow during periods of DW diversions. Reducing agricultural diversions and drainage from the DW project islands also may affect Delta EC values. EC has therefore been selected as a variable for impact assessment.

Dissolved Minerals

Beneficial uses of Delta water for agricultural, municipal, and industrial water supply can be limited by levels of dissolved minerals. Major parameters for judging Delta water quality have included salinity and concentrations of total dissolved solids (TDS); Cl^-; sodium (Na^+); and more recently, Br^- (Delta M&I Workgroup 1989).

Determining concentrations of specific anions or cations may be important for particular water uses. Cl^- and Br^- concentrations are important in evaluating domestic water supply quality, and sodium concentration is important for both agricultural and domestic water quality. The ratio of Cl^- to EC (using units of mg/l for Cl^- and microsiemens per centimeter [μS/cm] for EC) can be used to distinguish between sources of water from different inflows (e.g., Sacramento River, San Joaquin River, and seawater) sampled at different Delta locations.

DW project operations would influence relative contributions of water from different Delta inflow sources. Therefore, the project would affect mineral concentrations in the Delta. Cl^- and Br^- concentrations were selected as impact assessment variables. The Delta salinity model developed by RMA was used to simultaneously simulate EC and concentrations of Cl^-. These simulations were compared with historical EC measurements and were then summarized to provide estimates of Cl^- and Br^- concentrations for impact assessment with the DeltaDWQ model (see Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model").

Dissolved Organic Carbon

DOC concentration is one of the primary variables that influence the potential for formation of DBP. DBP concentrations are important in judging the quality of drinking water sources (Delta M&I Workgroup 1989).

The most common DBP is THM compounds formed during chlorination of DOC in drinking water supplies; these potentially carcinogenic substances include chloroform and bromoform (Bellar and Lichtenberg 1974; Wilkins et al. 1979). Chloroform has been shown to increase the risk of liver and kidney cancer in mice when administered at high doses (National Cancer Institute 1976). Using data of the National Cancer Institute (1976) and considering water treatability, EPA has established a maximum contaminant level (MCL) of 100 micrograms per liter (μg/l) or parts per billion (ppb) for THMs in finished (treated) drinking water (44 FR 68624).

The current MCL standard is under review by EPA and may be lowered in the near future. Proposed standards being discussed are an MCL of 80 μg/l for THM, as well as MCLs for individual THM compounds. The suspected carcinogenic risk to humans from THMs has led some communities to study and revise their methods of disinfecting drinking water.

THM levels in drinking water can be reduced through the use of alternatives to chlorination in treating water for human consumption (e.g., ozonation or chloromines), although other potentially harmful DBP compounds may be formed during these other disinfection processes. Disinfection itself is being more carefully regulated by EPA to avoid problems from various pathogens (i.e., viruses). Reducing DOC concentrations in raw water before chlorination with flocculation or granular activated carbon adsorption can reduce all DBP levels, but may be quite expensive.

Minimizing DOC concentrations in the raw water source is a major water quality goal for drinking water uses. DW operations may directly influence DOC concentrations in Delta channels and exports. DOC was selected as a variable for impact assessment. The DeltaDWQ model was used to estimate the potential impacts of DW operations on export DOC concentrations.

Trihalomethanes and Trihalomethane Formation Potential

THM formation potential (THMFP) is measured in the MWQI samples as an index of THM concentrations that could be produced by maximum chlorination of Delta water. Several types of laboratory tests have been developed to measure THMFP in water samples. Whereas THMFP is measured in raw untreated water, the regulatory requirement for THM concentrations applies to the finished or fully treated water delivered to homes and commercial users. THM concentrations generally increase with higher chlorine doses and with higher DOC and higher Br^- concentrations (DWR 1994).

There are four types of THM molecules, which can be differentiated by molecular weight: chloroform ($CHCl_3$), dichlorobromomethane ($CHCl_2Br$), dibromochloromethane ($CHClBr_2$), and bromoform ($CHBr_3$). Total THM concentration (by weight) is the basis for current EPA drinking water standards. The greater weight of total THMs resulting from increased bromine incorporation, however, complicates comparison of THM precursors from two water samples with different Br^- concentrations. One method to normalize the total THM concentrations is to use molar THM concentrations, the standard chemistry method, which essentially counts the number (moles) of THM molecules per liter of water.

A slightly different technique, giving equivalent results, is to measure only the carbon weight of each THM molecule because each molecule has one carbon atom. The carbon-fraction concentrations of the four THM molecules are added together to calculate the carbon equivalent of the THM concentration (C-THM), called the "total formation potential carbon" (TFPC) in the DWR MWQI program.

Dividing the C-THM concentration (μg/l) by the DOC concentration (μg/l) in a water sample gives the fraction of DOC molecules that were converted to THM molecules during the THMFP assay. This C-THM/DOC ratio is called the THM yield.

These THM-related variables are discussed in greater detail in Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data"; Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project"; and Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water".

Simulated THM concentration in treated drinking water using Delta exports as the raw water source, modeled with the EPA water treatment plant (WTP) model (described in Appendix C5), was selected as a variable for impact assessment.

Ultraviolet Absorbance and Color

Ultraviolet absorbance (UVA) is the absorbance of light with a wavelength of 254 nanometers (nm), as measured with a spectrophotometer and reported in units of 1/cm (fraction absorbed in one centimeter of water). UVA, used in the study of humic acids and THM precursors, has been found to be linearly related to both DOC and C-THM concentrations (see Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data").

UVA may be useful as a field measurement variable for estimating DOC and C-THM concentrations in DW discharges and Delta channels, but UVA was not selected as a variable for impact assessment because DOC and C-THM impact assessments will be sufficient (provide the same results). Color is a similar measure of light absorbance but is not selective for the humic and fulvic acid component of DOC materials.

Chlorophyll

Algal biomass and organic chemicals associated with algal processes may produce flavor and odor in water supplies as well as contribute to THM formation. Alternatively, algal biomass may be a desirable habitat constituent for fish and aquatic organisms. Chlorophyll concentration is the most common measure of algal biomass. Fluorometric devices have been developed that may provide a field measurement technique for chlorophyll. Algal biomass may increase during water storage on the DW reservoir islands and during wetland and wildlife management on the habitat islands. Chlorophyll is discussed qualitatively for impact assessment, with measurements proposed as part of impact mitigation.

Nitrate and Phosphate

Nitrate (NO_3^-) and phosphate (PO_4^{3-}), nutrients required for aquatic plant and algal growth, are supplied to the Bay-Delta estuary by river inflows, by agricultural drainage, from biochemical recycling in the water column, and from sediment releases. Macrophytes and wetland vegetation obtain these nutrients from the sediment. Ammonia from sources such as wastewater effluents and agricultural fertilizers is oxidized rapidly to nitrate in Delta channels, and ammonia concentrations are usually quite low.

Because DW operations are not likely to change the supply or concentrations of these nutrients in Delta channels, they were not selected as variables for impact assessment.

Contaminant Residues

Residues from pesticides, herbicides, trace metal compounds, and other agricultural or industrial chemicals may produce serious pollution conditions in Delta water and may bioaccumulate in Delta fish and aquatic organisms. These residues can be measured in water, soils, sediments, and organisms inhabiting Delta channels. The detection of a particular compound depends on its persistence and mobility in the environment, as well as its source characteristics. Contaminant residues were selected as a variable for impact assessment because of possible contamination of stored water on the DW reservoir islands. Appendix C6, "Assessment of Potential Water Contaminants on the Delta Wetlands Project Islands", describes sampling of the DW project islands for possible contaminants.

Water Quality of Delta Inflows and Exports

Concentrations of many water quality constituents are often higher in Delta exports than in Sacramento River inflow. Possible sources of water quality constituents in the Delta are seawater intrusion, inflows from the San Joaquin River and eastside streams, biological production in Delta channels, agricultural drainage from Delta islands, and treatment plant effluents. Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data", provides detailed information on the existing water quality characteristics of Delta inflows and exports and the observed changes in these characteristics during water transport through the Delta (data for EC, Cl^-, Br^-, DOC, and THMFP are presented and interpreted in this appendix). Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project", includes historical data on EC.

Historical water quality data from the Delta inflows (Sacramento and San Joaquin Rivers) and the export locations (CCWD Rock Slough, SWP Banks, and CVP Tracy Pumping Plants) were used to characterize Delta water quality and to confirm the simulations of historical EC conditions performed using the RMA Delta water quality model. These data on inflow water quality are used in the DeltaDWQ assessment model to evaluate effects of DW operations on water quality of the Delta exports. Selected historical data are briefly summarized in the following sections.

Temperature and Suspended Sediments

USGS operates monitoring stations for daily measurements of temperature and SS on the Sacramento River at Freeport and on the San Joaquin River at Vernalis. Data from these measurements indicate the seasonal and storm-event patterns of temperature and SS. Turbidity data collected by the MWQI program are described in Appendix C1. Available Delta temperature data are discussed as part of the fishery assessment in Chapter 3F, "Fishery Resources".

Electrical Conductivity Data

Figure 3C-3 shows monthly average EC measurements from the Sacramento River at Greene's Landing for water years 1968-1991 from EPA's STORET database (Baughman pers. comm.). Average EC is generally in the range of 100-200 μS/cm. Sacramento River EC measurements decrease with higher flows, exhibiting a typical flow-dilution relationship that can be approximated with the following equation, estimated from the 1968-1991 data:

$$\text{Sacramento River EC } (\mu\text{S/cm}) = 5{,}000 \cdot \text{flow (cfs)}^{-0.35}$$

This equation was used to develop an input data set relating inflow EC levels to inflow volume for RMA salt modeling, as described in Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project", and for DeltaDWQ modeling as described in Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model". The equation predicts that EC values would be greater than 200 μS/cm only when Sacramento River flows are less than 10,000 cfs. Some measured values were greater than 200 μS/cm when flows were higher than 10,000 cfs because of variations in the sources of minerals (EC) in the Sacramento River watershed.

The monthly average EC values for the San Joaquin River are usually higher than EC values for the Sacramento River, with typical values varying between 200 μS/cm and 1,000 μS/cm. Figure 3C-4 indicates that EC measurements from the San Joaquin River at Vernalis (Baughman pers. comm.) also generally decrease with increases in flow, exhibiting a flow-dilution relationship that can be approximated with the following equation, estimated from the 1968-1991 data:

$$\text{San Joaquin River EC (mS/cm)} = 25 \cdot \text{flow (cfs)}^{-0.5}$$

Several San Joaquin River monthly average EC values above 1,000 μS/cm (1.0 mS/cm) were observed during winter in recent years (1988-1991) (Figure 3C-4, upper panel). These values are higher than EC values estimated with the flow-dilution equation. These elevated EC values suggest that an additional load of salt may have been released in drainage into the San Joaquin River during recent years. For impact assessment purposes, however, this equation was used as an estimate of San Joaquin River EC values. Because the simulated inflows will be different from historical inflows (due to differences in reservoir operations and diversions), the historical EC values cannot be used directly.

Chloride and Bromide Concentrations

Each Delta inflow has a specific chemical composition that can be used to characterize the inflow source (see Appendix C1). Concentrations of each mineral constituent increase directly with EC. Cl^- and Br^- are the two minerals of greatest interest for the DW impact assessment. Where Br^- measurements are available, data indicate that all three sources of Delta water (Sacramento River, San Joaquin River, and seawater) have a nearly identical and constant Br^-/Cl^- concentration ratio of 0.0035 (see Figure C1-5 in Appendix C1). Variability in the Br^-/Cl^- ratio is greatest for the Sacramento River because of the low concentrations of Cl^- and Br^-. Estimating the Br^-/EC ratio driectly would provide identical results.

In Sacramento River inflows, EC values are generally between 100 μS/cm and 200 μS/cm, Cl^- concentrations are usually between 5 mg/l and 10 mg/l, and the Cl^-/EC value for Sacramento River inflows averages about 0.04 (Figure 3C-5). The graphical presentation of mineral concentrations in the Sacramento River shows much scatter because the low concentrations are reported in whole units of mg/l. Br^- concentrations are very low in the Sacramento River, averaging less than 0.05 mg/l (Br^-/Cl^- = 0.0035; Br^-/EC = 0.0001).

In San Joaquin River inflows, Cl^- concentrations fluctuate between about 20 mg/l and 150 mg/l. Cl^-/EC values increase from about 0.10 at low EC values to about 0.15 at high EC values (Figure 3C-6). The change in the Cl^-/EC ratio value may be explained by the fact that San Joaquin River inflow is a mixture of San Joaquin River water, containing significant agricultural drainage, and Stanislaus River water. Nevertheless, the Cl^-/EC value of 0.10 to 0.15 in the San Joaquin River inflow is distinct from the lower Cl^-/EC value of about 0.04 in the Sacramento River. Br^- concentration would be about 0.5 mg/l when Cl^- concentration is 150 mg/l (Br^-/Cl^- = 0.0035; Br^-/EC = 0.00035 to 0.00052).

The Cl^-/EC value for seawater is approximately 0.35. The Cl^-/EC value has averaged about 0.30 for MWQI samples from Mallard Island near the confluence of the Sacramento and San Joaquin Rivers (Figure 3C-7) because some mixture of Sacramento River water and ocean water was presumably collected in the samples. Br^- concentrations would be about 17.5 mg/l at Mallard Island when Cl^- concentration is 5 g/l (Br^-/Cl^- = 0.0035; Br^-/EC = 0.001).

Concentrations of Dissolved Organic Carbon

DOC concentrations in Sacramento River inflow are generally the lowest measured in the Delta, usually approximately 2.0 mg/l. Sacramento River DOC concentrations sometimes exceed 3.0 mg/l, however. Daily measurements during storm events in 1993 have confirmed that Sacramento River DOC concentrations can exceed 2.0 mg/l as the result of the presence of DOC material in surface runoff (Agee pers. comm.). DOC concentrations in the San Joaquin River (generally ranging between 3.0 mg/l and 6.0 mg/l) are usually higher than Sacramento River DOC concentrations. Available data on Delta DOC concentrations are discussed in Appendix C1. Flow regressions were estimated for river inflow concentrations of DOC using available data and were used to calculate inflow DOC concentrations in DeltaDWQ for impact assessment purposes.

Potential Water Contaminants on the DW Project Islands

Potential water contaminants on the DW project islands include residues from pesticides applied by agricultural operations, materials from waste disposal sites, and residues at maintenance and repair facilities for agricultural equipment.

Appendix C6, "Assessment of Potential Water Contaminants on the Delta Wetlands Project Islands", describes the results of soil sampling conducted on the DW project islands and laboratory analysis for pesticide residues. The results indicated that, in general, DW island soils do not contain significant concentrations of agricultural chemicals. Pesticide residues were low to nondetectable for agricultural chemicals known to have high potential to leach from soils. Detected residues of three herbicides observed in one soil sample from Bacon Island were the result of recent application and do not represent a concern regarding water contamination because herbicides undergo rapid chemical degradation.

Incidental discharges of petroleum-based materials, sewage, and litter into Delta channels and onto the DW project islands could occur in connection with the proposed recreational boating facilities and activities. Petroleum products contain chemicals toxic to aquatic organisms, and improperly treated sewage can introduce into Delta channels pathogens that are harmful to human health and nutrients that stimulate biological growth. The magnitude and significance of discharges depends on facility locations and services provided; types of boating activities and changes from existing conditions; timing of the activities; and quality factors associated with boat size, age, and maintenance. Information is provided in Appendix C6 regarding the potential for DW operations to contribute to water quality problems as a result of recreational boating. Boating activities associated with DW project implementation are not likely to cause significant adverse water quality impacts.

The following discussions describe other potential water contaminants on the four DW project islands.

Bacon Island

Bacon Island is the most densely populated of the DW project islands. Most of the domestic wastewater from homes and farm worker barracks is disposed of by septic tank systems. Before garbage collection service was provided by individual counties or private firms, many farm operators disposed of domestic trash at selected locations on the island. Abandoned vehicles, used automobile tires, various containers, and common household or farm-related trash can be found at these sites. Figure 3C-8 shows the locations of known or visible garbage disposal sites on Bacon Island.

Bacon Island has several permanent farm operation facilities, with designated areas for maintenance and repair of farm machinery. Fugitive diesel fuel and gear and motor oil drippings are evident in the soils in most of these areas. Used oils are stored in aboveground containers and are collected by a waste oil recycler as necessary (Shimasaki pers. comm.).

Partially filled or empty pesticide containers are stored in structures at selected sites on Bacon Island

(Figure 3C-8). Most of these structures are elevated above ground surface and their contamination of surface soils is unlikely. Disposal of metal, plastic, and paper pesticide containers is regulated by the California Department of Food and Agriculture (DFA) under a set of container guidelines. Under these regulations, containers are completely rinsed three times with tap water, allowed to dry, punctured by mechanical means, and stored in these areas until the number of containers accumulated is sufficient to be disposed of by a certified waste hauler. Rinse waters are typically applied to fields where the chemical was used. Staff members of the county agricultural commissioner's office inspect these areas during normal field visits to farm operations (Gianelli pers. comm.).

A potential source of contamination by heavy metals is the site of a discontinued copper salvaging operation, located at the northwestern corner of Bacon Island (Figure 3C-8). A hazardous waste investigation and site cleanup was conducted on the site and high levels of copper, zinc, lead, and other heavy metals were detected in soils surrounding the illegal operation area. Levels of copper and lead were found to exceed hazardous waste criteria established by DHS. Soils were also tested for EPA priority pollutants, most of which are synthetic organic compounds, but no compounds were observed to exceed their detection limits. DHS (Region One Surveillance and Enforcement Section) issued a letter stating that cleanup has been adequate and that constituents of concern are at background levels. (Ambacher pers. comm.)

Webb Tract

No indications of domestic garbage sites were observed on Webb Tract during field surveys in August and September 1988. Historically, few people have lived on Webb Tract and the potential for the presence of major trash deposits is thought to be fairly low. Some farmers live in small mobile homes during the growing season. Users of the few permanent structures on the island rely on septic systems for waste disposal. Few farm machine repair and pesticide storage areas are located on the island. Most of the farmers rebuild or repair machinery during idle periods, typically in workshops located off the island (Dinelli pers. comm.).

Bouldin Island

No visible signs of waste dumping have been observed during field visits to Bouldin Island, which accommodates several homes. All homes and office buildings on Bouldin Island use septic systems for domestic sewage disposal. Domestic trash is transported off the island by a certified waste disposal firm. Farm machinery repair facilities on Bouldin Island are located on the eastern end of the island, about ½ mile south of the SR 12 bridge at Terminous (Wilkerson pers. comm.). Oil and grease drippings are evident in localized areas.

Pesticide storage areas are absent from Bouldin Island because of the island's proximity to the Stockton-Lodi area, where major agricultural chemical distributors are located. Because pesticide formulations are mixed at distributors' facilities, minimal onsite storage or mixing is required (Wilkerson pers. comm.). Most farmers use the same chemical distributor each year and through experience know quantities of compounds needed to minimize waste and overuse. Additionally, many of the compounds are aerially applied; chemicals are handled and loaded at Bouldin Island airstrip.

Holland Tract

Domestic garbage dumps have not been observed on Holland Tract. Few people live on the island; most visitors to Holland Tract are boaters with berthing leases at the marinas (Lindquist pers. comm.). Trash generated at the marinas is collected by a private waste hauling firm. Domestic waste dumping was not evident during field surveys. No signs of pesticide storage areas were identified on Holland Tract during numerous field surveys.

Several landowners previously used Holland Tract lands to spread paper pulp waste produced by Gaylord Container Corporation's paper recycling facility in Antioch. The pulp waste was the byproduct of recycled corrugated cardboard, which was made into new paper products. The waste disposed of on the island consisted of short paper fibers, minor amounts of plastic, and adhesive compounds.

Information about the disposal of pulp recycling wastes on Holland Tract was obtained from the lessee of the property where the disposal operations took place. The pulp disposal operation began in 1979 and ended in 1993. Approximately 450 tons per day of wet material was delivered to the Holland Tract disposal site, where the material was stockpiled and allowed to dry. About 80% of the wet weight was water and 20%, or 90 tons per day, was actual pulp waste. Starting in 1987, the materials were disked or plowed into the soil to improve the soil's percolation and water-retention capabilities (Laxson pers. comm.).

Recycled pulp waste was disposed of on Holland Tract under a land use permit issued by the Contra Costa County Planning Department (Permit 2127). The permit included requirements for groundwater monitoring near the disposal sites; two 4-inch wells approximately 30 feet deep were installed to monitor groundwater quality. Quarterly analytical reports were forwarded to CCWD under the terms of the county permit. In 1984, monitoring was discontinued after one well was accidentally destroyed by a bulldozer.

A chemical analysis of waste pulp spread on Holland Tract was conducted for CCWD in 1988 (Gartrell pers. comm.). Concern had been raised over the potential effects that trace metals, particularly lead, could have on CCWD drinking water supplies in nearby Rock Slough. Testing was performed by the DHS laboratory to determine the maximum metal concentrations under worst-case conditions. Twenty-seven trace metals were analyzed but none were found at levels that exceeded DHS hazardous waste criteria. Extractable and purgable organics also were not detected. Additional data collected by Gaylord Container Corporation and analyzed by Emcon Associates in 1989 confirm that metal concentrations were similar to background soil concentrations (Hsiong and Isham pers. comm.).

The Central Valley Regional Water Quality Control Board (CVRWQCB), after reviewing results of chemical testing of the pulp waste, does not believe that metal concentrations in pulp wastes represent a potential threat to surface water or drinking water quality (Landau pers. comm.). Trace metals in pulp waste are under study by Gaylord Container Corporation for review by CVRWQCB (Roe pers. comm., Hsiong and Isham pers. comm.). Dioxin contamination of the pulp byproduct spread on Holland Tract is highly unlikely because the pulp was not subjected to chlorination, which is essential in the formation of dioxins (Landau pers. comm.).

IMPACT ASSESSMENT METHODOLOGY

DW project operations may cause water quality effects in the Delta by two primary mechanisms:

- DW project discharges may have EC levels or contain concentrations of water quality constituents, such as Cl^-, Br^-, or DOC, that may affect water quality in Delta channels and exports.
- DW project diversions or discharges may change Delta outflow or Delta channel flows, which might influence salinity intrusion or shift the contributions of water quality constituents from different Delta inflow sources. These changes may affect water quality in Delta channels and exports.

Table 3C-2 gives a summary of impact assessment methods for the major water quality variables selected for impact assessment: salinity (EC, Cl^-, Br^-) and DOC concentrations in the Delta, and THM concentrations in treated drinking water obtained from the Delta.

Overview of the Impact Assessment Models and Modeling Tasks

The following models were used for the assessment of potential DW project effects on the major water quality variables selected for impact assessments, the RMA water quality model, the DeltaDWQ model, and the EPA WTP model. This section provides an overview of the most important steps in the development, calibration, confirmation, and application of these models for the impact assessment for water quality.

The water quality assessment models rely on accurate hydrodynamic modeling of channel flows to allow simulation of salt transport and mixing in the Delta. The RMA Delta hydrodynamic model was used to simulate tidal and net channel flows in the major Delta channels, as described in Chapter 3B, "Hydrodynamics". The simulated net channel "flow-split" relationships were evaluated and summarized with equations that are incorporated into the DeltaSOS model (Appendix A2, "DeltaSOS: Delta Standards and Operations Simulation Model"). The assumed water budget for Delta agricultural islands is incorporated into the DeltaDWQ model (Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model").

There are many unpredictable processes and events that may affect water quality in the Delta that are not simulated with the assessment models developed for simulating likely effects of DW project operations. Examples of unpredictable factors that are expected to influence conditions under the No-Project Alternative and under the DW project alternatives include occassional slugs of relatively high-salinity San Joaquin River inflows, intensive agricultural salt leaching following periods of drought, and increases in DOC concentrations in storm runoff. These unpredictable water quality effects will be considered in actual DW operations, however, because they will be detected with routine monitoring data used to demonstrate compliance with the 1995

WQCP objectives and in data collection needed to satisfy mitigation requirements imposed on the DW project by SWRCB and the Corps.

Figure 3-1 in Chapter 3, "Overview of Impact Analysis Approach", shows the relationship between the assessments performed using these models. Table 3C-3 summarizes the preliminary model calibration and confirmation tasks described below for the models used in the water quality impat assessment. Table 3C-4 summarizes the modeling tasks for the impact assessment.

Methods for Assessing Impacts on Salinity (Electrical Conductivity, Chloride, Bromide)

There exist extensive historical data on EC from about 20 Delta locations. These measurements allow the RMA Delta water quality model to be calibrated and tested. Comparisons of EC data and RMA simulation results are summarized in this chapter and are described in detail in Appendix B2. The simulated end-of-month EC patterns are quite similar to the patterns of measured mean monthly EC at most of the available measurement locations most of the time. There is some variation between the simulated and measured EC patterns because the model simulations used mean monthly flows and exports rather than the actual daily flows. These differences are discussed in Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments". During periods of salinity intrusion caused by low Delta outflow, there are additional differences between measured and simulated EC patterns caused by uncertainties in estimated Delta channel depletion and estimated Delta outflow.

Historical daily Delta inflows and exports were used to test and calibrate the RMA water quality model (by adjusting tidal mixing coefficients) with daily EC measurements from 19 Delta locations for 1972. Flows and EC data for 1976 and 1978 were used to confirm the RMA water quality model results. These calibration results are shown in Smith and Durbin (1989).

Historical monthly average Delta inflows and exports for 1967-1991 were used to simulate monthly average net channel flows and end-of-month salinity patterns in the Delta. The historical Delta salinity simulations were used as a reference for judging the reliability of the RMA Delta water quality model. These results are described in Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project", and are summarized in this chapter.

The RMA Delta water quality model was also used to simulate the mean monthly contributions of each Delta inflow source (Sacramento and San Joaquin Rivers, Yolo Bypass and eastside streams, agricultural drainage, and tidal mixing from the downstream model boundary) at selected Delta channel and export locations. These simulated mean monthly source contributions were summarized and incorporated into the DeltaDWQ model for impact assessment of DW project operations on Delta EC and on Cl^- and Br^- concentrations in Delta exports.

Methods for Assessing Impacts on Dissolved Organic Carbon and Trihalomethane

The simulated effects of DW project operations on DOC concentrations depend on the estimated inflow concentrations and inflow source contributions, and on the assumed sources of DOC from Delta agricultural drainage and from the DW habitat and reservoir islands. The simulated effects of DW project operations on THM concentrations in drinking water also depend on the assumed chlorination and other treatment processes at the simulated water treatment plant.

The DWR MWQI program has collected water samples from Delta channel, export, and agricultural drainage locations. The MWQI program measurements are the primary water quality measurements used to estimate changes in DOC between the Delta inflows and the Delta export locations and the contribution of DOC from Delta agricultural drainage, in units of grams of DOC per square meter per year (g-DOC/m^2/year). The analyses of these data on Delta DOC and related variables are described in Appendices C1, "Analysis of Delta Inflow and Export Water Quality Data", and C2, "Analysis of Delta Agricultural Drainage Water Quality Data".

Because there are no measurements of agricultural drainage flows in the Delta, the MWQI measurements of DOC concentrations cannot be used to estimate the relative contributions of DOC from Delta agricultural land. Possible contributions of DOC from crop residue, wetlands plants, and peat soil leaching have not been measured. Several water quality experiments were conducted to estimate these potential DOC source contributions for impact assessment purposes. Results of these experiments are described in Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project".

There was no existing model for estimating the relationship between the water budget for Delta agricultural islands (diversions, ET, and drainage) and the corresponding salinity (EC) and DOC concentration patterns in agricultural drainage. The Delta drainage water quality model DeltaDWQ was developed for assessment of impacts associated with contributions of the DW project island discharges to DOC concentrations in Delta exports. This model combines the simulated monthly channel flows estimated in DeltaSOS with simulated monthly agricultural drainage and DW project discharge concentrations to estimate DOC concentrations in Delta exports.

Finally, the simulated export concentrations of DOC and Br^- were used to simulate expected monthly average THM concentrations in a typical water treatment plant obtaining its water supply from Delta exports. The EPA WTP model was used for the THM impact assessment. Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water", describes this model and the results of THM impact assessment for the DW project alternatives.

This chapter summarizes the use of these water quality impact assessment models, selected criteria for judging impact significance, and the results of the impact assessments for the constituents selected for impact assessment. However, the accompanying technical appendices should be consulted for many details that are not repeated in this chapter.

Analytical Approach and Impact Mechanisms

Assessment of water quality impacts requires establishing a point of reference with which conditions under DW project operations can be compared. The point of reference used for this assessment is the No-Project Alternative. The simulated No-Project Alternative represents Delta water quality conditions that are likely to exist in the absence of DW project operations, with a repeat of the hydrologic conditions represented by the Delta hydrologic record, but with existing facilities, water demands, and Delta standards. The relationship between the No-Project Alternative and historical water quality conditions is described below.

The 1962-1991 25-year period was used because:

- the range of hydrologic conditions of the 25-year period is similar to those of the 70-year 1922-1991 period (Appendix A1),
- most reservoirs and diversion facilities were operational during this period, and
- historical EC and water quality data are available for this period.

Conditions under the No-Project Alternative and the DW project alternatives were simulated using models discussed in the following sections. For a model to be considered a reliable predictive tool, simulations produced by the model are confirmed through comparison with observed historical conditions. For this analysis of water quality effects of DW project operations, simulated historical conditions were compared with historical data from the sampling programs described above under "Sources of Information".

The following four locations in the Delta were selected for assessment of impacts related to Delta salinity conditions:

- Chipps Island, usually considered to be the primary station for monitoring Delta outflow water quality because it is located downstream of the confluence of the Sacramento and San Joaquin Rivers, where river flows and Delta agricultural drainage have combined;
- Emmaton, one of the locations for Delta agricultural salinity objectives located on the Sacramento River downstream of Threemile Slough;
- Jersey Point, one of the locations for Delta agricultural salinity objectives, and an important location for monitoring effects of agricultural drainage contributions to water quality in central Delta outflows; and
- Delta exports from the southern Delta, assumed to be representative of CCWD diversions at Rock Slough intake #1; SWP exports at Banks Pumping Plant, where water is diverted from the Delta across Clifton Court Forebay into the California Aqueduct; and CVP exports at Tracy Pumping Plant, where Delta water is diverted into the Delta-Mendota Canal (DMC).

A representative Delta export location was used because the impact assessment methods cannot reliably distinguish between water quality conditions at the three major export locations. Localized effects of agricultural drainage at the CCWD Rock Slough intake and effects of water quality of San Joaquin River inflows at the CVP Tracy Pumping Plant are described in Appendix B2, "Salt Transport Modeling Methods and Results for the Delta

Wetlands Project". For impact assessment purposes, the likely effects of DW project operations on Delta export water quality were assessed for representative south Delta exports with the DeltaDWQ model, described in Appendix C4. The representative export water quality might be compared with historical water quality collected from Old River at Holland Tract.

Impacts related to DOC and THM concentrations were assessed for Delta exports only.

Water Quality Effects of DW Discharges: Contributions of Constituents

DW project discharges may contain elevated levels of water quality constituents that could affect water quality in Delta channels and Delta exports. Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data", describes likely average monthly concentrations of water quality constituents in drainage water from Delta upland and lowland islands. The estimates for lowland islands were used to represent DW island discharges under the No-Project Alternative. Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model)", describes conceptual water, salt, and DOC budgets for typical Delta agricultural islands. Estimated agricultural drainage concentrations of EC and DOC under the No-Project Alternative are presented. Cl^- and Br^- concentrations were also estimated with DeltaDWQ. Likely concentrations of these constituents in discharges under the DW project alternatives were estimated for comparison with conditions under the No-Project Alternative.

DW discharges may change export water quality and potentially affect THM concentrations in treated drinking water. The EPA WTP model, described in Appendix C5, "Modeling Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water", was used to simulate THM concentrations in Delta export water chlorinated in a typical water treatment plant.

Water Quality Effects of DW Operations: Changes in Channel Flows and Outflow

DW project operations may influence salinity intrusion to the Delta and contributions of water quality constituents from different inflow sources by changing Delta channel flows and outflows. Chapter 3B, "Hydrodynamics", describes hydrodynamic modeling of the DW project performed by RMA for JSA and the lead agencies using its link-node hydrodynamic model of the Delta. RMA also performed salt transport modeling of monthly average Delta conditions under contract to DW and provided modeling results to JSA for use in performing water quality impact analyses. Appendix B1, "Hydrodynamic Modeling Methods and Results for the Delta Wetlands Project", describes the hydrodynamic modeling results and Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project", describes the salinity modeling results. The RMA modeling was based on 25-year (1967-1991) historical inflows and exports.

The RMA Delta salinity model uses the results from the RMA Delta hydrodynamic model and provides detailed simulations of salinity in all Delta channels. For impact assessment purposes, the observed relationships between effective Delta outflow and salinity at selected locations were used to summarize the likely effects of changes in Delta outflow caused by DW project operations on EC at the four locations selected for impact assessment. The next section of this chapter shows that the DeltaDWQ results and the RMA Delta salinity model results indicated similar relationships between effective Delta outflow and EC at the locations selected for impact assessment. The detailed RMA modeling and the effective outflow relationships provided similar results. The negative exponential relationships between effective Delta outflow and EC were incorporated into the DeltaDWQ model and used for impact assessment of the alternatives. Comparisons between the historical EC data and the RMA salinity model results and the effective Delta outflow relationships are more fully described in Appendix B2.

