Appendix A2. DeltaSOS: Delta Standards and Operations Simulation Model

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Appendix A2. DeltaSOS: Delta Standards and Operations Simulation Model

INTRODUCTION

This appendix describes the development and application of the Delta Standards and Operations Simulation model (DeltaSOS) for evaluating Delta water management operations for compliance with likely future Delta standards. DeltaSOS uses monthly average inflows and monthly flow specifications of Delta standards at 12 locations to evaluate Delta flow conditions and possible Delta exports satisfying all specified Delta standards.

DeltaSOS, a simulation and analysis tool, is necessary to reliably describe the effects of several types of existing and proposed Delta standards on likely future operations of the Delta. Environmental assessment of the proposed Delta Wetlands (DW) project depends on reliable descriptions of these likely future Delta conditions. The DeltaSOS monthly model provides a general analysis tool for evaluating a wide range of possible future Delta standards and operations.

DeltaSOS is built on these general concepts:

- Applicable Delta standards for water quality and fish protection are specified as monthly flow values for each of the 5 water-year types (wet, above normal, below normal, dry, and critical).
- The Delta standards are specified as monthly flows at 12 locations.
- An initial monthly 1922-1991 Delta water budget is specified consisting of terms for Sacramento and San Joaquin River inflows, Yolo Bypass and Eastside stream inflows, Delta channel depletion (including North Bay Aqueduct Pumping), combined Central Valley Project (CVP) and State Water Project (SWP) exports, Contra Costa Water District (CCWD) diversions, and initial Delta outflow at Collinsville (Chipps Island and Montezuma Slough).
- Incremental changes in Delta operations required to meet each of the specified Delta standards are calculated and compared to the initial specified Delta water budget. Revised Delta water budget terms that satisfy the specified standards are reported.

This appendix briefly describes the DeltaSOS spreadsheet model to allow agency staff and other interested parties to review simulation results and perform independent analyses with DeltaSOS. A computer disc copy of the spreadsheet DELTASOS.WK1 and other supporting spreadsheets with instructions for using them is available from Jones & Stokes Associates.

POSSIBLE HYDROLOGIC INPUTS

DeltaSOS requires an initial monthly water budget of the Delta for water years 1922-1991 to calculate monthly conditions in the Delta. Initial monthly Delta inflows and exports can be estimated from three general sources of data: historical records (i.e., DAYFLOW), simulation results from a monthly SWP or CVP operations planning model (i.e., DWRSIM or PROSIM), or results from a previous Delta simulation by the DeltaSOS model.

Historical Flows

The historical monthly Delta water budget is provided by the California Department of Water Resources (DWR) in the DAYFLOW data set, available beginning with water year 1930. JSA has used DWR estimates of unimpaired flows for 1922-1929 to extend the historical record of Delta inflows to encompass 70 years.

DAYFLOW is an accounting of actual Delta inflows and outflows and therefore includes effects of changing water use patterns and physical water resource facilities. Historical upstream diversions and storage patterns could be adjusted to reflect present facilities and operations.

Simulation Results from Operations Planning Models

Results from a monthly operations planning model, such as DWRSIM or PROSIM, constitute the second possible source for an initial monthly Delta water budget. Results from these models provide an estimate of likely Delta conditions represented by a particular set of assumed facilities, operations rules, water demands, and applicable Delta standards. The supporting spreadsheet, INPUTS.WK1, provides several representative Delta water budgets developed from DWRSIM and PROSIM model results that are available to describe initial conditions for DeltaSOS model evaluations.

Iterative DeltaSOS Results

A modified monthly Delta water budget produced by DeltaSOS to satisfy a set of proposed Delta standards may be used as the initial conditions for investigating the effects of slightly different Delta standards. The DeltaSOS model includes an option to reset the initial monthly Delta water budget terms to the most recent revised values of the terms calculated to satisfy the previously specified set of Delta standards. The water budget terms for Sacramento and San Joaquin River inflows, Delta exports, and Delta outflow are updated using this option.

Hydrologic Year-Type Classification

Selection of the year-type classification scheme is important because Delta standards can differ between year-type classifications. The D-1485 year-type classification includes a "subnormal snowmelt" year type that replaces wet, above normal, and below normal types when the snowpack is below normal. Required Delta outflows for May-July are substantially modified under this year type.

