Appendix C4. DeltaDWQ: Delta Drainage Water Quality Model

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SUMMARY

This appendix describes the Delta Drainage Water Quality model (DeltaDWQ), which was developed for estimating monthly Delta agricultural island drainage and Delta export water quality. The model represents monthly water, salt, and dissolved organic carbon (DOC) budgets for agricultural islands in both the Delta lowlands and the Delta uplands. Delta export water quality is determined from approximate percentage source contributions and source water quality estimates. DeltaDWQ was used to analyze the effects of Delta Wetlands (DW) project discharges on Delta export water quality. This appendix summarizes DeltaDWQ estimates of electrical conductivity (EC) values and DOC concentrations in DW discharges and in Delta exports.

INTRODUCTION

The available Delta channel and agricultural drainage water quality data have been reviewed and evaluated in Appendices C1, "Analysis of Delta Inflow and Export Water Quality Data"; C2, "Analysis of Delta Agricultural Drainage Water Quality Data"; and C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project". The data are not sufficient for estimating average Delta agricultural drainage volumes and EC or DOC concentrations. For impact assessment purposes, a water quality model of Delta drainage effects on Delta export concentrations of salt and DOC was required. The model, DeltaDWQ, was used to integrate and interpret the available water quality data and estimate likely effects of DW project operations on Delta export salt and DOC concentrations. DeltaDWQ was used to estimate monthly Delta EC and DOC for the 25-year period of 1967-1991.

Estimates of Island Discharge Water Quality

DeltaDWQ simulates monthly patterns of Delta agricultural water management, soil salt buildup and leaching, and DOC loading. DeltaDWQ-estimated concentrations of salt and DOC in proposed DW project discharges were compared with estimated drainage concentrations under current agricultural practices on Delta lowland islands. DeltaDWQ results were used to estimate effects of the proposed DW project discharges from the reservoir and habitat islands on the overall Delta water, salt, and DOC budgets.

Effects on Delta Export Water Quality

Patterns of Delta island drainage water quality estimated with DeltaDWQ were then used to estimate likely effects on Delta export water quality. The movement of DW discharges and agricultural drainage to Delta export locations was determined from the results of hydrodynamic transport modeling performed by Resource Management Associates (RMA) with its Delta transport model. The RMA Delta transport model was used to simulate the movement of tracers from various inflow locations, including DW discharges and agricultural drainage, to Delta export locations at Rock Slough intake of Contra Costa Water District (CCWD), Banks Pumping Plant of the State Water Project (SWP), and Tracy Pumping Plant of the Central Valley Project (CVP). The RMA Delta transport model results have been used in DeltaDWQ to estimate the monthly average proportion of Delta exports that is discharged from the DW islands under DW project operations for each month of Delta inflow and export conditions. Estimates of DW discharge contribution to export volume were then used to estimate possible changes in monthly average DOC concentrations in Delta exports that may be attributable to DW project discharges, or the reduced agricultural drainage from the DW project islands.

DESCRIPTION OF THE DELTA DRAINAGE WATER QUALITY MODEL

The DeltaDWQ model simulates Delta agricultural island drainage water quality by simultaneously accounting for water, salt, and DOC budgets on agricultural Delta uplands and lowlands. Figure C4-1 shows the assumed water, salt, and DOC budget terms for Delta agricultural islands. The following sections describe the basic assumptions for each of these mass-balance DeltaDWQ modules and presents general results from DeltaDWQ modeling.

Delta Water Budget Terms

DeltaDWQ estimates water budgets for three types of Delta landscapes. These types and their corresponding water budget terms are as follows:

- **Open-water, riparian, and urban acreage.** Water budget terms include only evapotranspiration (ET) and rainfall; there are no soil moisture terms.

- **Delta upland agricultural island acreage.** Water budget terms include ET, rainfall, soil moisture storage, applied irrigation water, and pumped drainage water (all drainage is assumed to return to Delta channels without infiltration losses to regional groundwater recharge). Salt leaching is not included in the upland water budget terms because rainfall and irrigation drainage are sufficient to prevent salt buildup.

- **Delta lowland agricultural island acreage.** Water budget terms include ET, rainfall, soil moisture storage, seepage, water applied for irrigation and for salt leaching, and pumped drainage water.

Table C4-1 gives the average monthly water budget values for the open-water, riparian, and urban acreage. Table C4-2 gives average monthly values for the Delta upland region water budget. Table C4-3 gives average monthly values for the Delta lowland region water budget. The monthly water budget terms in DeltaDWQ are specified as inches of water.

Monthly rainfall is measured at several Delta locations and the estimated average is recorded in California Department of Water Resource's (DWR's) DAYFLOW database. Monthly average ET rates for open water, uplands, and lowlands are estimated from pan evaporation data, crop acreage, and assumed crop ET rates. A repeating monthly evaporation pattern totaling 55.4 inches per year was assumed for DeltaDWQ (Table C4-1). Estimates of irrigation leaching fraction (the ratio of drainage water to applied water), lowland seepage rates, minimum and maximum monthly soil moisture depths, and monthly drainage depths for salt leaching are more difficult to obtain. Because few of the Delta water budget terms are measured directly, confirmation of the assumed DeltaDWQ values is difficult. The model allows the uncertainty associated with these assumed water budget terms to be identified through sensitivity testing. The selected values for the DW impact assessments are described in the following sections.

Delta Consumptive Use

Comparison of DeltaDWQ estimates with those of other monthly water budget models of net consumptive use for the entire Delta cannot confirm individual water budget term assumptions. Net channel depletion values for the Delta as a whole are bounded by total rainfall and gross ET estimates, but net monthly water use patterns on Delta islands are modified by soil moisture storage changes and salt leaching practices, and the irrigation efficiency (ET/applied water) must be estimated independently.

Figure C4-2 shows simulated monthly net consumptive use, or "channel depletion", from the entire Delta for water years 1982-1991 from the DWR statewide operations model DWRSIM, the DWR Delta water budget database DAYFLOW, and DeltaDWQ. Figure C4-2 indicates that the maximum monthly channel depletion estimated with DeltaDWQ is slightly (300 cfs) higher than the values provided by DAYFLOW and DWRSIM. The DeltaDWQ estimate of average annual Delta net consumptive use of 820 thousand acre-feet per year (TAF/yr) was close to the average used in DWRSIM (844 TAF/yr) and about 15% higher than the DAYFLOW value (702 TAF/yr) for the same period (1967-1991).

Net channel depletion (i.e., consumptive use) is the only Delta water budget term required as input for monthly operations models (e.g., DWRSIM). Net channel depletion does not represent a complete Delta water budget because diversion and drainage terms are not specified.

Cropland Evapotranspiration

Tables C4-2 and C4-3 present monthly crop ET values assumed in DeltaDWQ for Delta uplands and lowlands that were obtained from the consumptive use model used by DWR for the Delta uplands and lowlands (DWR 1979). These ET values are the basis for Delta channel depletion estimates for summer months. Only irrigated portions of Delta uplands and lowlands contribute to net channel depletion volumes; idle or natural lands generally retain rainfall until ET losses deplete the soil moisture. In its consumptive use analysis, DWR uses estimates of about 50,000 acres of idle and natural land in the Delta uplands (26% of total) and about 54,000 acres in the Delta lowlands (14% of total).

Leaching Fraction

A common estimate of irrigation efficiency is 70%; thus, a leaching fraction of 30% is often assumed for estimating drainage volume associated with irrigation water. Under this assumption, for each inch of water required for crop ET, 1.43 inches (1.0/0.7) of water would be applied as irrigation water, and 0.43 inch (30% of water applied) would leach and appear as drainage. DeltaDWQ assumes this 30% leaching fraction for Delta uplands for all months with applied irrigation water (Table C4-2). The leaching fraction assumed in DeltaDWQ for Delta lowlands is 50% because water use is generally higher on Delta lowland islands, reflecting the peat soils, irrigation methods, and crop types of the Delta lowlands.

For the Delta lowlands, DeltaDWQ also assumes constant seepage from Delta channels of 1 inch per month (Table C4-3). Seepage is assumed to flow directly to drainage ditches and is therefore not used to satisfy crop ET. Delta lowlands also have a significant amount of salt leaching water applied and drained during winter to remove accumulated salts from the soil crop root zone. Applied leaching water was simulated in DeltaDWQ through specification of additional seepage (and drainage) depths during winter months. For December, January, and February, an additional 2 inches of applied water per month (6 inches per year) were specified to approximate salt leaching water practices on the Delta lowland islands (Table C4-3). DeltaDWQ can be used to determine the sensitivity of water use to different assumed ET, irrigation efficiency, leaching, and seepage rates, but these water budget terms were assumed to remain constant for DW impact assessment purposes.

Soil Moisture Storage

Because soil water (moisture) storage is difficult to estimate or measure, fairly simple assumptions are made in DeltaDWQ. These assumptions follow methods used in the DWR monthly consumptive use model of the Delta uplands and lowlands (DWR 1979). A minimum and maximum soil water storage depth is specified for each month. Rainfall increases soil water storage to the maximum specified depth before drainage occurs. Irrigation is required only if the soil water storage falls below the specified minimum storage depth.

The DWR consumptive use model represents several crop types with separate minimum and maximum soil water storage depths (corresponding to the root zone depth of each crop type). DeltaDWQ uses a single minimum and maximum soil water depth representing the average soil water depths of the irrigated crops for each month. The uplands and lowlands are modeled separately with different specified monthly soil water storage depths. Tables C4-2 and C4-3 give the assumed minimum and maximum monthly soil moisture storage depths for Delta uplands and Delta lowlands, respectively.

DW Island Drainage Records

The best available data for confirming Delta agricultural island water balance terms are records of drainage-pump power consumption. Power consumption is converted to flow volumes, using pump efficiency test results expressed as acre-feet per kilowatt-hour (af/kWh). Monthly pumping records for the four DW islands have been obtained for 1986-1991. Monthly pumping records are available beginning in 1986 for Bouldin Island, beginning in 1988 for Bacon Island, and beginning in 1990 for Webb and Holland Tracts.

Figure C4-3 compares DeltaDWQ estimates of Delta lowland drainage and measured pumping from the four lowland DW islands. Monthly pumping measurements from the four DW islands vary from 0 to 10 inches per month. Simulated pumping generally follows a double-peak pattern, with high pumping in winter in response to excess rainfall and salt leaching practices, and high summer pumping in response to excess irrigation drainage. There is considerable variation in the measured drainage between the four islands and from one year to the next. DeltaDWQ represents as assumed average lowland water budget that is required for incremental impact assessment of the DW project. The simulated drainage patterns are substantially different from some of the measured drainage patterns. Uncertainties in the estimated drainage volumes will not change the impact assessment results.

Simulated Drainage and Application Volumes

DeltaDWQ simulated Delta lowland drainage averaged 42.4 inches per year, for an annual Delta lowland island drainage volume of 1,210 TAF. Approximately one-half of annual lowlands island drainage occurs during the irrigation season, and the remainder occurs in winter following rainfall or salt leaching periods. Delta rainfall averaged 16.3 inches per year but varied from about 8 inches to 30 inches during 1967-1991 (DAYFLOW). The corresponding applied water simulated by DeltaDWQ, including seepage and water applied for salt leaching, averaged about 57 inches, for a total volume of 1,632 TAF/yr. About 342 TAF/yr (1 inch per month) was assumed to be seepage, and the remainder of 1,290 TAF/yr was assumed to be diverted through unscreened siphons in the Delta lowlands.

The lowland island drainage pattern simulated by DeltaDWQ most closely matches measured drainage pumping for Bouldin Island (Figure C4-3). Bacon Island drainage pumping was similar to modeled drainage in winter, but measured drainage on Bacon Island during the irrigation season was much higher than simulated drainage, averaging 8 inches per month. High summer pumping was apparently a result of the water management required for the row crops grown on Bacon Island soils. Drainage pumping from Webb and Holland Tracts for 1990 and 1991 was lower than simulated Delta lowlands drainage because of reduced agricultural irrigation during levee rehabilitation work and participation in the DWR emergency water bank program.

Delta Salt Budget Terms

Salt budget terms in DeltaDWQ are directly associated with the water budget terms. Salt concentrations are represented by EC because this is the most common field measurement of salinity. Agricultural island soil water EC values are lowered by rainfall and raised by water loss through ET. ET is the basic mechanism for salt buildup in soil water and for increases in salt concentrations between applied water and drainage water.

Seawater intrusion and other source water may increase salt concentrations in applied water and influence soil water and drainage salinity on agricultural islands. Because of different salinity conditions in Delta channels, DeltaDWQ separately represents salinity budgets for the Sacramento River and San Joaquin River regions of both the Delta uplands and lowlands. Channel water salinities in these four regions of the Delta are estimated separately. The water budgets are identical in the two uplands and two lowlands regions.

Applied Water Salinity

DeltaDWQ estimates applied water salinity (EC) for Delta uplands from Sacramento and San Joaquin River flow-EC regressions (power equations) and includes the effects of Delta outflow on seawater intrusion into the Sacramento and San Joaquin River lowlands with outflow-EC regressions (negative exponential equations). More accurate estimates of channel salinity can be obtained from a Delta hydraulic and salt transport model such as the RMA Delta transport model or the DWR Delta Simulation Model (DWRDSM) but may not be necessary for impact assessment of likely DW project operations on Delta export salinity.

Historical monthly EC measurements were used to adjust the DeltaDWQ estimates of inflow salinity and seawater intrusion effects. Figure C4-4 shows the simulated and measured monthly average EC values for the Sacramento River (Greene's Landing), the San Joaquin River (Vernalis), and Jersey Point. Simple flow regressions are sufficiently reliable for an assessment model such as DeltaDWQ for evaluating relative differences between DW project alternatives.