As described in Appendix B2, the effective Delta outflow is the equivalent steady-state outflow that will maintain the observed EC value at a particular monitoring station. Calculations of effective outflow incorporate the sequence of previous Delta outflows. The monthly change in effective outflow is calculated as a function of the previous month's effective outflow and this month's average outflow:

Change in effective outflow = (outflow - effective outflow) · (1 - exp[-effective outflow/R])

where R is a "response" factor that is approximately 5,000 cfs for monthly average flows, as simulated in the DeltaSOS and DeltaDWQ impact assessment models.

This effective Delta outflow calculation was used to allow impact assessment of Delta salinity intrusion to be estimated at selected locations in the DeltaDWQ model. EC values or Cl^- concentrations at selected channel locations resulting from salinity intrusion were estimated from negative exponential relationships with effective Delta outflow, as described in Appendix B2. Following are the equations for the selected channel locations for impact assessment:

$$\text{Chipps Island EC } (\mu S/cm) = 30{,}000 \cdot \exp(-0.00025 \cdot \text{effective outflow})$$

$$\text{Emmaton EC } (\mu S/cm) = 10{,}000 \cdot \exp(-0.00040 \cdot \text{effective outflow})$$

$$\text{Jersey Point EC } (\mu S/cm) = 8{,}000 \cdot \exp(-0.00040 \cdot \text{effective outflow})$$

$$\text{Delta export EC } (\mu S/cm) = 5{,}000 \cdot \exp(-0.00050 \cdot \text{effective outflow})$$

$$\text{Delta export } Cl^- \text{ (mg/l)} = 1{,}667 \cdot \exp(-0.00050 \cdot \text{effective outflow})$$

At high outflows, the Delta salinity will no longer be influenced by salinity intrusion effects and each of these negative exponential equations will approach zero. The salinity at each channel location will then be determined by the mass balance of salinity from Delta inflows and from agricultural drainage. These salinity mass-balance relationships are included in the DeltaDWQ assessment model as described in Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model".

The DeltaDWQ model results for historical inflows and exports were confirmed with measured EC and Cl^- data for 1968-1991. Salinity intrusion effects resulting from changes in effective Delta outflow, simulated with the DeltaSOS model for DW project alternatives, are adequately estimated in the DeltaDWQ model. The effects of river inflows and agricultural drainage are also adequately represented by the DeltaDWQ model. Model uncertainties in monthly Sacramento and San Joaquin River inflow EC values or monthly flow and EC values of agricultural drainage discharges do not reduce the accuracy of impact assessment results because the same estimates of river inflows and drainage discharges are used for each of the DW project alternatives.

Confirmation of Salinity Simulations Performed Using the RMA and DeltaDWQ Models

The following sections summarize observed historical Delta salinity patterns. The sections also compare observed and simulated values to describe confirmation of the RMA and DeltaDWQ model simulations of Delta salinity conditions with historical inflows and exports.

The RMA model confirmation, performed through comparison between simulations of historical monthly average Delta salinity conditions and measured historical EC data for 1968-1991, is described in detail in Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project". The DeltaDWQ estimates are compared with the historical EC data for 1968-1991 at the four locations selected for impact assessment.

Historical EC data are missing for some periods; Table B2-1 in Appendix B2 provides a statistical summary of the historical EC data and the model results. The following discussion is based on graphical summaries, rather than statistical summaries, to demonstrate the correspondence between simulation results and general patterns of data.

Chipps Island (Pittsburg). Figure 3C-9 shows the measured monthly average EC at Pittsburg (near Chipps Island) for 1968-1991 and the RMA model EC simulations and DeltaDWQ model EC estimates for historical Delta inflows, outflows, and exports. The RMA model simulations and the DeltaDWQ estimates of EC match the measured monthly average EC values relatively well. The negative exponential relationship with effective Delta outflow is generally confirmed. Some of the scatter in the monthly average EC data may be attributed to uncertain monthly outflow estimates, and some scatter may be caused by monthly averaging of EC during periods of large EC changes. The scatter is largest during periods of low Delta outflow, when salinity intrusion effects are greatest.

EC values at Chipps Island increase above 3 mS/cm at an effective outflow of about 10,000 cfs. Chipps Island has EC values that are within the entrapment zone (5-15 mS/cm) for flows between 3,500 cfs and 7,500 cfs. Both the RMA model and the DeltaDWQ estimates provide adequate simulations of Chipps Island historical EC patterns. The response of EC at Chipps Island to changes in Delta outflow caused by DW project operations can be adequately simulated with the DeltaDWQ estimates based on DeltaSOS calculations of effective Delta outflow.

Emmaton. Figure 3C-10 shows the measured monthly average EC at Emmaton for 1968-1991 and the RMA model EC simulations and DeltaDWQ model EC estimates for historical Delta inflows, outflows, and exports. The RMA model simulations and the DeltaDWQ estimates of EC match the measured monthly average EC values relatively well. The negative exponential relationship with effective Delta outflow is generally confirmed. Some of the scatter in the measurements may be attributed to uncertain monthly outflow estimates, and some scatter may be caused by monthly averaging of EC during periods of large outflow changes.

EC values at Emmaton increase above 3 mS/cm at an effective outflow of about 3,000 cfs. Emmaton has EC values that are within the entrapment zone (5-15 mS/cm) only for flows of less than about 2,000 cfs (not allowed under the 1995 WQCP objectives). Both the RMA model and DeltaDWQ estimates provide adequate simulations of Emmaton historical EC patterns. The response of EC at Emmaton to changes in Delta outflow caused by DW project operations can be adequately simulated with the DeltaDWQ estimates based on DeltaSOS calculations of effective Delta outflow.

Jersey Point. Figure 3C-11 shows the measured monthly average EC at Jersey Point for 1968-1991 and the RMA model EC simulations and DeltaDWQ model EC estimates for historical Delta inflows and exports. The RMA model simulations and the DeltaDWQ estimates of EC match the measured monthly average EC values relatively well. The negative exponential relationship with effective Delta outflow is generally confirmed. Some of the scatter in the measurements may be attributed to uncertain monthly outflow estimates, and some scatter may be caused by monthly averaging of EC during periods of large outflow changes.

EC values at Jersey Point increase above 3 mS/cm at an effective outflow of about 2,500 cfs. During 1967-1991, Jersey Point had no measured monthly average EC values within the entrapment zone (greater than 5 mS/cm). Both the RMA model and DeltaDWQ estimates provide generally accurate simulations of Jersey Point historical EC patterns. The response of EC at Jersey Point to changes in Delta outflow caused by DW project operations can be adequately simulated with the DeltaDWQ estimates based on DeltaSOS calculations of effective Delta outflow.

Delta Exports. Figure 3C-12 shows the measured monthly average EC at the CCWD Rock Slough intake for 1968-1991 and the RMA model EC simulations and DeltaDWQ model EC estimates for historical Delta inflows and exports. The RMA model simulations and the DeltaDWQ estimates of EC match the measured monthly average EC values relatively poorly for the CCWD diversions compared with the other stations. The negative exponential relationship with effective Delta outflow is generally confirmed at low Delta outflow. Some of the scatter in the CCWD EC measurements may be attributed to uncertain monthly outflow estimates, and some scatter may be caused by monthly averaging of EC during periods of large outflow changes. The effects of San Joaquin River inflows and local agricultural drainage on CCWD EC measurements are also likely causes for some of the differences between measured and simulated EC values at the CCWD diversion. Appendix B2 gives a more complete discussion of the differences between CCWD and Old River EC measurements (see Figure B2-16).

The monthly average EC value for CCWD diversions has never been greater than 1.5 mS/cm. Both the RMA model and DeltaDWQ estimates provide similar estimates of CCWD historical EC patterns. The deviations between simulated and measured EC at the CCWD diversion are likely caused by local agricultural drainage or tidal gate failures in Sand Mound Slough; the salinity intrusion effects follow those simulated for and observed at Jersey Point. Therefore, the response of EC at the CCWD location (and other export locations) to changes in Delta outflow caused by DW project operations can be adequately simulated with the DeltaDWQ estimates based on DeltaSOS calculations of effective Delta outflow.

Figure 3C-13 shows the measured monthly average Cl^- concentration at the CCWD diversion for 1968-1991 and the RMA model and DeltaDWQ Cl^- estimates for historical Delta inflows and exports. The CCWD diversions are assumed to be similar to other southern Delta export locations (Cl^- measurements are not available from other export locations). The RMA model and DeltaDWQ estimates of Cl^- concentrations match the measured monthly average Cl^- concentrations relatively well, although there is considerable deviation from measured Cl^- concentrations in many months. The negative exponential relationship with effective Delta outflow is generally confirmed at low Delta outflow. Some of the scatter in the measurements may be attributed to uncertain monthly outflow estimates, and some scatter may be caused by monthly averaging of Cl^- during periods of large outflow changes. The effects of San Joaquin River inflows and local agricultural drainage on CCWD Cl^- measurements are also likely causes for some of the differences between measured and simulated Cl^- concentrations.

The monthly average Cl^- concentration at CCWD diversions has never been greater than 300 mg/l. Both the RMA model and the DeltaDWQ estimates provide generally similar simulations of CCWD historical Cl^- patterns as a function of effective Delta outflow. The deviations between simulated and measured Cl^- at the CCWD diversions is likely caused by local agricultural drainage or tidal gate failures in Sand Mound Slough; the salinity intrusion effects follow those simulated and observed at Jersey Point. Therefore, the response of Cl^- at the CCWD diversion (and other export locations) to changes in Delta outflow caused by DW project operations can be adequately simulated with the DeltaDWQ estimates based on DeltaSOS calculations of effective Delta outflow.

Simulated Water Quality for the No-Project Alternative

Possible impacts of the DW project alternatives are compared with Delta water quality conditions represented as the No-Project Alternative. The No-Project alternative is simulated with DWRSIM and DeltaSOS, as described in Chapter 3A, "Water Supply and Water Project Operations", to represent likely Delta conditions that would result from a repeat of the historical hydrologic sequence, but with existing water project facilities (reservoirs, diversions, and canals) and with current levels of demands for upstream diversions and Delta exports. Delta conditions are assumed to be controlled by objectives of the 1995 WQCP and other applicable water rights, agreements, and requirements.

No-Project Alternative conditions and historical conditions are different because of the differences in upstream reservoir operations and diversions, Delta standards and requirements, and demands for Delta exports. The comparison between salinity levels simulated for the No-Project Alternative and simulated for historical conditions are presented here to provide a reference for describing the No-Project Alternative as estimated with DeltaDWQ for impact assessment purposes. The previous section of this chapter has described the differences between measured EC and simulated historical EC.

Simulated EC or Cl^- for the No-Project Alternative and for historical Delta outflows at the four locations selected for impact analysis are shown to demonstrate the simulated similarities between the No-Project Alternative and simulated historical conditions. Differences in inflow, export, and outflow between these simulated cases are shown in Appendix B1. Appendix B2 describes the comparison of simulated historical and No-Project Alternative salinity in detail. The purpose here is to better understand conditions under the No-Project Alternative as the basis for impact assessment. Simulated historical conditions are used so that the natural variability in measured EC and Cl^- is removed from the comparisons.

Simulated Electrical Conductivity at Chipps Island. Figure 3C-14 shows simulated patterns of EC at Chipps Island for 1968-1991 for the No-Project Alternative and for historical Delta outflow.

During periods of high Delta inflow, salts at Chipps Island are flushed and salinity becomes similar to river inflow EC (assumed to be 150 μS/cm). During periods of low Delta inflow, outflow is often controlled by required minimum outflow objectives or salinity standards. Some monthly values differ between the two cases, but the maximum seawater intrusion (during periods of lowest Delta outflow) simulated for each year under the No-Project Alternative is generally similar to EC simulations based on historical outflows, as shown by the peak values of EC simulated for Chipps Island. The maximum monthly EC value for Chipps Island was about 16,000 μS/cm for the simulated No-Project Alternative. The maximum monthly simulated EC values were slightly lower for the No-Project Alternative than for historical conditions because the simulated minimum Delta outflow for the No-Project Alternative required under the 1995 WQCP objectives was higher than historical outflows.

Simulated Electrical Conductivity at Emmaton. The lower panel of Figure 3C-14 shows simulated patterns of EC at Emmaton for 1968-1991 for historical Delta outflows and for the No-Project Alternative outflows. Simulated peak EC values for the No-Project Alternative outflows were generally lower than for historical conditions at Emmaton because of higher simulated minimum Delta outflows for the No-Project Alternative. Some years had higher EC for the No-Project Alternative. The simulated maximum EC values for Emmaton for the No-Project Alternative were about 5,000 μS/cm, less than the maximum simulated historical EC values at Emmaton of about 7,000 μS/cm. The reduced peak EC values for the No-Project Alternative are the result of minimum Delta outflows simulated under the No-Project Alternative being higher than historical outflows because of the 1995 WQCP objectives.

Simulated Electrical Conductivity at Jersey Point. Figure 3C-15 shows simulated patterns of EC at Jersey Point for 1968-1991 for historical Delta outflows and for the No-Project Alternative outflows. Simulated peak EC values were generally lower for the No-Project Alternative than for the historical conditions at Jersey Point because simulated minimum Delta outflows for the No-Project Alternative were higher than historical outflows because of the 1995 WQCP outflow objectives.

Simulated values for the No-Project Alternative were lower than simulated values for historical conditions during several months at the ends of many of the water years with greatest seawater intrusion. For such years, Delta outflow values for the No-Project Alternative as simulated by DeltaSOS to satisfy the 1995 WQCP objectives were greater than historical Delta outflow values. The simulated maximum EC values for the No-Project Alternative at Jersey Point of about 3,000 μS/cm were less than the maximum simulated EC values for historical outflows of about 4,000 μS/cm.

Simulated Chloride Concentrations of Delta Exports. Figure 3C-15 also shows the patterns of Cl^- concentration in Delta exports simulated for 1968-1991 for historical Delta outflows and for the No-Project Alternative outflows. Maximum simulated Cl^- concentrations in Delta exports were sometimes lower for the No-Project Alternative than for historical conditions because of higher simulated minimum Delta outflows for the No-Project Alternative.

Seawater intrusion effects are much less pronounced in Delta exports than at Jersey Point because Sacramento River diversions through the DCC and Georgiana and Threemile Sloughs into the central Delta mix with tidal flows from the lower San Joaquin River to produce relatively freshwater conditions in Delta exports. In addition to seawater intrusion episodes, other fluctuations in simulated Cl^- concentrations in Delta exports are caused by variations in San Joaquin River inflow and agricultural drainage effects. These effects are included in the DeltaDWQ estimates of Delta export Cl^- concentrations.

Simulated Concentrations of Dissolved Organic Carbon and Trihalomethanes in Delta Exports for the No-Project Alternative. Monthly export concentrations of DOC were estimated using the DeltaDWQ model (Appendix C4, "DeltaDWQ: Delta Drainage Water Quality Model"). THM concentrations in treated drinking water were estimated on a monthly basis using the EPA WTP model (Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water").

Figure 3C-16 shows simulated monthly values for DOC concentrations in Delta exports and for THM concentrations in Delta exports treated as drinking water for 1968-1991 under the No-Project Alternative. The simulated DOC concentrations were highest in winter as a result of rainfall drainage and salt leaching from the agricultural islands. Many of the simulated peak DOC concentrations each year exceeded 5 mg/l. Simulated DOC concentrations in the remainder of the year were generally between 3 mg/l and 5 mg/l. Simulated DOC and THM concentrations for historical Delta inflows and exports are also shown.

The THM concentrations for treated (chlorinated) drinking water from Delta exports simulated for the No-Project Alternative fluctuated between about 30 μg/l and 125 μg/l. High DOC concentrations simulated in the winter drainage period contributed to increased THM concentrations. Elevated summer temperatures necessitate higher chlorination doses for treatment and result in highest THM concentrations. Because THM drinking water standards are based on annual averages (as described in the next section), the 12-month moving average pattern of simulated THM concentrations is shown in Figure 3C-16 for the No-Project Alternative.

Measures of Potential Water Quality Impacts and Criteria for Determining Impact Significance

The selected water quality impact assessment variables and the methods that were used to evaluate potential impacts of DW operations on each impact assessment variable are described below and identified in Table 3C-5. The significance criteria developed for each variable (as described in this section) and the location for assessing each variable are also identified.

The impact significance criteria for water quality variables that have regulatory objectives or numerical standards, such as those contained in the 1995 WQCP, are developed from the following general considerations:

- Numerical water quality objectives have been established to protect beneficial uses, and therefore represent concentrations or values that should not be exceeded; violation of the limits would be significant.
- Natural variablity caused by tidal flows, river inflows, agricultural drainage, and biological processes in the Delta channels is sometimes quite large relative to the numerical standards or mean values of water quality variables.
- Changes in water quality variables that are greater than natural variations, but are within the limits established by numerical water quality objectives, may cause potential significant impacts; a criterion for determining significant changes is necessary.

For variables with numerical water quality criteria, the numerical limits are assumed to adequately protect beneficial uses and provide the basic measure of an allowable limit that will adequately protect benefical uses. Because it is assumed that there are benefits in maintaining water quality that is better than that specified by the numerical water quality criteria, a significance criterion is established at 90% of the specified water quality limit. Increases in a water quality variable resulting in exeedence of 90% of the numerical standard at a location is considered a significant water quality impact. Variables without numerical limits would not have a maximum significance criterion.

Natural variability is difficult to describe with a single value, but it is assumed that 10% of the specified numerical criterion (for variables with numerical criteria) or 10% of the mean value (for variables without numerical criteria) would be a reasonable representation of natural variability that would be expected to occur without causing a significant impact. Measurement errors and modeling uncertainties are likewise assumed to be about 10% of the measured or modeled values. Simulated changes that are less than 10% of the numerical criterion or less than 10% of the measured or simulated mean value of the variable would not be considered significant water quality impacts because the simulated change would not be greater than natural variablity and model uncertainty.

A second significance criterion is based on the assumption that some changes may be substantial in comparison with natural variablity of the water quality variable, and could result in significant impacts. Because the change in water quality that should be considered substantial is not known, judgment must be applied to establish an appropriate significance threshold. Based on professional experience, the second significance criterion has been selected to be 20% of the numerical limits (for variables with numerical limits), or 20% of the mean value (for variables without numerical limits). It is assumed that this 20% change criterion would prevent relatively large changes that may have potentially significant impacts on benefical uses.

The selected 20% change significance criterion is a relatively simple rule that is used in this impact assessment for all water quality variables. However, it may be determined that some benefical uses are more sensitive to specific water quality variables than to others, and that other significance criteria should be applied. Because the proposed mitigation measure for all water quality variables is to limit the estimated effects of DW operations on water quality so that they remain less than the specified significance criterion (90% of limit and 20% change), the significance criterion used for impact significance can be adjusted, as appropriate, in the terms and conditions of the water right permits and in the mitigation measures and monitoring plan required by the lead agencies.

Criteria for Electrical Conductivity and Chloride

EC and Cl^- concentrations are directly controlled by existing (1995 WQCP) Delta objectives for agricultural, fishery, and water supply uses and Suisun Marsh standards for estuarine and fish and wildlife habitat uses. Current (1995 WQCP) Delta EC and Cl^- objectives vary with month and water-year type. The 1995 WQCP objectives only apply for some months and at some locations. The applicable objectives for Cl^- are either 150 mg/l or 250 mg/l at the three south Delta export locations (CCWD Rock Slough, SWP Banks, and CVP Tracy). Applicable EC objectives are specified for Chipps Island, Emmaton, Jersey Point, and the export locations. Significance criteria for EC and Cl^- may therefore be different for each month at each Delta location

Increases in EC values and Cl^- concentrations resulting in exceedance of 90% of these standards at specified locations in the Delta are considered to be significant water quality impacts. Changes in EC values and Cl^- concentrations are also considered to be significant if they exceed 20% of the applicable objective.

The selected thresholds for impact significance for EC values and Cl^- concentrations (see Table 3C-5) may vary with month and water-year type at locations with applicable Delta objectives. For example, estuarine EC objectives specified in the 1995 WQCP are applicable at Chipps Island during several months (February to June of some years). The minimum applicable EC objective at Chipps Island is about 2,400 μS/cm (corresponding to the 2-ppt salinity location [X2] at Chipps Island). The 1995 WQCP agricultural objectives for EC, ranging from 450 μS/cm to 2,200 μS/cm, are applicable at Jersey Point from April through August 15. Similar EC objectives are applicable at Emmaton. The 1995 WQCP contains an EC objective for Delta exports of 1,000 μS/cm for all months.

The selected significance threshold of a 20% change relative to the EC objective also applies at these locations. For Chipps Island, the threshold of 20% change is equivalent to an allowable increase of 520 μS/cm when the 2,600-μS/cm estuarine objective is applicable. At Emmaton and Jersey Point, the threshold of 20% change is equivalent to an allowable increase of 90 μS/cm when the 450-μS/cm EC objective is applicable. The threshold of a 20% change is equivalent to an allowable increase of 200 μS/cm in Delta exports.

The 1995 WQCP includes Cl^- objectives that apply at the three export locations. The Cl^- objective at the CCWD intake is 150 mg/l for some portion of each water-year type, and 250 mg/l for the remainder of the year. The applicable Cl^- objective at the other export locations is 250 mg/l. The selected significance criteria of 90% of the Cl^- objective (i.e., 135 mg/l or 225 mg/l) and a 20% change relative to the objective (i.e., 30 mg/l or 50 mg/l) applies at these locations.

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Bromide Criteria

Although Br^- concentrations are generally correlated with Cl^- concentrations, no water quality objectives apply to Br^-. The bromide-to-chloride ratio (Br^-/Cl^-)of 0.0035 in seawater and San Joaquin River water indicates that a Cl^- concentration of 150 mg/l (the lowest Cl^- objective for water supply) corresponds to a Br^- concentration of about 0.5 mg/l (150 mg/l • 0.0035 = 0.525 mg/l). An increase in Br^- of 0.1 mg/l would correspond to a 20% increase relative to the equivalent Cl^- concentration at the applicable Cl^- objective of 150 mg/l. For a 250-mg/l Cl^- objective, the 20% increase in Br^- concentration would be about 0.175 mg/l. Therefore, increases in Br^- concentrations in Delta exports exceeding 0.1 mg/l are considered to be significant water quality impacts. Field monitoring of Cl^- concentrations can be used to estimate the Br^- concentration for mitigation purposes. Mitigation for Cl^- would also control Br^-.

Criteria for Dissolved Organic Carbon

DOC concentrations in the Delta exhibit relatively large fluctuations (see Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data"). Although no water quality objectives apply to DOC concentrations, criteria for DOC can be determined from average data on Delta DOC and the estimated effects of DOC concentrations on THM concentrations in treated drinking water (see Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water"). Increases in export DOC of more than 20% of the mean DOC concentration (5 mg/l), or about 1 mg/l, are considered to be significant water quality impacts. DOC concentrations can be reliably estimated using UVA field measurements for mitigation monitoring purposes (see Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project"). Because THM standards involve annual average criteria, the estimated export DOC increases might also be averaged for purposes of mitigation monitoring compliance.

Trihalomethane Criteria

The EPA standard for THM concentrations in drinking water is currently specified at 100 μg/l. THM concentrations vary seasonally because of DOC and temperature variations. Therefore, averages of quarterly or monthly samples are used for EPA compliance monitoring. An increase in THM resulting in a concentration of more than 90% of the EPA standard of 100 μg/l (as simulated on a monthly average basis) or an increase of more than 20% of the standard, or 20 μg/l, is considered to be a significant impact. Because the THM criterion is an annual average value, simulated monthly THM concentrations might be averaged for purposes of mitigation monitoring compliance.

DW discharges would likely be exported for only a few months during a year. The increase in monthly THM concentrations resulting from DW discharges would therefore not be expected to increase the annual average THM concentrations substantially. THM concentrations can be estimated based on field monitoring of UVA measurements from Delta channels and stored water and the simulated relationship between the UVA of raw water and expected THM concentrations in treated water, as described in Appendix C3.

Other Water Quality Criteria

Temperature, SS, DO, and chlorophyll are considered to be highly transient variables exhibiting significant daily or hourly fluctuations that cannot be predicted quantitatively in this water quality assessment. These variables cannot be quantitatively assessed because DW project operations are simulated based on average monthly flows and modeling techniques are not available to reliably simulate patterns of these variables.

The water quality impacts of these variables, however, can be assessed qualitatively. The following significance criteria for these other water quality variables are based on their observed fluctuations in the Delta (DWR 1989). Mitigation monitoring to compare DW discharge water quality with channel water quality should be required.

Temperature. Based on the threshold for salmon mortality effects of water temperature increases (see Chapter 3F, "Fishery Resources"), increases of more than 1°F in water temperatures in channels near DW project discharge locations, when channel temperature exceeds 60°F, are considered significant impacts that must be mitigated. The temperature criteria and apropriate monitoring methods would be specified by SWRCB as part of the terms and conditions of water right permits.

Suspended Sediments. SS concentrations in Delta channels typically average approximately 15 mg/l, and standard deviations are typically 50% of the mean value (DWR 1989). Therefore, increases in channel SS concentrations of more than 20% of the channel SS concentration are considered significant impacts that must be mitigated. The SS criteria and appropriate monitoring methods would be specified by SWRCB.

Dissolved Oxygen. DO concentrations in Delta channels are normally near saturation values that range from about 11.5 mg/l at 10°C to about 8.5 mg/l at 25°C. Diurnal variations in DO caused by algal photosynthesis often exceed 1 mg/l. Based on fish response to water low in DO (i.e., less than 5 mg/l), decreases in channel DO concentrations of more than 20% or resulting in DO concentrations below 5 mg/l are considered significant impacts that must be mitigated. The DO criteria and appropriate monitoring methods would be specified by SWRCB.

Chlorophyll. Chlorophyll concentrations in Delta channels average about 10 μg/l on an annual basis (DWR 1989). In spring and summer, however, chlorophyll concentrations often exceed 20 μg/l, with maximum values greater than 50 μg/l during phytoplankton "blooms". Chlorophyll concentrations can be estimated in the field with calibrated fluorometric monitors. Based on available data on chlorophyll in south Delta channels, increases of more than 20% in channel chlorophyll concentrations are considered significant impacts that must be mitigated. The chlorophyll criteria and appropriate monitoring would be specified by SWRCB.

Pollutant Contamination

Another water quality variable that cannot be quantitatively predicted in this water quality assessment is pollutant contamination. The DW project islands contain several sites of potential soil contamination caused by historical agricultural operations or waste disposal. These sites potentially could release pollutants into water stored on the reservoir islands at concentrations that might exceed water quality standards. Contamination of stored water exceeding applicable water quality standards is considered a significant impact that would be prevented through mitigation.

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 1

Alternative 1 involves potential year-round diversion and storage of surplus water on Bacon Island and Webb Tract (reservoir islands). Bouldin Island and Holland Tract (habitat islands) would be managed primarily as wildlife habitat.

Under Alternative 1, DW diversions could occur in any month with surplus flows. In DeltaSOS modeling, it is assumed that discharges of water from the DW project islands would be exported in any month when unused capacity within the permitted pumping rate exists at the SWP and CVP pumps and the 1995 WQCP "percent inflow" export limits do not prevent use of that capacity. Such unused capacity would exist when the amount of available water (i.e., total inflow less Delta channel depletion and Delta outflow requirements) is less than the amount specified by the export limits, or when pumping capacity is not being used for other reasons.

Water would be diverted to the reservoir islands (238-TAF water storage capacity) at a maximum average monthly diversion rate of 4,000 cfs, which would fill the two reservoir islands in one month. The maximum initial daily average diversion rate would be 9,000 cfs during several days when siphoning of water onto empty reservoirs begins; at this time, the maximum head differential would exist between island bottoms and channel water surfaces. The maximum initial daily average discharge rate would be 6,000 cfs, but the maximum monthly average discharge rate is assumed to be 4,000 cfs, allowing the two reservoir islands to empty in one month.

Delta Salinity Conditions (Electrical Conductivity, Chloride, and Bromide)

Water quality impacts of salinity increases were assessed for four selected locations in the Delta: Chipps Island, Emmaton, Jersey Point, and Delta exports (representative of the CCWD Rock Slough intake, the SWP Banks Pumping Plant, and the CVP Tracy Pumping Plant). Impacts were measured based on changes in EC values and Cl^- concentrations from the values simulated for the No-Project Alternative. The monthly results for the 1968-1991 period are shown in Table B2-2 in Appendix B2.

DW project diversions would potentially occur during months with relatively high Delta outflows, when EC values in the Delta are low. Because DW discharges and export of DW discharges would not change Delta outflow, effects of DW discharges on Delta EC would be minor. DW discharge salinity may be less than export salinity, creating a small water quality benefit.

Chipps Island

Figure 3C-17 shows the simulated monthly EC values for Alternative 1 at Chipps Island and the changes from the simulated monthly EC values for the No-Project Alternative for 1968-1991. Appendix B2 (Table B2-2) gives the monthly results for the 1968-1991 simulations.

DWRSIM results that were used in the DeltaSOS simulations required Delta outflows that would constrain DW project operations to satisfy applicable 1995 WQCP objectives for outflow and EC. Thus, simulated DW operations would not have caused significant adverse impacts by exceeding the applicable EC standards for Chipps Island. Some of the simulated EC values may have exceeded the 90% significance criterion because this criterion was not included in the DeltaSOS simulations. The selected significance criterion for change (20% of the applicable maximum EC limit) may also have been violated, because it was not included in the DeltaSOS simulations.

Table 3C-6 show an example of the procedure that should be used to determine significant water quality impacts of DW project operations, which would require mitigation of reducing DW project operations to comply with the selected significance criteria, as specified in DW mitigation requirements. Table 3C-6 shows changes in EC at Chipps Island simulated to result from operations under Alternative 1 for the 1922-1991 period, compared with the selected monthly significance criteria for Chipps Island. The significance criteria depend on the applicable EC objective, which may change with month or with year type or runoff conditions, as specified in the 1995 WQCP.

Significance criteria for Chipps Island have been estimated from the 1995 WQCP minimum outflow objectives, using the relationship between effective Delta outflow and EC at Chipps Island (Figure 3C-9). These outflow objectives may vary for some water-year types. Once the equivalent EC objective is determined, the significance criteria are estimated as 90% and 20% of the maximum EC limit.

The applicable estuarine salinity (X2) objective for Chipps Island for February to June (of some years) requires an effective outflow of 11,400 and is equivalent to an EC value of about 2,600 μS/cm. However, for some months with lower runoff, the estuarine salinity objective is at Collinsville (requiring an effective outflow of 7,100 cfs), and the Chipps Island EC value would be approximately 5,000 μS/cm (Figure 3C-9). During most other months, the required Delta outflow is between 3,000 cfs and 4,500 cfs, corresponding to EC values of between 10,000 μS/cm and 14,000 μS/cm. These designated monthly significance criteria for Chipps Island are therefore approximate, and may not accurately reflect the applicable standard in each year of simulated operation.

Significant water quality impacts of DW operations will occur only during months for which DW diversions are simulated. Table 3C-6 evaluates significant impacts at Chipps Island for September through March, which are the only months with DW diversions of more than 500 cfs (Table B2-2). Most DW diversions are simulated for October-January. In October, DW diversions of greater than 500 cfs were simulated for 16 years of the 70-year (1922-1991) simulation period. The 90% criterion of 9,900 μS/cm was never exceeded, but changes in EC of more than the 20% change criterion of 2,200 μS/cm were simulated in 8 of the years. These changes in EC are considered significant and would require mitigation. Similar results were determined for November and September. Very few significant changes were simulated in December through March. During these months, the simulated outflows were higher and the changes in EC caused by DW diversions were correspondingly lower. No significant changes are shown for April through August because DW diversions were not simulated for these months under Alternative 1.

The determination of significant EC changes at Chipps Island shown in Table 3C-6 is based on the monthly simulation results and approximate significance criteria estimated from the outflow objectives. These results are presented to illustrate the method for determining significant impacts. Mitigation requirements to be specified by the lead agencies would incorporate all applicable EC objectives and anticipated DW operations, as estimated with daily flows and appropriate averaging periods (see Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments"). Mitigation monitoring would incorporate both field measurements and calculations of likely effects because EC monitoring and other water quality measurements would be affected once DW begins operations. Impacts would be estimated based on changes from the conditions estimated for the No-Project Alternative from the monitoring measurements.

For some months at Chipps Island, simulated EC values were lower for Alternative 1 than for the No-Project Alternative (see Table B2-2 in Appendix B2). These reductions in EC values would occur because agricultural diversions for irrigation on the DW project islands would be reduced and Delta outflow would be slightly increased.

Emmaton

Figure 3C-17 also shows the simulated monthly EC values for Alternative 1 at Emmaton and the changes from the monthly EC values simulated for the No-Project Alternative for 1968-1991. Applicable EC objectives for Emmaton for April to August range from 450 μS/cm to 2,780 μS/cm, depending on water-year type. DWRSIM results that were used in the DeltaSOS simulations required Delta outflows that would constrain DW project operations to correspond with the applicable objectives in each month of each water-year type. Thus, the simulated DW operations could not have caused significant adverse impacts by exceeding the applicable EC objectives for Emmaton. The only possible significant impacts would result from DW project operations exceeding the selected threshold of a 20% change.

Some of the simulated changes between Alternative 1 and the No-Project Alternative at Emmaton were greater than 90 μS/cm but did not occur during a month with applicable EC objectives for Emmaton. However, if a change in EC is greater than 20% of the applicable EC objective, the change in EC would be considered a significant impact at Emmaton and would require mitigation. Mitigation requirements would be similar to those discussed above for Chipps Island.