DeltaSOS allows the San Joaquin River year type to vary independently of the Sacramento River year type. DeltaSOS can thus simulate Delta standards similar to the proposed D-1630 standards. The Vernalis inflow standard and Old River barrier closure input specifications depend on San Joaquin River water year type.

Under the year-type classification schemes, the hydrologic year type cannot be accurately determined until approximately halfway into a new water year. The DeltaSOS model establishes a new year type in February of each year to properly match relatively large spring outflow requirements with the contemporary year type. DeltaSOS simulates flows in the months of October-January according to the previous year-type standards.

Delta outflow and Rio Vista flows are the only D-1485 standards that changes substantially with year type. Other proposed Delta standards may vary substantially between year-type classifications.

DELTA STANDARDS SIMULATED IN DELTASOS

Delta standards consist of numerical criteria or limits that are specified in narrative decisions, opinions, agreements, and other documents from various regulatory or water management agencies. The best known are those contained in California State Water Resources Control Board (SWRCB) water rights decisions, but the cooperative operating agreement (COA), recent Endangered Species Act requirements, and other legislative requirements (CVP Improvement Act) have introduced additional Delta standards that must also be satisfied.

SWRCB established its currently applicable Delta standards in D-1485 (issued in 1978, partially amended in 1985, and commonly referred to as D-1485 standards). SWRCB listed these standards according to the resource use they are protecting at certain locations and specified selected parameters (i.e., minimum flow, pumping limit, salinity, electrical conductivity [EC], or chloride) during certain periods of the year (dates or days per year) for particular year types.

DeltaSOS uses input matrices of monthly Delta standards specifying required monthly flows (minimum or maximum) at a location for each month for each year type. Translating the wide variety of possible Delta standards into a matrix of required flows can be difficult and requires interpretation. Important assumptions, such as flow-salinity relationships, are sometimes necessary.

Specifying monthly flow requirements at appropriate Delta locations for the full set of applicable standards provides an objective basis for systematically analyzing likely future Delta conditions. DeltaSOS can thus describe flow conditions that satisfy the specified set of Delta standards at a monthly time scale appropriate for planning studies.

The DeltaSOS user specifies the input set of matrices for Delta standards to test and modify the initial Delta water budget. The supporting file, MATRICES.WK1, contains several matrices of reference standards to guide users. One set of reference matrices includes all applicable D-1485 standards. The reference matrices for D-1485 standards can be used to test whether the initial Delta water budget satisfies all D-1485 requirements. Another set of reference matrices includes currently proposed Federal Ecosystem Directorate requirements (U.S. Bureau of Reclamation, U.S. Environmental Protection Agency [EPA], U.S. Fish and Wildlife Service, and National Marine Fisheries Service).

The following sections define the input matrices in DeltaSOS used to specify possible standards or requirements at 12 Delta locations, as shown in Figure A2-1. Some important Delta standards, such as maximum chloride concentrations at CCWD, are not directly simulated and must be protected indirectly using other specified standards.

Sacramento River Flow at Freeport

The input matrix for minimum Sacramento River flows at Freeport can be used to specify pulse-flow requirements to assist migrating fish or transport eggs and larvae from the Sacramento River through the Delta to Suisun Bay. Pulse flows that may be required for less than a month must be averaged with requirements for the remainder of the month to establish monthly values of the DeltaSOS matrix. The D-1485 Delta standards do not contain Freeport minimum flow requirements.

Diversions from Sacramento River at Hood

Facilities do not currently exist at Hood to allow diversion of exports from the Sacramento River. DeltaSOS includes a switch, however, to allow simulation of possible diversions at Hood into an isolated facility to transfer water directly to the CVP and SWP pumps. If this option is used, three matrices of input standards are needed to specify operational controls for the Hood diversions and the transfer facility.

Hood diversions as simulated in DeltaSOS would be limited by two different control matrices. A maximum diversion rate can be specified to limit the diversions at Hood for each month of each year type. A second control matrix specifies the allowable fraction of Sacramento River flow that could be diverted at Hood. In combination, these two control matrices can simulate a wide range of operational limits for possible Hood diversions. A third matrix in DeltaSOS can be used to specify required releases from the transfer facility to provide inflows to sloughs that connect with Mokelumne River or San Joaquin River.