Salt Leaching Factors

DeltaDWQ estimates salt concentrations (EC) of soil water by mass balancing separately for the Sacramento and San Joaquin regions of the Delta uplands and lowlands. Mass balancing starts with the previous salt content of soil water plus the salt in the applied water minus the salt in the drainage water, assuming some monthly ratio between the drainage EC value and the soil water EC value. This monthly ratio is called the "leaching factor" in DeltaDWQ. Monthly "leaching factors" are the only salt budget coefficients required by the DeltaDWQ model. The leaching factor is an estimate of how effectively the salt in the soil moisture is removed by the drainage water.

The available drainage EC data indicate that the salt leaching factor is relatively high in winter, when rainfall and leaching water efficiently moves salt from the soil water to island drainage networks. The salt leaching factor generally decreases to relatively low values during the summer irrigation season because most excess applied water goes directly to drainage water, bypassing the soil water in the crop root zone, and does not provide efficient salt leaching.

The salt leaching factors used in DeltaDWQ were derived to match the seasonal patterns observed in drainage EC measurements from DW islands obtained as part of the DWR Municipal Water Quality Investigations (MWQI) program (see Table C2-3 in Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data"). Monthly salt leaching factors for the Delta uplands and lowlands are shown in Tables C4-2 and C4-3. These fixed monthly values are only approximations; actual salt leaching will depend on the rainfall, soil moisture salt storage, and irrigation practices (DWR 1994). The uncertainty in the assumed salt leaching factor will not change the impact assessment results but will change the simulated drainage EC patterns.

Electrical Conductivity Measurements of DW Island Drainage

Figure C4-5 shows periodic EC grab-sample measurements from Webb Tract and Bouldin Island (from two drainage pumping plants on each island) for 1987-1991 (see Appendix C2) compared with the monthly average drainage EC values simulated by DeltaDWQ for Delta lowlands in both the Sacramento and San Joaquin regions. The EC measurements show a seasonal pattern, with the highest EC values in drainage water during winter. Bouldin Island EC values were generally 0.2-0.4 millisiemens per centimeter (mS/cm) in the summer irrigation season, indicating very little increase above the EC values of water diverted onto the island in summer. For Bouldin Island, winter EC values were generally several times higher than summer values. The Bouldin Island measurements generally confirm the simulated pattern for Sacramento lowlands shown in Figure C4-5. The available drainage EC data for Webb Tract are higher than drainage EC data for Bouldin Island.

Figure C4-5 also shows periodic EC grab-sample measurements from Bacon Island and Holland Tract (with two pumping plants on Bacon Island and three on Holland Tract) during 1990 and 1991 (see Appendix C2). Reduced farming during levee rehabilitation and participation in the DWR emergency water bank program reduced drainage pumping from these islands during both years with EC measurements. DeltaDWQ simulates average conditions for the overall San Joaquin region Delta lowlands. The EC measurements from Bacon Island and Holland Tract generally follow the basic simulated pattern for San Joaquin lowlands shown in Figure C4-5. Much more drainage EC data will be needed to confirm the simulated Delta lowland drainage EC patterns.

Estimated Electrical Conductivity of Soil Water

Confirmation of simulated soil-water EC values is difficult because relatively few measurements of soil-water EC are available. Soil-water EC values simulated by DeltaDWQ for the Sacramento region of the Delta lowlands fluctuated from about 1 mS/cm to 3 mS/cm (Figure C4-6). Simulated soil-water EC values for the San Joaquin region of Delta lowlands fluctuated between about 1 mS/cm and 10 mS/cm (Figure C4-6). Most of the variation in soil-water EC is caused by dilution as the soil-water storage is increased by rainfall and leaching water.

Several field observations are available to confirm the approximate magnitude of DeltaDWQ simulations of soil-water EC. Saturated soil-water EC measurements from Holland Tract in 1992 were generally in the range of 0.5-5 mS/cm (see Table C3-7 in Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project"). In August 1989, 18 soil samples for Holland and Webb Tracts were analyzed for agricultural nutrients; 10 saturated soil extract samples from Holland Tract had EC values that averaged 7.9 mS/cm (range of 2.8-21.0 mS/cm) and eight samples from Webb Tract had EC values that averaged 6.0 mS/cm (range of 2.5-7.8 mS/cm) (Taylor pers. comm.). The model simulates soil-water EC values of 3 mS/cm for Delta lowlands with Sacramento River source water, and 10 mS/cm for San Joaquin River source water (Figure C4-6).

Delta Dissolved Organic Carbon Budget Terms

DOC budget terms in DeltaDWQ for Delta uplands and lowlands are similar to the EC budget terms, with the addition of source terms representing residues of vegetation decay and peat soil decomposition. Once released through vegetation decay or peat soil oxidation, DOC is assumed to be conservative and to accumulate like salt in the soil water of the crop root zone (see Appendix C2 for further discussion of DOC characteristics). Salt leaching factors used in the EC budget are also used in the DOC budget to account for leaching and drainage of accumulated soil water DOC.

Dissolved Organic Carbon Sources

Inflowing DOC concentrations are estimated using flow-DOC regressions for the Sacramento and San Joaquin Rivers that are similar to those for estimating inflowing EC. The only additional model coefficients required for the DOC budget are monthly DOC source terms for the Delta uplands and lowlands, and DOC source terms for DW reservoir islands and habitat islands.

Monthly DOC source terms for agricultural operations and DW project operations on the two habitat islands and two reservoir islands have been estimated from the water quality experiments described in Appendix C3. The annual load of DOC from Delta lowland islands was estimated from data presented in Appendix C3 to be approximately 12 g/m^2 (Table C4-3). The monthly distribution of DOC loading from Delta lowland agricultural islands was assumed to be uniform at 1 g/m^2. The loading of DOC from Delta uplands was estimated from data presented in Appendix C3 to be considerably less than that from the Delta lowlands. The annual upland DOC loading is assumed to be 6 g/m^2 with a uniform monthly distribution of 0.5 g/m^2 in DeltaDWQ (Table C4-2).

For the habitat islands, DOC was assumed to be released from decaying vegetation in flooded wetlands at a uniform rate of 3 g/m^2/month during the flooded wetland period of November through January, and to be released from peat soil leaching at a uniform rate of 1 g/m^2/month for the remainder of the flooded period, giving a total assumed loading of 12 g/m^2/year (Table C4-4).

For the DW reservoir islands, the source of DOC may depend on the sequence of water storage operations. If the islands are flooded, the peat soil oxidation will likely be lower than on Delta lowland agricultural islands because of expected moisture and temperature conditions. DeltaDWQ assumes 50% of the lowland agricultural loading rate of 1.0 g/m^2/month. If the reservoir islands are dry, the monthly rate is equal to the assumed lowland agricultural loading rate of 1.0 g/m^2/month. Wetland vegetation is simulated to grow during May-September. The additional loading of 8 g/m^2/year was assumed if vegetation was fully developed (dry conditions for 5 months). The loading was assumed to be proportional to the number of dry months during the growing season.

The assumed total loading from dry wetlands would be 20 g/m^2/year, corresponding to the experimental results from the Holland Tract demonstration wetlands (Appendix C3). The vegetation loading of 8 g/m^2 corresponds to the results from the vegetation experiments (Appendix C3). The assumed loading from "wet" DW reservoir islands with no vegetative growth would be reduced to 6 g/m^2/year.

Although these assumed DOC loading rates are somewhat uncertain for both lowland agricultural islands and the DW project islands, the magnitude of DOC loading from lowland agricultural islands and the DW project islands is assumed to be approximately the same (each about 12 g/m^2).

The possible effects of DW project operations on DOC concentrations will depend on the estimated discharge of DOC loading from the DW project islands compared with the agricultural drainage of DOC loading from the DW project islands under No-Project Alternative conditions. Because the entire Delta lowland region contributes DOC loading at about the same rate as the DW project islands, likely impacts result from the assumed seasonal shift in DOC loading from the DW project islands. The DeltaDWQ results for DOC will be described in the following sections.

Dissolved Organic Carbon Concentrations in DW Island Drainage

Figure C4-7 shows periodic grab-sample DOC measurements from drains on the four DW project islands (see Appendix C2 for other Delta drainage DOC measurements) compared with monthly average DOC simulations of lowland agricultural DOC drainage concentrations from DeltaDWQ. Like EC, DOC concentrations are generally lower during the summer irrigation period and are much greater during winter. The DeltaDWQ simulated DOC concentration pattern for Delta lowlands agricultural islands appears consistent with the available data. DOC concentrations generally remained less than 20 mg/l during the irrigation season but increased to greater than 50 mg/l during winter. Grab samples collected once per month may not correspond well to average monthly concentrations that DeltaDWQ is estimating.

Many of the measured DOC concentrations from Webb Tract and Bouldin Island (Figure C4-7) are greater than the DeltaDWQ-simulated values. However, the measurements from Bacon Island and Holland Tract (Figure C4-7) are considerably lower than the simulated values. DeltaDWQ simulates the average drainage concentration with average drainage volumes for Delta lowland islands. Increasing the assumed DOC loading may provide a better match with the measured Webb Tract and Bouldin Island DOC concentrations, but this would increase the simulated Delta export DOC concentrations above the measurements, as described in a later section of this appendix. These simulated Delta lowland agricultural drainage DOC concentrations provide a reasonable basis for impact assessment of DW project effects on DOC concentrations in the Delta.

Estimated Soil-Water Dissolved Organic Carbon

Verification of the simulated soil-water DOC values is difficult because relatively few measurements of soil-water DOC are available. Delta lowland soil-water DOC values simulated by DeltaDWQ fluctuated between about 60 mg/l and 180 mg/l (Figure C4-8). Saturated soil-water DOC measurements from Holland Tract (described in Appendix C3) were generally in the range of 50-250 mg/l. Simulated soil-water DOC patterns are similar for the Sacramento and San Joaquin regions of the Delta lowlands because the applied water has about the same DOC concentrations, and the loading from vegetation and peat soil decay is the major source for the soil-water DOC concentrations.

Both EC values and DOC concentrations in the soil water increase as a result of ET, but DOC concentrations are also increased by the addition of DOC from vegetation and soil decomposition processes. Therefore, the ratio of DOC to EC in the drainage water increases above that of the applied Delta channel water. Drainage DOC concentrations in excess of those calculated from the drainage water EC value and the applied water DOC/EC ratio can provide an indirect measure of the fraction of the drainage DOC originating in the Delta lowland island peat soil and vegetation decomposition processes.

Figure C4-9 shows measured DOC concentrations plotted against measured EC values for the DW island drainage samples. The DOC/EC ratio of 0.01 (2 mg/l DOC: 200 mS/cm EC), which is the expected ratio based on Sacramento River DOC and EC data, is shown as a line in Figure C4-9. The DOC/EC ratio for the San Joaquin River is approximately 0.005 (3 mg/l DOC: 600 mS/cm EC). DOC values above these lines are higher than expected (in the absence of an island source of DOC). The fraction of the DOC value above this line provides a rough estimate of the portion of the drainage DOC in that sample that originated on the island from decomposition sources. The portion of the DOC below the line can be explained by ET accumulation and salt leaching practices, without an island source of DOC from vegetation decay and peat soil oxidation.

DW DISCHARGE ELECTRICAL CONDUCTIVITY VALUES AND CONCENTRATIONS OF DISSOLVED ORGANIC CARBON

The DeltaDWQ model estimated monthly average EC values and DOC concentrations in discharges from the proposed DW project using the results of DeltaSOS simulations of the proposed DW project for 1967-1991 (see Appendix A3). Monthly diversion, storage, and discharge volumes for the reservoir islands simulated in DeltaSOS were used in DeltaDWQ to estimate EC and DOC concentrations in drainage from the reservoir islands.

Under the proposed DW project, two of the DW islands would be managed for wildlife habitat. A portion of these habitat islands would be flooded to provide waterfowl habitat beginning in September and continuing through May. A specified volume of water (1 TAF) is assumed to remain in borrow ponds and ditches throughout the year. During the waterfowl habitat period, some water from the flooded wetlands (0.5 TAF) would be circulated (discharged and diverted) each month. An assumed water budget for the habitat islands is used in DeltaDWQ to estimate EC and DOC concentrations in drainage water from the specified acreage of habitat islands. The assumed water budget terms for the habitat islands are given in Table C4-4.

Figure C4-10 shows the simulated monthly storage volume for the DW reservoir islands for 1967-1991 for Alternative 2 (slightly greater average DW discharges than under Alternative 1). During some years, the reservoir islands were simulated to fill and empty more than once, while in other simulated years water was not available and the reservoir islands remained empty. In a few years, the reservoir islands were simulated to remain full for an extended period until pumping capacity was available at the Delta export locations. Figure C4-10 shows the simulated discharge flows corresponding to the storage patterns. DeltaDWQ assumes that a specified minimum seepage flow of 30 cfs would circulate each month (2 inches/month), so that the buildup of DOC concentrations from the continuous loading would be limited during periods when the reservoir islands are empty.

Figure C4-11 shows monthly DOC concentrations simulated by DeltaDWQ for DW habitat islands. The DeltaDWQ estimates of Delta lowland agricultural drainage DOC concentrations are shown for comparison. Although the specified annual DOC loading is assumed to be the same for agricultural and habitat islands, the monthly patterns of DOC loading, drainage discharge, and resulting DOC concentrations are somewhat different.

Figure C4-11 also shows monthly DOC concentrations simulated by DeltaDWQ for the DW reservoir islands under Alternative 2. The annual DOC loading from flooded reservoir islands is assumed to be half that from agricultural and habitat islands because the leaching of peat soil is expected to be less and vegetation will be greatly reduced. During periods when the reservoir islands would be empty, however, decay of vegetation is assumed to add 8 g/m^2 of DOC to the reservoir islands and greatly increase the DOC concentration in the small amount of circulating water. The reservoir island DOC concentrations would be reduced by filling of DW storage water, so the possible effect on export concentrations would be limited. The monthly pattern of discharge concentrations from the DW reservoir islands is therefore quite different from the pattern of agricultural drainage concentrations (Figure C4-7).