For some months at Emmaton, simulated EC values were lower for Alternative 1 than for the No-Project Alternative. These reductions in EC values would occur because agricultural diversions for irrigation on the DW project islands would be reduced and Delta outflow would be slightly increased. Simulated EC values were increased by simulated DW diversions during other months but did not exceed a significance criterion because there are no applicable EC objectives for Emmaton for those months.

Jersey Point

Figure 3C-18 shows the simulated monthly EC values for Alternative 1 at Jersey Point and the changes from the monthly EC values simulated for the No-Project Alternative for 1968-1991. Applicable EC objectives for Jersey Point for April to August range from 450 μS/cm to 2,200 μS/cm, depending on water-year type. DWRSIM results that were used in the DeltaSOS simulations required Delta outflows that would constrain DW project operations to correspond with the applicable objectives in each month of each water-year type. Thus, the simulated DW operations would not have caused significant adverse impacts by exceeding the applicable EC objectives for Jersey Point. The only possible significant impacts would result from DW project operations exceeding the selected threshold of a 20% change.

Some of the simulated changes between Alternative 1 and the No-Project Alternative at Jersey Point were greater than 90 μS/cm but did not occur during a month with applicable EC objectives for Jersey Point. However, if a change in EC is greater than 20% of the applicable EC objective, the change in EC would be considered a significant impact at Jersey Point and would require mitigation.

For some months at Jersey Point, simulated EC values for Alternative 1 were less than those for the No-Project Alternative. These reductions in EC values would occur because agricultural diversions for irrigation on the DW project islands would be reduced and Delta outflow would be slightly increased. Simulated EC values were increased by simulated DW diversions during other months but did not exceed significance criteria because there are no applicable EC objectives for Jersey Point for those months.

Delta Exports

Figure 3C-18 also shows the simulated monthly Cl^- concentrations for Alternative 1 in Delta exports and the changes from the monthly Cl^- concentrations for the No-Project Alternative for 1968-1991. Monthly values are given in Table B2-2 for the 1968-1991 period. The applicable Cl^- objective for all Delta exports is 250 mg/l, with some periods of 150 mg/l required for CCWD diversions (depending on water-year type). DWRSIM results that were used in the DeltaSOS simulations required Delta outflows that would constrain DW project operations to correspond with the applicable objectives in each month of each water-year type. Thus, the simulated DW operations could not have caused significant adverse impacts by exceeding the applicable Cl^- objectives for CCWD (or other export locations). The only possible significant impacts would result from DW project operations exceeding the selected threshold of a 20% change.

Some of the simulated changes between Alternative 1 and the No-Project Alternative in Delta exports were greater than 30 mg/l but may not have occurred during a month with applicable 150-mg/l Cl^- objectives for CCWD. However, if a change in Cl^- is greater than 20% of the applicable Cl^- objective, the change in Cl^- would be considered a significant impact in Delta exports and would require mitigation. Because the 250-mg/l objective is applicable in all months, any increase in Delta export Cl^- concentration of greater than 50 mg/l or above the significance criterion of 225 mg/l would be considered a significant impact that would require mitigation.

For some months, simulated Delta export Cl^- concentrations for Alternative 1 were less than those for the No-Project Alternative. These reductions in Cl^- concentrations would occur because agricultural diversions for irrigation on the DW project islands would be reduced and Delta outflow would be slightly increased. Simulated Cl^- concentrations were increased during other months by simulated DW diversions that reduce Delta outflow, while some increased Cl^- concentrations were the result of DW discharges of water with relatively high Cl^- concentrations compared with southern Delta channel Cl^- concentrations. Figure 3C-18 indicates that no Cl^- changes of geater than 50 mg/l were simulated during the 1968-1991 period.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-1: Salinity (EC) Increase at Chipps Island during Months with Applicable EC Objectives. Implementation of Alternative 1 may cause reductions in Delta outflow during periods of several weeks of DW project diversions. These outflow reductions may result in significant adverse impacts on salinity near Chipps Island. Although proposed DW project operations would not violate established water quality objectives for Chipps Island, changes in salinity (EC) may exceed the 90% maximum criterion or exceed 20% of the applicable objective in some months with DW diversions, as indicated by the simulation results. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-1 would reduce Impact C-1 to a less-than-significant level.

Mitigation Measure C-1: Restrict DW Diversions to Limit EC Increases at Chipps Island. DW shall obtain daily EC measurements for Chipps Island and calculate the change in EC attributable to scheduled DW diversions, and shall restrict daily diversions whenever the 90% maximum criterion or 20% change criterion would be exceeded. DW shall submit to SWRCB a monthly report of measured EC, estimated No-Project Alternative conditions, and calculated EC contribution from DW operations.

The estimated EC without DW diversions would be compared with the expected EC value produced by maximum possible DW diversions each day. Possible DW diversions would be restricted if the expected maximum effect on the Chipps Island EC value exceeded the selected significance criterion of an EC increase. The magnitude of the decrease in Delta outflow that would be allowable without this criterion being exceeded can be estimated by the approximate relationship between effective Delta outflow and EC at Chipps Island (Appendix B2, "Salt Transport Modeling Methods and Results for the Delta Wetlands Project"). DW diversions would be more restricted at lower Delta outflows to satisfy this mitigation condition.

Impact C-2: Salinity (EC) Increase at Emmaton during April-August. Implementation of Alternative 1 may cause reductions in Delta outflow during periods of several weeks of DW project diversions that would significantly increase salinity near Emmaton. Although DW project operations under Alternative 1 would not violate established water quality objectives for Emmaton, changes in salinity (EC) may exceed the 90% maximum criterion or exceed 20% of the applicable objective in these months during periods of low Delta outflow, as indicated by the simulation results. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-2 would reduce Impact C-2 to a less-than-significant level.

Mitigation Measure C-2: Restrict DW Diversions to Limit EC Increases at Emmaton. DW shall obtain daily EC measurements for Emmaton and calculate the change in EC attributable to scheduled DW diversions, and shall restrict daily diversions whenever the 90% maximum criterion or 20% change criterion would be exceeded. DW shall submit to SWRCB a monthly report of measured EC, estimated No-Project Alternative conditions, and calculated EC contribution from DW operations.

The estimated EC without DW diversions would be compared with the expected EC value produced by maximum possible DW diversions each day. Possible DW diversions would be restricted if the expected maximum effect on the Emmaton EC value exceeded the selected significance criterion of an EC increase during periods with applicable EC objectives for Emmaton. The magnitude of the decrease in Delta outflow that would be allowable without this criterion being exceeded can be estimated by the approximate relationship between effective Delta outflow and EC at Emmaton (Appendix B2). DW diversions would be more restricted at lower Delta outflows to satisfy this mitigation condition.

Impact C-3: Salinity (EC) Increase at Jersey Point during April-August. Implementation of Alternative 1 may cause reductions in Delta outflow during periods of several weeks of DW project diversions that would significantly increase salinity near Jersey Point. Although DW project operations under Alternative 1 would not violate established water quality objectives for Jersey Point, changes in salinity (EC) may exceed 20% of the applicable objective in these months during periods of low Delta outflow. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-3 would reduce Impact C-3 to a less-than-significant level.

Mitigation Measure C-3: Restrict DW Diversions to Limit EC Increases at Jersey Point. DW shall obtain daily EC measurements for Jersey Point and calculate the change in EC attributable to scheduled DW diversions, and shall restrict daily diversions whenever the 90% maximum criterion or 20% change criterion would be exceeded. DW shall submit to SWRCB a monthly report of measured EC, estimated No-Project Alternative conditions, and calculated EC contribution from DW operations.

The estimated EC without DW diversions would be compared with the expected EC value produced by maximum possible DW diversions each day. Possible DW diversions would be restricted if the expected maximum effect on the Jersey Point EC value exceeded the selected significance criterion of an EC increase during periods with applicable EC objectives for Jersey Point. The magnitude of the decrease in Delta outflow that would be allowable without this criterion being exceeded can be estimated by the approximate relationship between effective Delta outflow and EC at Jersey Point (Appendix B2). DW diversions would be more restricted at lower Delta outflows to satisfy this mitigation condition.

Impact C-4: Salinity (Chloride) Increase in Delta Exports. Implementation of Alternative 1 may cause reductions in Delta outflow during periods of DW project diversions that would cause increases in Cl^- concentrations of more than the selected criterion (i.e., 20% of the applicable objective) of 30 mg/l or 50 mg/l. DW discharges of high-salinity water could also cause a significant adverse impact on Delta exports. Simulation of DW project operations under Alternative 1 did not show violations of water quality objectives for Delta exports. Even so, actual DW project operations may cause changes in salinity (Cl^- concentration) that exceed 20% of the applicable objective under the right combination of Delta conditions. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-4 would reduce Impact C-4 to a less-than-significant level.

Mitigation Measure C-4: Restrict DW Diversions or Discharges to Limit Chloride Concentrations in Delta Exports. DW shall obtain daily Cl^- concentration measurements from CCWD Rock Slough intake and calculate the change in concentration attributable to scheduled DW diversions, and shall restrict daily diversions whenever the 90% maximum criterion or 20% change criterion would be exceeded. DW shall submit to SWRCB a monthly report of measured Cl^-, estimated No-Project Alternative conditions, and calculated Cl^- contribution from DW operations.

The estimated Cl^- concentration without DW diversions would be compared with the expected Cl^- value produced by maximum possible DW diversions each day. Possible DW diversions would be restricted if the expected maximum effect on Cl^- concentration of Delta exports exceeded the selected significance criterion of 30 mg/l or 50 mg/l or exceeded the 90% maximum criterion. The magnitude of the decrease in Delta outflow that would be allowable without this threshold being exceeded can be estimated by the approximate relationship between effective Delta outflow and EC at Chipps Island (Appendix B2). DW diversions would be more restricted at lower Delta outflows to satisfy this mitigation condition. Measurement of Cl^- concentration in DW storage water could be used to calculate expected Cl^- concentration in Delta exports with maximum DW discharges. DW discharges would be limited if necessary to avoid violation of the significance criteria.

Export Concentrations of Dissolved Organic Carbon

Water quality impacts resulting from increases in export DOC concentrations were assessed for Delta exports in the south Delta. Impacts were measured based on DOC concentrations for Alternative 1 and the change in DOC concentration from No-Project Alternative conditions, as simulated by the DeltaDWQ model.

Figure 3C-19 shows simulated monthly DOC concentrations for Alternative 1 and the changes from the simulated No-Project Alternative DOC concentrations in Delta exports for 1968-1991. Measurements of DOC from the Penitencia Water Treatment Plant for 1991 are shown for reference. The simulation results indicate that Alternative 1 would slightly reduce export DOC concentrations during many months without DW diversions or DW discharges. During these months, the amounts of DW island agricultural drainage containing relatively high DOC concentrations would be reduced under Alternative 1 compared with DOC concentrations expected under the No-Project Alternative. Slightly less agricultural drainage would be exported, and the export DOC concentrations would be slightly reduced. The monthly results are given in Table C5-3 in Appendix C5 for 1968-1991.

Simulated export DOC concentrations were also slightly decreased under Alternative 1 during months with DW diversions because DW diversions reduced the relative contribution of agricultural drainage and San Joaquin River inflow to Delta exports. DW diversions would require a greater contribution of Sacramento River inflow to Delta exports.

For example, during a month with approximately 12,000 cfs of export pumping and 3,000 cfs of agricultural drainage, the contribution of agricultural drainage in exported water would be about 25% (3,000/12,000). DW diversions of 3,000 cfs would increase the total diversions to 15,000 cfs, and thereby reduce the agricultural drainage contribution in exports to 20% (3,000/15,000). The agricultural drainage would be replaced by Sacramento River water. In this example, about 20% of the agricultural drainage would be diverted onto the DW reservoir islands.

The effects of Alternative 1 on export DOC concentrations during months with DW discharges for export would depend on the difference between the estimated DOC concentration in DW discharge and the DOC simulated for operations under the No-Project Alternative. For some months, the DeltaDWQ simulations indicated that DW discharges could increase the export DOC concentrations slightly.

The selected significance criterion for a change in export DOC concentration is 0.8 mg/l, 20% of the mean value (4 mg/l).

Table 3C-7 gives a summary of the changes in export DOC concentrations (from No-Project Alternative DOC concentrations) simulated to result from DW operations under Alternative 1 for 1967-1991 (see Appendix C5 for monthly results). The DeltaDWQ results are reported for each month as either increases in DOC concentration or decreases in DOC concentration. The number of months (out of 25) and the average change in DOC concentration are given for both increases and decreases. For example, the largest average monthly increase in DOC of 0.17 mg/l occurs in July. Increases in DOC during July were simulated in 15 years, with decreases simulated in 10 years. The five largest simulated changes, and the five greatest percentage changes (from No-Project Alternative values) are also shown for each month. The highest simulated DOC concentration change in July was 1.0 mg/l. All other simulated changes were less than 0.8 mg/l.

Table 3C-7 indicates that Alternative 1 caused only one month of simulated changes in export DOC concentrations from the No-Project Alternative DOC concentrations that were more than the selected significance criterion of 0.8 mg/l. Any simulated change in export DOC concentration of more than 0.8 mg/l would be considered a significant impact and would require mitigation.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-5: Elevated DOC Concentrations in Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy). Discharges from the DW project islands may have relatively high DOC concentrations that may significantly increase DOC concentrations in Delta exports. The DeltaDWQ simulation results indicate that possible increases in export DOC concentrations caused by implementation of Alternative 1 would be rare (Figure 3C-19). Those results predict that in some months DOC increases would exceed 0.8 mg/l. Based on the selected significance criterion, these increases would be considered a significant impact.

Implementing Mitigation Measure C-5 would reduce Impact C-5 to a less-than-significant level.

Mitigation Measure C-5: Restrict DW Discharges to Prevent DOC Increases of Greater Than 0.8 mg/l in Delta Exports. DW shall make measurement of DOC concentrations in stored DW project water and in channels receiving the DW discharge water and shall estimate the increase in export DOC that would result from maximum DW discharges. DW shall limit project discharges if this expected maximum effect on export DOC exceeds the selected significance criterion of an allowable change in export DOC concentration of 0.8 mg/l. DW shall submit to SWRCB a monthly report of DOC concentrations in water stored on the DW reservoir islands, DOC channel concentrations estimated for the No-Project Alternative, and DOC increases in Delta exports attributable to DW project operations.

The DOC measurements could be obtained through conversion of field measurements of UVA using known relationships with DOC concentrations (Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data", and Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data").

Trihalomethane Concentrations in Treated Drinking Water

Impacts of increases in THM concentrations in treated drinking water caused by implementation of Alternative 1 were assessed based on simulated THM concentrations and changes from THM concentrations under the No-Project Alternative. Figure 3C-19 (lower panel) gives the monthly patterns of simulated THM concentrations in treated drinking water for Alternative 1 and the changes between the No-Project Alternative and Alternative 1. Measurements of THM from the Penitencia Water Treatment Plant for 1991 are shown for reference.

Implementation of Alternative 1 would cause a significant adverse impact on THM levels in treated drinking water exported from the Delta if the following significance criteria are exceeded because of DW project discharges:

- 90% of the current THM objective for treated drinking water of 100 μg/l (90 μg/l) or
- an increase of THM concentration of more than 20% of the current THM objective (20 μg/l).

Figure 3C-19 indicates that the monthly THM concentrations under Alternative 1 were simulated to be greater than 90 μg/l only for 1977, and the change in THM concentrations were always simulated to be less than 20 μg/l. The monthly results for 1968-1991 are given in Table C5-3 in Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water".

Table 3C-8 gives a summary of the changes in THM concentrations in treated (chlorinated) export water (from No-Project Alternative THM concentrations) simulated to result from DW operations under Alternative 1 for 1967-1991 (see Appendix C5 for monthly results). The results from the EPA WTP model are reported for each month as either increases or decreases in DOC concentrations. The number of months (out of 25) and the average change in THM concentration are given for both increases and decreases. For example, the largest average monthly increase in THM of 3.21 μg/l occurs in July. Increases occurred in 15 years, with decreases simulated in 10 years. The five largest simulated changes, and the five greatest percentage changes (from No-Project Alternative values) are also shown for each month. None of the simulated monthly changes were greater than 20 μg/l.

Under Alternative 1, THM concentrations would be reduced slightly in most months without DW discharges because agricultural drainage amounts from the DW islands would be reduced from amounts expected to be discharged under the No-Project Alternative. Agricultural drainage contains relatively high DOC concentrations that would be converted to THMs by chlorination of Delta export water.

The effects of Alternative 1 on THM concentrations during discharge and export of DW stored water would depend on changes in DOC concentration caused by implementation of the DW project and the temperature of the Delta export water. Temperature has a strong influence on the conversion of DOC to THM in the simulated water chlorination process (see Appendix C5).

Because of substantial monthly variations in THM concentrations, the current EPA monitoring requirements allow monthly or quarterly THM samples to be averaged; the THM objective is an annual average of 100 ug/l. Because DW project discharges would occur for a limited period each year, the possible effects on annual average THM concentrations are much less than the increases attributable to increased DOC or Br^- concentrations during the discharge period. Therefore, the significance criteria for THM concentrations applied during periods of DW discharge is a worse-case approach that will reduce any possible increase in THM concentrations to a less-than-significant level.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-6: Elevated THM Concentrations in Treated Drinking Water from Delta Exports (CCWD Rock Slough, SWP Banks, and CVP Tracy). Discharges from the DW project islands may have relatively high DOC concentrations that may result in increases in THM concentrations in treated (chlorinated) drinking water from the Delta export locations. Possible increases in THM in treated water resulting from implementation of the Alternative 1 are expected to be rare based on the simulation results shown in Figure 3C-19. This impact is considered significant.

Implementing Mitigation Measures C-6 would reduce Impact C-6 to a less-than-significant level.

Mitigation Measure C-6: Restrict DW Discharges to Prevent Increases of More Than 20 μg/l in THM Concentrations or THM Concentrations of Greater Than 90 μg/l in Treated Delta Export Water. DW shall make daily estimates of DOC and Br^- concentrations in stored DW project water and in Delta channels receiving DW discharge water and predict THM increases likely to be caused by DW project discharges, and shall restrict discharges whenever the 20% change criterion would be exceeded. DW shall submit to SWRCB a monthly report of measured DOC and Br^- concentrations, estimated No-Project Alternative conditions, and calculated THM increases that could be attributable to DW operations.

The DOC measurements could be obtained from the relationship between field measurements of UVA and DOC concentrations (see Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data"). Br^- concentrations could be estimated from Cl^- measurements.

Estimates of THM increases likely to be caused by DW project discharges would be accomplished using the predictive relationships for DOC increases in export water described above for Mitigation Measure C-5. THM formation could then be predicted based on relationships among DOC, Br^-, temperature, and chlorination dose (see Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water").

An allowable DW discharge flow would be estimated each day during an intended discharge period based on the relationships described above. The allowable DW discharge flow would be defined as the discharge rate that would not cause an increase in THM level in treated export water exceeding 20 $\mu g/l$ or a resulting THM concentration exceeding 90 $\mu g/l$. Restricting DW discharges to avoid violation of the significance criterion would avoid significant adverse impacts on water quality of treated export water.

Changes in Other Water Quality Variables

Other water quality variables include temperature, SS, DO, and chlorophyll (Table 3C-5). Under Alternative 1, levels of these water quality characteristics will vary widely with daily fluctuations in conditions affecting them (e.g., DW storage volumes, weather patterns, flow characteristics, and water quality of receiving water for DW discharges).

The high variability typical of these parameters and the uncertainty regarding daily conditions that may coincide to produce adverse impacts do not allow a quantitative impact assessment to be performed. It is likely that conditions will occasionally combine under operation of Alternative 1 to produce impacts exceeding the significance criteria for these transient water quality variables. Habitat island discharges would be relatively small and are likely to have better water quality than agricultural drainage under the No-Project Alternative. The significance criteria and mitigation requirements for changes in these water quality variables would be determined by SWRCB and would be included in project operation permits.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-7: Changes in Other Water Quality Variables in Delta Channel Receiving Waters. Discharges of stored water from the DW reservoir islands may adversely affect channel water quality under some daily patterns of water quality conditions in the channel receiving waters and in the stored DW project water. For example, stored DW project water with a low DO level discharged at a high flow rate may decrease DO levels by more than 1 mg/l in a receiving Delta channel. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-7 would reduce Impact C-7 to a less-than-significant level.

Mitigation Measure C-7: Restrict DW Discharges to Prevent Adverse Changes in Delta Channel Water Quality. DW shall monitor water quality variables in water stored on the reservoir islands during intended discharge periods and in Delta channel receiving waters, and shall limit discharges as needed to avoid significant adverse effects on levels of these variables in the receiving channels. DW shall submit to SWRCB a monthly report of measurements of variables in reservoir and channel water. It is possible that monitoring could be integrated with monitoring being performed under existing programs (e.g., IEP and MWQI), but DW would be required to monitor and report in any case.

Field measurements of the four selected variables could be obtained using the following techniques:

- temperature - temperature probes,
- SS - turbidity measurements,
- DO - calibrated DO probes, and
- chlorophyll - calibrated fluorometric monitors.

Levels of the four variables in stored water and receiving water would be related using the expected dilution ratio at each location of a DW discharge pumping station. The expected dilution ratio would be estimated based on channel flow rates and intended DW discharge rates using specified mixing-zone assumptions.

Effects of Pollutant Contaminants

Sites of potential soil contamination resulting from historical agricultural operations or waste disposal exist on the DW islands (Figure 3C-8).

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-8: Potential Contamination of Stored Water by Pollutant Residues. Water storage on the reservoir islands could mobilize soil contaminants at historical pollution sites. If the contaminant concentrations are sufficiently high, mobilization in the stored water may cause a significant adverse impact on stored water quality and on Delta channel water quality after DW discharges stored water. Therefore, this impact is considered significant.

Implementing Mitigation Measure C-8 would reduce Impact C-8 to a less-than-significant level.

Mitigation Measure C-8: Conduct Assessments of Potential Contamination Sites and Remediate as Necessary. DW shall conduct preliminary site assessments at potential contamination sites, in addition to those already performed for this analysis, including assessment of sites associated with agricultural airstrip operations. If the results of a preliminary site assessment indicate that contamination at a site is likely to contaminate stored water, DW shall initiate an appropriate site investigation to either rule out the site as a pollutant source or confirm the need for site cleanup or remediation. Such site assessments and remediation typically would be performed under the supervision of DHS. All required assessments and remediation would be completed prior to the beginning of DW project operations.

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 2

Alternative 2 represents DW operations with two reservoir islands (Bacon Island and Webb Tract) and two habitat islands (Bouldin Island and Holland Tract).

Under Alternative 2, DW diversions could occur in any month with surplus flows, as under Alternative 1. In DeltaSOS modeling, it is assumed that discharges from the DW project islands would be exported in any month when unused capacity within the permitted pumping rate exists at the SWP and CVP pumps. Under this alternative, export of DW discharges would be allowed in any month when such capacity exists and would not be constrained by the 1995 WQCP "percent inflow" export limits. Export of DW discharges would be limited by Delta outflow requirements and the permitted combined pumping rate of the export pumps but would not be subject to strict interpretation of the "percent inflow" export limit.

The maximum monthly average diversion rate to reservoir island storage would be 4,000 cfs (maximum initial daily average diversion rate of 9,000 cfs). The maximum monthly average discharge rate is assumed to be 4,000 cfs (maximum initial daily average discharge rate of 6,000 cfs).

The impacts on water quality under Alternative 2 operations would be similar to impacts described for Alternative 1, but the frequency and severity of adverse impacts generally would be higher because opportunities to export DW water would be increased. Figures 3C-20 and 3C-21 show the simulated salinity variables for Alternative 2. Figure 3C-22 shows the simulated export DOC and treated drinking water THM concentrations for Alternative 2. Tables B2-2 in Appendix B2 and C5-3 in Appendix C5 give the monthly values for Alternative 2 for 1968-1991.

Patterns of changes for all water quality variables between the No-Project Alternative and Alternative 2 are very similar to the changes for Alternative 1.

Mitigation monitoring would be required to prevent significant water quality impacts under Alternative 2. The mitigation measures proposed for Alternative 2 would be the same as those described above under "Impacts and Mitigation Measures of Alternative 1".

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 3

Alternative 3 involves storage of water on Bacon Island, Webb Tract, Bouldin Island, and Holland Tract, with secondary uses for wildlife habitat and recreation. The portion of Bouldin Island north of SR 12 would be managed as a wildlife habitat area and would not be used for water storage. Diversions to the reservoir islands (406-TAF capacity) would be allowed during any month with available surplus flows. The diversion and discharge operations for Alternative 3 would be the same as for Alternative 2, but the assumed diversion and discharge rates are higher. The maximum average monthly diversion rate would be about 6,000 cfs, which would fill the four reservoir islands in about one month (maximum diversion rate of 9,000 cfs). The maximum monthly discharge rate is assumed to be 6,000 cfs (maximum discharge rate of 12,000 cfs).

Delta Salinity Conditions (Electrical Conductivity, Chloride, and Bromide)

Water quality impacts of salinity increases were assessed for four selected locations in the Delta: Chipps Island, Emmaton, Jersey Point, and Delta exports (representative of the CCWD Rock Slough intake, the SWP Banks Pumping Plant, and the CVP Tracy Pumping Plant). Impacts were measured based on changes in EC values and Cl^- concentrations from the values simulated for the No-Project Alternative. The impacts on salinity under Alternative 3 would be similar to those described above under "Impacts and Mitigation Measures of Alternative 1", but the severity of impacts generally would be greater because of increased diversions and discharges. Figures 3C-23 and 3C-24 show the simulated salinity variables for Alternative 3. Tables B2-2 in Appendix B2 and C5-3 in Appendix C5 give the monthly results for Alternative 3 for 1968-1991.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-9: Salinity (EC) Increase at Chipps Island during Months with Applicable EC Objectives. This impact is described above under Impact C-1. This impact is considered significant. Implementing Mitigation Measure C-1 would reduce Impact C-9 to a less-than-significant level.

Mitigation Measure C-1: Restrict DW Diversions to Limit EC Increases at Chipps Island. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-10: Salinity (EC) Increase at Emmaton during April-August. This impact is described above under Impact C-2. This impact is considered significant. Implementing Mitigation Measure C-2 would reduce Impact C-10 to a less-than-significant level.

Mitigation Measure C-2: Restrict DW Diversions to Limit EC Increases at Emmaton. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-11: Salinity (EC) Increase at Jersey Point during April-August. This impact is described above under Impact C-3. This impact is considered significant. Implementing Mitigation Measure C-3 would reduce Impact C-11 to a less-than-significant level.

Mitigation Measure C-3: Restrict DW Diversions to Limit EC Increases at Jersey Point. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-12: Salinity (Chloride) Increase in Delta Exports. This impact is described above under Impact C-4. This impact is considered significant. Implementing Mitigation Measure C-4 would reduce Impact C-12 to a less-than-significant level.

Mitigation Measure C-4: Restrict DW Diversions or Discharges to Limit Chloride Concentrations in Delta Exports. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Export Concentrations of Dissolved Organic Carbon

Water quality impacts of increases in export DOC concentrations were assessed for Delta exports in the south Delta. Impacts were measured based on DOC for Alternative 3 and the change in DOC from No-Project Alternative conditions, as simulated by the DeltaDWQ model. Figure 3C-25 shows simulated monthly DOC concentrations for Alternative 3 and the changes from the simulated No-Project Alternative DOC concentrations in Delta exports for 1968-1991.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-13: Elevated DOC Concentrations in Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy). This impact is described above under Impact C-5. This impact is considered significant. Implementing Mitigation Measure C-5 would reduce Impact C-13 to a less-than-significant level.

Mitigation Measure C-5: Restrict DW Discharges to Prevent DOC Increases of Greater Than 0.8 mg/l in Delta Exports. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Trihalomethane Concentrations in Treated Drinking Water

Impacts of increases in THM concentrations in treated drinking water caused by implementation of Alternative 3 were assessed based on simulated THM concentrations and changes from THM concentrations under the No-Project Alternative. Figure 3C-25 (lower panel) gives the seasonal patterns of simulated THM concentrations in treated drinking water for Alternative 3 and the changes between the No-Project Alternative and Alternative 3.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-14: Elevated THM Concentrations in Treated Drinking Water from Delta Exports (CCWD Rock Slough, SWP Banks, and CVP Tracy). This impact is described above under Impact C-6. Implementing Mitigation Measure C-6 would reduce Impact C-14 to a less-than-significant level.

Mitigation Measure C-6: Restrict DW Discharges to Prevent Increases of More Than 20 μg/l in THM Concentrations or THM Concentrations of Greater Than 90 μg/l in Treated Delta Export Water. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Changes in Other Water Quality Variables

Other water quality variables include temperature, SS, DO, and chlorophyll. Under Alternative 3, levels of these water quality characteristics will vary widely with daily fluctuations in conditions affecting them (e.g., DW storage volumes, weather patterns, flow characteristics, and water quality of receiving water for DW discharges).

The high variability typical of these parameters and the uncertainty regarding daily conditions that may coincide to produce adverse impacts do not allow a quantitative impact assessment to be performed. It is likely that conditions will combine under operation of Alternative 3 to produce impacts exceeding the significance criteria for these transient water quality variables. The significance criteria and mitigation requirements would be determined by SWRCB and would be included in project operation permits.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-15: Changes in Other Water Quality Variables in Delta Channel Receiving Waters. This impact is described above under Impact C-7. This impact is considered significant. Implementing Mitigation Measure C-7 would reduce Impact C-15 to a less-than-significant level.

Mitigation Measure C-7: Restrict DW Discharges to Prevent Adverse Changes in Delta Channel Water Quality. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Effects of Pollutant Contaminants

Sites of potential soil contamination resulting from historical agricultural operations or waste disposal exist on the proposed DW reservoir islands.

Summary of Project Impacts and Recommended Mitigation Measures

Impact C-16: Potential Contamination of Stored Water by Pollutant Residues. This impact is described above under Impact C-8. This impact is considered significant. Implementing Mitigation Measure C-8 would reduce Impact C-16 to a less-than-significant level.

Mitigation Measure C-8: Conduct Assessments of Potential Contamination Sites and Remediate as Necessary. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

IMPACTS AND MITIGATION MEASURES OF THE NO-PROJECT ALTERNATIVE

The No-Project Alternative (intensified agricultural use of the four DW project islands) represents Delta water quality conditions predicted under the 1995 WQCP. Compared with existing agricultural land uses, irrigation diversions and agricultural drainage would be somewhat greater under the intensified agriculture conditions of the No-Project Alternative. At the scale of monthly water quality modeling (e.g., DeltaSOS and DeltaDWQ models), effects on Delta salinity and export water quality generally would be similar to those under existing conditions.

The DeltaDWQ results for the No-Project Alternative were described above under "Impact Assessment Methodology".

The No-Project Alternative, as simulated by DeltaSOS, DeltaDWQ, and the EPA WTP model, would not cause measurable water quality effects relative to existing conditions.

CUMULATIVE IMPACTS

Cumulative impacts are the result of the incremental impacts of the proposed action when added to other past, present, and reasonably foreseeable future actions. DW project effects on Delta water quality conditions are inextricably tied to past and present environmental factors and conditions. Cumulative water quality impacts are bounded by the requirements and controls mandated by various regulatory measures, such as the swrcb 1995 WQCP objectives and the regional water quality control board basin plans and National Pollutant Discharge Elimination System (NPDES) discharge permits.

The cumulative water quality effects of the DW alternatives therefore were evaluated in conjunction with past and present actions in the previous sections, which assumed the recently adopted 1995 WQCP objectives; existing agricultural drainage loading patterns; and continued operation of existing Delta export pumping plants, gate and barrier facilities, and diversions. The focus of this section is on the evaluation of impacts of the DW project alternatives added to impacts of other likely future projects. This cumulative impact evaluation is based on the following scenario: increased upstream demands; increased demands south of the Delta; an increased permitted pumping rate at the SWP Banks Pumping Plant (see Chapter 3A, "Water Supply and Water Project Operations"); implementation of DWR's South Delta and North Delta Programs; additional storage south of the Delta in the Kern Water Bank, Los Banos Grandes Reservoir, MWD's Domenigoni Reservoir and Arvin-Edison projects, and CCWD's Los Vaqueros Reservoir.

Future activities affecting water quality in the Delta will include continued agricultural and municipal diversions, discharges from treated municipal wastewater and agricultural drainage, and maintenance of existing channels and levees. New facilities (e.g., channel gates and barriers) may be constructed, and existing channels may be modified for navigation or for increased water conveyance (e.g., DWR North and South Delta Programs). Some existing agricultural lands may be converted to urban development or to wetlands and other wildlife habitat uses, changing the water diversion and discharge patterns for these lands. Increasing populations in the watershed may result in higher concentrations of water quality variables associated with wastewater and increased surface runoff.

Cumulative water quality impacts were assessed qualitatively without specific DeltaDWQ simulations being performed. As described in Chapter 3A, "Water Supply and Water Project Operations", the cumulative water supply impacts of the DW project alternatives and the No-Project Alternative were evaluated with a slightly different set of Delta export pumping limitations (SWP pumping at full capacity), which represents reasonably foreseeable future Delta conditions and regulatory objectives.