DeltaSOS does not allow Hood diversions to exceed the specified maximum diversion or the maximum specified fraction of Sacramento River inflow. Hood diversions are also limited indirectly in DeltaSOS by the need to satisfy required Delta outflow and required Rio Vista flows. Thus, five separate standards in DeltaSOS can be used to limit simulated Hood diversions.

Sacramento River Flow at Rio Vista

D-1485 specifies minimum flows at Rio Vista to protect migrating salmon. Sacramento River flows at Rio Vista are equivalent to flows at Freeport, minus any Hood diversions, minus the Delta Cross Channel (DCC) and Georgiana Slough flows, plus any Yolo Bypass inflows. Rio Vista is upstream of the Threemile Slough connection to the lower San Joaquin River.

Sutter and Steamboat Slough diversions from the Sacramento River below Hood rejoin the Sacramento River at Rio Vista. The diversions are calculated in DeltaSOS, but no gates or tidal controls for Sutter or Steamboat Sloughs are simulated in DeltaSOS.

Delta Cross Channel and Georgiana Slough Operations

Operations of the DCC gates are controlled on a daily basis and may depend on both the Sacramento River inflow and Delta outflow at Chipps Island. A flood control standard specifies that DCC will be closed to protect the Mokelumne River channel levees whenever Sacramento River inflow is greater than 25,000 cubic feet per second (cfs). D-1485 contains additional daily DCC closure provisions in the months of January-June, whereby DCC is to be closed whenever the Delta outflow "index" is greater than 12,000 cfs.

Approximating the DCC daily operation requirements with monthly average flows introduces some inaccuracy for months that have average flows near the DCC closure criteria. If the monthly flows are either very low or very high compared to the criteria, however, the closure condition specified as a monthly average flow is a good approximation of the average of the daily closure conditions.

DeltaSOS requires two flow standard matrices to simulate the DCC closure standards because they depend on flows at two different Delta locations. The first matrix specifies the maximum monthly Sacramento River flow below Hood for the DCC to remain open. This flood control standard is simulated at 25,000 cfs in all months of all year types. Complete closure of DCC for a month is specified in DeltaSOS with a value of 0 cfs in the input matrix. Because Sacramento River inflow is always greater than 0 cfs, DCC will be closed during this month.

The second DCC flow matrix specifies the maximum Delta outflow for the DCC to remain open (i.e., at higher outflows, DCC will be closed). D-1485 outflow standards are simulated at 12,000 cfs in the months of January-April and at 75,000 cfs in other months. Delta outflow in the initial Delta water budget is used to determine DCC closure based on this standard. Because DCC closure in combination with minimum QWEST flows may limit allowable export pumping, Delta outflow may be increased as the result of export cutbacks to satisfy the QWEST limits.

If the initial Delta outflow is below the outflow standard (such that DCC remains open) but exports are reduced by other specified standards (e.g., QWEST or pumping limits), DeltaSOS will allow the revised Delta outflow to increase above the specified Delta outflow for DCC closure. In this case, DeltaSOS will not satisfy the Delta outflow DCC closure standard.

A third flow matrix specifies the maximum monthly Sacramento River flow below Hood for simulated Georgiana Slough gates to remain open. These potential gates have not been constructed, and a matrix value of 80,000 cfs will simulate Georgiana Slough maintained in an open configuration because Sacramento River flows remain below 80,000 cfs.

San Joaquin River Flow at Vernalis

DeltaSOS estimates minimum flows at Vernalis indirectly from maximum allowable salinity (TDS) values, as generally specified in Condition 5 of SWRCB D-1422, which governs the water rights for New Melones Reservoir. The EC-flow relationship used to approximate flows equivalent to the Vernalis salinity standards is shown in Figure A2-2. The D-1422 TDS standard of 500 parts per million is equivalent to an EC value of about

833 $\mu S/cm$, assuming an EC/TDS ratio of 1.67, which requires a flow of approximately 900 cfs at Vernalis. Agricultural drainage EC during the winter periods of 1988, 1989, and 1990 was much higher than the general flow regression estimates.