The simulated annual loading from the DW reservoir islands for Alternative 2 averaged 11.8 g/m^2 which was about the same as the assumed loading from agricultural drainage. These DeltaDWQ-simulated EC and DOC concentrations of discharges from the DW project habitat and reservoir islands cannot be directly confirmed because there are no measurements from existing habitat or reservoir islands in the Delta lowlands. The DeltaDWQ model can be used to determine the sensitivity of the simulated discharge EC and DOC concentrations to the specified water budget, salt leaching factors, and DOC loading terms, but these were all assumed to remain constant for impact assessment purposes. Simulation of the 25-year period (water years 1967-1991) provides an indication of the range of possible discharge concentrations caused by variations in Delta hydrologic conditions. Similarly, in the next section, the possible effects of DW operations on Delta export EC and DOC concentrations are estimated for the range of Delta hydrologic conditions represented by the 1967-1991 period.

ESTIMATED ELECTRICAL CONDUCTIVITY AND CONCENTRATIONS OF DISSOLVED ORGANIC CARBON IN DELTA EXPORTS

Water quality of Delta exports can be estimated using percentage contributions from each source of Delta water and estimated EC and DOC concentrations in the source water. Sources of Delta export water include the Sacramento and San Joaquin Rivers, Yolo Bypass and eastside rivers, tidal exchange (seawater intrusion), agricultural drainage, and DW discharges. DeltaDWQ uses simplified estimates of the source contributions to calculate expected EC values and DOC concentrations in Delta exports.

Figure C4-12 shows the simplified Delta flow pathways assumed in DeltaDWQ. Sacramento River water flows through half the Delta uplands acreage, and some portion of the Sacramento River flow (determined by DeltaSOS model) enters the Delta lowlands through the Delta Cross Channel (DCC), Georgiana Slough, and Threemile Slough. San Joaquin River water flows through the other half of the Delta uplands and is exported directly or enters the Delta lowlands. Eastside streams enter the Delta lowlands directly. Tidal exchange (seawater intrusion) in the vicinity of Jersey Point increases EC in Delta lowland channels.

DeltaDWQ assumes that each Delta export location has identical water quality, with water flowing from the Delta lowland channels with agricultural drainage and DW discharges added in. The RMA Delta transport model was used to provide more accurate estimates of agricultural drainage and DW discharge contributions to water at each of the export locations (CCWD, SWP, and CVP). The RMA Delta transport model uses the monthly Delta upland and lowland drainage volumes that are estimated with DeltaDWQ but accounts for actual discharge locations and monthly flow patterns within the Delta to calculate the percentage of agricultural drainage that is transported to each export location (see Appendix B1, "Hydrodynamic Modeling Methods and Results for the Delta Wetlands Project"). The differences between the export locations was not considered substantial, so the DeltaDWQ assessment model was used.

Figure C4-13 shows estimated EC values in Delta exports simulated by DeltaDWQ using historical inflows without the proposed DW project for 1982-1991. Periods of high San Joaquin River inflows and seawater intrusion episodes contribute to the highest simulated EC values in Delta exports. Observed EC values at the three export locations (see Appendix C2) are shown for comparison in Figure C4-13. The simulated export EC values generally are representative of measured EC at the three Delta export locations.

Figure C4-14 shows the DeltaDWQ-simulated DOC concentrations in Delta exports, using historical inflows without the DW project for 1982-1991. The observed DOC concentrations at the three export locations (see Appendix C2) are shown for comparison. The simulated export DOC concentrations generally are representative of measured DOC at the three export locations.

Figure C4-15 shows the measured and predicted Sacramento and San Joaquin River DOC concentrations for 1982-1991. Many months had measured DOC concentrations that were higher than the DeltaDWQ estimates for both the Sacramento and San Joaquin Rivers. During these months, the expected Delta export DOC concentrations may actually be higher than the simulated concentrations.

Simulated Delta export DOC concentrations are often higher than the measured DOC at the three export locations, suggesting that the assumed DOC loading from Delta agricultural drainage or the inflow DOC estimates are too high in DeltaDWQ. However, the estimated inflow DOC concentrations are often lower than measured and the specified upland DOC load of 6 g/m^2/year and the specified lowland DOC load of 12 g/m^2/year are relatively low compared with estimates from available field data described in Appendix C3, "Water Quality Experiments on Potential Sources of Dissolved Organics and Trihalomethane Precursors for the Delta Wetlands Project". Although there are remaining uncertainties in simulating Delta drainage water quality, the DeltaDWQ simulations of export EC and DOC concentrations are determined to be adequate for impact assessment of DW project operations.

Figure C4-16 shows DeltaDWQ monthly simulations of DOC at the export locations with Alternative 2 operations. The difference in DOC concentration in Delta exports from the No-Project Alternative is also shown. The maximum increase in DOC predicted during months of DW storage discharges is about 1.0 mg/l, and simulated DW operations reduced Delta export DOC concentrations during most months. The simulated export DOC concentrations without any Delta agricultural drainage are shown for comparison. Simulated DOC without Delta agricultural drainage averaged 2.75 mg/l for the 1967-1991 period. Delta export DOC with Delta agricultural drainage but without DW operations averaged 4.06 mg/l. Delta export DOC with DW operations averaged 4.00 mg/l. Estimated DOC concentrations in Delta exports constitute the primary input required for the water treatment plant simulation model, described in Appendix C5, "Modeling of Trihalomethane Concentrations at a Typical Water Treatment Plant Using Delta Export Water".

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Table C4-1. Monthly Water Budget Terms for Delta Open-Water, Riparian, and Urban Acreage

Month	Water Evapotranspiration[a] (inches)	Rain[b] (inches)
October	3.7	0.8
November	1.7	2.2
December	0.9	2.6
January	1.0	3.2
February	1.9	2.5
March	3.4	2.7
April	5.1	1.2
May	6.9	0.4
June	7.9	0.1
July	9.0	0.1
August	8.0	0.1
September	5.9	0.4
Annual	55.4	16.3

Notes: Acreages by landform category:

Open water = 54,000 acres
Riparian = 9,000 acres
Urban (rain only) = 26,200 acres.

[a] Davis Evaporation Pan (adjusted for open water) monthly averages.

[b] Historical monthly rainfall values from DAYFLOW.

Table C4-2. Monthly Water, Salt, and DOC Budget
Terms for the Delta Uplands

Month	Assumed Crop ET (inches)	Leaching Fraction	Minimum Soil Moisture Depth (inches)	Maximum Soil Moisture Depth (inches)	Leaching Factor (drainage EC/soil water EC)	DOC Load (g/m_2)
October	1.8	0.30	2	4	0.2	0.5
November	1.2	0.30	2	4	0.3	0.5
December	0.6	0.30	2	4	0.4	0.5
January	0.7	0.30	2	4	0.5	0.5
February	1.5	0.30	2	4	0.4	0.5
March	2.1	0.30	2	4	0.3	0.5
April	2.7	0.30	2	4	0.2	0.5
May	4.1	0.30	2	4	0.1	0.5
June	5.6	0.30	2	4	0.1	0.5
July	6.9	0.30	2	4	0.1	0.5
August	5.4	0.30	2	4	0.1	0.5
September	3.3	0.30	2	4	0.1	0.5
Total						6.0

Notes:

Irrigated	142,500 acres	
Idle and natural	49,900 acres	(26%)
Total	192,400 acres	

Table C4-3. Monthly Water, Salt, and DOC Budget
Terms for the Delta Lowlands

Month	Assumed Crop ET (inches)	Leaching Fraction	Minimum Soil Moisture Depth (inches)	Maximum Soil Moisture Depth (inches)	Seepage and Leaching Applied (inches)	Leaching Factor (drainage EC/soil water EC)	DOC Load (g/m^2)
October	1.4	0.50	4	8	1.0	0.2	1.0
November	1.1	0.50	4	8	1.0	0.3	1.0
December	0.6	0.50	4	8	3.0	0.4	1.0
January	0.7	0.50	4	8	3.0	0.5	1.0
February	1.5	0.50	4	8	3.0	0.4	1.0
March	2.1	0.50	4	8	1.0	0.3	1.0
April	2.7	0.50	4	8	1.0	0.2	1.0
May	3.8	0.50	4	8	1.0	0.1	1.0
June	4.9	0.50	4	8	1.0	0.1	1.0
July	5.8	0.50	4	8	1.0	0.1	1.0
August	4.3	0.50	4	8	1.0	0.1	1.0
September	2.3	0.50	4	8	1.0	0.1	1.0
Total					18.0		12.0

Notes: Acreages by land use category:

	Lowlands Total		DW Project	
Irrigated	342,400		17,000	
Idle and natural	54,200	(14%)	3,000	(15%)
Total	396,600		20,000	

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Table C4-4. Monthly Water and DOC Budget Terms
for the DW Reservoir and Habitat Islands

Month	Reservoir Islands		Habitat Islands			
	Vegetation DOC Load (g/m²)	Peat DOC Load[a] (g/m²)	Active Storage[b] (TAF)	Diversion[c] (TAF)	Discharge[c] (TAF)	DOC Load (g/m²)
October	2.0	1.0	2.0	1.4	0.6	1.0
November	2.0	1.0	3.4	2.4	1.0	3.0
December	2.0	1.0	5.0	3.3	1.7	3.0
January	2.0	1.0	4.5	2.0	2.5	3.0
February	0.0	1.0	4.3	2.0	2.2	1.0
March	0.0	1.0	1.4	0.0	2.9	1.0
April	0.0	1.0	0.5	0.0	0.9	0.0
May	0.0	1.0	0.0	0.0	0.5	0.0
June	0.0	1.0	0.0	0.0	0.0	0.0
July	0.0	1.0	0.0	0.0	0.0	0.0
August	0.0	1.0	0.0	0.0	0.0	0.0
September	0.0	1.0	1.2	1.2	0.0	0.0
Total	8.0	12.0				12.0

Note: Minimum circulation flow of 30 cfs (1.8 TAF) on reservoir islands.

[a] Assuming dry conditions; 0.5 g/m2 assumed for flooded periods because of lower oxidation rates.

[b] Based on the HMP for Holland and Bouldin Islands. Minimum storage of 1 TAF includes wetlands and ponds.

[c] Rainfall would be added to discharge or subtracted from diversion.

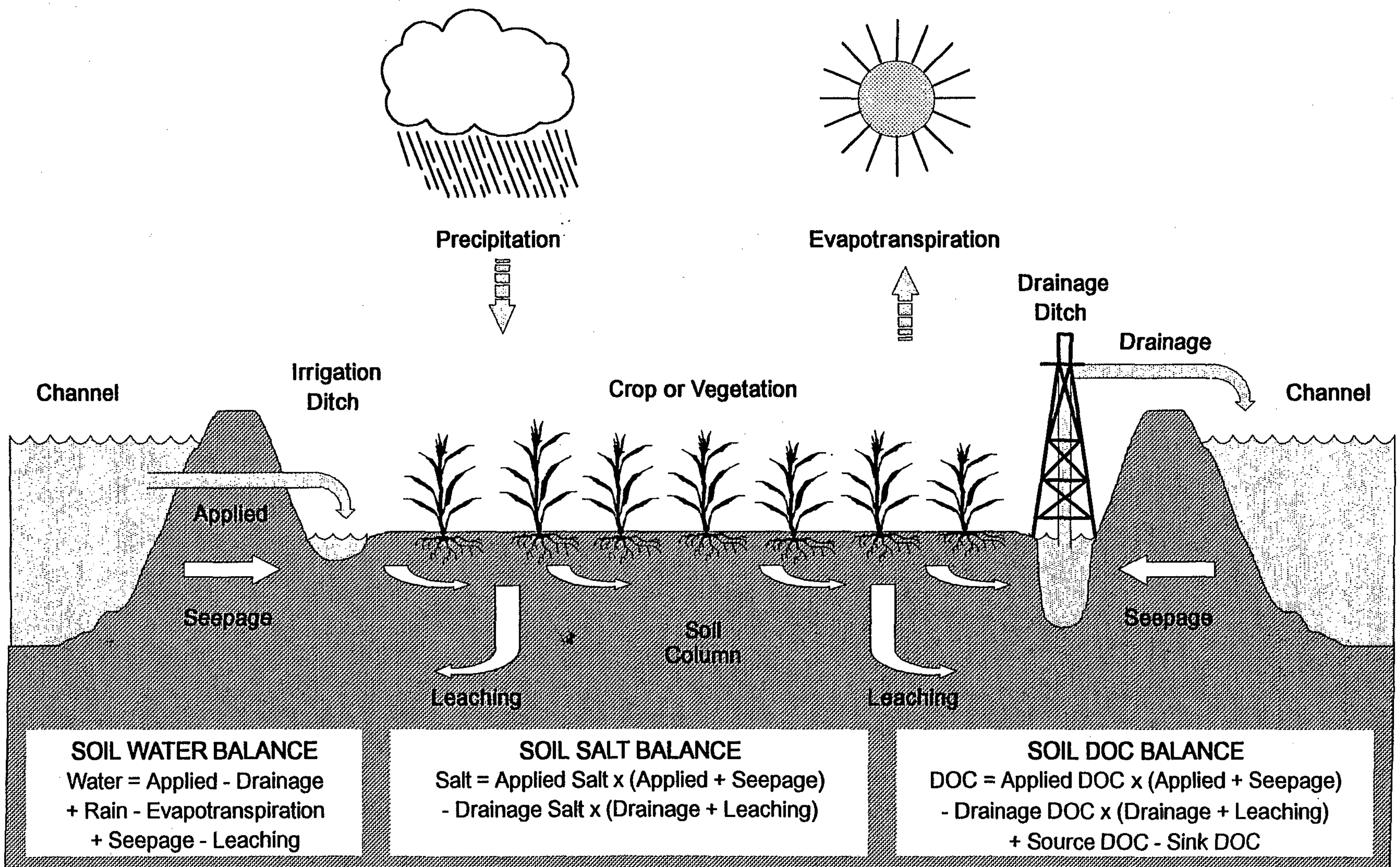

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Figure C4-1.
Conceptual Water, Salt, and Dissolved Organic Carbon Budgets for Delta Agricultural Islands