Because total diversions (exports and DW diversions) are limited by the percentage of inflow criteria specified in the 1995 WQCP, the increased export capacity reduces the available water for DW diversions in some months. However, slightly higher DW project discharges and export of DW discharges would be possible. Delta outflow would be reduced during months of increased exports or increased DW project diversions. Results of the DeltaSOS simulations (Table A3-25) indicate that cumulative water quality impacts would be similar to the impacts described above for the DW project alternatives, and the same mitigation measures would apply.

Cumulative Impacts, Including Impacts of Alternative 1

The DeltaSOS simulations of Alternative 1 under cumulative future conditions are summarized in the cumulative impacts section of Chapter 3A and are described in Appendix A3. Alternative 1 would be operated in fewer years under cumulative conditions than under existing conditions because of limited availability of water for DW diversions. Because of greater assumed export pumping capacity, however, greater DW exports were simulated in several of the years. The average annual simulated DW diversion for Alternative 1 under cumulative future conditions was 191 TAF/yr, with discharges for export of 161 TAF/yr (Table 3A-3).

Delta Salinity Conditions (Electrical Conductivity, Chloride, and Bromide)

Because Delta salinity conditions are directly linked with Delta outflow, which will be changed by cumulative future conditions as well as DW operations, Alternative 1 will have significant cumulative impacts whenever DW project operations change cumulative future salinity conditions in excess of the selected significance criterion (i.e., maximum of 90% of established objectives or maximum change of 20% of established objectives).

Although the 1995 WQCP is assumed to remain the applicable water quality objectives, and the 70-year historical hydrologic conditions are assumed to represent the likely cumulative future hydrologic conditions, other factors may change the Delta inflows and therefore affect Delta outflow. It is likely that the cumulative future water quality impacts of Alternative 1 would be similar to those simulated for Alternative 1, in comparison with operations under the No-Project Alternative. Similar mitigation measures to limit DW operations during periods of moderate Delta outflow would be required to prevent the occurrence of significant water quality impacts.

Impact C-17: Salinity (EC) Increase at Chipps Island during Months with Applicable EC Objectives under Cumulative Conditions. This impact is described above under Impact C-1. This impact is considered significant. Implementing Mitigation Measure C-1 would reduce Impact C-17 to a less-than-significant level.

Mitigation Measure C-1: Restrict DW Diversions to Limit EC Increases at Chipps Island. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-18: Salinity (EC) Increase at Emmaton during April-August under Cumulative Conditions. This impact is described above under Impact C-2. This impact is considered significant. Implementing Mitigation Measure C-2 would reduce Impact C-18 to a less-than-significant level.

Mitigation Measure C-2: Restrict DW Diversions to Limit EC Increases at Emmaton. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-19: Salinity (EC) Increase at Jersey Point during April-August under Cumulative Conditions. This impact is described above under Impact C-3. This impact is considered significant. Implementing Mitigation Measure C-3 would reduce Impact C-19 to a less-than-significant level.

Mitigation Measure C-3: Restrict DW Diersions to Limit EC Increases at Jersey Point. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact C-20: Salinity (Chloride) Increase in Delta Exports under Cumulative Conditions. This impact is described above under Impact C-4. This impact is considered significant. Implementing Mitigation Measure C-4 would reduce Impact C-20 to a less-than-significant level.

Mitigation Measure C-4: Restrict DW Diversions or Discharges to Limit Chloride Concentrations in Delta Exports. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Export Concentrations of Dissolved Organic Carbon

The assessment of Alternative 1 effects on export DOC concentrations, using the Delta channel flows simulated with DeltaSOS and Delta inflow and agricultural drainage concentrations simulated with DeltaDWQ, provide the basis for the qualitative assessment of impacts of Alternative 1 under cumulative future conditions. Although the average effects of operations under Alternative 1 on cumulative future export DOC concentrations are expected to be generally small, the possibility of high export DOC concentrations in DW discharges relative to cumulative future export DOC concentrations under the No-Project Alternative must be considered significant and be mitigated with a combination of DOC measurements and limitations on DW discharges. The significant impacts of Alternative 1 under future conditions would be similar to those described for Alternative 1.

Impact C-21: Elevated DOC Concentrations in Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy) under Cumulative Conditions. This impact is described above under Impact C-5. This impact is considered significant. Implementing Mitigation Measure C-5 would reduce Impact C-21 to a less-than-significant level.

Mitigation Measure C-5: Restrict DW Discharges to Prevent DOC Increases of Greater Than 0.8 mg/l in Delta Exports. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Trihalomethane Concentrations in Treated Drinking Water

The assessment of effects of Alternative 1 on THM concentrations in treated drinking water, using Delta export DOC concentrations simulated with DeltaDWQ and THM simulated with the EPA WTP model, provide the basis for the qualitative assessment of significant impacts of Alternative 1 under cumulative future conditions. Water quality objectives for THM concentrations, as well as treatment technology for drinking water disinfection are likely to change in the future.

Although the average effects of operations under Alternative 1 on cumulative future THM concentrations in treated drinking water are expected to be generally small, the possibility of high DOC concentrations in DW discharges relative to cumulative future export DOC concentrations under the No-Project Alternative must be considered significant and be mitigated with a combination of DOC measurements, estimates of THM concentrations, and limitations on DW discharges. The significant impacts of Alternative 1 under future conditions would be similar to those described for Alternative 1.

Impact C-22: Elevated THM Concentrations in Treated Drinking Water from Delta Exports (CCWD Rock Slough, SWP Banks, and CVP Tracy) under Cumulative Conditions. This impact is described above under Impact C-6. Implementing Mitigation Measure C-6 would reduce Impact C-22 to a less-than-significant level.

Mitigation Measure C-6: Restrict DW Discharges to Prevent Increases of More Than 20 μg/l in THM Concentrations or THM Concentrations of Greater Than 90 μg/l in Treated Delta Export Water. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Changes in Other Water Quality Variables

The effect of operations of Alternative 1 under cumulative future conditions would be similar to the effects described for Alternative 1 compared with operations under the No-Project Alternative. Similar significant impacts are possible and similar mitigation measures would be required. Significance criteria and mitigation requirements will be determined by SWRCB and would be included in project operation permits.

Impact C-23: Changes in Other Water Quality Variables in Delta Channel Receiving Waters under Cumulative Conditions. This impact is described above under Impact C-7. This impact is considered significant. Implementing Mitigation Measure C-7 would reduce Impact C-23 to a less-than-significant level.

Mitigation Measure C-7: Restrict DW Discharges to Prevent Adverse Changes in Delta Channel Water Quality. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Effects of Pollutant Contaminants

Appendix C6, "Assessment of Potential Water Contaminants on the Delta Wetlands Project Islands", analyzes pollutant loading effects from the recreational use of DW boating facilities. Sources of potential pollution resulting from the presence of recreation facilities and from boating activities include the discharge of petroleum-based materials (e.g., fuel, oil, and grease), sewage, and litter. Although the direct effects are considered minor (based on a 5% increase in boating use in the Delta as described in Chapter 3J, "Recreation and Visual Resources"), the potential increase in pollutant loading from the DW project facilities and boating activities, in combination with other boating facilities in the Delta, could cause periodic pollution problems in Delta waters.

Impact C-24: Increase in Pollutant Loading in Delta Channels. Pollutant loading associated with recreational boat use in the Delta, including pollutant loading effects caused by the DW project, could result in periodic pollution problems in Delta waters. This cumulative impact is considered significant and unavoidable.

Implementing Mitigation Measure C-9 would reduce this impact, but not to a less-than-significant level.

Mitigation Measure C-9: Clearly Post Waste Discharge Requirements, Provide Waste Collection Facilities, and Educate Recreationists regarding Illegal Discharges of Waste. Prior to operation of the DW recreation facilities, DW shall post notices at all DW recreation facilities describing proper methods of disposing of waste. Waste discharge requirements shall be posted and enforced in accordance with local and state laws and ordinances. Prior to operation of the DW recreation facilities, DW shall provide waste collection receptacles on and around the boat docks for the boaters using the DW recreation facilities. Prior to operation of the DW recreation facilities, DW shall provide educational materials to inform recreationists about the deleterious effects of illegal waste discharges and the location of waste disposal facilities throughout the Delta.

Cumulative Impacts, Including Impacts of Alternative 2

Effects of operations of Alternative 2 under future cumulative conditions would be the same as those described above for operations of Alternative 1 under future cumulative conditions. The impacts and mitigation measures would be the same as described for Alternative 1 cumulative conditions.

Cumulative Impacts, Including Impacts of Alternative 3

Effects of operations of Alternative 3 under future cumulative conditions would be the same as those described above for operations of Alternative 1 under future cumulative conditions. The impacts and mitigation measures would be the same as described for Alternative 1 cumulative conditions.

Cumulative Impacts, Including Impacts of the No-Project Alternative

The No-Project Alternative would not contribute to cumulative Delta water quality impacts.

CITATIONS

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Table 3C-1. Important Delta Water Quality Variables and Characteristics

Variable	Unit	Characteristic
Physical habitat parameters		
Flow	cfs	Governs dilution, transport, and mixing; both tidal flow and flow from inflows and pumping may be significant
Temperature	°F	Governs biochemical rates and regulates biological production; determines dissolved oxygen saturation concentration
Suspended sediments (SS)	mg/l	Sediments or other particulates that adsorb chemicals and block light transmission through water
Dissolved oxygen (DO)	mg/l	Dissolved oxygen concentration in water; available to supply oxidation and respiration requirements
pH	standard unit	Measure of acidity or alkalinity of water
Electrical conductivity (EC)	μS/cm	Measure of dissolved anions and cations; conservative variable, easily measured with monitors
Dissolved minerals		
Salinity	ppt	Measure of salt content of water (measured in ppt)
Total dissolved solids (TDS)	mg/l	Measure of total dissolved materials
Chloride (Cl^-)	mg/l	Dominant anion; important to agricultural soil condition; 1995 WQCP water supply objective
Bromide (Br^-)	mg/l	Trace anion; important for trihalomethane (THM) production
Cl^-/EC ratio	mg/l/μS/cm	Ratio of chloride (mg/l) to EC (μS/cm); helps to identify the source of the water
Nutrient and organic constituents		
Dissolved organic carbon (DOC)	mg/l	Measure of dissolved organic content
Trihalomethanes (THMs)	μg/l	Disinfection byproducts (DBPs) formed during the chlorination of water for municipal use
Trihalomethane formation Potential (THMFP)	μg/l	Measure of potential formation of THMs when water is chlorinated
C-THM	μg/l	Carbon-fraction concentrations of THM compounds
Cl-THM	μg/l	Chlorine-fraction concentrations of THM compounds
Br-THM	μg/l	Bromine-fraction concentrations of THM compounds

Table 3C-1. Continued

Constituent	Unit	Characteristic
UVA	1/cm	Ultraviolet light (254-nm wavelength) absorption of water; has been found to be directly related to the DOC content
Color	standard unit	Measure of dissolved organics expressed in color absorbance units
Chlorophyll	μg/l	Measure of algal pigment indicating algal biomass
Nitrate (NO_3^-)	mg/l	Major nitrogen nutrient essential for plant growth
Phosphate (PO_4^{3-})	mg/l	Major phosphorus nutrient essential for plant growth
Contaminants		
Pesticides	μg/l	Agricultural pest control residues with potential toxicity
Herbicides	μg/l	Agricultural vegetation control residues with potential toxicity
Trace metals	μg/l	Industrial residues with potential toxicity

Table 3C-2. Summary of Assessment of DW Project Impacts on Water Quality

I. Water quality effects on EC, Cl^-, Br^-, and DOC are directly linked with the assumed water budget on Delta islands (estimated in DeltaDWQ) and Delta channel flows (estimated in DeltaSOS). DOC effects also depend on the assumed sources of DOC resulting from agricultural drainage and DW habitat or reservoir island operations (estimated in DeltaDWQ). THM concentrations in treated drinking water were simulated with the EPA WTP model.

II. EC, Cl^-, and Br^- effects are governed by:

- inflows (Sacramento and San Joaquin Rivers),
- seawater intrusion (governed by Delta outflow),
- Delta exports and channel flows, and
- Delta island drainage and evapotranspiration (ET).

III. DOC effects are governed by:

- inflows,
- Delta channel processes (vegetation and sediments),
- Delta exports and channel flows, and
- Delta island drainage (sources).

IV. Changes in DOC sources can be comparatively described as a function of land use. DOC sources on the DW project islands may therefore change:

DOC Source	Agriculture	Habitat Islands	Reservoir Islands
Peat soil oxidation	f(Temp, O_2)	reduced source	reduced source
Peat soil leaching	f(water flow)	reduced source	reduced source
Vegetation residue	(biomass)	reduced source	reduced source

V. THM effects are governed by:

- Delta export DOC and Br^- concentrations and
- Water treatment processes (temperature or chlorination dose).

VI. DW project operations will change Delta water quality variables by reducing outflow during diversion periods and by discharging water that may have elevated salinity or DOC concentrations. Reducing agricultural diversions onto the DW islands may reduce salinity and reduce the contribution of DOC from agricultural drainage.

Table 3C-3. Preliminary Model Calibration and Confirmation Tasks and Summary of Preliminary Analyses for the Assessment of Impacts of the DW Project on Water Quality

Data	Model	Analysis	Results
Historical Delta inflows and exports for 1972, 1976, and 1978	RMA Delta water quality model	Calibration with daily EC measurements at 19 Delta locations	Smith and Durbin (1989)
Historical 1968-1991 data on Delta EC and CCWD Cl^- concentrations	RMA Delta water quality model and DeltaDWQ model	Confirmation of simulated historical EC patterns	Appendix B2
Historical 1982-1991 MWQI measurements of channel and drainage samples	DeltaDWQ model	Simulation of Delta agricultural drainage (flow, EC, DOC) and export water quality (EC, Cl^-, Br^-, DOC) for the No-Project Alternative	Appendices C1, C2, and C4
DW demonstration wetlands water quality experiments	DeltaDWQ model	Comparison of source loading of DOC from agricultural drainage and wetlands	Appendix C3
THM measurements from Penitencia Water Treatment Plant	EPA WTP model	Confirmation of simulated THM concentrations	Appendix C5

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Table 3C-4. Modeling Tasks for Assessment of Impacts of the DW Project on Water Quality

Data	Model	Analysis	Results
DeltaSOS-simulated flows for the No-Project Alternative and the DW project alternatives	DeltaDWQ model	Simulation of water quality impacts (EC, Cl^-, Br^-, DOC) of the DW project alternatives	Chapter 3C Appendix B2 Appendix C4
DeltaDWQ-simulated export water quality for the No-Project Alternative and the DW project alternatives	EPA WTP model	Simulation of treated drinking water THM concentrations	Chapter 3C Appendix C5

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Table 3C-5. Water Quality Response Variables and Significance Criteria for Impact Assessments

Variable	Impact Assessment Method	Significance Threshold	Location of Assessment
Electrical conductivity	RMA Delta model results for 1967-1991 incorporated in DeltaDWQ model	a. Increase of 20% of applicable standards or b. 90% of applicable standard	Chipps Island, Emmaton, Jersey Point, and representative exports (CCWD, SWP, and CVP)
Chloride	RMA Delta model results for 1967-1991 incorporated in DeltaDWQ model	a. Increase of 20% of applicable standards or b. 90% of applicable standard	Representative exports
Bromide	RMA Delta model results for 1967-1991 incorporated in DeltaDWQ model	Increase of 20% equivalent of Cl^- standards	Representative exports
Dissolved organic carbon	DeltaDWQ model	Increase of 0.8 mg/l (or 20% of mean value)	Representative exports
Trihalomethanes	EPA WTP modeling	a. Increase of 20% of standard (20 μg/l) or b. 90% of applicable standard (90 μg/l)	Treated water from representative exports
Temperature	Evaluation of historical Delta field data[a]	Increase of 1°F, when channel temperature exceeds 60°F	Delta channel waters receiving DW discharges
Suspended sediments	Evaluation of historical Delta field data[a]	Increase of 20% of mean channel concentration	Delta channel waters receiving DW discharges
Dissolved oxygen	Evaluation of historical Delta field data[a]	Decrease of 20% of mean channel concentration	Delta channel waters receiving DW discharges
Chlorophyll	Evaluation of historical Delta field data[a]	Increase of 20% of mean channel concentration	Delta channel waters receiving DW discharges
Pollutant contaminants	Survey of DW project islands for contaminant sites	Presence of significant contamination from waste disposal or agricultural operations	Specific contaminated sites on DW project islands

[a] Source: DWR 1989.

Table 3C-6. Example of Determination of Significant Water Quality Impacts and Mitigation Requirements for Alternative 1 at Chipps Island Based on 1922–1991 DeltaDWQ Simulation Results

October (Outflow Objective: 4,000 cfs; Equivalent EC: 11,000 μS/cm; 20% Change: 2,200 μS/cm; 90% Limit: 9,900 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
8,343	3,262	3,267	7,765
8,362	3,871	3,251	7,728
7,858	3,019	3,195	8,252
7,791	2,867	3,097	8,237
8,376	3,019	2,945	7,406
7,640	2,451	2,818	8,151
7,409	2,610	2,785	8,426
10,769	3,871	2,222	4,742
6,977	1,710	2,041	8,309
11,600	3,213	1,784	3,860
11,882	3,726	1,763	3,707
11,730	3,871	1,742	3,756
11,706	1,020	1,017	3,043
5,417	631	887	10,071
13,812	1,263	850	2,107
19,597	3,871	210	621

November (Outflow Objective: 4,500 cfs; Equivalent EC: 10,000 μS/cm; 20% Change: 2,000 μS/cm; 90% Limit: 9,000 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
8,176	3,606	3,248	7,932
9,162	4,000	2,991	6,683
7,107	2,939	2,979	9,050
8,389	1,328	2,029	6,477
11,338	4,000	1,779	3,986
11,639	4,000	1,741	3,798
6,609	1,196	1,416	8,272
14,110	3,373	958	2,136
13,857	4,000	939	2,185
13,846	654	648	1,896
15,371	4,000	544	1,444
18,663	2,258	354	833
17,638	4,000	346	922
25,347	906	78	290
31,138	4,000	14	178
40,244	4,000	1	153

December (Outflow Objective: 4,500 cfs; Equivalent EC: 10,000 μS/cm; 20% Change: 2,000 μS/cm; 90% Limit: 9,000 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
11,083	3,871	1,978	4,320
6,883	1,744	1,879	8,292
7,497	1,686	1,773	7,295
7,022	1,198	1,719	7,919
10,949	1,040	1,220	3,636
13,339	3,784	1,189	2,586
10,987	1,627	970	3,365
6,604	863	835	7,700
25,725	3,871	53	260
27,368	3,871	31	219
32,649	2,726	15	175
49,670	3,871	0	150
51,188	3,871	0	150

January (Outflow Objective: 4,500 cfs; Equivalent EC: 10,000 μS/cm; 20% Change: 2,000 μS/cm; 90% Limit: 9,000 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
9,798	3,326	2,128	5,300
11,465	3,871	1,857	3,999
7,721	2,005	1,839	7,067
9,858	2,491	1,798	4,924
10,094	2,047	1,797	4,753
8,728	1,593	1,557	5,655
7,133	990	1,047	7,079
14,277	3,845	945	2,081
6,947	869	912	7,226
15,311	3,871	731	1,642
15,206	3,871	691	1,622
15,055	3,871	675	1,637
16,802	3,871	447	1,122
15,763	1,479	185	1,016
22,329	3,293	102	383
19,685	1,065	52	457
38,413	3,871	2	154

February (Outflow Objective: 11,400 cfs; Equivalent EC: 2,600 μS/cm; 20% Change: 520 μS/cm; 90% Limit: 2,340 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
17,380	3,684	412	1,016
16,169	2,520	336	1,101
24,242	3,354	101	333
25,005	3,132	53	270
24,946	634	52	271
20,498	742	27	385
29,069	4,000	26	200
32,451	4,000	10	171
34,625	2,465	5	161
36,089	4,000	4	158

March (Outflow Objective: 11,400 cfs; Equivalent EC: 2,600 μS/cm; 20% Change: 520 μS/cm; 90% Limit: 2,340 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
25,740	3,769	57	263
22,185	1,106	34	320
35,067	3,871	6	161
38,043	1,091	1	153
43,558	3,210	1	151

Note: No April–August DW Diversions of greater than 300 cfs.

September (Outflow Objective: 3,000 cfs; Equivalent EC: 14,000 μS/cm; 20% Change: 2,800 μS/cm; 90% Limit: 12,600 μS/cm)

No-Project Effective Outflow (cfs)	DW Diversion (cfs) (>500 cfs)	Change in Chipps EC (μS/cm)	Alt 1 Chipps EC (uS/cm)
8,852	3,879	3,804	7,781
8,853	3,880	3,805	7,782
8,854	3,881	3,806	7,783
7,683	2,749	3,192	8,469
8,425	3,000	2,977	7,387
11,302	4,000	2,131	4,356
13,292	4,000	1,306	2,717
6,730	734	878	7,535

1. Specify appropriate EC criteria based on the 1995 WQCP outflow or EC objectives.
2. Estimate Chipps Island EC for the No-Project Alternative and DW project operations.
3. Determine DW project effects and mitigation requirements.
4. Shading indicates significant impacts that would require mitigation.

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Table 3C-7. Summary of Changes between Alternative 1 and the No-Project Alternative in DeltaDWQ-Simulated Export DOC Concentrations (mg/l) for 1967-1991

October

x>0	%	x<=0	%
Five Largest Values			
0.13	2.70	-0.52	-15.7
0.07	1.71	-0.52	-14.5
0.07	1.69	-0.44	-14.5
0.04	1.49	-0.42	-13.7
0.04	1.08	-0.42	-13.0
25-yr Summary			
Number of months			
9		16	
Average			
0.04	1.13	-0.17	-5.15

November

x>0	%	x<=0	%
Five Largest Values			
0.31	7.89	-0.51	-18.0
0.15	3.56	-0.51	-17.0
0.12	3.51	-0.49	-16.3
0.09	2.64	-0.49	-16.3
0.08	2.49	-0.43	-13.5
25-yr Summary			
Number of months			
12		13	
Average			
0.08	2.23	-0.22	-7.25

December

x>0	%	x<=0	%
Five Largest Values			
0.09	1.69	-1.21	-22.9
0.07	1.55	-0.77	-16.9
0.07	1.28	-0.68	-13.9
0.04	0.68	-0.43	-12.0
0.03	0.64	-0.41	-9.96
25-yr Summary			
Number of months			
7		18	
Average			
0.05	0.90	-0.27	-5.93

January

x>0	%	x<=0	%
Five Largest Values			
0.195	3.18	-1.78	-26.0
0.10	1.79	-0.87	-17.3
0.10	1.66	-0.86	-15.7
0.08	1.46	-0.78	-15.2
0.05	1.20	-0.68	-12.4
25-yr Summary			
Number of months			
9		16	
Average			
0.07	1.26	-0.37	-6.60

February

x>0	%	x<=0	%
Five Largest Values			
0.15	3.20	-0.60	-15.8
0.12	2.58	-0.04	-0.86
0.09	1.77	-0.03	-0.65
0.08	1.47	-0.03	-0.62
0.07	1.47	-0.02	-0.39
25-yr Summary			
Number of months			
14		11	
Average			
0.05	1.04	-0.07	-1.79

March

x>0	%	x<=0	%
Five Largest Values			
0.40	11.1	-0.39	-14.7
0.20	6.02	-0.33	-12.1
0.18	5.05	-0.12	-3.57
0.13	4.77	-0.11	-3.38
0.12	3.71	-0.03	-1.17
25-yr Summary			
Number of months			
20		5	
Average			
0.11	2.96	-0.20	-6.99

April

x>0	%	x<=0	%
Five Largest Values			
0.40	12.0	-0.34	-7.51
0.36	8.37	-0.15	-3.98
0.29	6.94	-0.09	-2.70
0.14	3.40	-0.02	-0.46
0.10	2.08	-0.00	-0.08
25-yr Summary			
Number of months			
20		5	
Average			
0.09	2.28	-0.12	-2.94

May

x>0	%	x<=0	%
Five Largest Values			
0.39	10.3	-0.29	-7.52
0.33	8.65	-0.18	-5.76
0.30	8.43	-0.18	-5.15
0.21	6.37	-0.17	-4.71
0.15	4.16	-0.14	-3.95
25-yr Summary			
Number of months			
17		8	
Average			
0.11	2.87	-0.13	-3.70

June

x>0	%	x<=0	%
Five Largest Values			
0.71	14.0	-0.20	-4.48
0.15	4.44	-0.15	-4.09
0.07	2.35	-0.08	-2.09
0.07	2.17	-0.07	-1.98
0.07	2.10	-0.06	-1.73
25-yr Summary			
Number of months			
18		7	
Average			
0.07	1.81	-0.08	-2.24

July

x>0	%	x<=0	%
Five Largest Values			
1.00	27.8	-0.18	-5.15
0.53	12.0	-0.09	-3.06
0.35	11.0	-0.09	-3.05
0.24	6.71	-0.05	-1.22
0.17	5.36	-0.02	-0.84
25-yr Summary			
Number of months			
15		10	
Average			
0.17	4.72	-0.05	-1.48

August

x>0	%	x<=0	%
Five Largest Values			
0.75	13.2	-0.39	-11.9
0.32	11.1	-0.15	-4.36
0.31	9.40	-0.08	-2.37
0.21	6.67	-0.05	-1.63
0.18	4.70	-0.02	-0.75
25-yr Summary			
Number of months			
17		8	
Average			
0.14	3.64	-0.09	-2.75

September

x>0	%	x<=0	%
Five Largest Values			
0.26	10.4	-0.50	-17.6
0.17	4.53	-0.48	-16.4
0.13	3.58	-0.44	-15.8
0.11	3.57	-0.42	-14.8
0.08	2.31	-0.13	-4.43
25-yr Summary			
Number of months			
15		10	
Average			
0.07	2.17	-0.20	-6.98

Note: The value "x" represents the calculated change in units of measurement.

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Table 3C–8. Summary of Changes between Alternative 1 and the No–Project Alternative in DeltaDWQ–Simulated Export THM Concentrations (μg/l) for 1967–1991

October

x>0	%	x<=0	%
Five Largest Values			
2.9	3.46	–5.30	–13.6
1.3	2.20	–5.00	–11.9
1.2	1.61	–4.30	–11.8
1.0	1.59	–4.00	–11.1
0.5	1.23	–3.80	–10.1
25–yr Summary			
Number of months			
9		16	
Average			
0.86	1.31	–1.66	–4.31

November

x>0	%	x<=0	%
Five Largest Values			
3.7	6.50	–4.8	–17.5
2.6	3.16	–4.8	–15.8
1.4	3.12	–4.4	–13.9
1.1	2.73	–4.2	–13.7
1.0	2.45	–3.6	–10.8
25–yr Summary			
Number of months			
12		13	
Average			
1.03	2.04	–1.86	–6.05

December

x>0	%	x<=0	%
Five Largest Values			
1.3	2.02	–13.7	–27.3
0.5	1.18	–6.5	–15.0
0.5	1.05	–5.7	–13.2
0.3	0.63	–3.1	–11.7
0.2	0.43	–2.9	–8.50
25–yr Summary			
Number of months			
6		19	
Average			
0.48	0.93	–2.18	–5.33

January

x>0	%	x<=0	%
Five Largest Values			
1.8	0.00	–14.6	–28.3
0.6	1.52	–7.1	–18.1
0.6	1.45	–6.4	–16.6
0.6	1.37	–5.3	–14.9
0.5	1.24	–4.9	–12.5
25–yr Summary			
Number of months			
7		18	
Average			
0.66	1.02	–2.49	–6.01

February

x>0	%	x<=0	%
Five Largest Values			
1.1	2.64	–4.7	–14.8
1.1	2.53	–0.3	–0.73
1.0	2.09	–0.2	–0.56
0.8	1.96	–0.2	–0.55
0.5	1.46	–0.2	–0.53
25–yr Summary			
Number of months			
10		15	
Average			
0.58	1.41	–0.40	–1.23

March

x>0	%	x<=0	%
Five Largest Values			
1.1	2.64	–4.7	–14.8
1.1	2.53	–0.3	–0.73
1.0	2.09	–0.2	–0.56
0.8	1.96	–0.2	–0.55
0.5	1.46	–0.2	–0.53
25–yr Summary			
Number of months			
20		5	
Average			
1.04	2.68	–1.9	–6.56

April

x>0	%	x<=0	%
Five Largest Values			
5.5	10.8	–4.9	–9.04
4.3	8.45	–2.8	–6.10
3.5	8.16	–1.3	–3.23
1.4	2.77	–0.7	–1.36
1.1	1.88	–0.2	–0.49
25–yr Summary			
Number of months			
19		6	
Average			
1.13	2.29	–1.67	–3.41

May

x>0	%	x<=0	%
Five Largest Values			
6.8	11.3	–4.0	–7.62
5.7	9.93	–3.8	–7.52
4.3	8.24	–2.8	–5.59
3.0	6.41	–2.5	–5.27
2.6	5.11	–2.0	–4.77
25–yr Summary			
Number of months			
14		11	
Average			
1.93	3.50	–1.53	–3.11

June

x>0	%	x<=0	%
Five Largest Values			
14.7	15.1	–3.4	–4.83
2.7	4.99	–2.6	–4.38
1.9	3.49	–1.4	–2.33
1.7	3.35	–0.7	–1.43
1.3	2.44	–0.6	–1.13
25–yr Summary			
Number of months			
14		11	
Average			
1.54	2.21	–1.34	–2.21

July

x>0	%	x<=0	%
Five Largest Values			
16.8	26.1	–4.4	–7.33
14.8	15.0	–3.3	–5.63
5.6	8.05	–3.0	–4.80
4.3	7.50	–1.5	–2.95
2.6	4.81	–1.5	–2.23
25–yr Summary			
Number of months			
15		10	
Average			
3.21	4.61	–1.65	–2.86

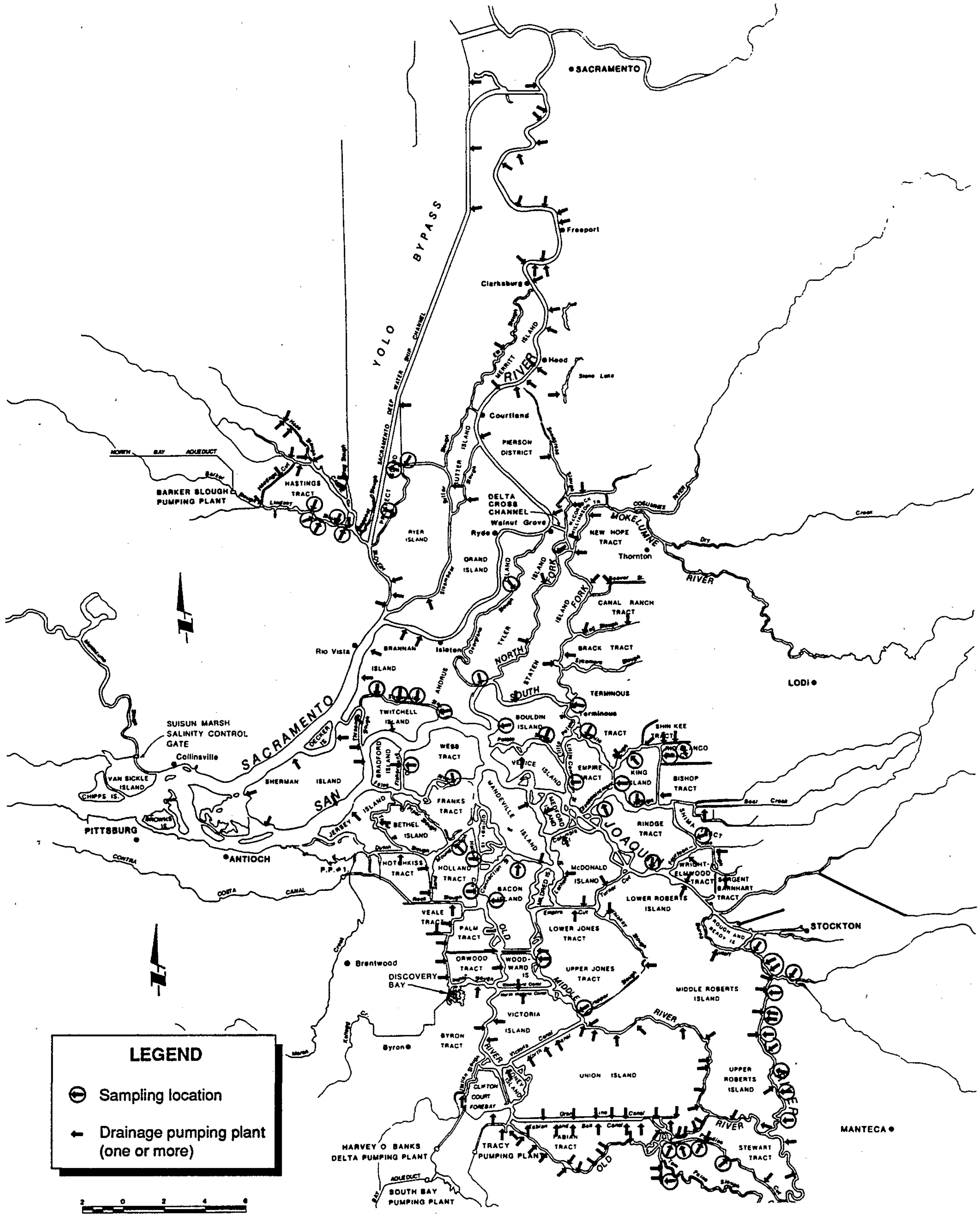
August

x>0	%	x<=0	%
Five Largest Values			
19.3	15.6	–8.7	–16.2
4.6	6.17	–4.2	–7.75
3.2	4.41	–3.9	–7.33
2.4	4.38	–3.7	–6.68
2.2	4.25	–0.8	–1.65
25–yr Summary			
Number of months			
15		10	
Average			
2.89	3.68	–2.29	–4.29

September

x>0	%	x<=0	%
Five Largest Values			
3.9	5.65	–5.7	–15.2
2.3	3.81	–5.7	–14.2
2.3	3.48	–5.2	–14.1
1.7	2.43	–4.3	–11.5
1.2	1.93	–1.7	–3.99
25–yr Summary			
Number of months			
14		11	
Average			
1.02	1.64	–2.42	–6.13

Note: The value "x" represents the calculated change in units of measurement.