Head of Old River Barrier

DeltaSOS estimates flows from San Joaquin River into Old River based on results of the Resource Management Associates (RMA) Delta Tidal Hydraulic Model. Flow into Old River is potentially blocked by a barrier at the head of Old River. Temporary barriers have been placed to prevent diversions to Old River and thus to increase flows in the San Joaquin River past Stockton. Increased flows in the San Joaquin River will maintain dissolved oxygen concentrations and improve conditions for salmon migration.

DeltaSOS requires a control matrix that specifies the maximum monthly San Joaquin River flow at Vernalis for the head of Old River barrier to remain closed. DeltaSOS will open the barrier for flood control purposes if San Joaquin River flows exceed the specified threshold. At a threshold value of 8,000 cfs, DeltaSOS will close the barrier unless the San Joaquin River flow is greater than 8,000 cfs. A value of 0 cfs will open the barrier during the month for any San Joaquin River flow.

San Joaquin River Flow from Central Delta (QWEST)

QWEST is a variable calculated to be equivalent to the net San Joaquin River flow moving from near the mouth of the Mokelumne River and Old River (Franks Tract) toward Antioch. Requirements for QWEST minimum flows are a new feature of Delta standards, first introduced in proposed D-1630 requirements. Subsequently, QWEST limits were specified as protection measures for fish in 1993 biological opinions under the federal Endangered Species Act for both winter-run salmon and Delta smelt. Minimum QWEST flows are specified to minimize the net upstream movement of passive larval and juvenile fish life stages from the Antioch region (western Delta) into the central Delta where they would become vulnerable to potential entrainment losses at the export pumps.

Net flow in the San Joaquin River at Antioch or Jersey Point (on the north side of Jersey Island) may not be well represented by the QWEST value, depending on which channel flows are included in QWEST calculations (Figure A2-1). For example, results of the RMA Delta hydraulic model indicate that approximately 40% of San Joaquin River flow from the central Delta moves through Franks Tract, False River, and Dutch Slough to the lower San Joaquin River in the vicinity of Antioch (Figure A2-3). Also complicating calculation of QWEST is the fact that Threemile Slough connects the Sacramento River with the lower San Joaquin River just upstream of Jersey Point.

In DAYFLOW calculations, QWEST flows are estimated as those in the San Joaquin River upstream of its junction with Threemile Slough (Figure A2-1). Thus, DAYFLOW estimates for QWEST do not include the contribution of Sacramento River flow from Threemile Slough.

In contrast, the U.S. Geological Survey (USGS) proposes to install a device to measure San Joaquin River tidal flow at Jersey Point, downstream from the junction with Threemile Slough and downstream from the False River inflow from Franks Tract (Figure A2-1). The USGS measurements will therefore not correspond to the QWEST values estimated in DAYFLOW. Flows measured by USGS at Jersey Point will be slightly less than San Joaquin River flows at Antioch because approximately 5% of net San Joaquin River flow moves through Dutch Slough between Franks Tract and Big Break, thus entering the San Joaquin River downstream of Jersey Point (Figure A2-3).

QWEST values (whether calculated with or without Threemile Slough flows) are largely determined by the balance between diversions from the Sacramento River to the central Delta through DCC and Georgiana Slough, which increase QWEST, and Delta export pumping, which decreases QWEST. Delta inflows from the San Joaquin River and eastside streams also contribute to QWEST. In addition, QWEST flows are diminished by approximately 65% of the Delta channel depletions (i.e., irrigation and evaporation) that are assumed to occur upstream of QWEST, along the Mokelumne and San Joaquin River channels. Under these circumstances, specified QWEST minimum flows may limit Delta export pumping, especially if DCC is closed and Sacramento River diversions to the central Delta are limited to Georgiana Slough flows.

In DeltaSOS, the user can apply QWEST standards either with or without Threemile Slough flows included in the QWEST calculation. Calculation of QWEST, including Threemile Slough flows, would allow the future USGS tidal flow measurements at Jersey Point to be used for Delta management decisions and for standards compliance purposes. Prior calculations of QWEST values have been based on DAYFLOW with Threemile Slough flows excluded. Therefore, QWEST standards that include Threemile Slough flows might appropriately have slightly higher values to reflect the inclusion of Sacramento River water flowing through Threemile Slough.