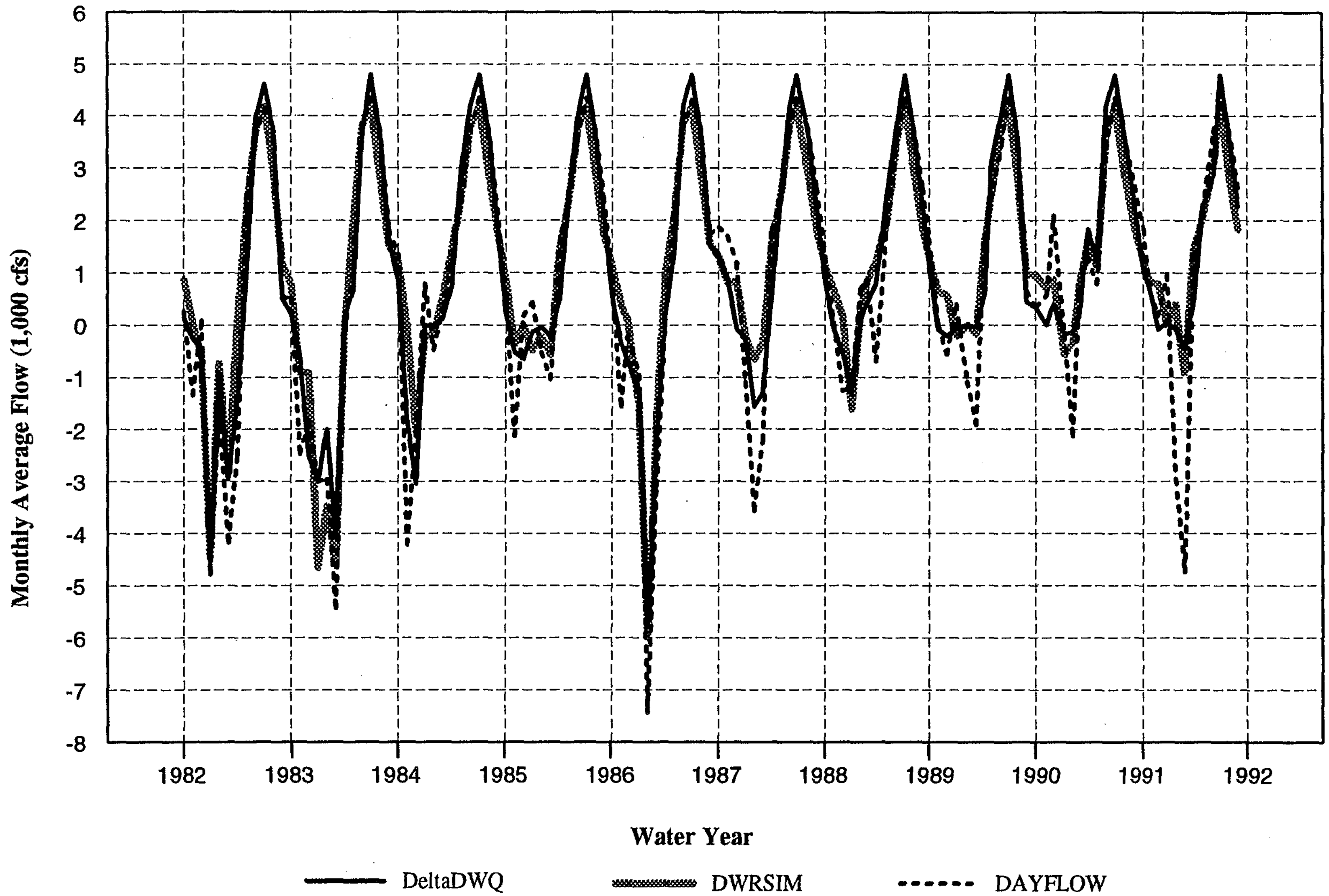

Figure C4-2.
Comparison of Estimated Net Delta Depletion for Water Years 1982-1991

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

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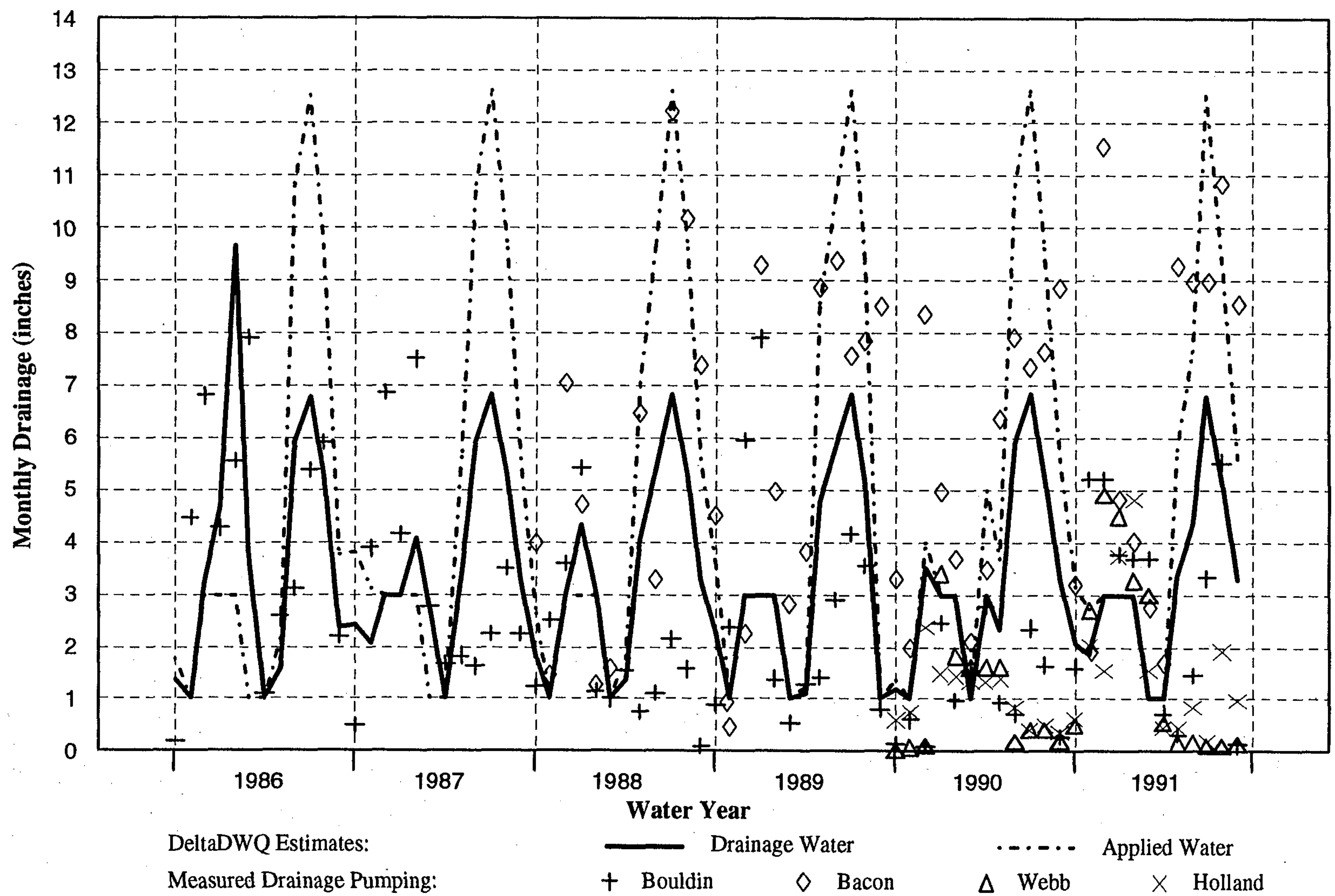

Figure C4-3.
DeltaDWQ Estimates of Delta Lowlands Drainage and Measured Drainage Pumping from the DW Project Islands for Water Years 1986-1991

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

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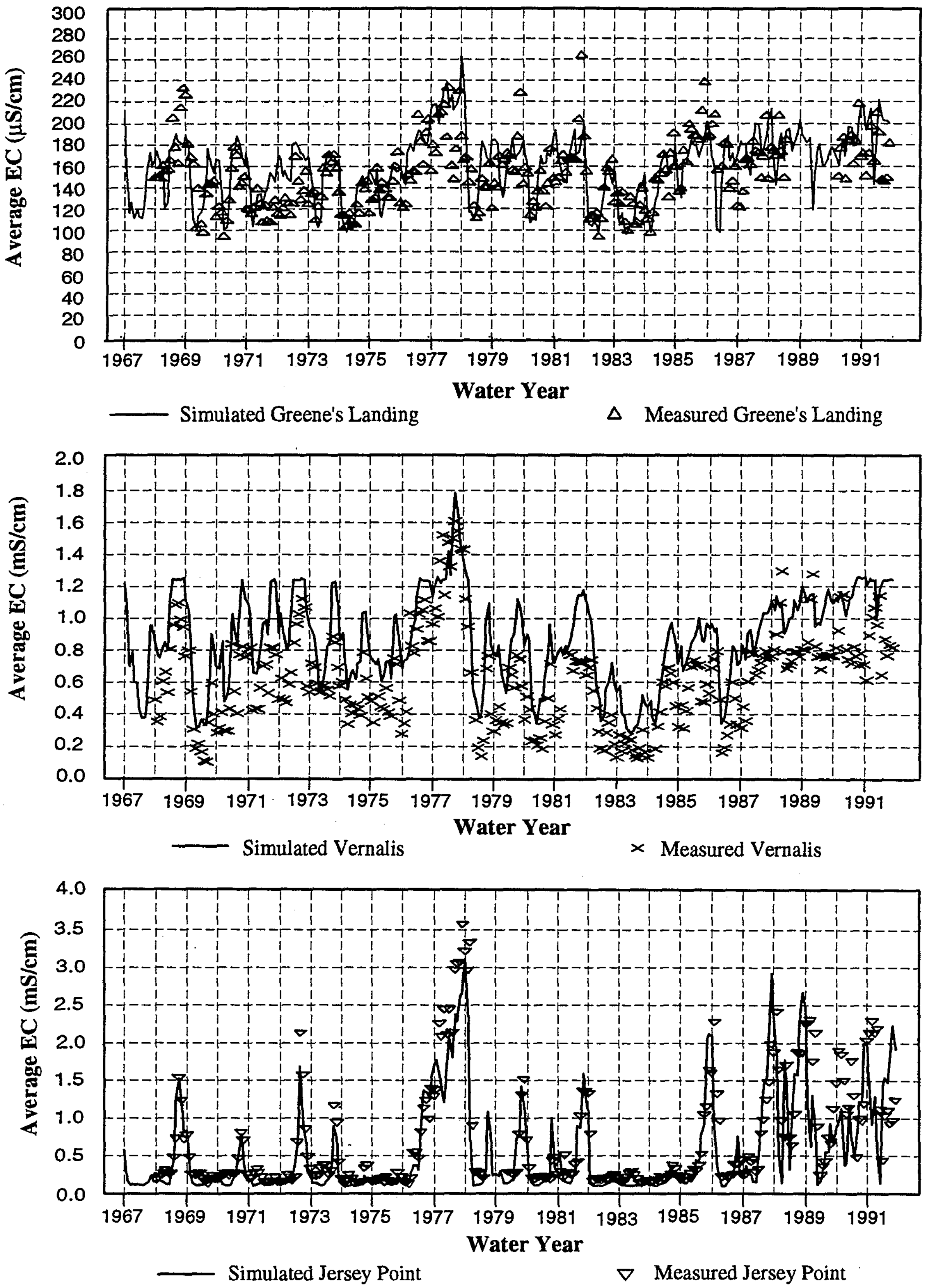
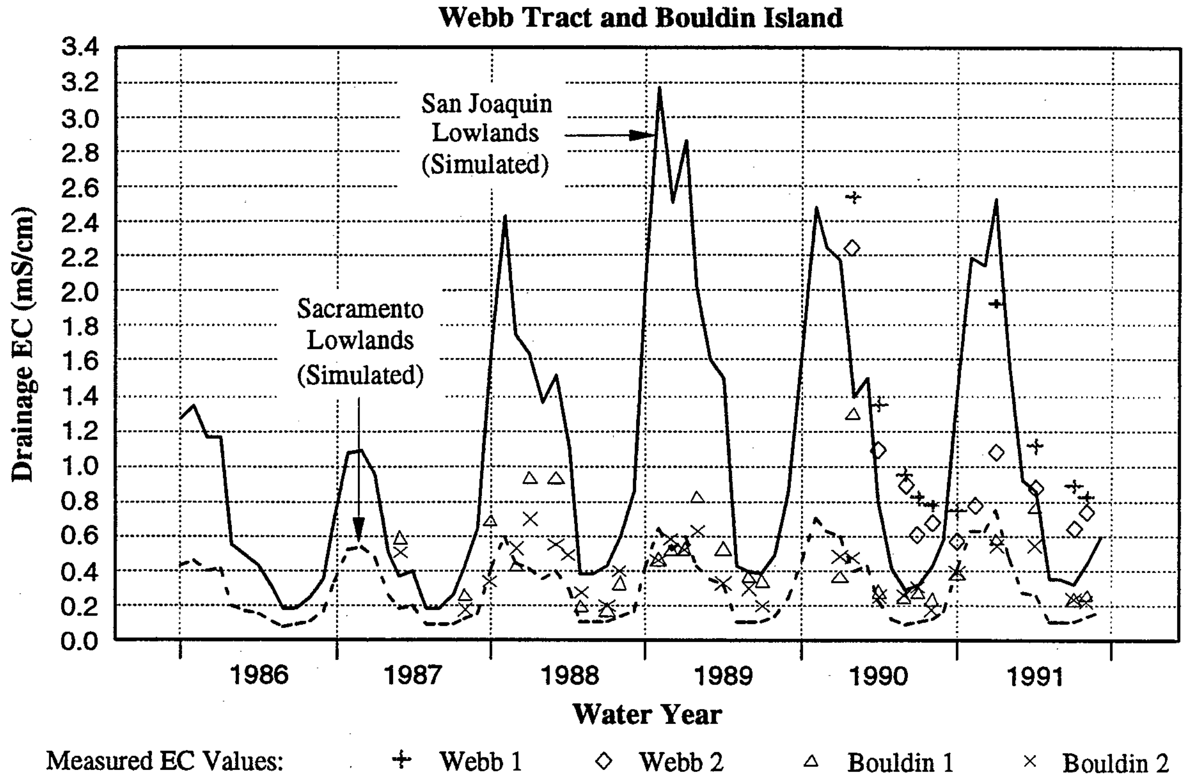