Source: California Department of Water Resources 1993.

Figure 3C-1.
Agricultural Drainage Returns in the Delta and MWQI Sampling Locations

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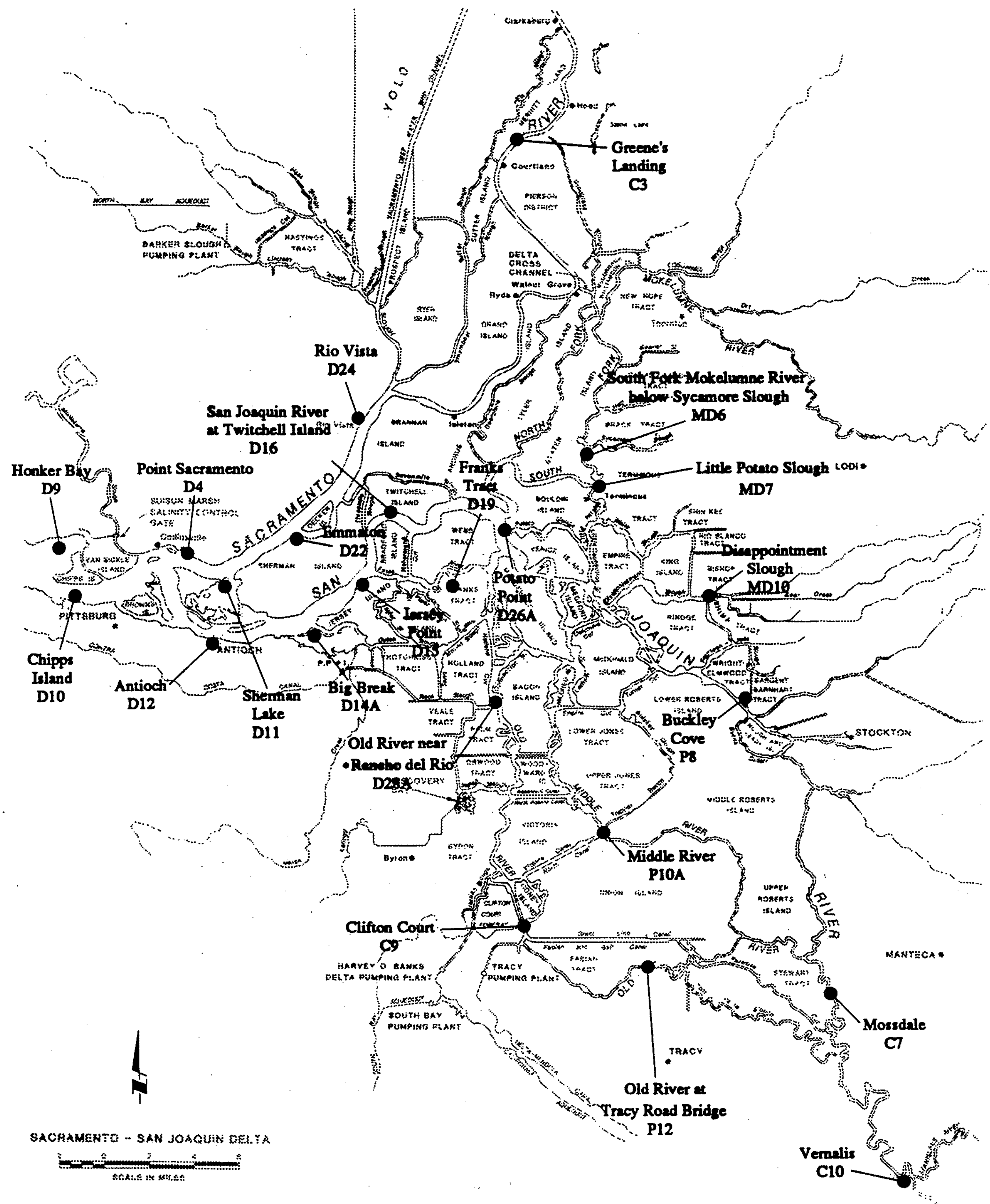

Source: Adapted from California Department of Water Resources 1993.

Figure 3C-2.
D-1485 Water Quality Monitoring Locations

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Prepared by: Jones & Stokes Associates

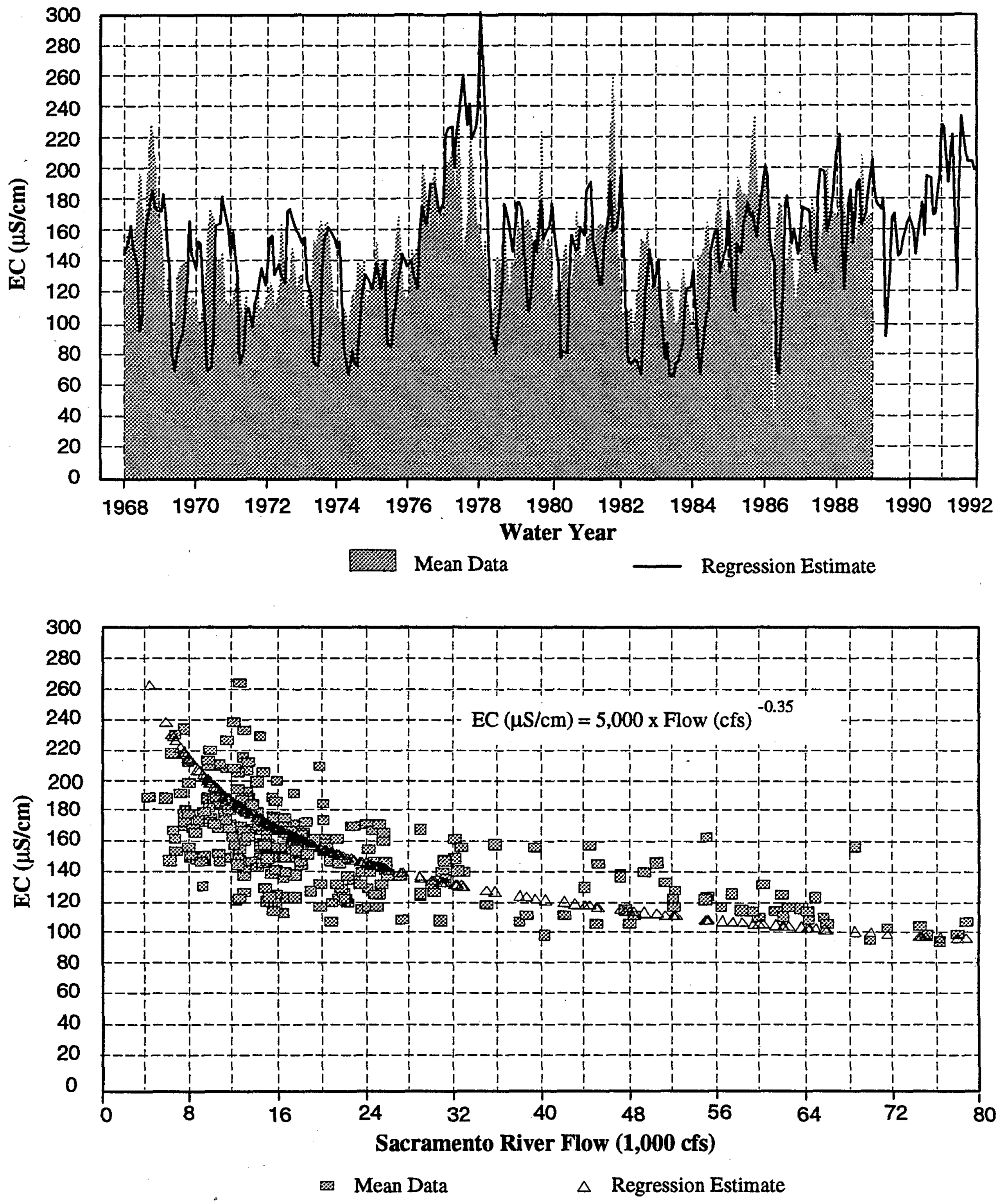

Figure 3C-3.
Relationship between Simulated End-of-Month and Measured Mean Monthly EC at Greene's Landing and Sacramento River Flow for 1968-1991

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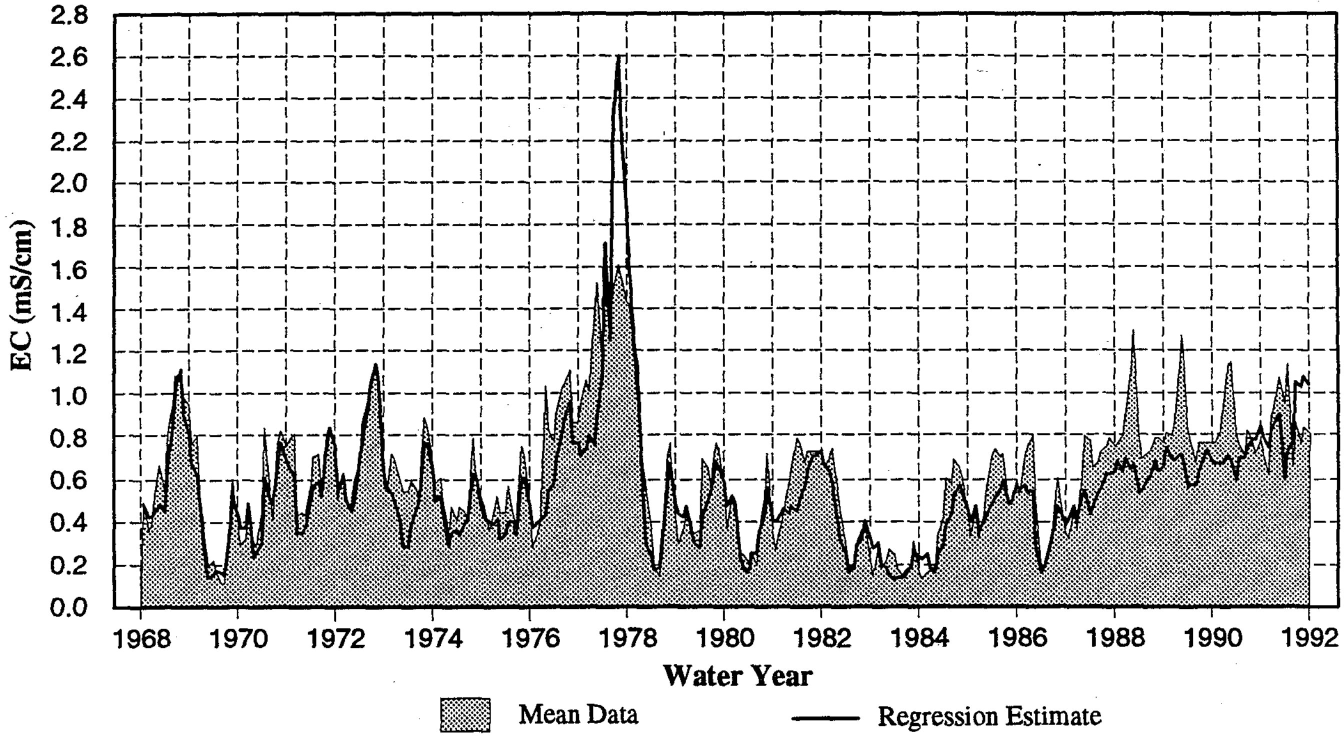
Prepared by: Jones & Stokes Associates



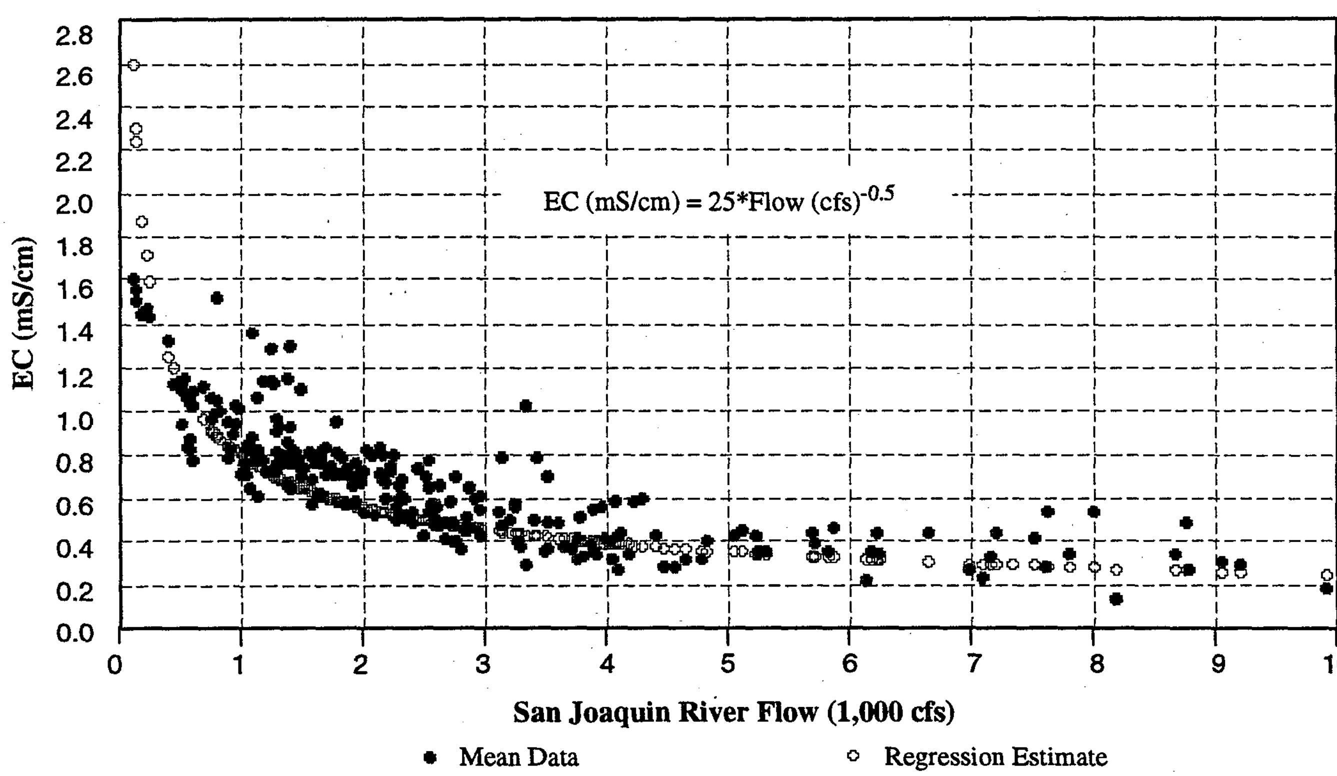


Figure 3C-4.
Relationship between Simulated End-of-Month and Measured Mean Monthly EC at Vernalis and San Joaquin River Flow for 1968-1991.

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Prepared by: Jones & Stokes Associates

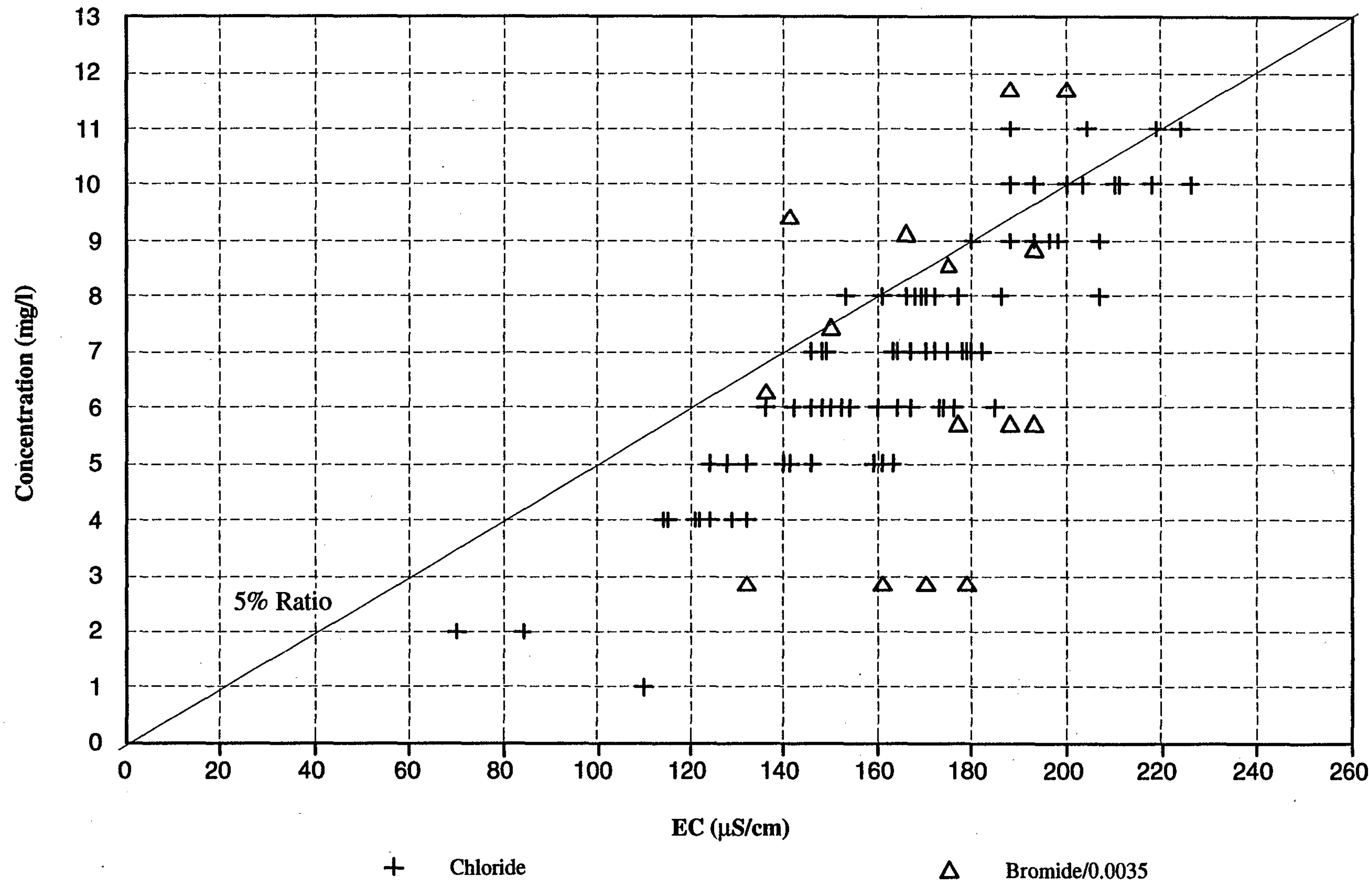

Figure 3C-5.
Relationship between EC and Concentrations of Chloride and Bromide in the Sacramento River at Greene's Landing (1982-1991 MWQI Monthly Samples)

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PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

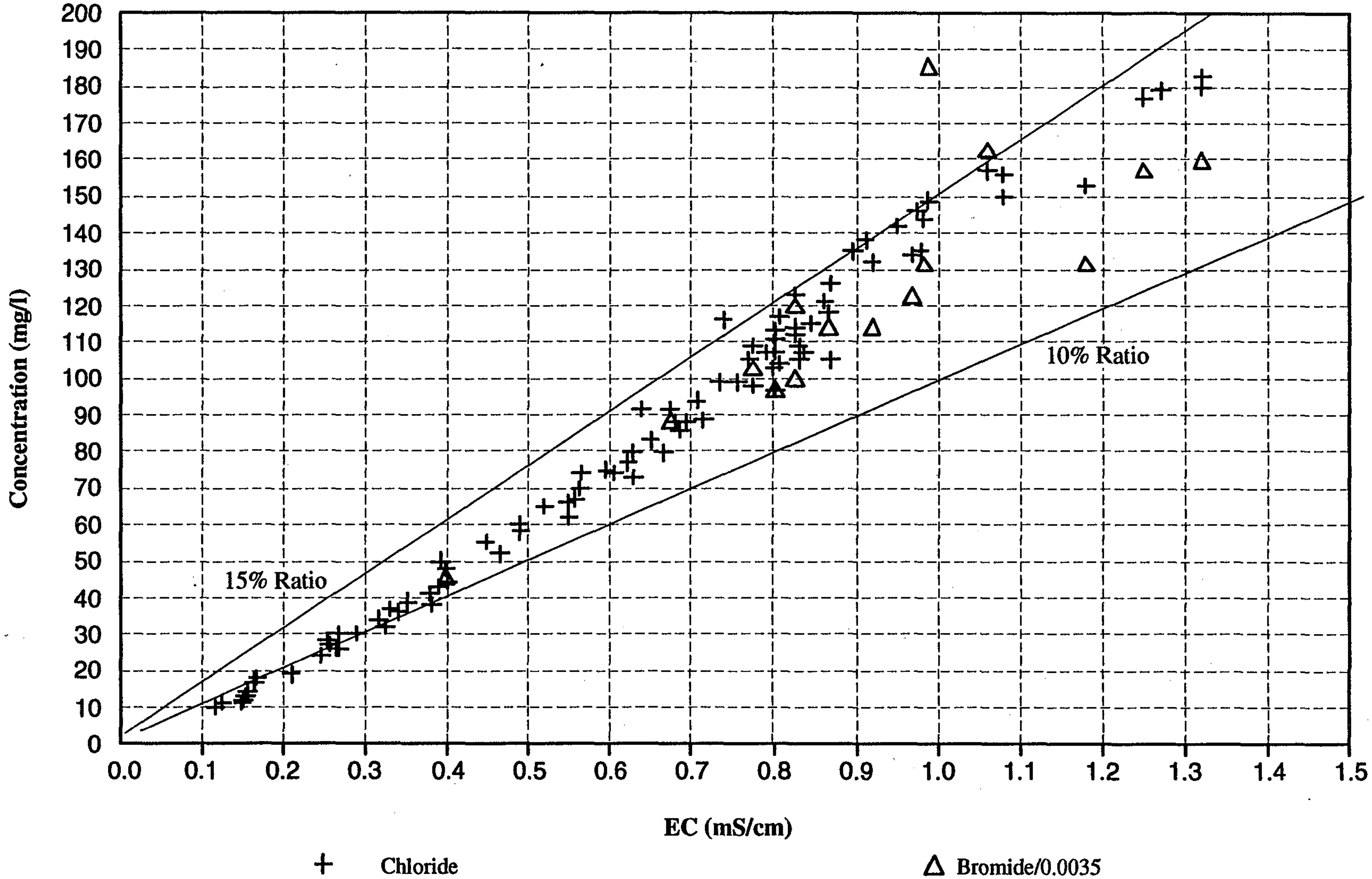

Figure 3C-6.
Relationship between EC and Concentrations of Chloride and Bromide in the San Joaquin River at Vernalis (1982-1991 MWQI Monthly Samples)

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PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

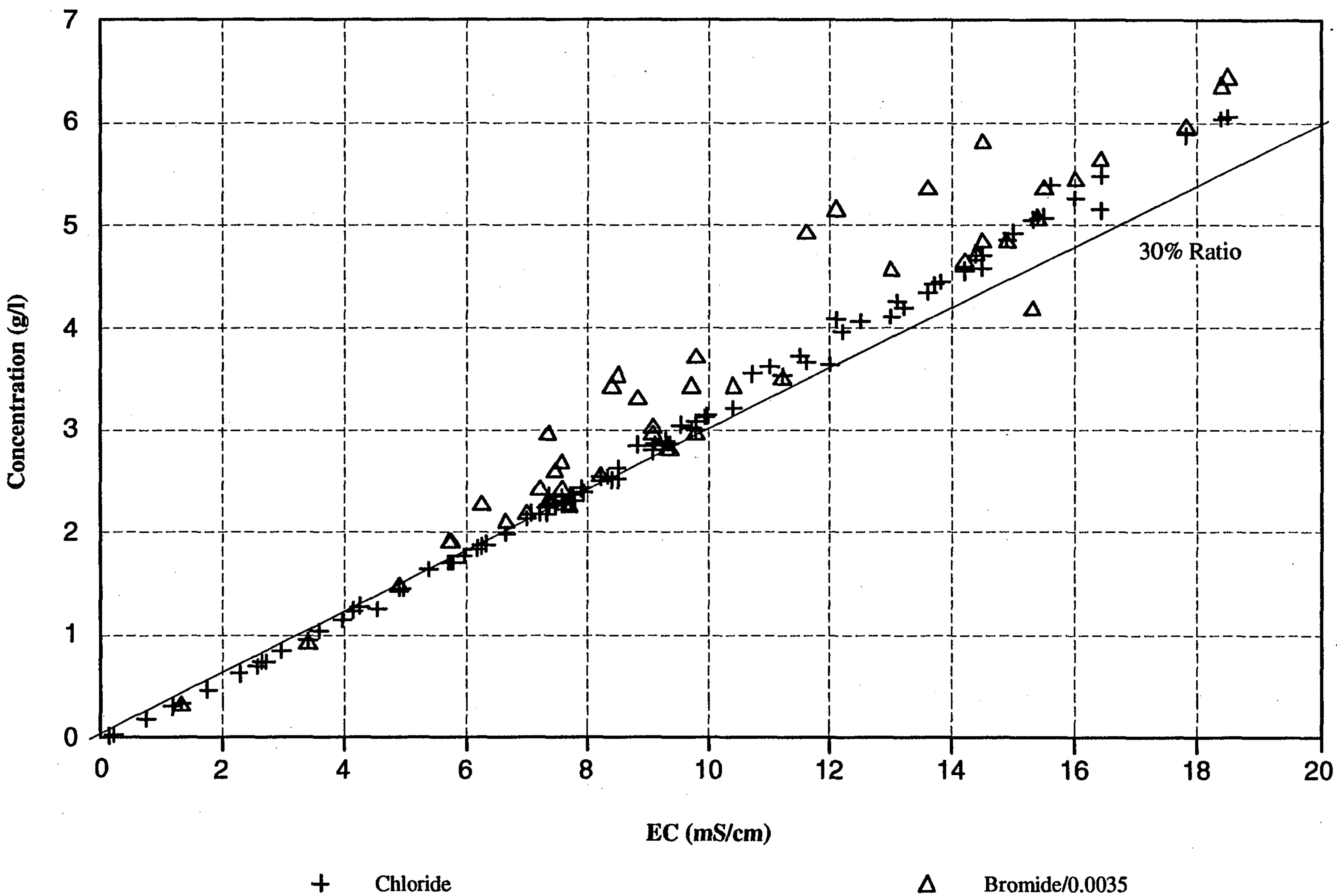

Figure 3C-7.
Relationship between EC and Concentrations of Chloride and Bromide in Water from Mallard Island (Chipps Island) (1982-1991 MWQI Monthly Samples)

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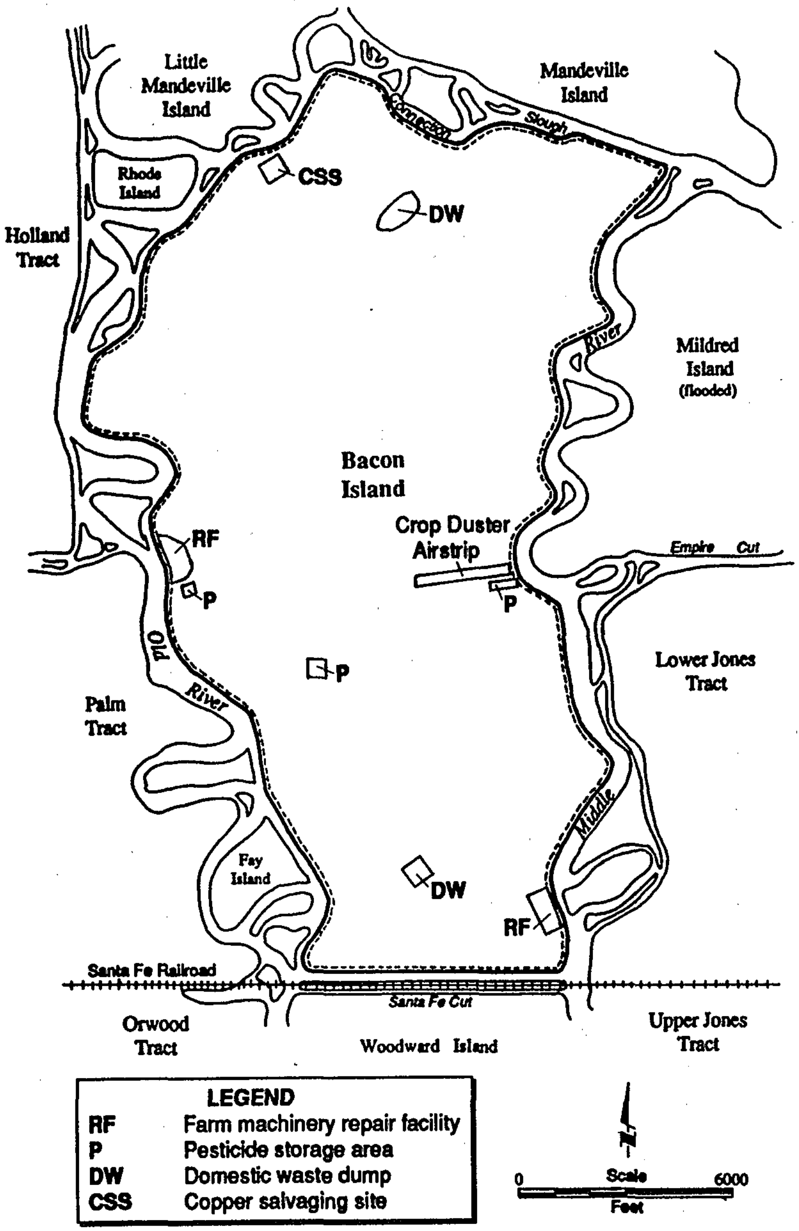

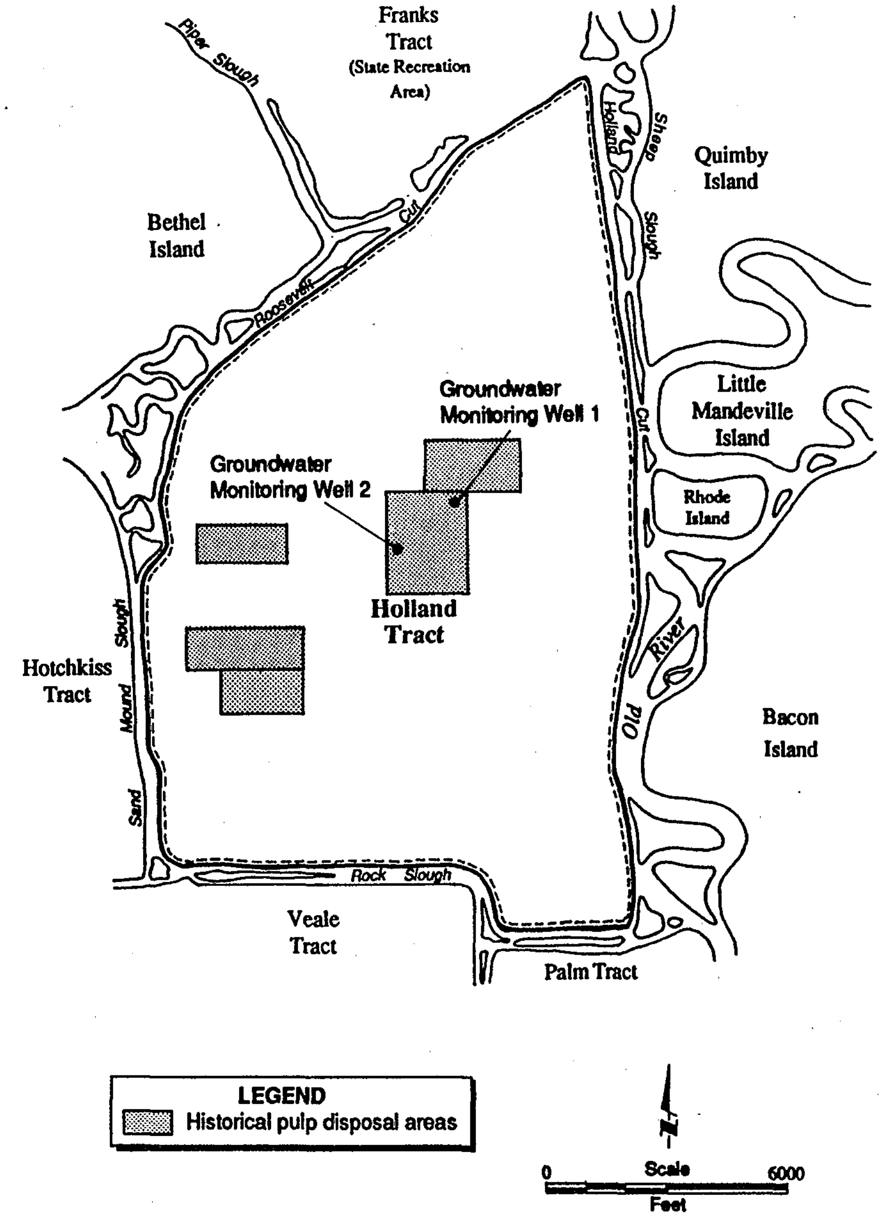

Note: Only Bacon Island and Holland Tract are shown because no potential contaminant sites exist on Webb Tract and Bouldin Island.