Including Threemile Slough flows in the QWEST calculations would cause the values specified in the QWEST standard to better represent actual net San Joaquin River flows at Antioch. Including Threemile Slough flows in QWEST might also allow greater Delta exports because Sacramento River flows through Threemile Slough to the San Joaquin River would balance more exports while maintaining the specified QWEST limits.

In the DeltaSOS standards input matrix, the QWEST variable is given a value of -15,000 cfs in months with no QWEST flow limits. This input value thus represents a minimum possible QWEST that allows full export pumping even when no inflows to the central Delta are occurring.

Montezuma Gate Operation

The Montezuma Slough Salinity Control Gate was constructed to maintain more suitable salinity in Suisun Marsh by allowing Sacramento River outflow into the marsh on ebb tide and blocking movement of water from the marsh to the Sacramento River during flood tide. This gate operation scheme produces a net flow into Montezuma Slough from the Sacramento River at Collinsville. In the DeltaSOS input standards matrix, the user specifies whether the gate is operating (1=operate) each month of each year type.

DeltaSOS estimates net flow through Montezuma Slough as a function of total Delta outflow at Collinsville, based on results from the RMA Delta hydraulic model. The RMA Delta hydraulic model indicates that approximately 2% of total Delta outflow at Collinsville enters Suisun Marsh through Montezuma Slough when the gates are open throughout the tidal cycle (i.e., not operating) (Figure A2-4). The RMA model results indicate a net flow of about 2,200 cfs plus 0.5% of total Delta outflow enter Suisun Marsh through Montezuma Slough, when the Montezuma Slough gates are operated. This net Montezuma Slough flow can be a significant portion of total Delta outflow.

The effects of the diversion of Delta outflow into Montezuma Slough on net flow at Chipps Island are easily calculated, but the effects on Delta salinity may not be as easily estimated. With regard to salinity control at Chipps Island, DWR estimates that the effective diversion of outflow through Montezuma Slough may only be 15% of the actual diversion, because the majority of the diversion flow returns as outflow into Suisun Bay (Russell pers. comm.).

The DeltaSOS model allows the effective Montezuma Slough diversion fraction to be specified by the user. DeltaSOS also provides a switch to allow Montezuma Slough diversions to be reduced if an outflow deficit is calculated, thus preventing diversions of Delta outflow to Montezuma Slough from causing a potential Delta outflow deficit.

Delta Outflow

Chipps Island, just below the confluence of the Sacramento and San Joaquin Rivers near Pittsburg, is the traditional location for specification of minimum Delta outflow requirements. Prior to the recent introduction of requirements for flushing flows, QWEST limits, and Suisun Marsh salinity standards, all Delta salinity and flow requirements could be approximately combined into minimum Delta outflow requirements at Chipps Island. DWR has used a computer program called Minimum Delta Outflow (MDO) to estimate the monthly Delta outflow requirements for use as minimum flow constraints in DWRSIM modeling of SWP and CVP operations.

For DeltaSOS input standards, various Delta outflow and salinity requirements can be approximated as a single matrix of monthly flows, using the specified salinities and salinity-outflow relationships such as have been assumed by DWR in the MDO program. In cases where different salinity standards apply at different Delta locations (i.e., Chipps Island, Emmaton, or Jersey Point), the flows required to maintain the specified salinities are compared and the largest necessary flow is used as the minimum outflow requirement. When standards apply for only part of a month, or when cumulative standards apply (e.g., 150 mg/l chloride at Rock Slough for a certain number of days for each water-year type), the monthly flow value is estimated as the average of the daily values.

The matrix of minimum Delta outflows at Chipps Island under D-1485 can be derived from a combination of specified flows for striped bass, EC standards to protect Suisun Marsh, and EC standards at Emmaton to protect agricultural uses. Each EC standard at each location must be interpreted as an outflow standard based on an assumed EC-outflow relationship. For example, DWR has assumed that the 12.5 mS/cm EC Chipps Island D-1485 standard for October through May can be approximated with an outflow of 4,500 cfs. The 15.6 mS/cm EC standard for October-December following dry and critical years has been interpreted by DWR to be an outflow requirement of 3,400 cfs. The Emmaton EC standard of 0.45 mS/cm has been interpreted to be an outflow requirement of 7,600 cfs. Table A2-1 represents D-1485 outflow requirements prepared by SWRCB staff.