Figure C4-4.
Measured and Simulated Monthly EC at Greene's Landing, Vernalis, and Jersey Point for 1967-1991

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



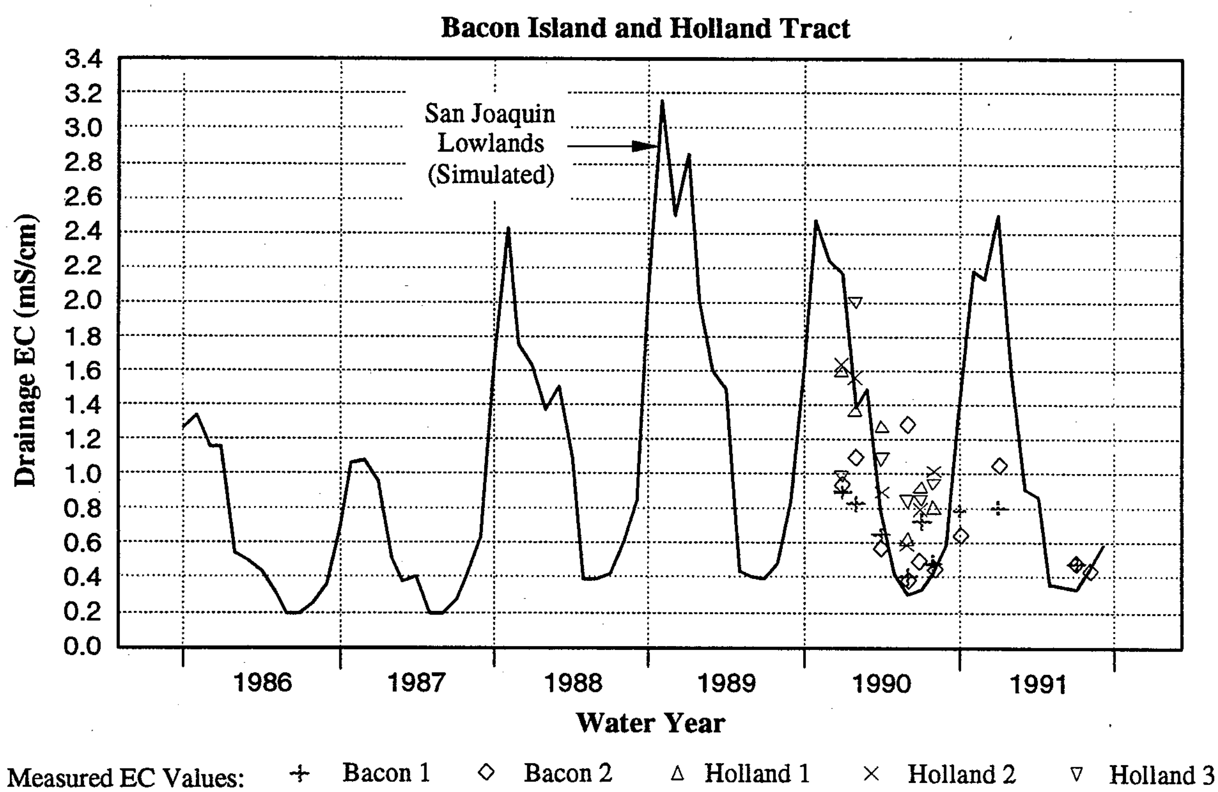


Figure C4-5.
Measured and Simulated Drainage EC Values for the DW Project Islands for 1986-1991

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

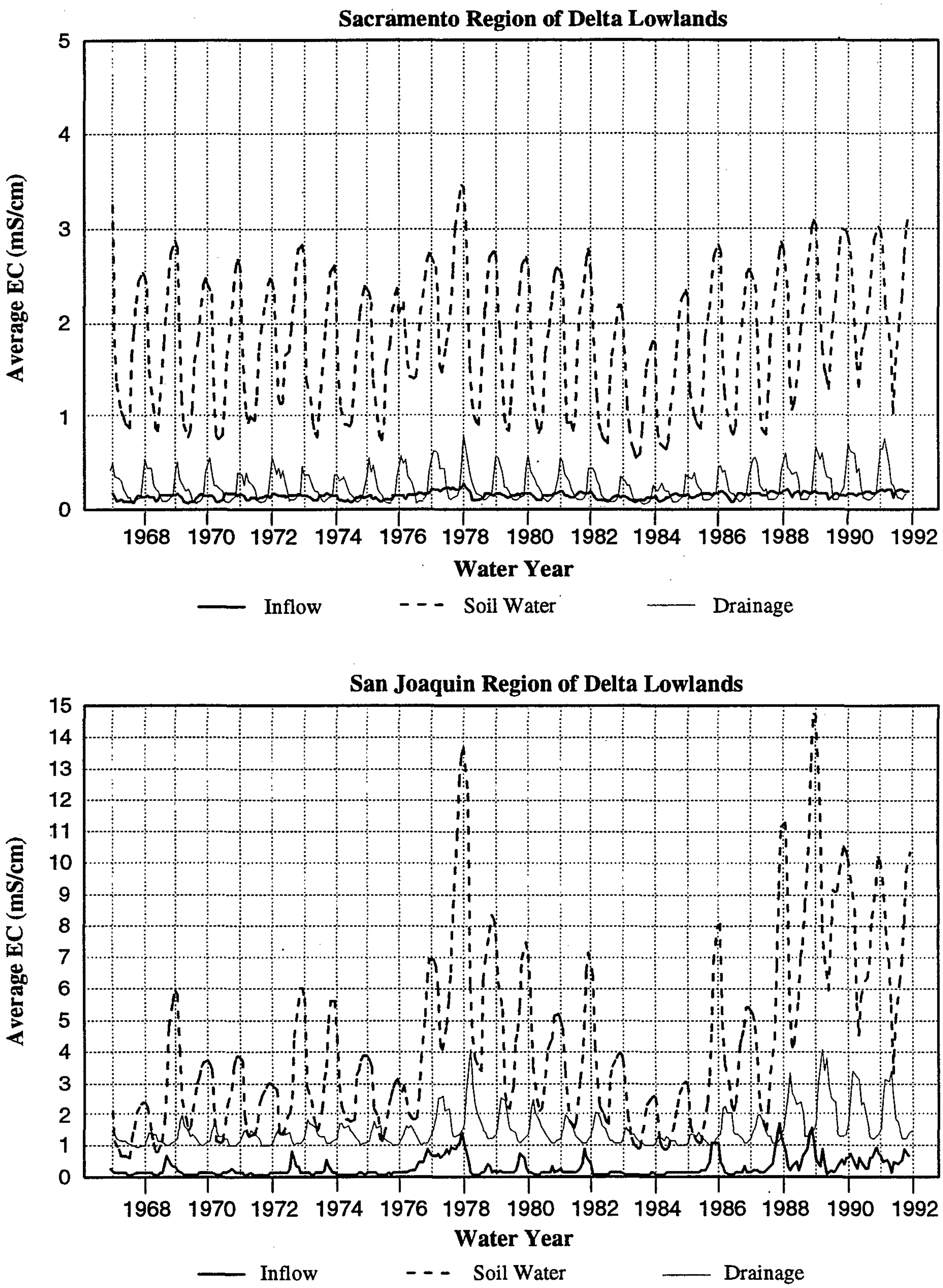
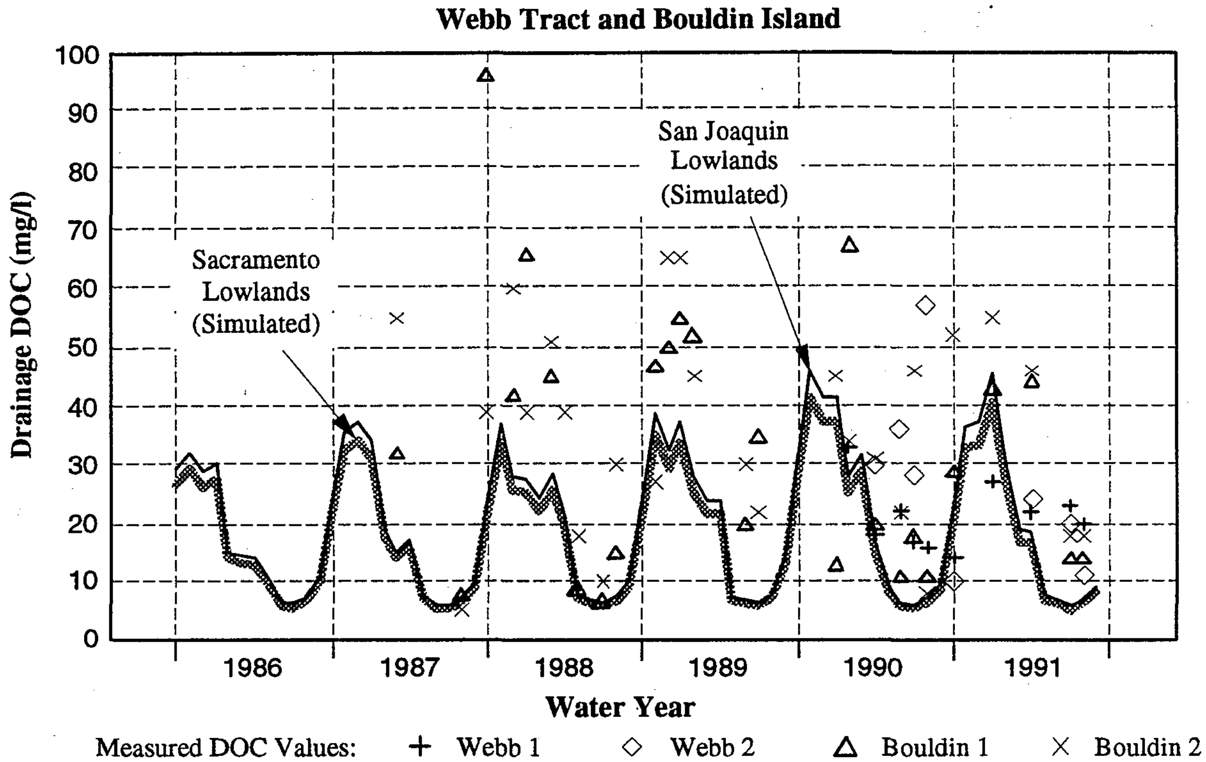


Figure C4-6.
Simulated Soil-Water EC for the Sacramento and San Joaquin Regions of Delta Lowlands with Historical Inflows and Exports for 1967-1991