Figure 3C-8.
Potential Contaminant Sites on the DW Project Islands

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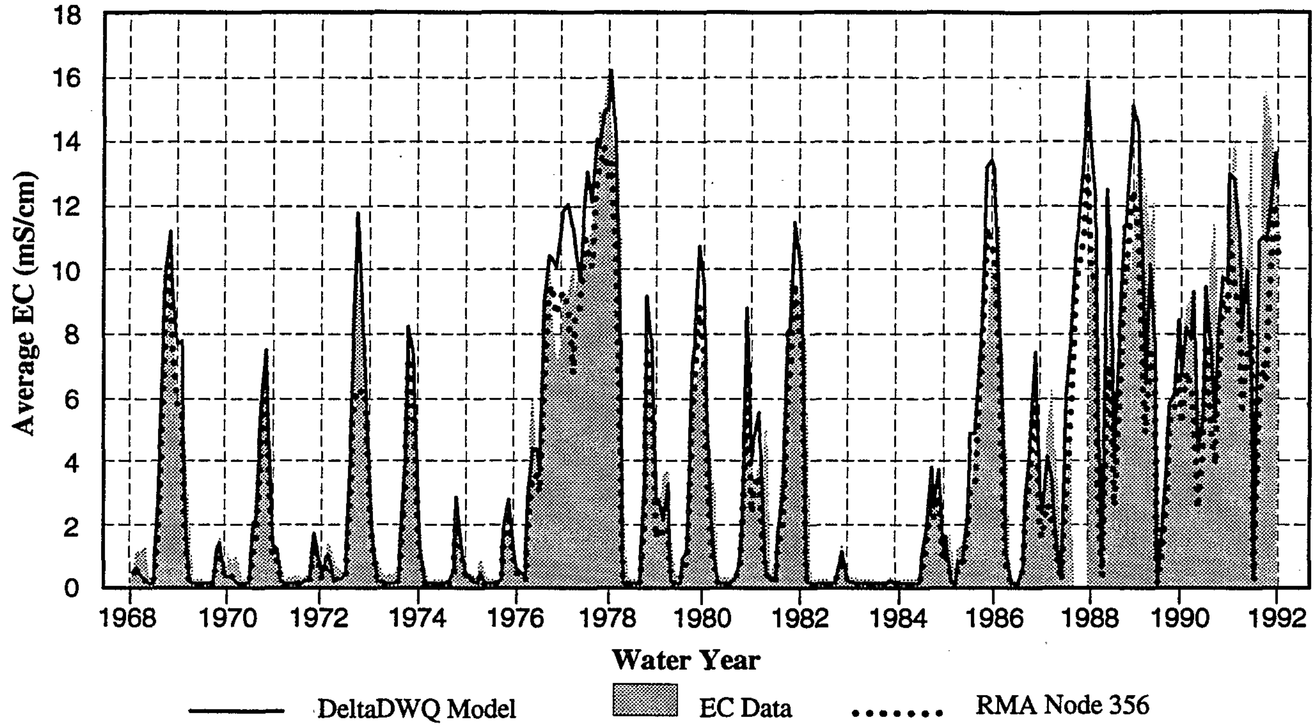
C-060582



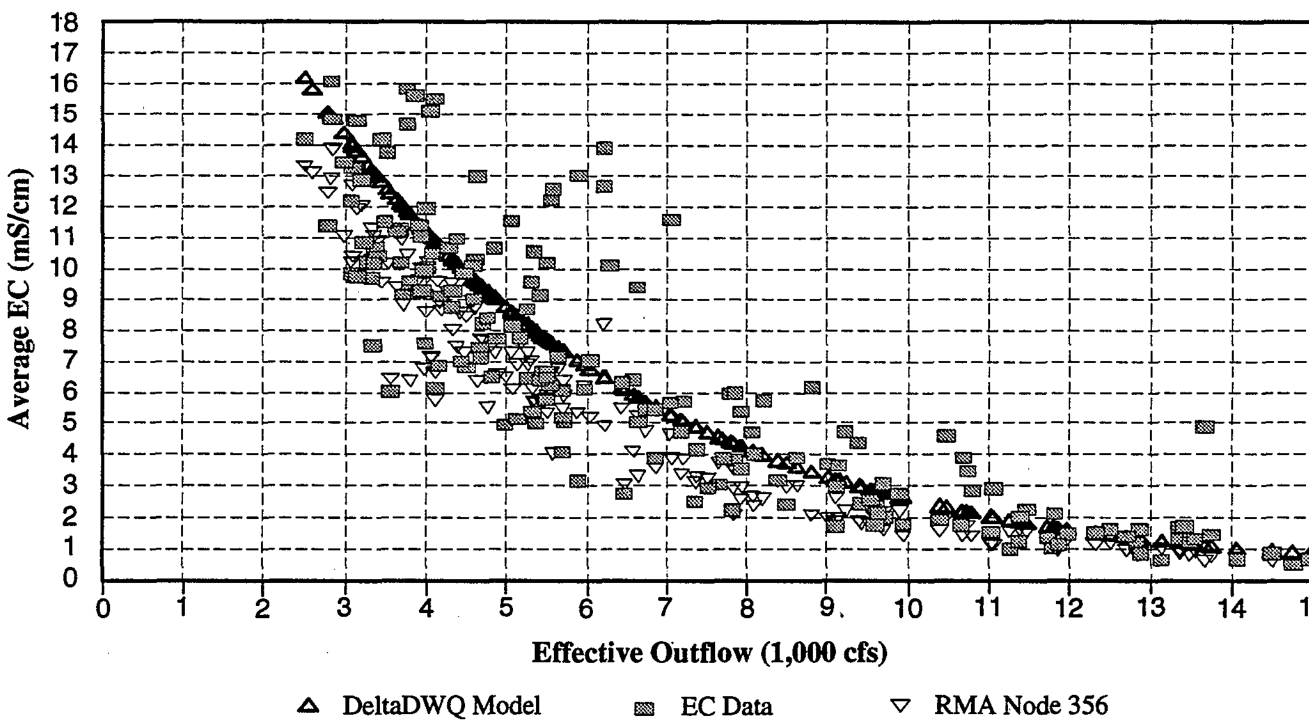


Figure 3C-9.
Comparison of Average Monthly Measured EC at Pittsburg (Chipps Island) with RMA and DeltaDWQ Model Simulations for 1968-1991

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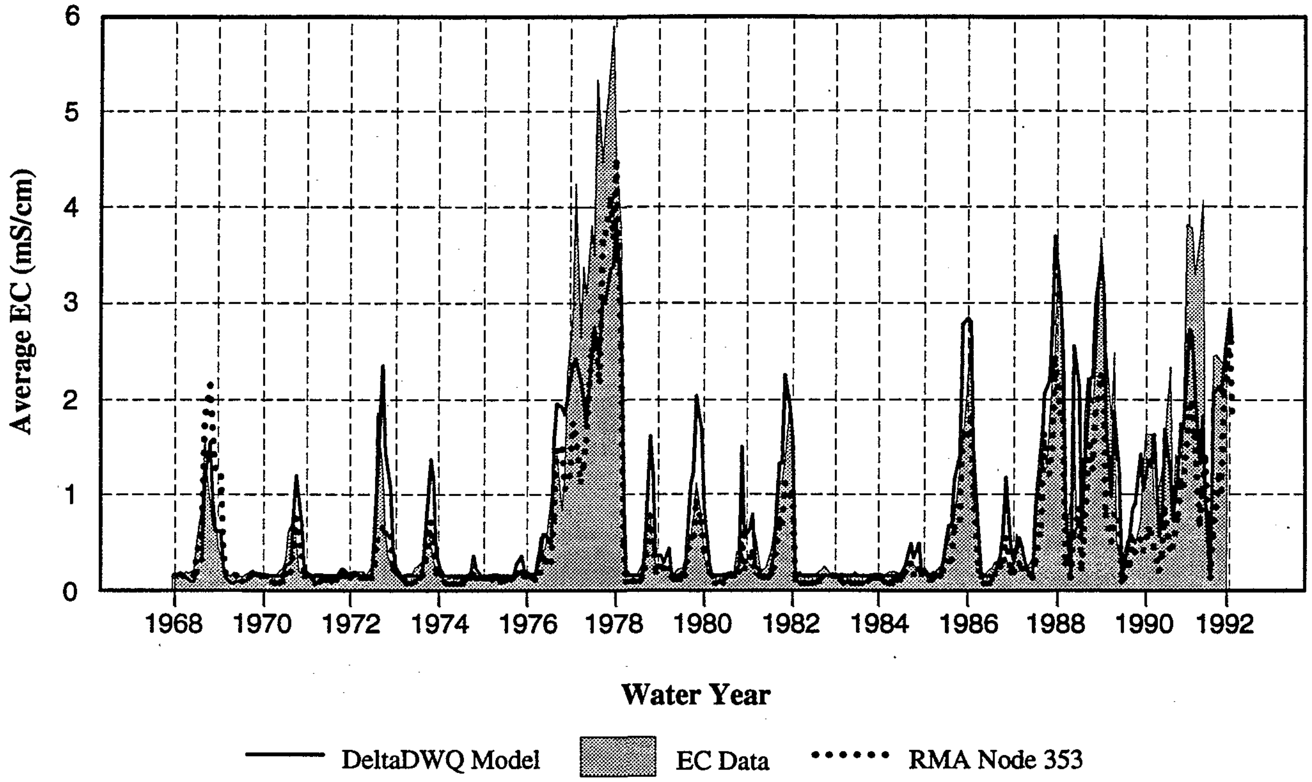
Prepared by: Jones & Stokes Associates



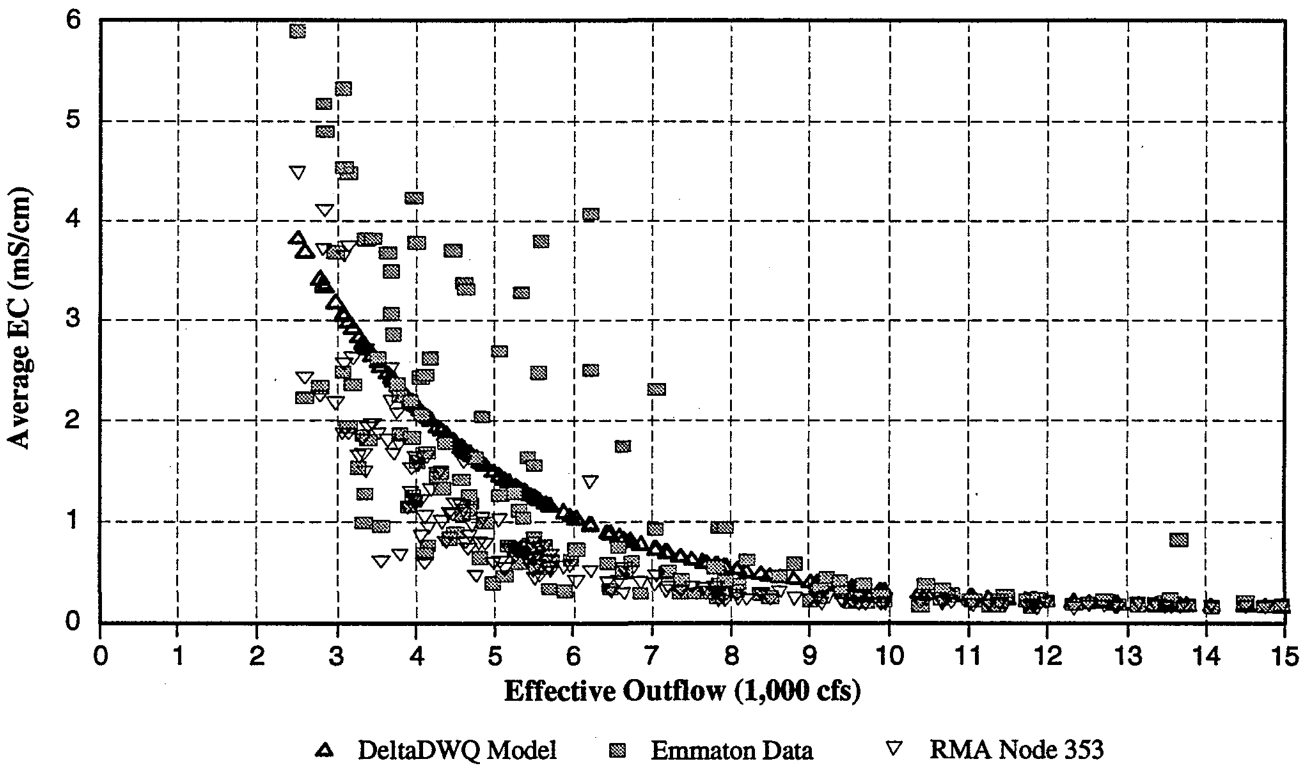


Figure 3C-10.
Comparison of Average Monthly Measured EC at Emmaton with RMA and DeltaDWQ Model Simulations for 1968-1991

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

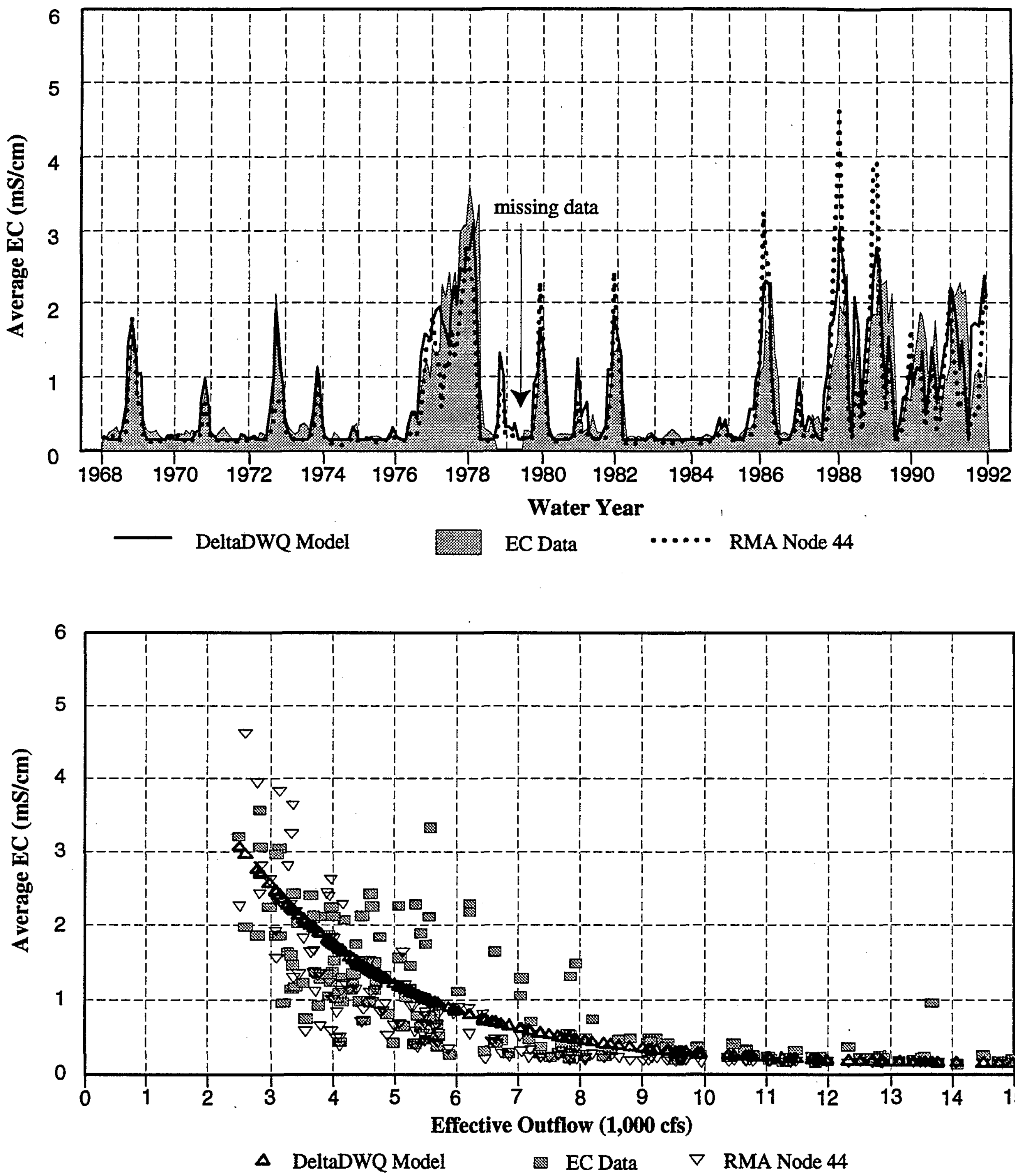


Figure 3C-11.
Comparison of Average Monthly Measured EC at Jersey Point with RMA and DeltaDWQ Model Simulations for 1968-1991

DELTA WETLANDS
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Prepared by: Jones & Stokes Associates

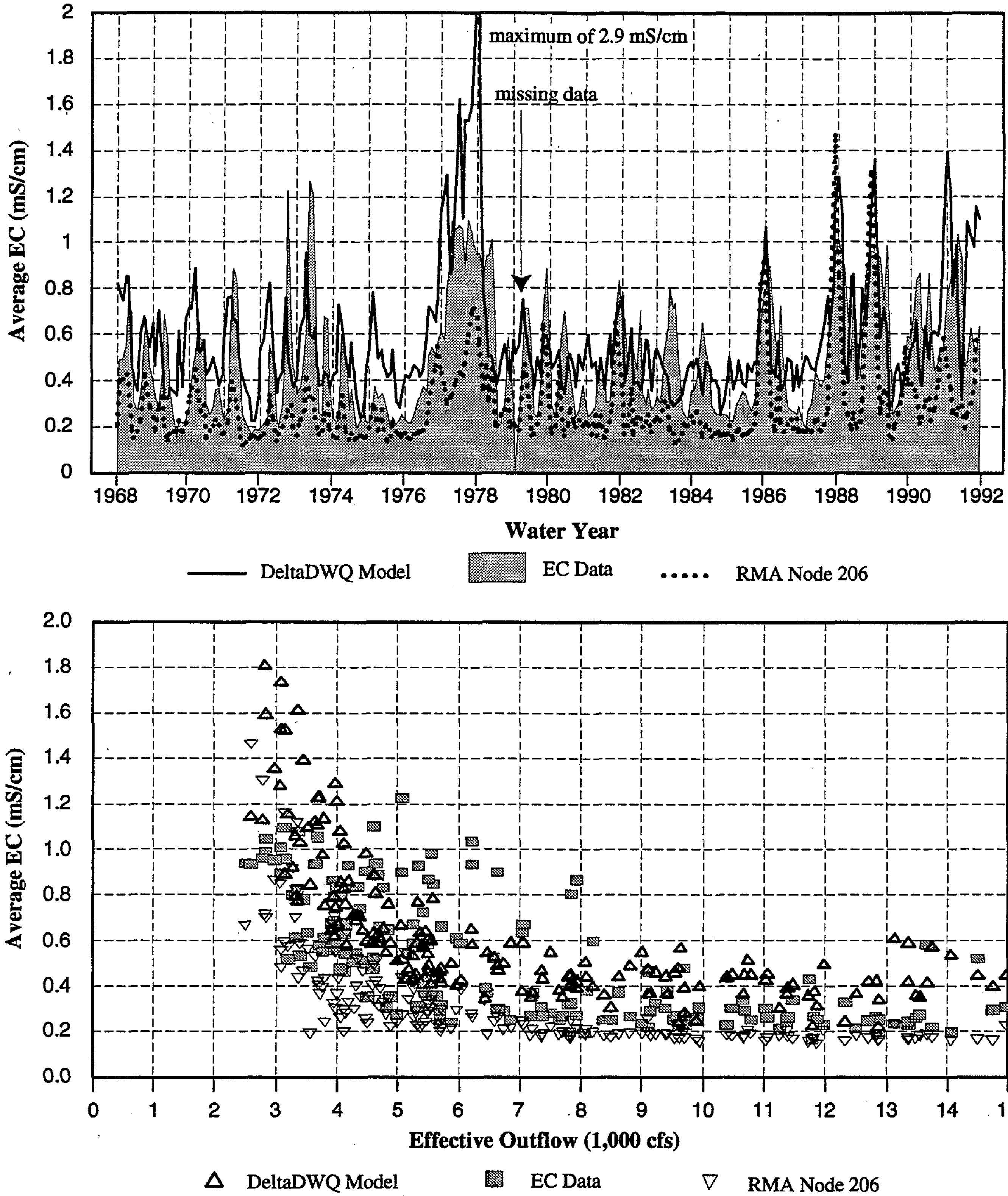

Figure 3C-12.
Comparison of Average Monthly Measured EC at the CCWD Rock Slough Diversion with RMA and DeltaDWQ Model Simulations for 1968-1991

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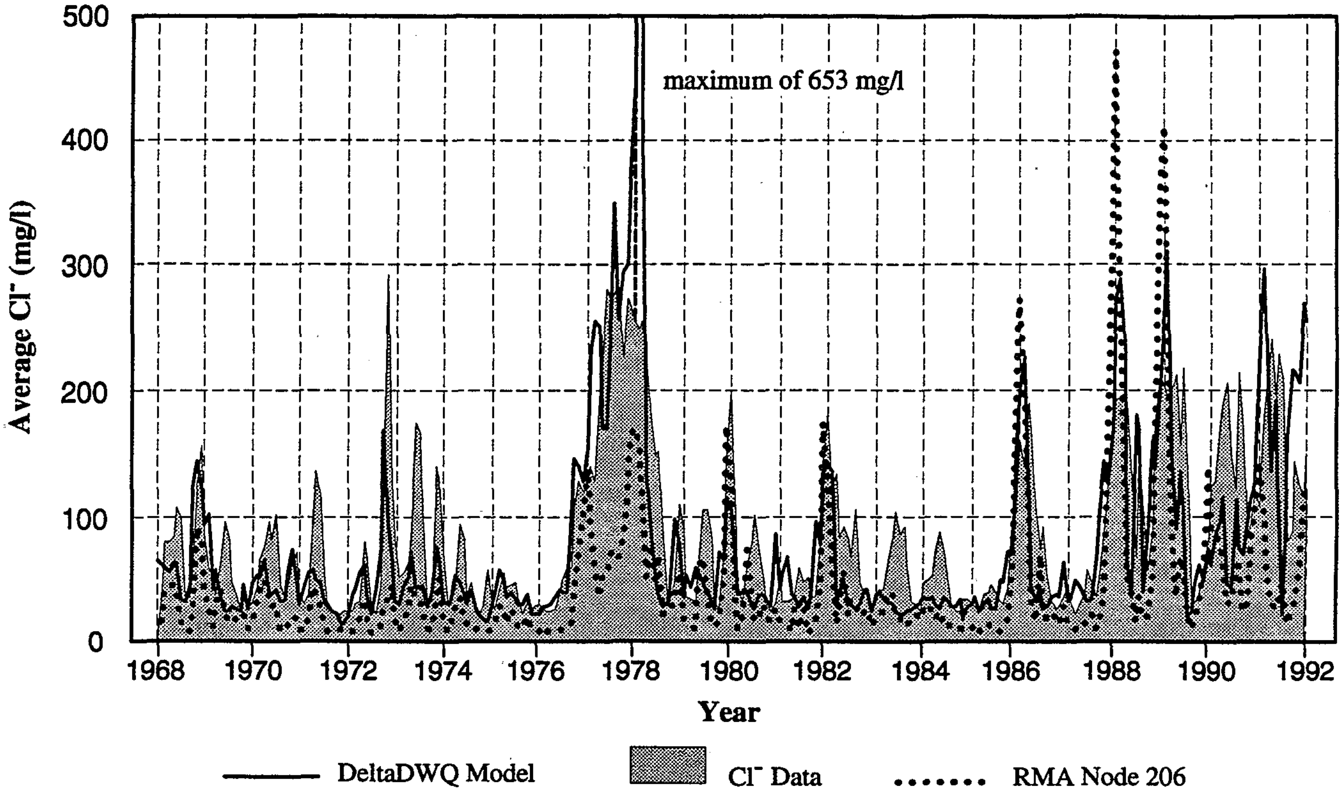
Prepared by: Jones & Stokes Associates



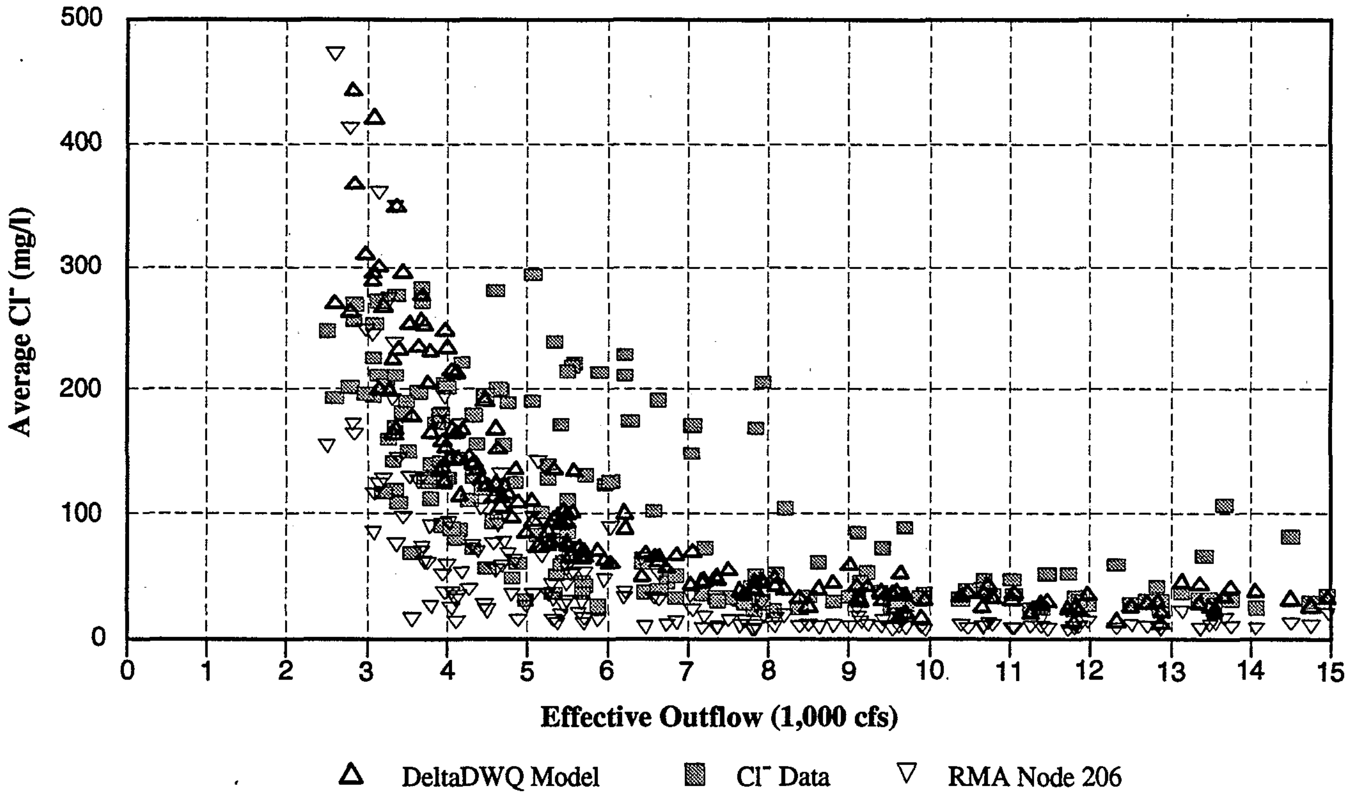


Figure 3C-13.
Comparison of Average Monthly Measured Chloride at the CCWD Rock Slough Diversion with RMA and DeltaDWQ Model Simulations for 1968-1991

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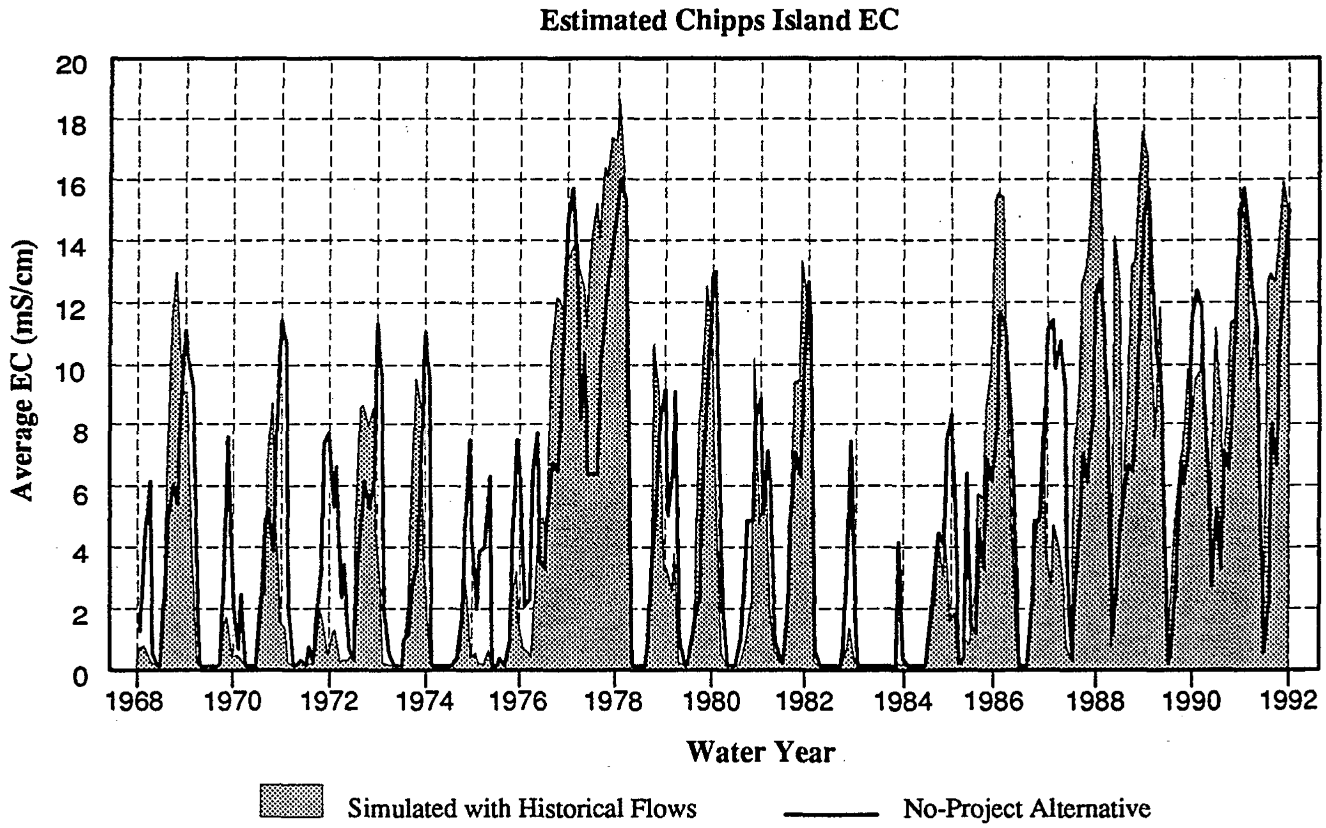