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



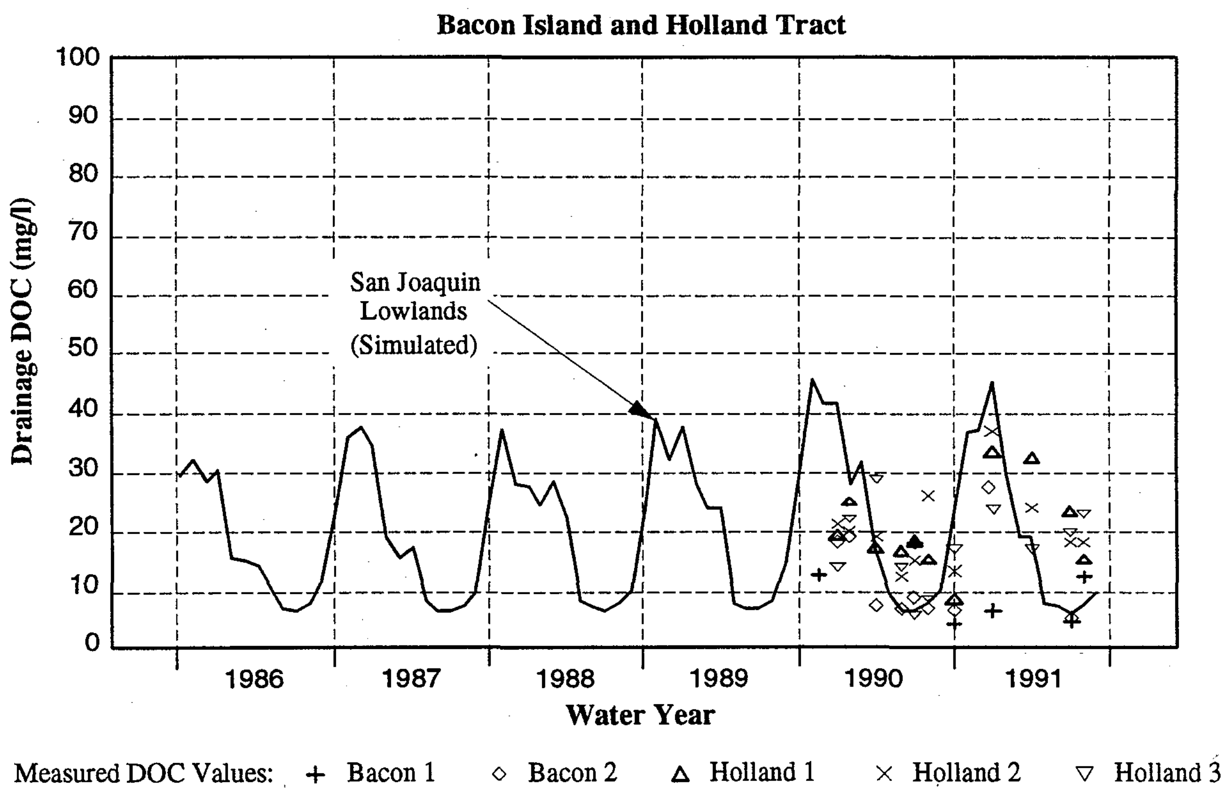
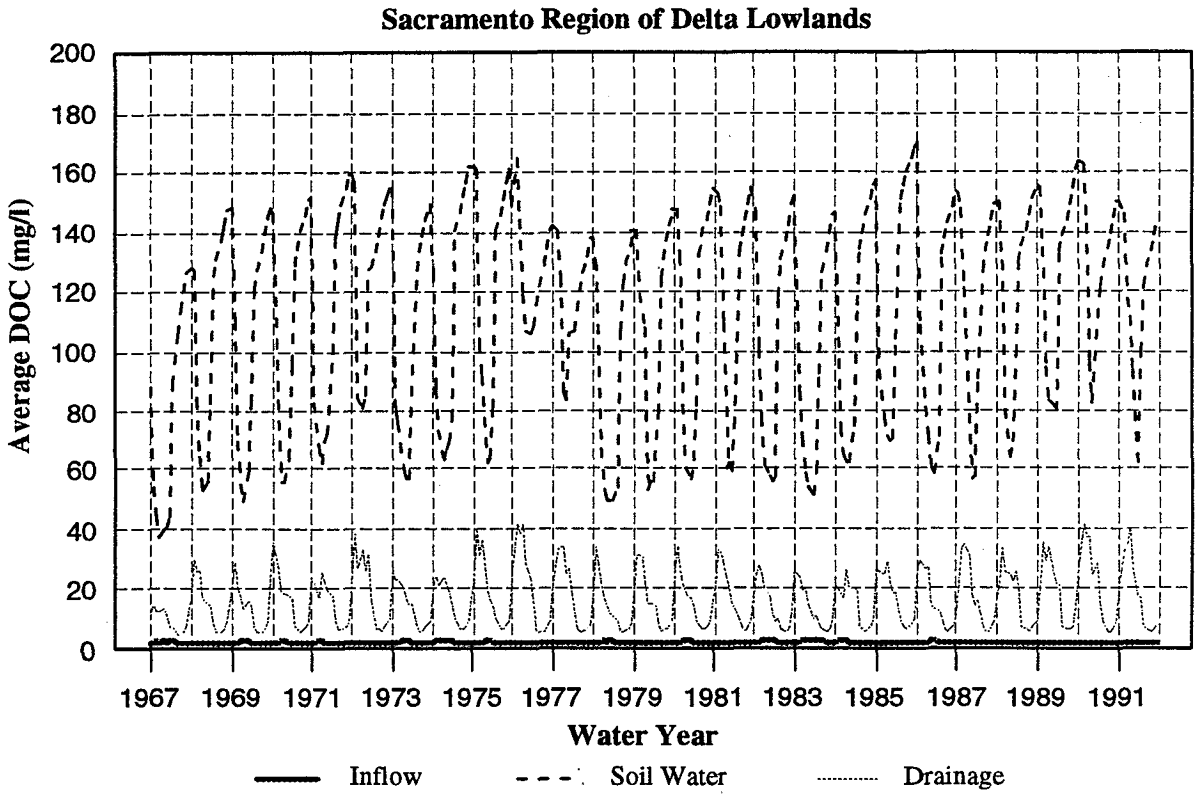


Figure C4-7.
Measured and Simulated Drainage DOC Values for the DW Project Islands for 1986-1991

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



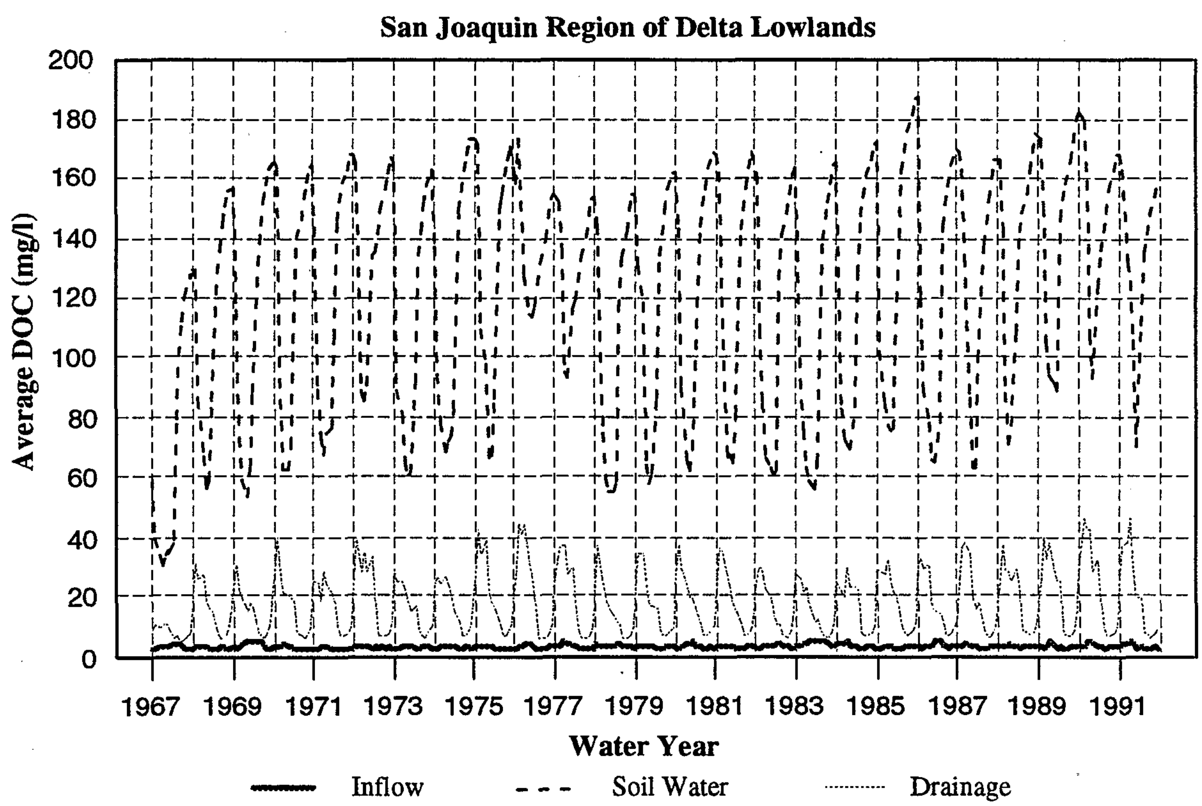


Figure C4-8.
Simulated Soil-Water DOC for the Sacramento and San Joaquin Regions of Delta Lowlands with Historical Inflows and Exports for 1967-1991

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

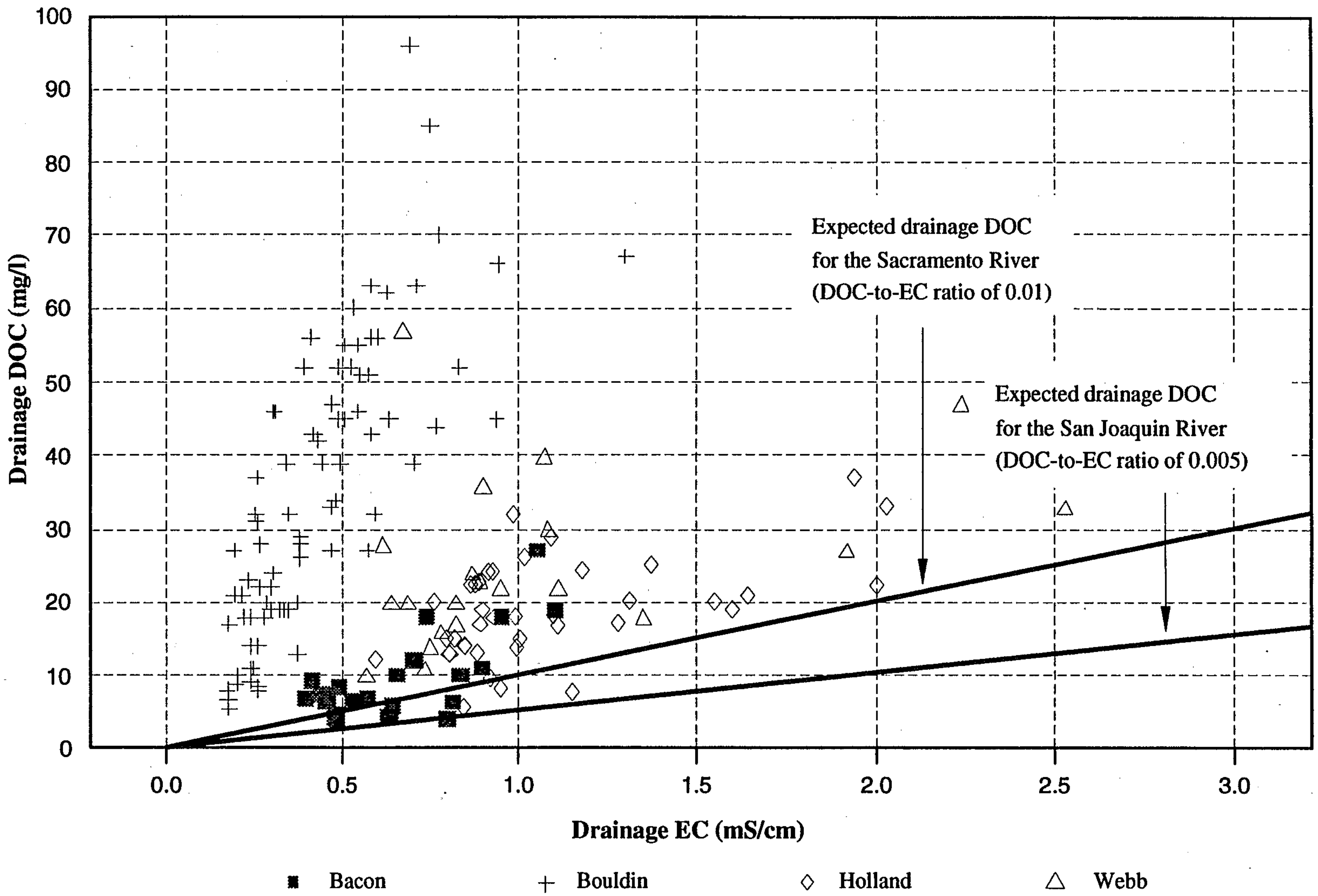


Figure C4-9.
Relationship between DW Island Drainage DOC Concentrations and EC Values for 1986-1991

DELTA WETLANDS
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Prepared by: Jones & Stokes Associates

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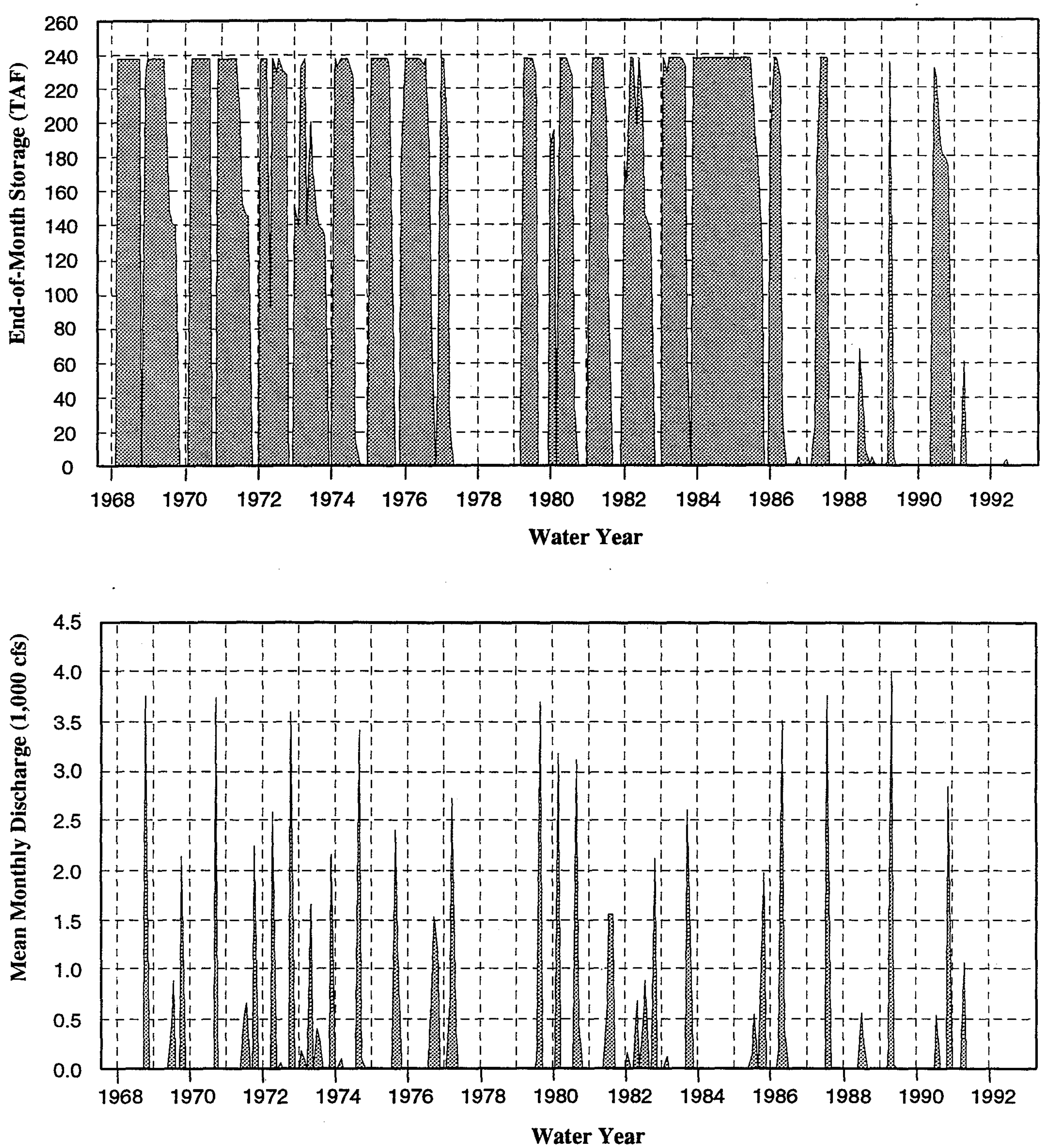

Figure C4-10.
Simulated End-of-Month Storage Volumes and Discharges for DW Reservoir Islands under Alternative 2 for 1967-1991

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

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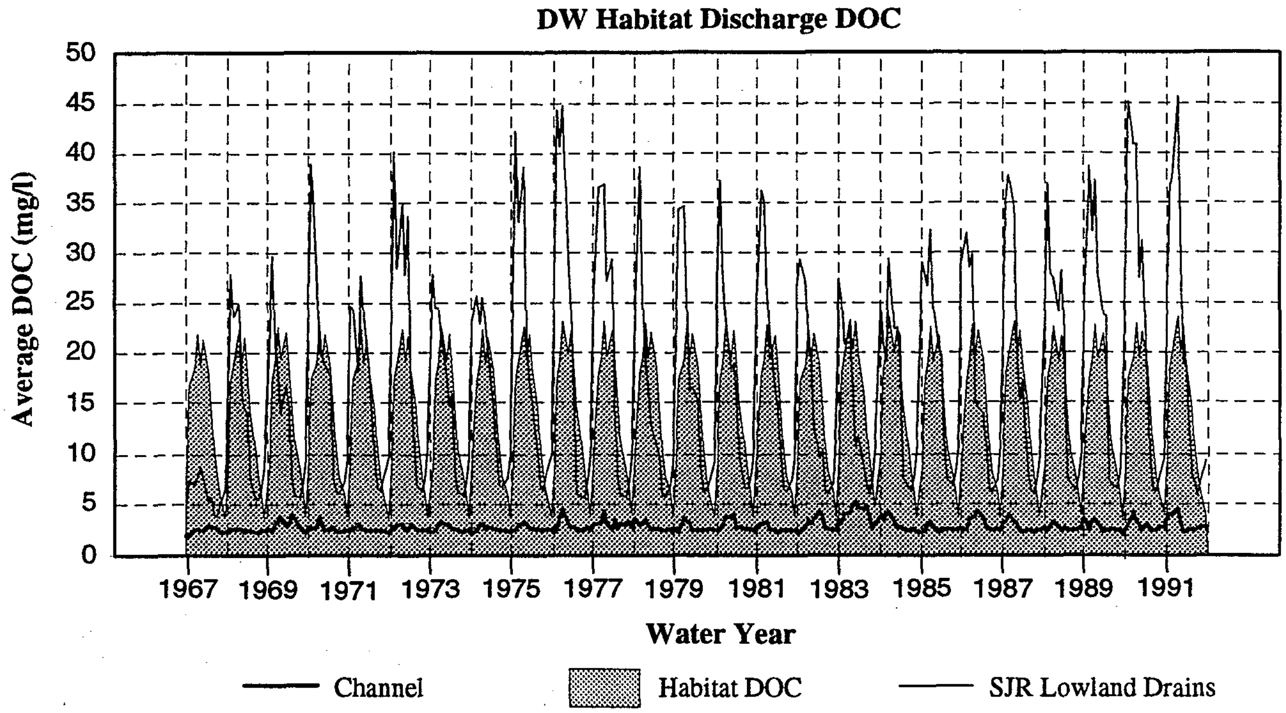

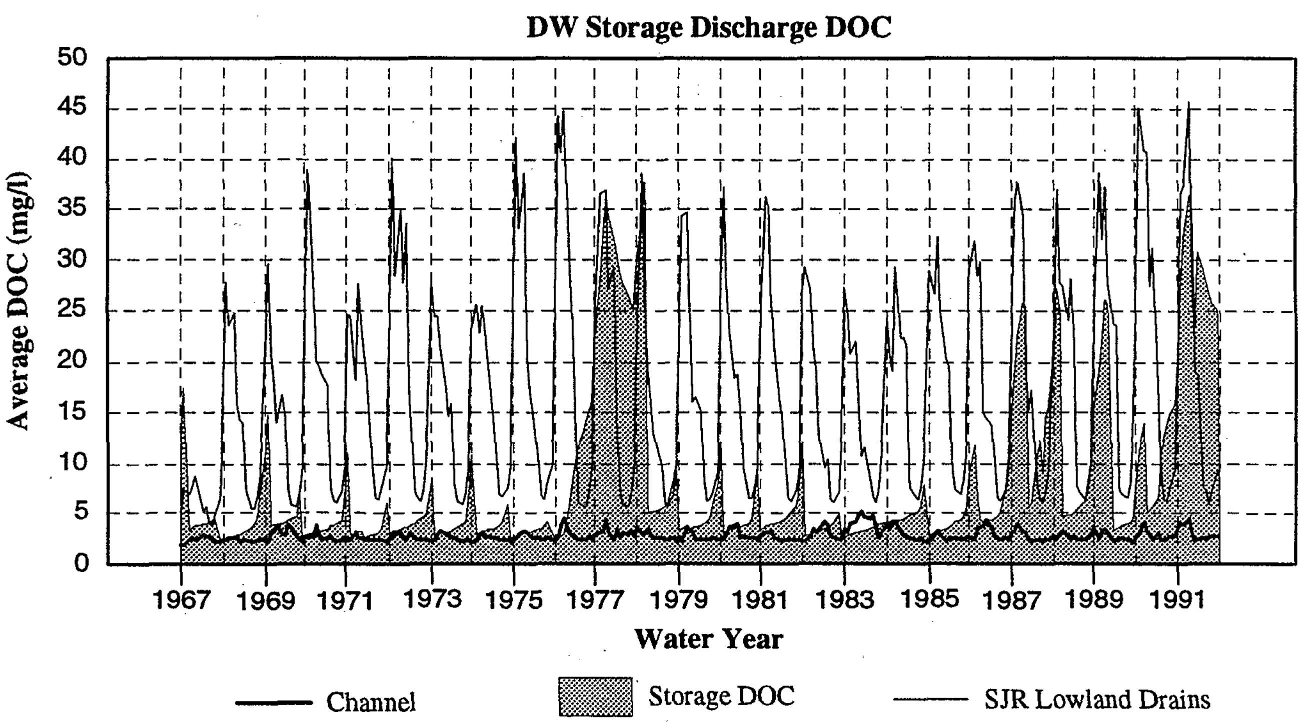

Figure C4-11.
Simulated Discharge DOC Concentrations from DW Habitat and Reservoir Islands for Alternative 2 for 1967-1991

DELTA WETLANDS
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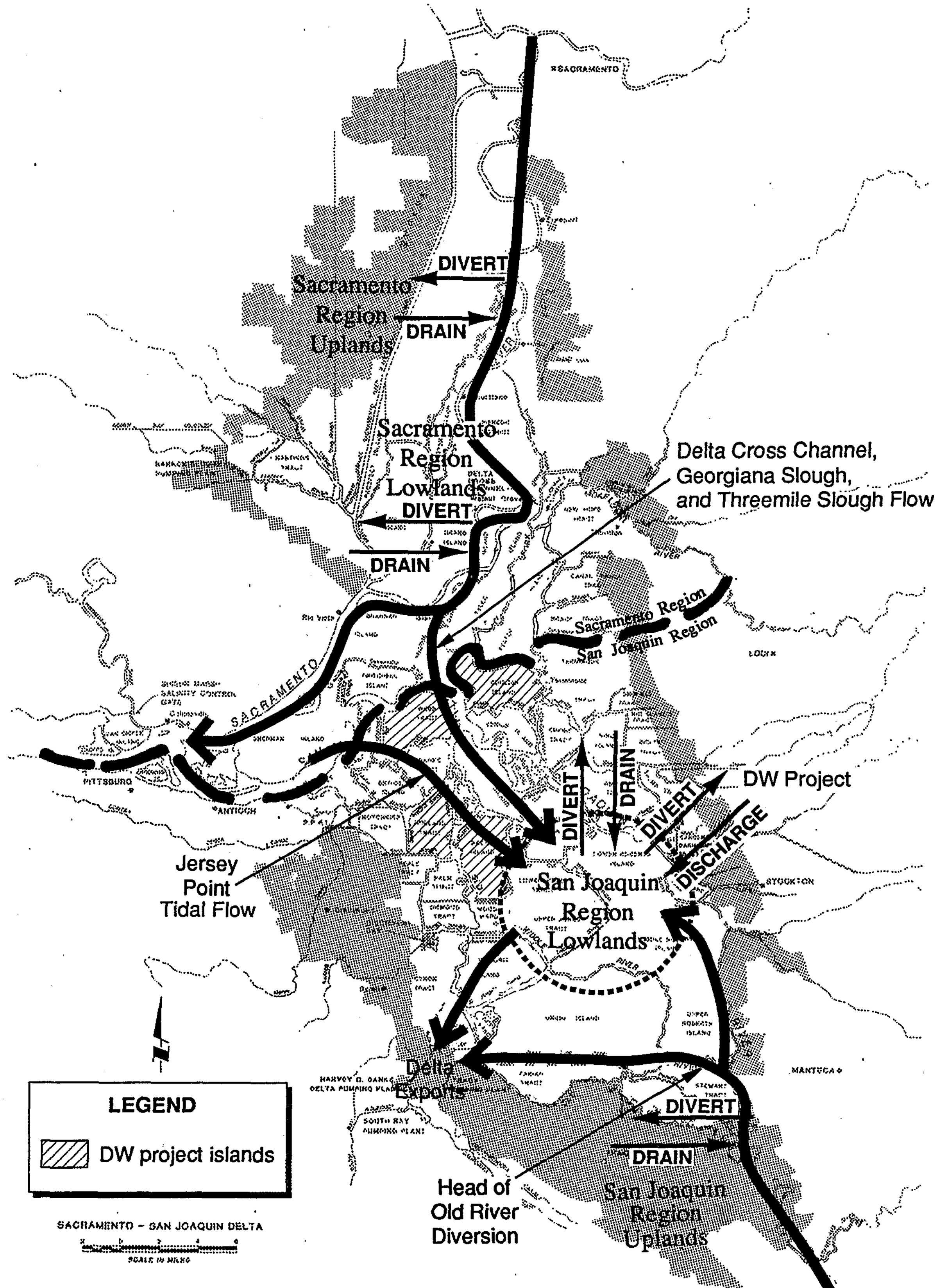
Prepared by: Jones & Stokes Associates



Source: California Department of Water Resources 1993.

Figure C4-12.
DeltaDWQ Delta Regions and Flow Pathways

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

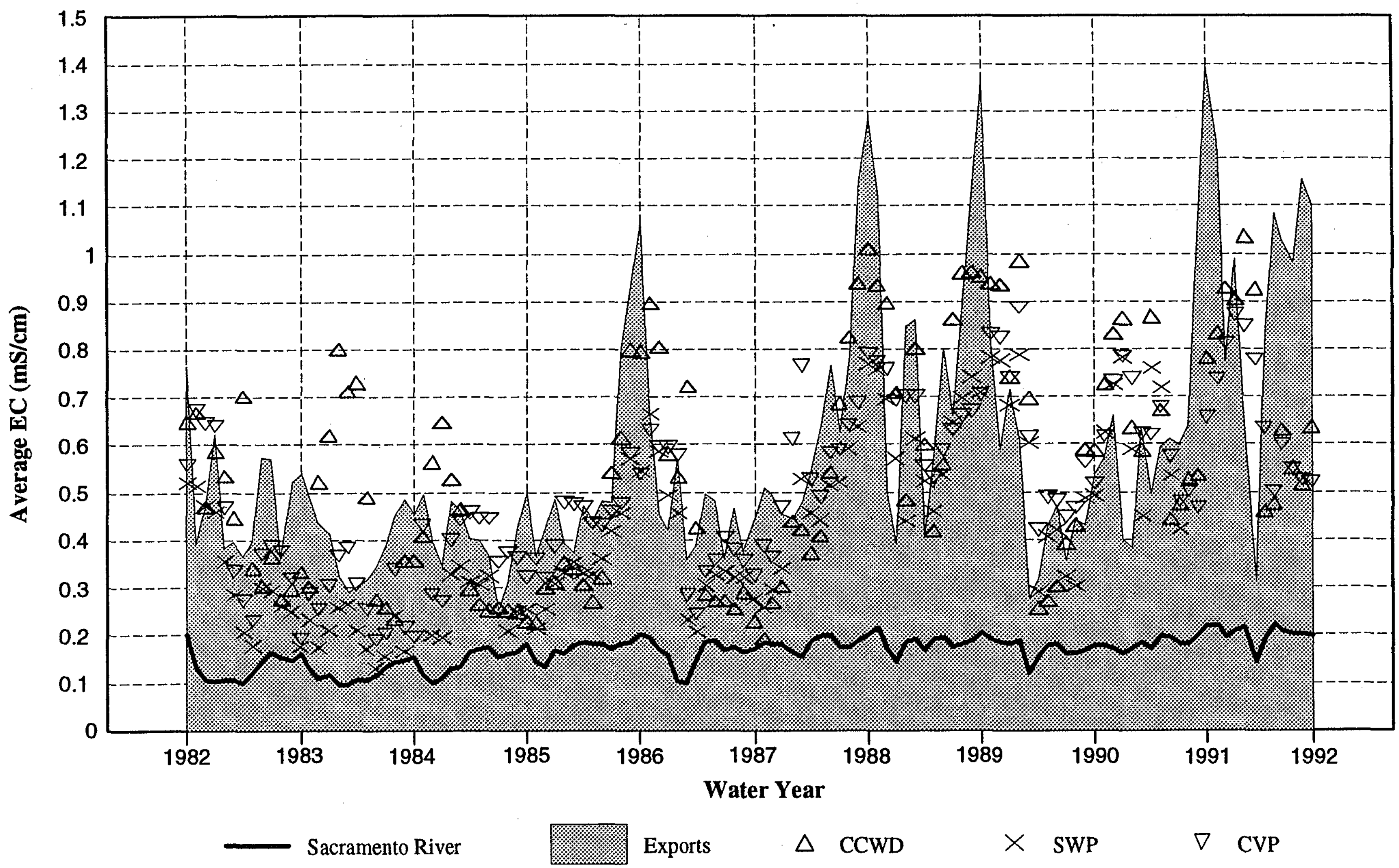


Figure C4-13.
DeltaDWQ Estimated Monthly Average Delta Export EC Values with Historical Inflows and Exports for 1982-1991