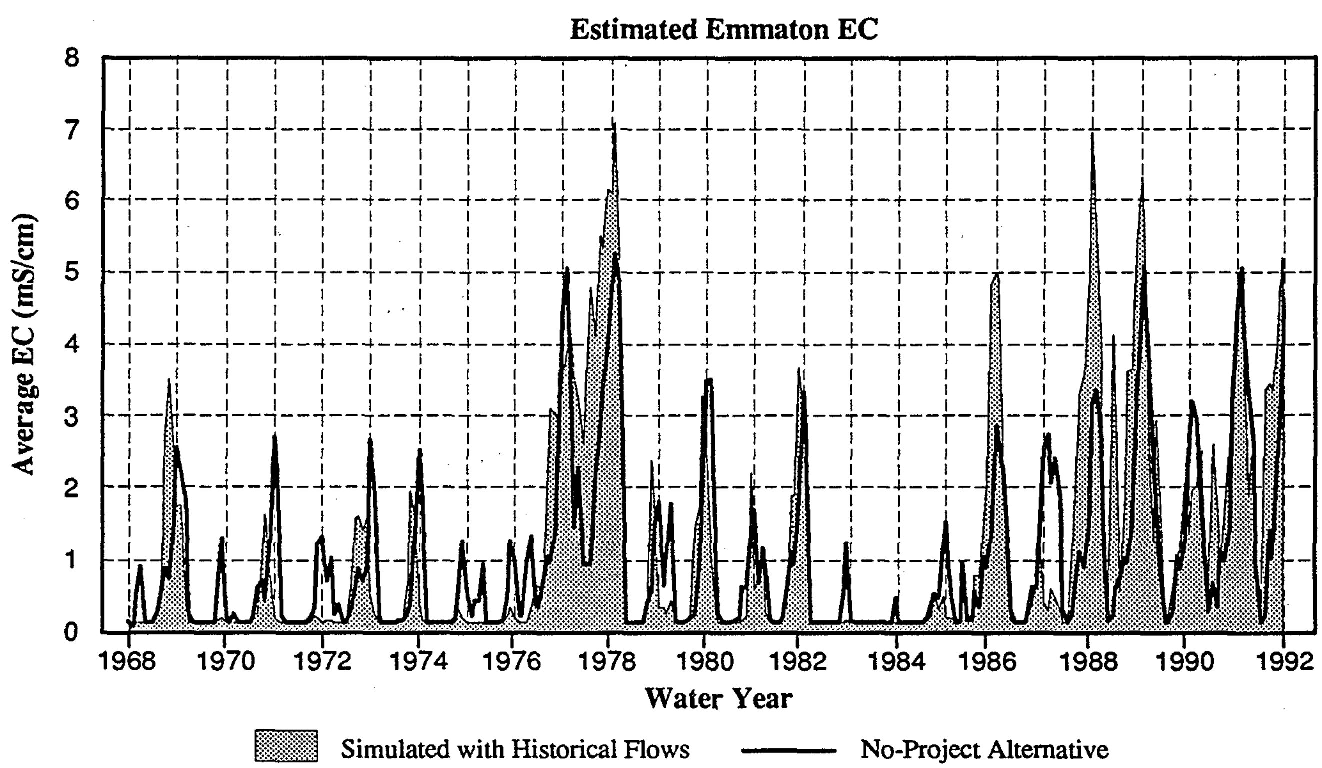

Figure 3C-14.
Comparison of EC at Chipps Island and EC at Emmaton Simulated for the No-Project Alternative and for Historical Outflows for 1968-1991

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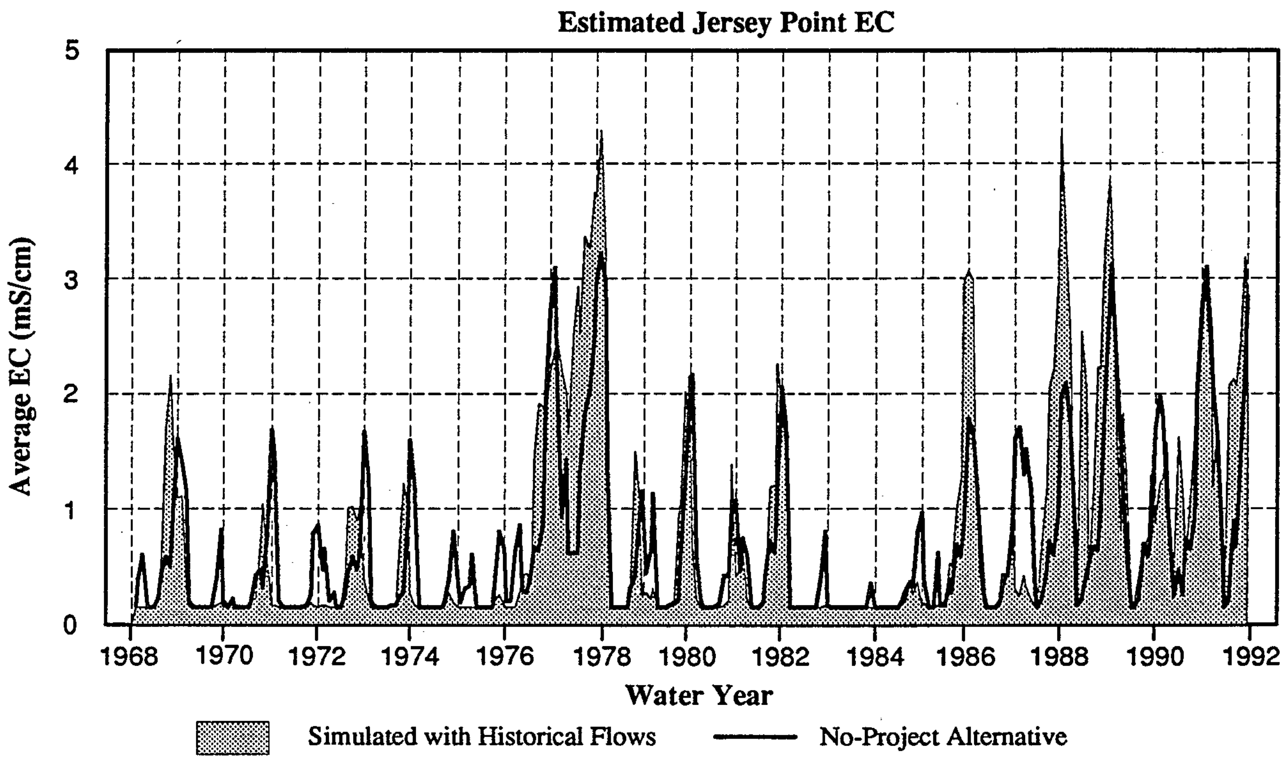

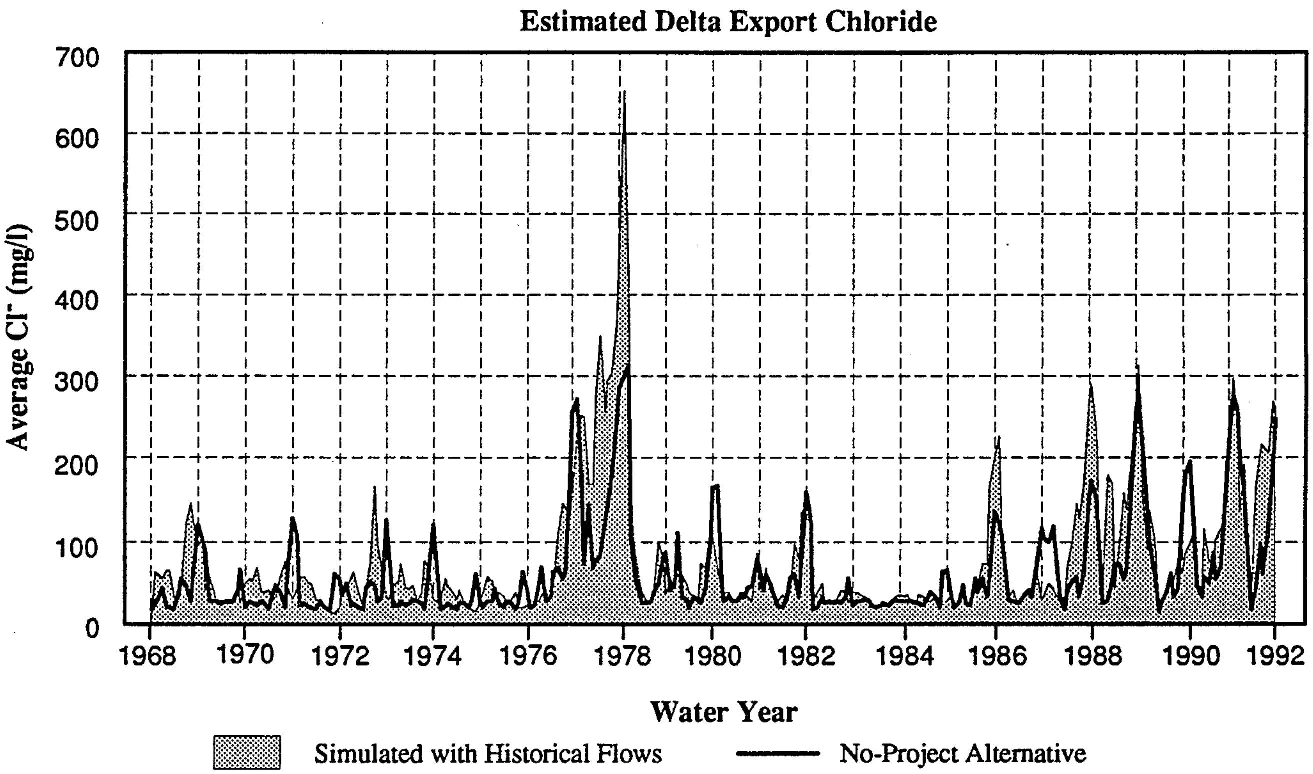

Figure 3C-15.
Comparison of EC at Jersey Point and Chloride in Delta Exports Simulated for the No-Project Alternative and for Historical Outflows for 1968-1991

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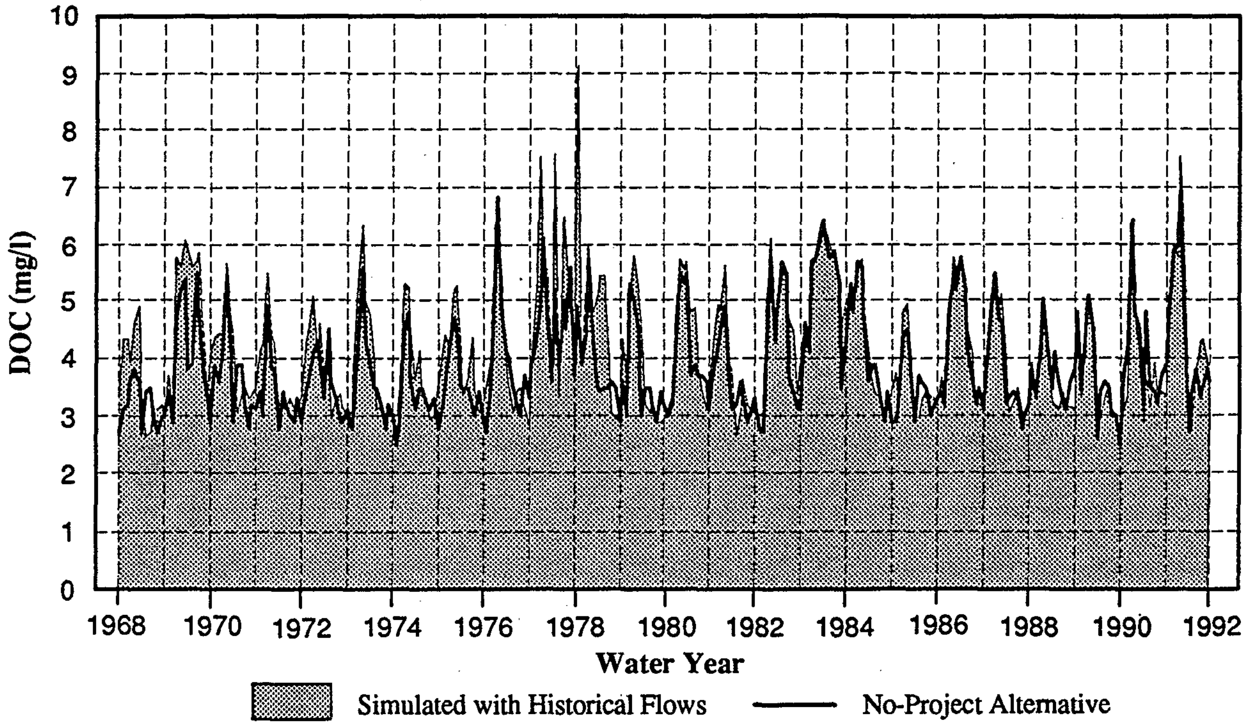
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates



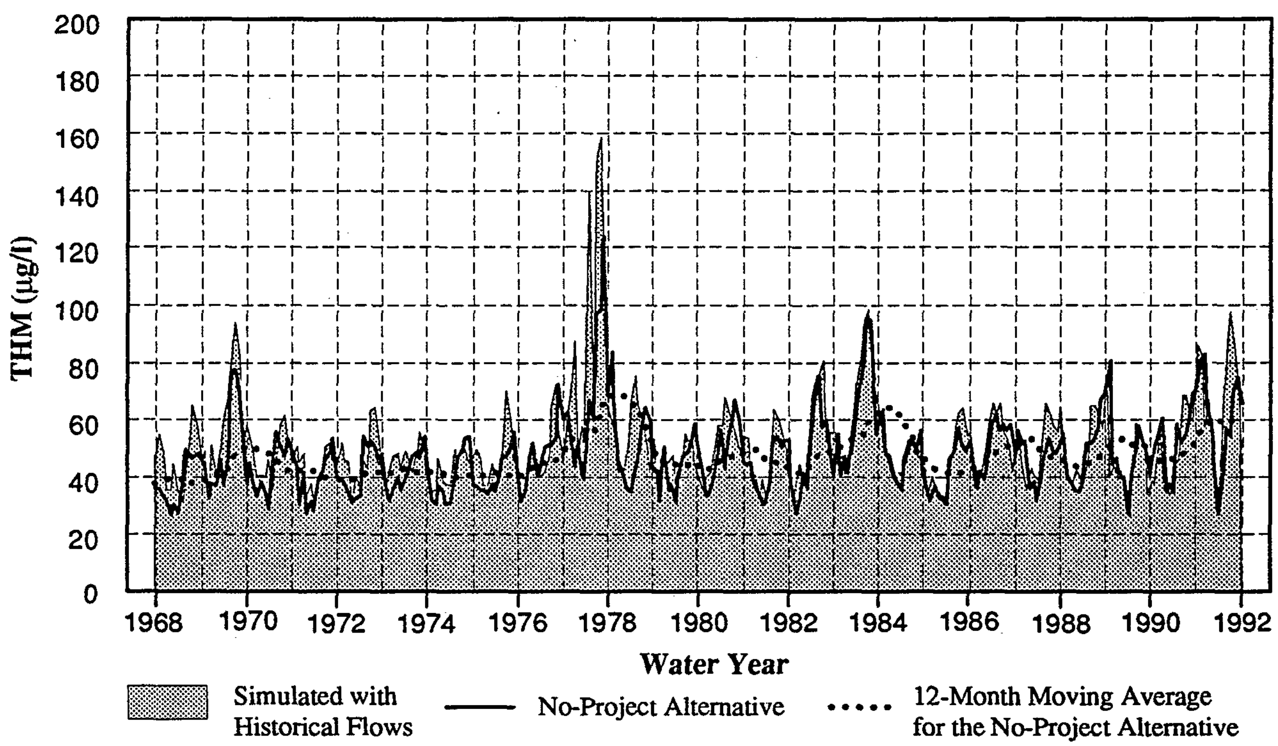


Figure 3C-16.
Comparison of Export DOC and THM Concentrations Simulated for the No-Project Alternative and for Historical Inflows and Exports for 1968-1991

DELTA WETLANDS
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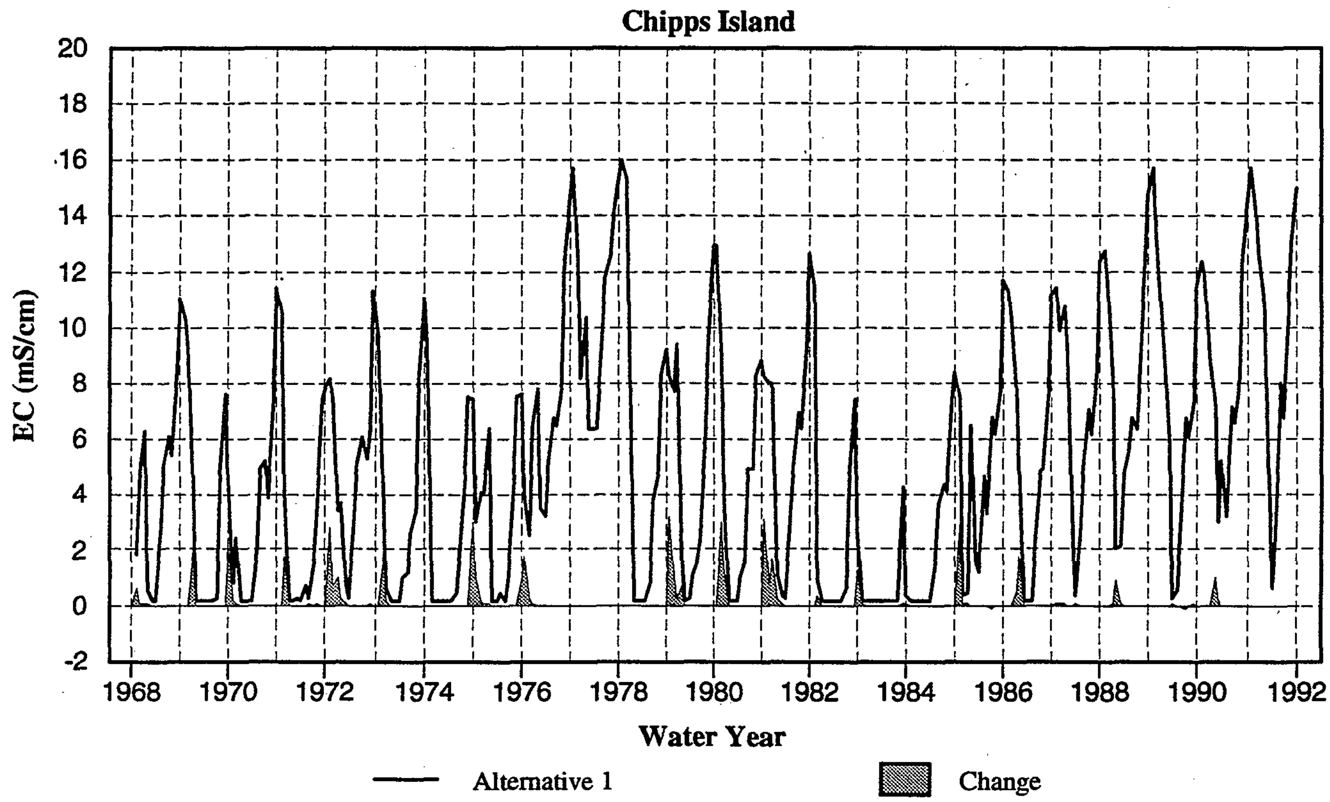
Prepared by: Jones & Stokes Associates



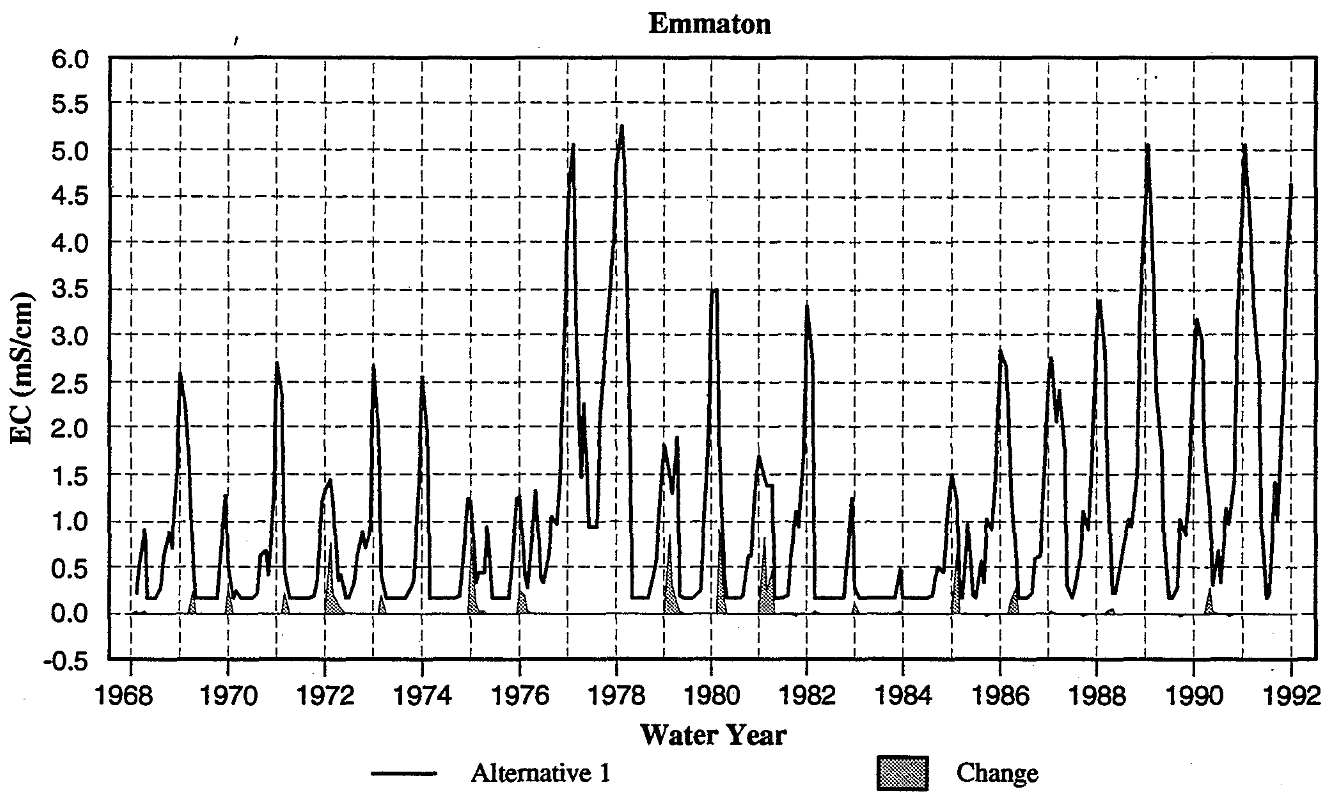
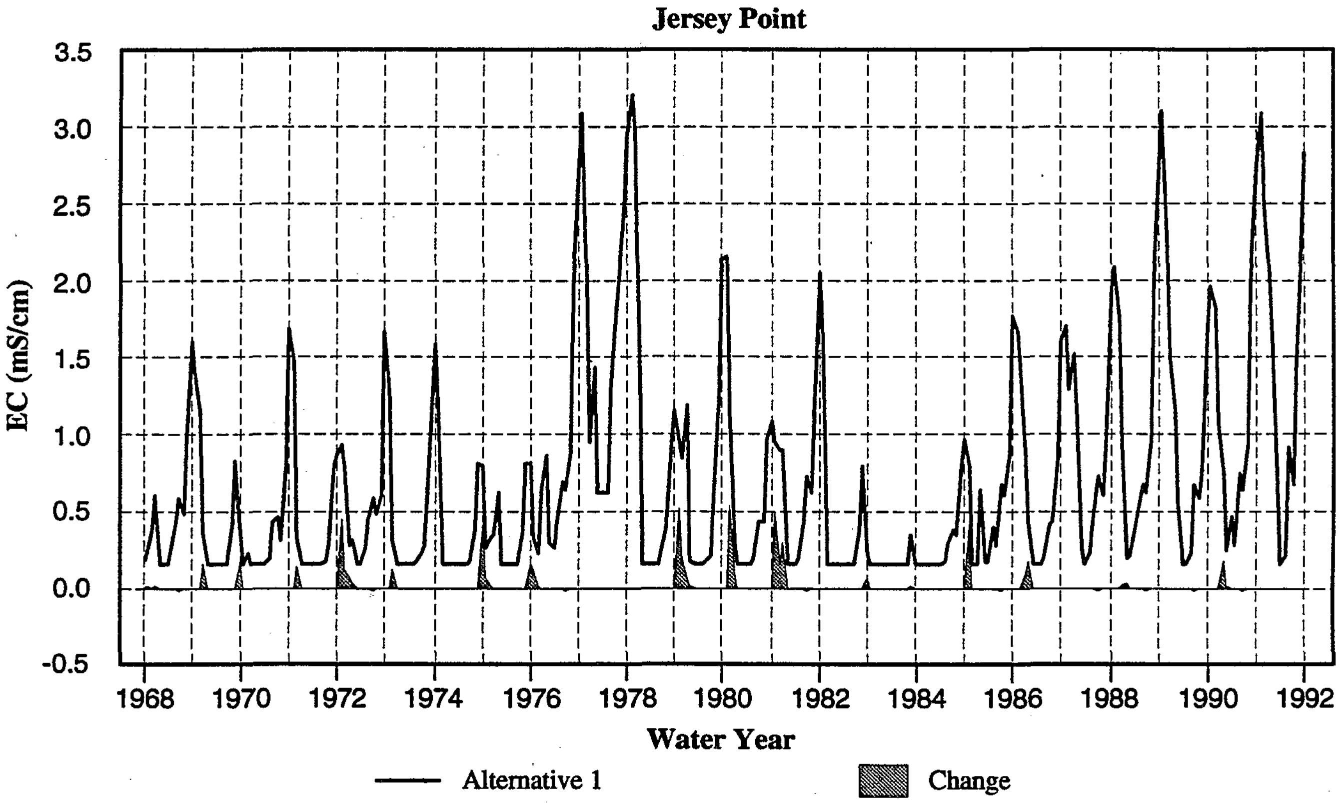


Figure 3C-17.
Simulated End-of-Month EC Values and Predicted Changes in EC at Chipps Island and Emmaton under Alternative 1 Operations for 1968-1991

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates



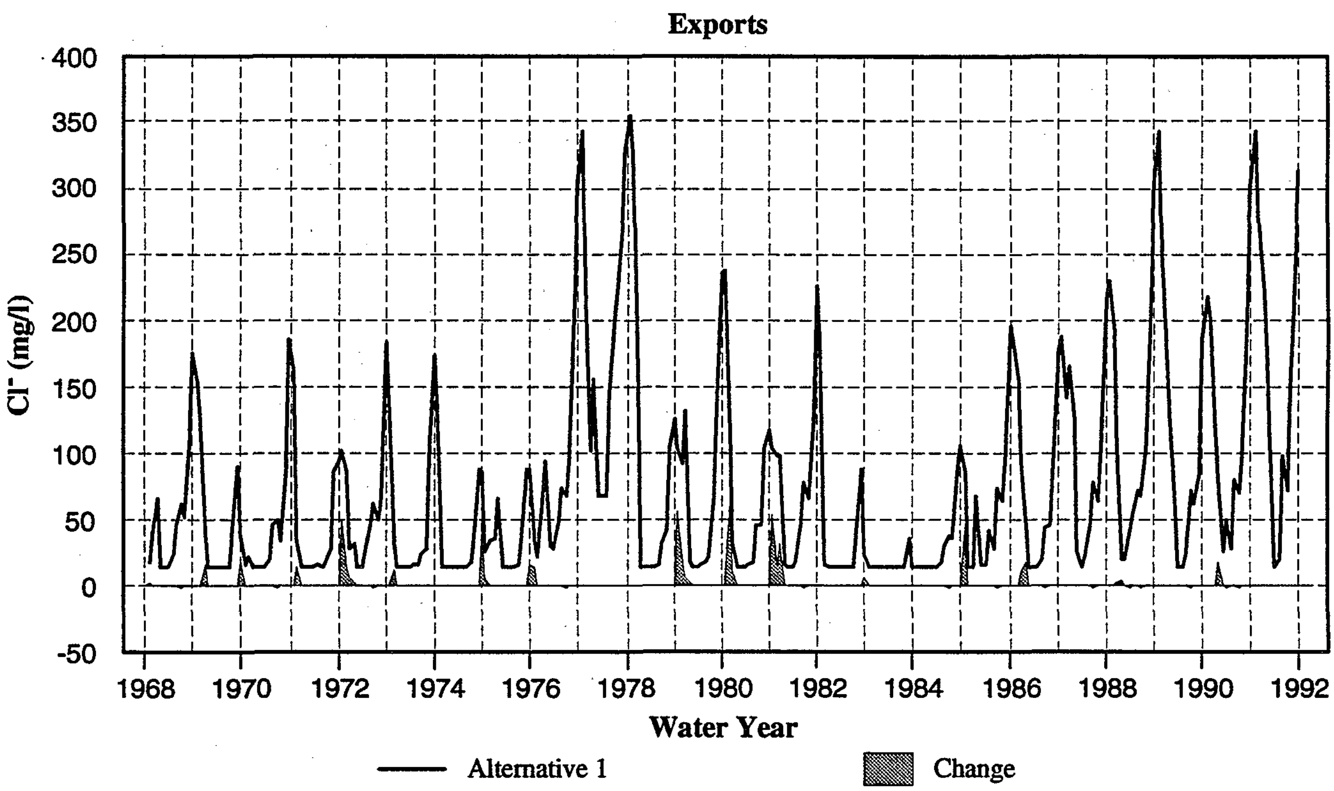


Figure 3C-18.
Simulated End-of-Month Values for and Predicted Changes in Jersey Point EC and Export Chloride under Alternative 1 Operations for 1968-1991

DELTA WETLANDS
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Prepared by: Jones & Stokes Associates

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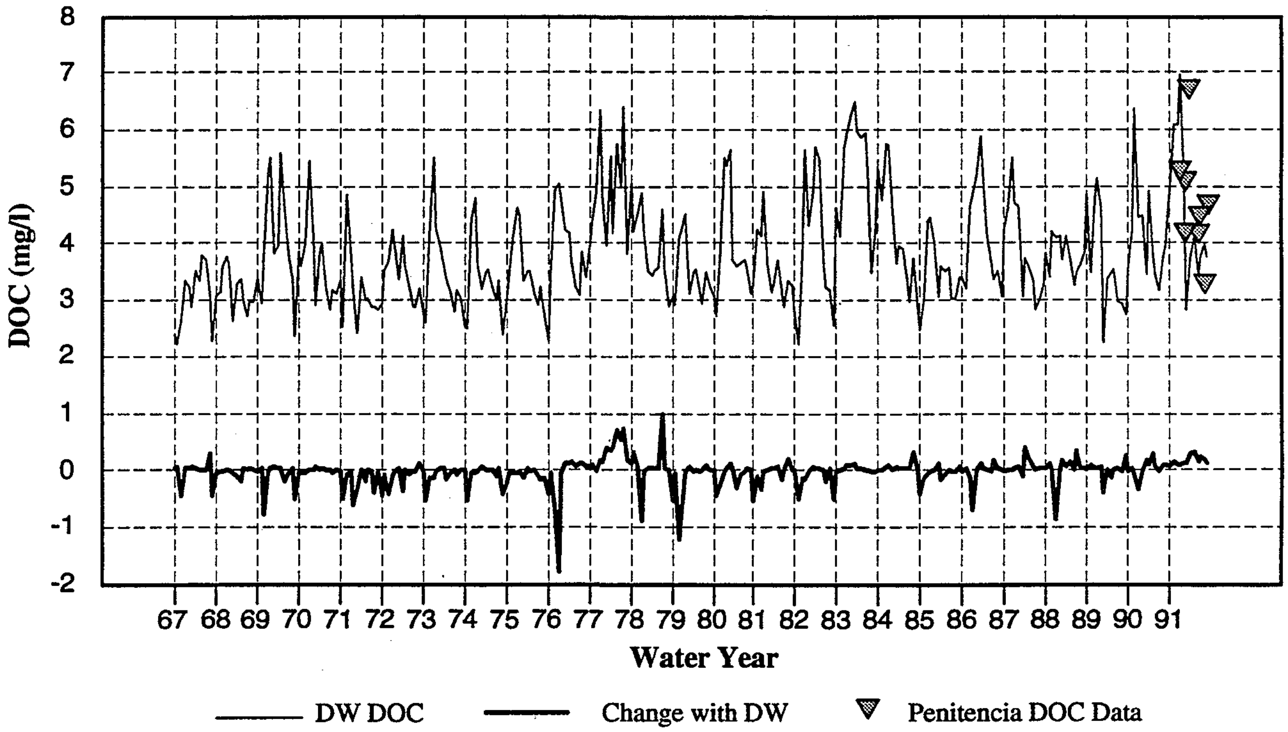


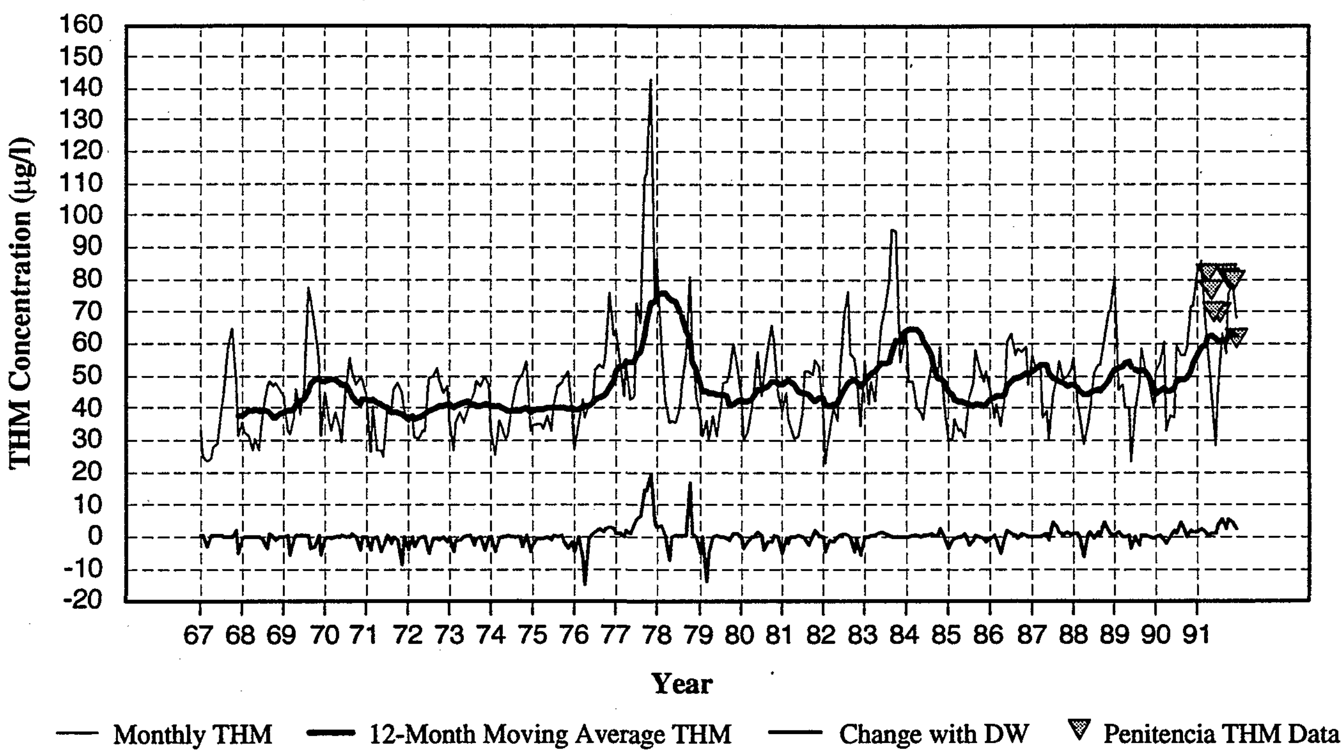


Figure 3C-19.
Simulated Inflow DOC and Final THM Concentration in Delta Exports under Alternative 1 Compared with the No-Project Alternative

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

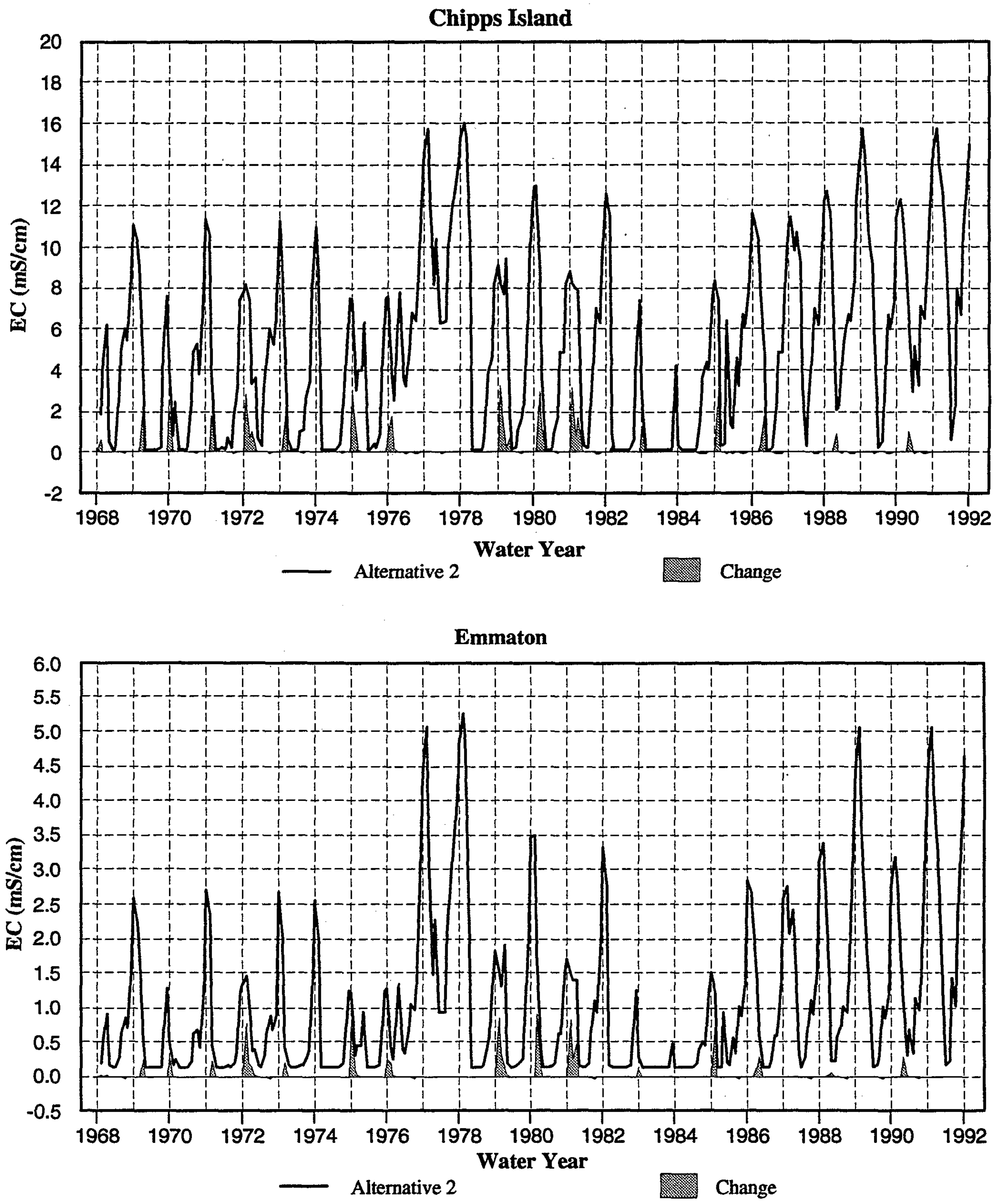
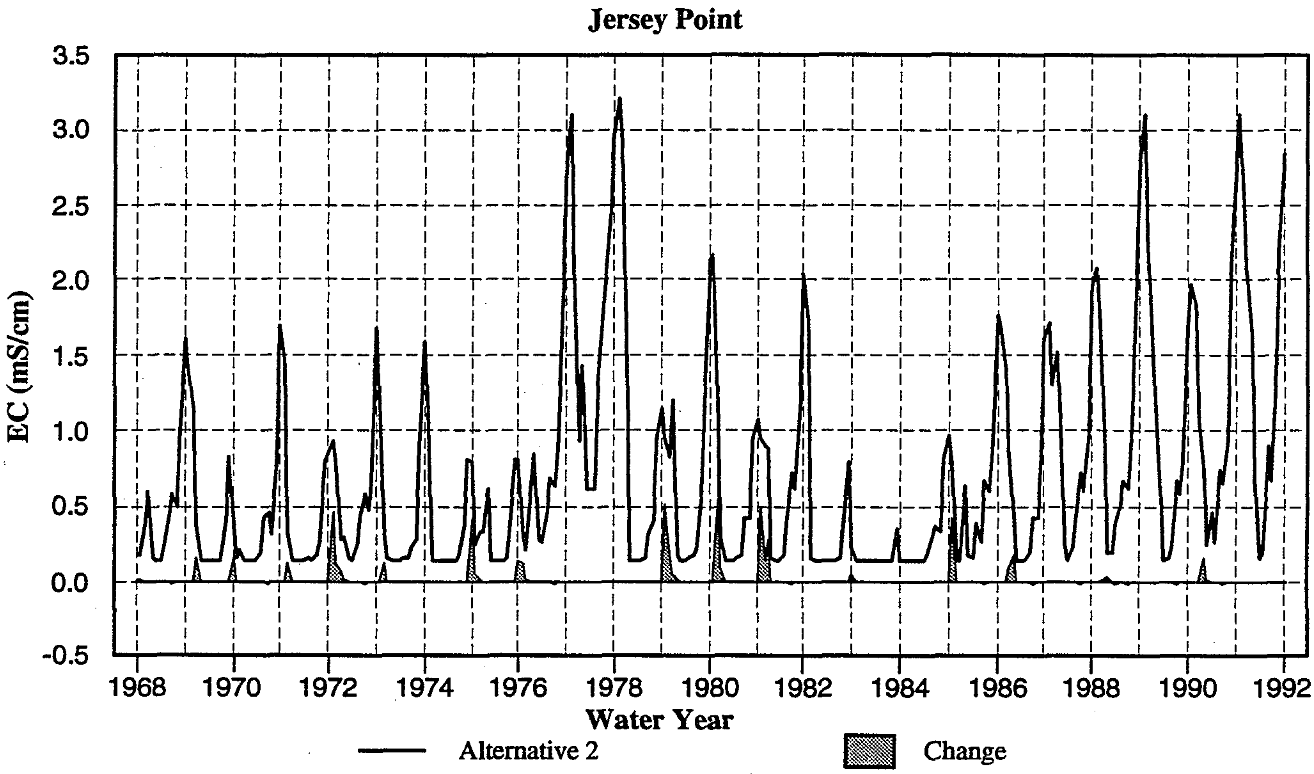


Figure 3C-20.
Simulated End-of-Month EC Values and Predicted Changes in EC at Chipps Island and Emmaton under Alternative 2 Operations for 1968-1991

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates



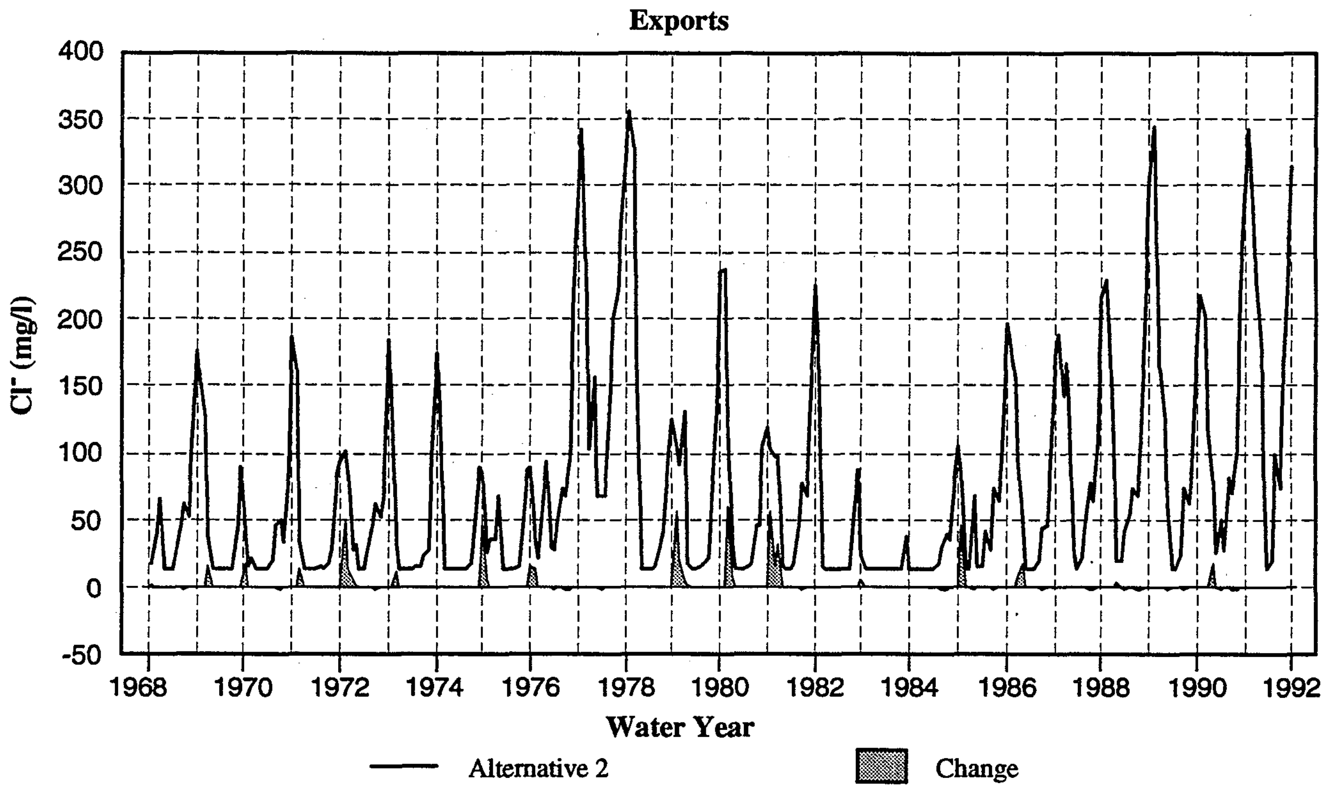


Figure 3C-21.
Simulated End-of-Month Values for and Predicted Changes in Jersey Point EC and Export Chloride under Alternative 2 Operations for 1968-1991

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

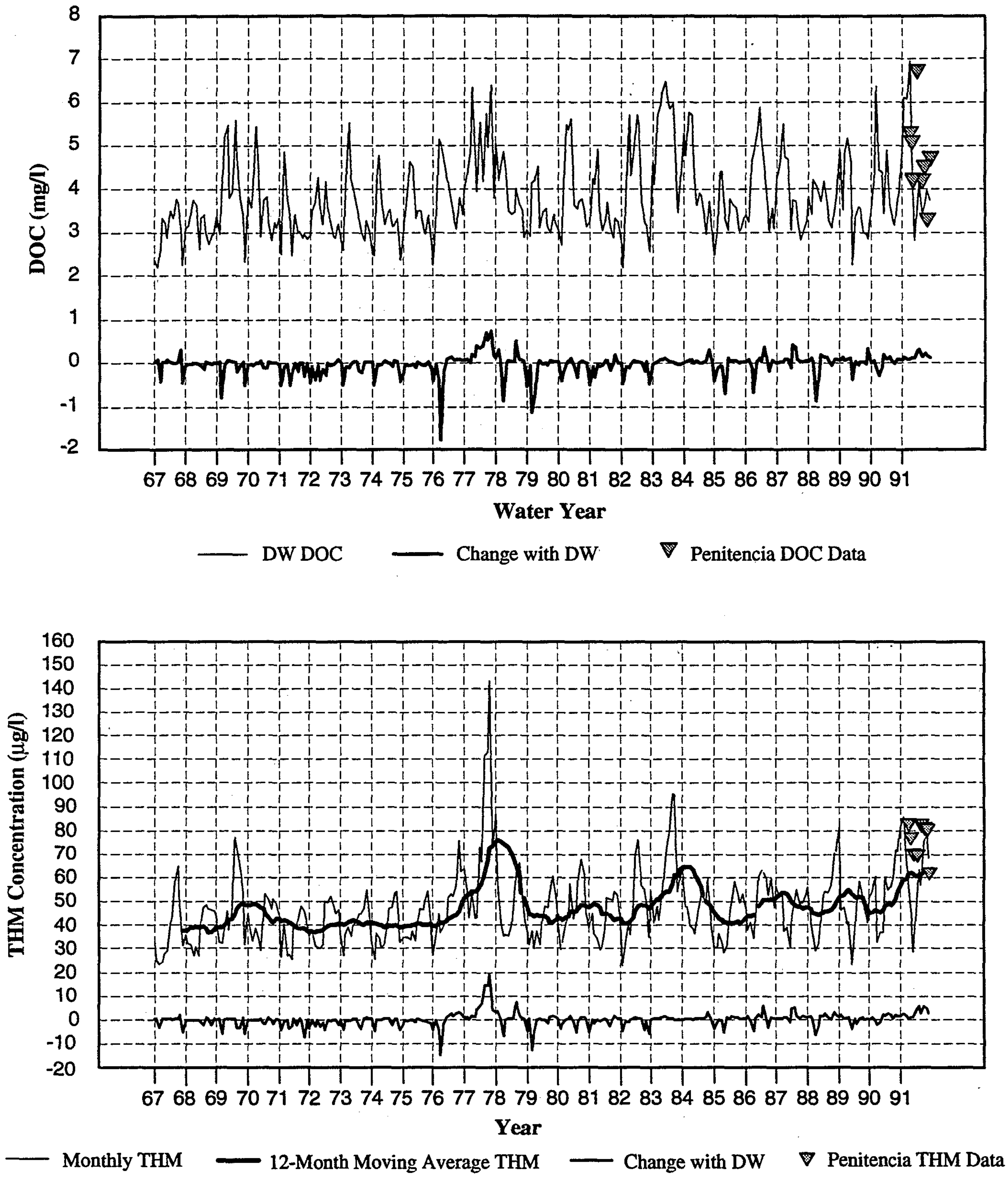


Figure 3C-22.
Simulated Inflow DOC and Final THM Concentration in Delta Exports under Alternative 2 Compared with the No-Project Alternative

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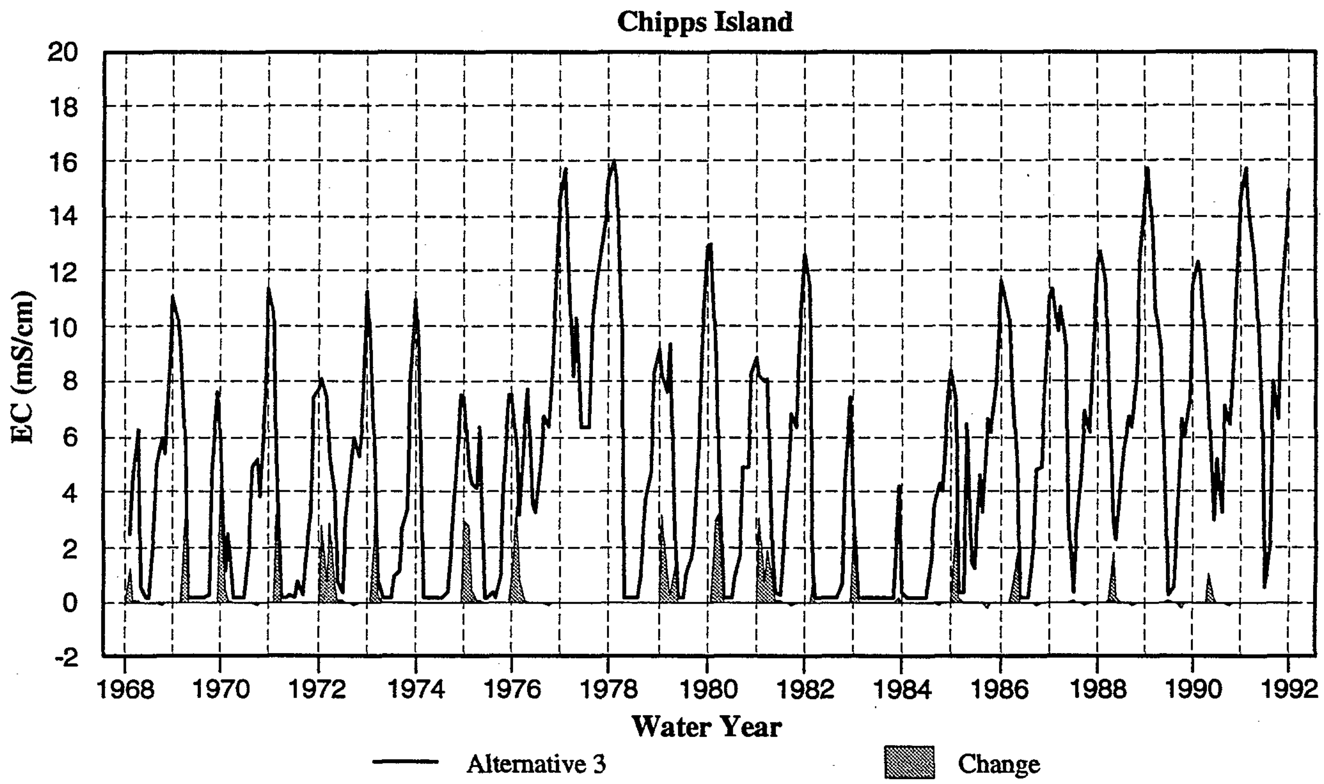
Prepared by: Jones & Stokes Associates



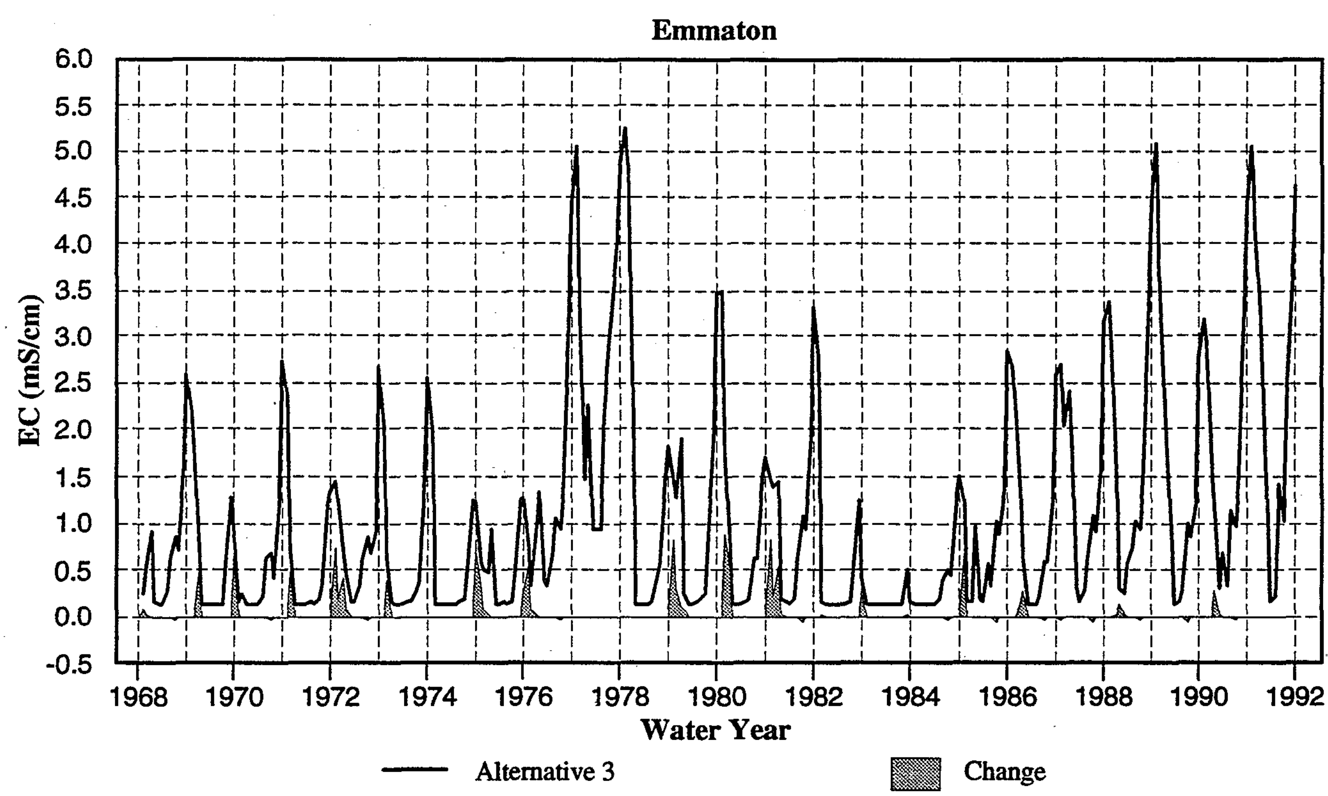


Figure 3C-23.
Simulated End-of-Month EC Values and Predicted Changes in EC at Chipps Island and Emmaton under Alternative 3 Operations for 1968-1991

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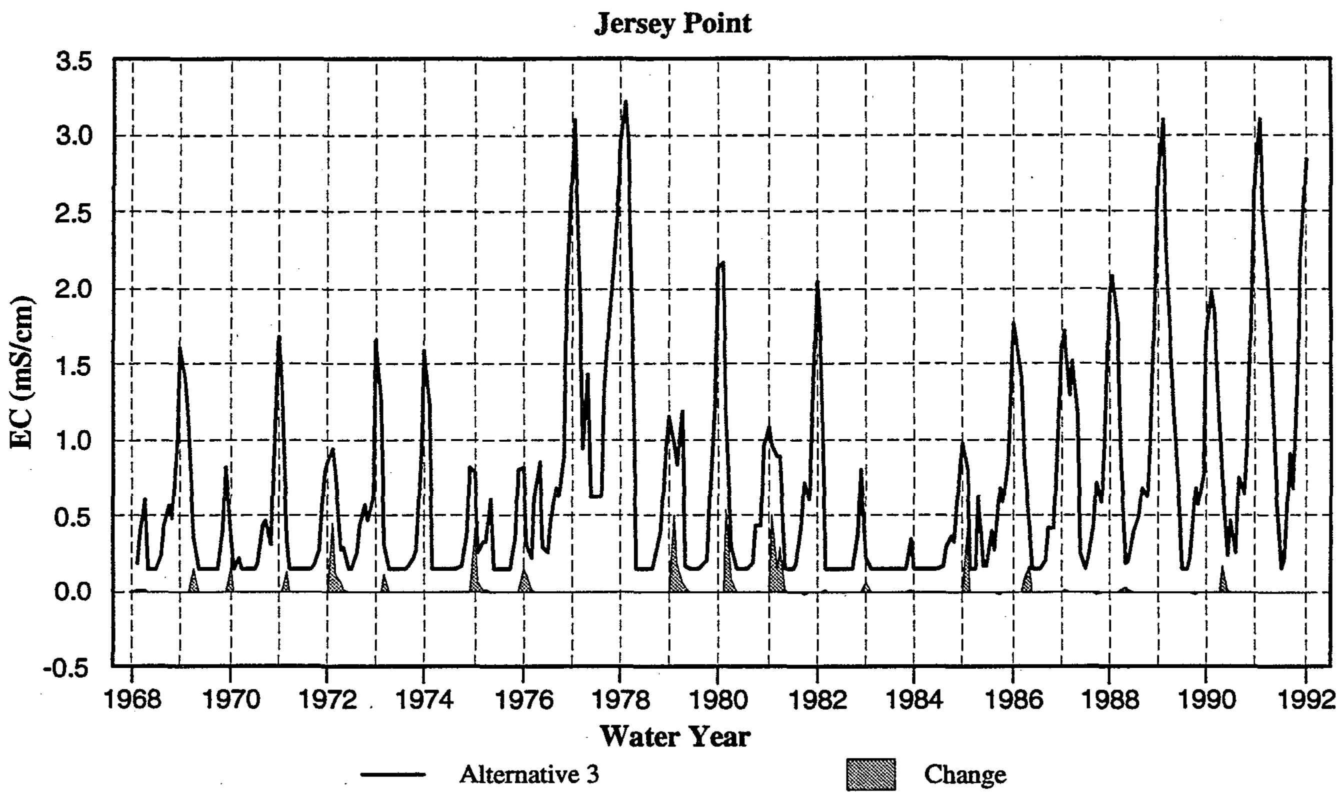

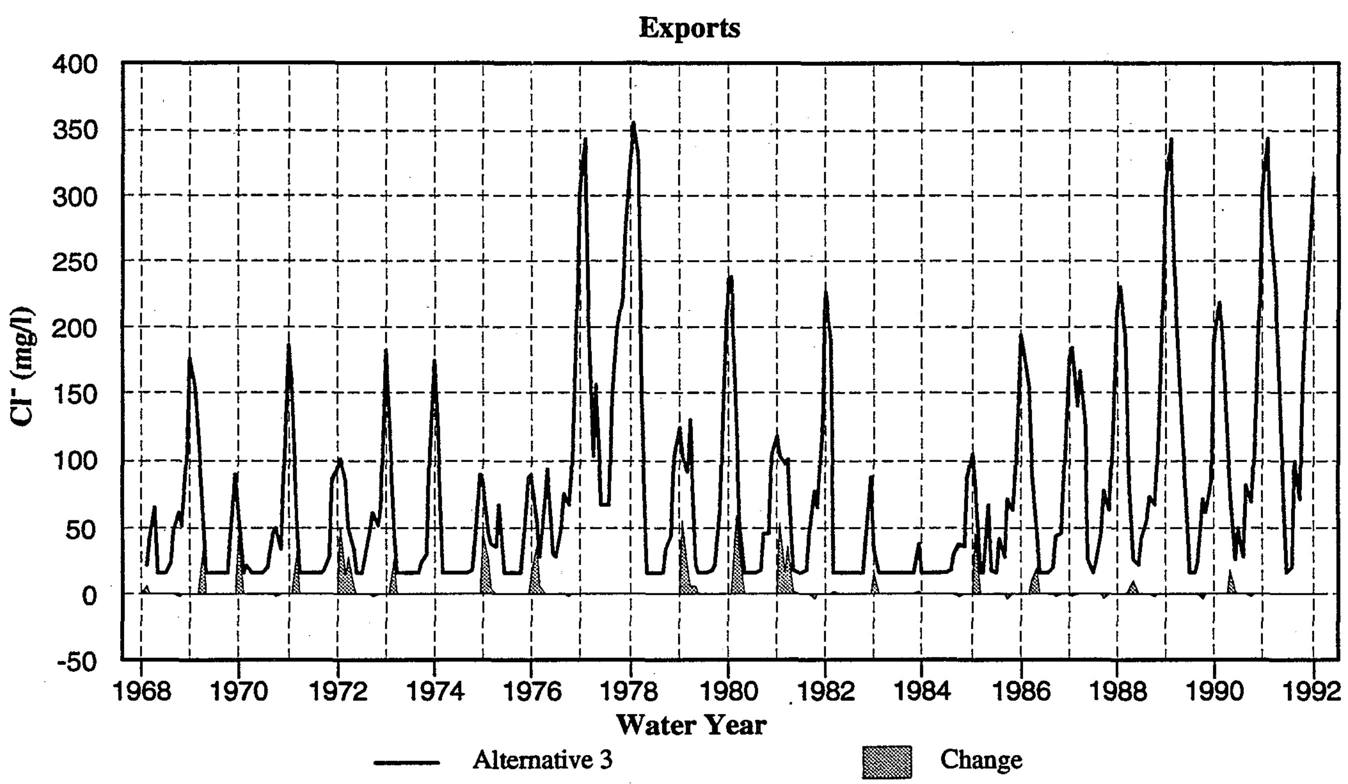

Figure 3C-24.
Simulated End-of-Month Values for and Predicted Changes in Jersey Point EC and Export Chloride under Alternative 3 Operations for 1968-1991

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Prepared by: Jones & Stokes Associates

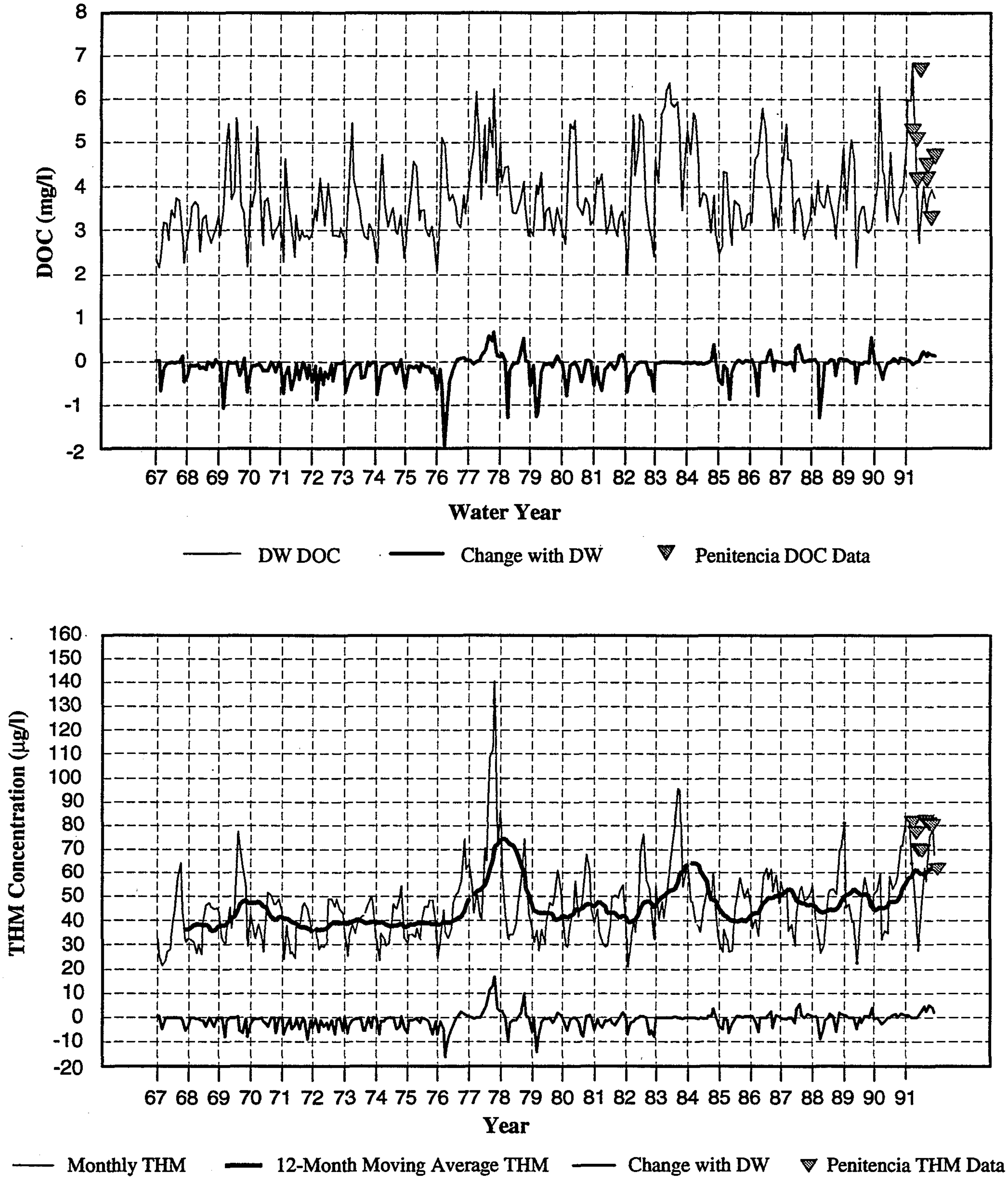

Figure 3C-25.
Simulated Inflow DOC and Final THM Concentration in Delta Exports under Alternative 3 Compared with the No-Project Alternative

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