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

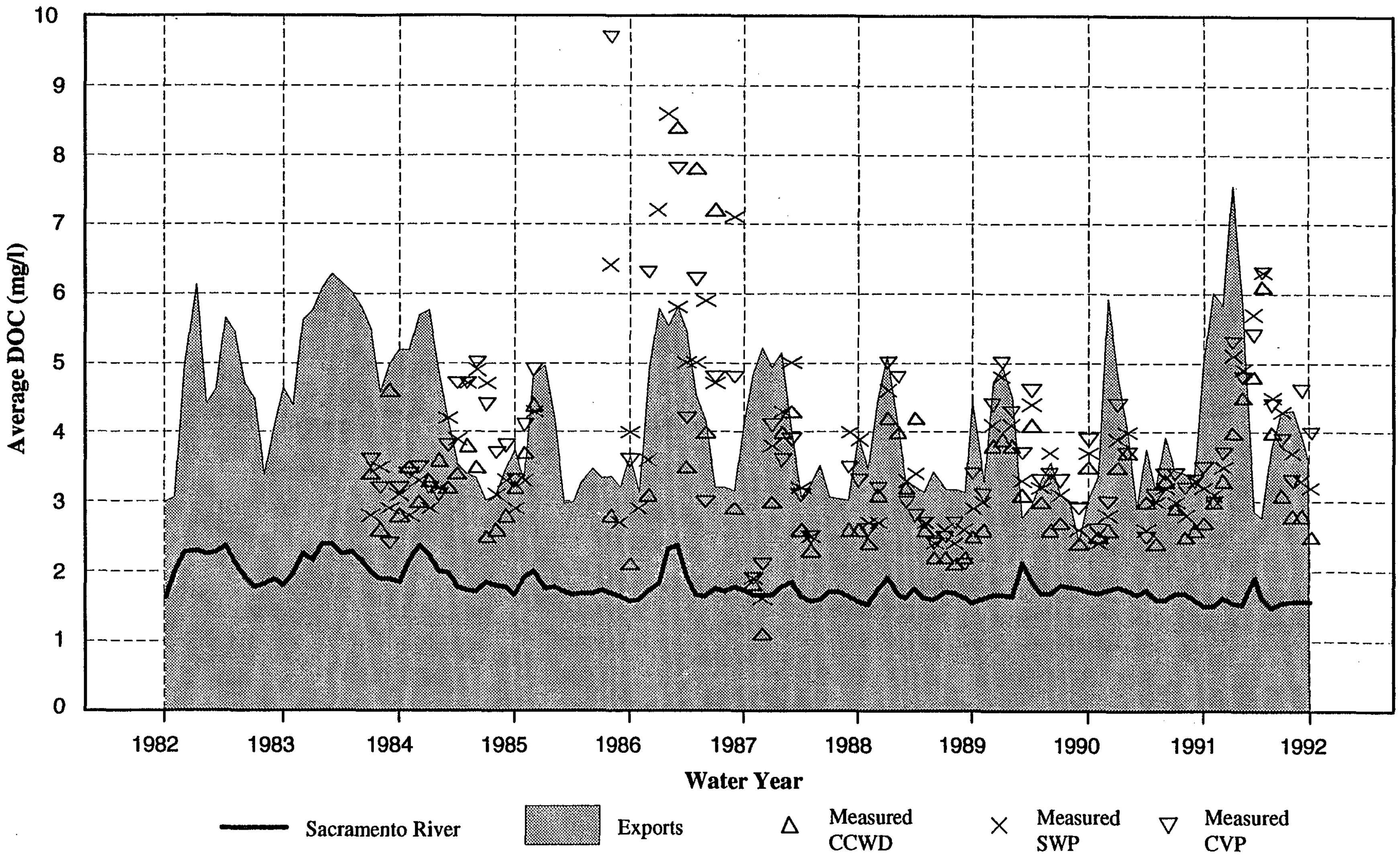


Figure C4-14.
DeltaDWQ Estimated Monthly Average Delta
Export DOC Concentrations with Historical Inflows and Exports for 1982-1991
Compared with DWR-MWQI Measurements

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

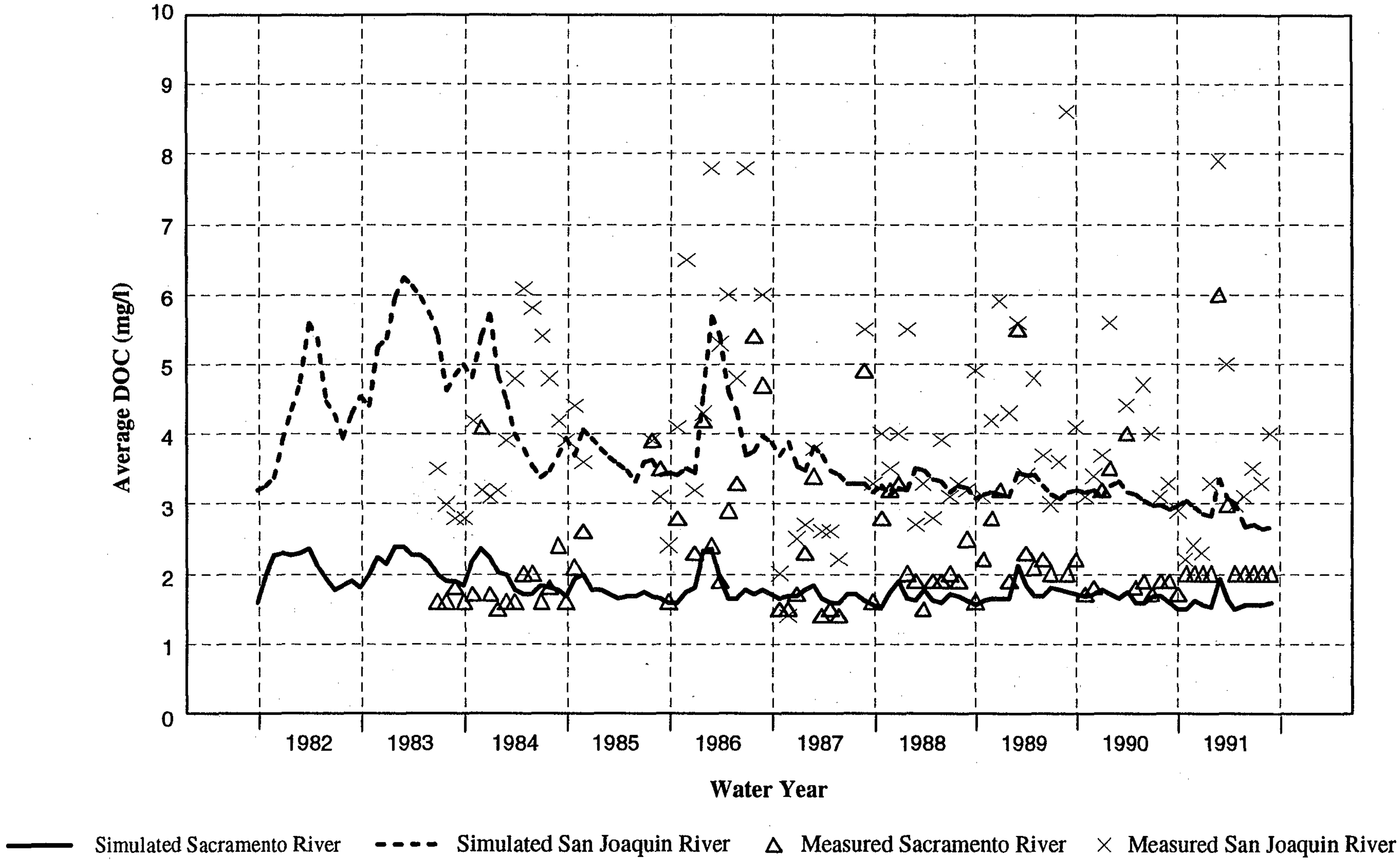


Figure C4-15.
Measured and Simulated Monthly DOC Concentrations in the Sacramento and San Joaquin Rivers with Historical Inflows for 1982-1991

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

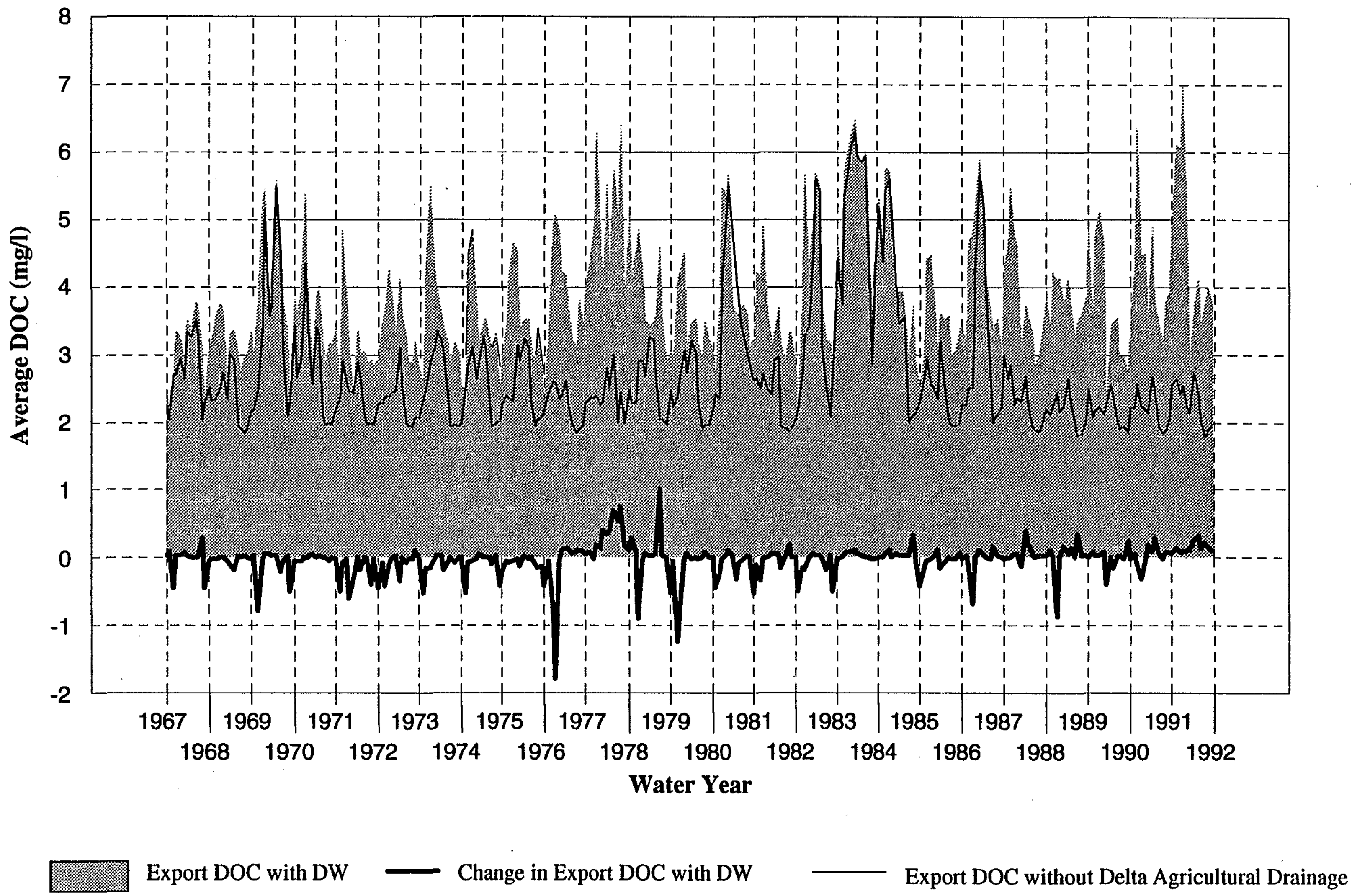


Figure C4-16.
Effects of DW Project Operations on
Estimated Delta Export DOC Concentrations for
Alternative 2 for 1967-1991

DELTA WETLANDS
PROJECT EIR/EIS
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