One of the Suisun Marsh EC standards in D-1485 requires a flow of 12,000 cfs for 2 out of 4 months (January-April) in above-normal and below-normal year types. This type of Delta standard cannot be specified as fixed monthly flow requirements in DeltaSOS. An additional matrix (OUTQ) is used to represent this D-1485 Suisun Marsh EC standard in DeltaSOS.

OUTQ specifies the required number of months within the selected control period that must have an outflow greater than the specified flow for each year type. The OUTQ matrix includes three specified outflow values. In DeltaSOS, the 4-month D-1485 control period of January-April has been shifted 1 month later in the year and increased to 5 months to correspond with the 5-month control period of February-June for another D-1485 Suisun Marsh standard.

The D-1485 outflow standards for Suisun Marsh salinity require 6,600 cfs for each of the 5 months (February-June) in all year types. These minimum flows could be included in the outflow matrix, but are included in the OUTQ matrix as the first specified outflow value, with 5 out of 5 months required for each year type.

Proposed Environmental Protection Agency Outflow Standards for Estuarine Habitat

The EPA has recently proposed (December 1993) additional Delta outflow requirements during the February-June control period to limit salinity in the estuarine habitat of Suisun Bay. If the EPA standards were specified flows for particular months of each year type, the Delta outflow matrix could be changed to represent them accordingly.

The proposed EPA standards require that the specified salinity (flow) standard be met for a certain number of days within a 5-month control period of February-June. The proposed EPA standards have been formulated in terms of the number of days that the 3 mS/cm EC (2 parts per thousand [ppt] TDS) salinity zone must be located downstream of three control locations. Furthermore, the outflow requirements will be adjusted based on actual hydrologic conditions. Therefore, a fixed outflow matrix cannot be used to represent the proposed EPA standards.

DeltaSOS approximately represents the proposed EPA standards using the OUTQ matrix described above. Three outflow thresholds can be specified in OUTQ. DeltaSOS represents the EPA standards using estimated steady-state, salinity-flow relationships to approximate the salinity standards at each of the three EPA control locations with outflow requirements. The required number of days for each outflow threshold has been approximated by the number of required months for each outflow threshold in DeltaSOS.

The most upstream point for EPA salinity control is located at the confluence of the Sacramento and the San Joaquin Rivers near Collinsville. In DeltaSOS, the EPA salinity standard of 2 ppt at this location is approximated with a minimum required outflow of 6,870 cfs. At the middle EPA salinity control location near Chipps Island (Mallard Slough), the salinity standard is approximated with a minimum required outflow of 12,000 cfs. At the downstream EPA salinity control location near Port Chicago (Roe Island), the EPA standard is approximated with a required outflow of 28,000 cfs. DeltaSOS therefore uses similar threshold flow values of 6,600 or 6,870 cfs; 12,000 cfs; and 28,000 cfs in the OUTQ matrix for the D-1485 outflow standards and the outflow approximations for the anticipated EPA salinity standards.

The DeltaSOS model determines that the EPA outflow levels are required toward the end of the control period if outflow has not already exceeded the specified flows for the required number of months. For example, if February outflow is greater than the threshold, the remaining number of months needed to satisfy the outflow requirement is reduced by one. When the remaining number of months in the control period is equal to the remaining number of months needed to satisfy the EPA standard, DeltaSOS sets the minimum Delta outflow to be equal to the estimated EPA outflow requirement for the remainder of the control period.

The proposed EPA outflow requirement to maintain 2 ppt TDS near Port Chicago (Roe Island) is not activated until an initial monthly Delta outflow (with the initial monthly export estimate) exceeds the flow threshold. For example, if Delta outflow first exceeds 28,000 cfs in May, outflow is required to be maintained above 28,000 cfs for a maximum of 2 months (May and June). If Delta outflow never exceeds the 28,000-cfs threshold during the control period of a particular year, the 28,000-cfs outflow standard is never activated.

An additional difficulty exists in simulating the proposed EPA salinity standards. Because Delta flows in future months are unknown, a management choice exists when the initial Delta outflow for a month is less than the specified threshold, but outflow is required at the specified threshold during subsequent months in the 5-month period. If Delta outflow is relatively close to the specified threshold, it may be efficient to satisfy the outflow threshold for the present month, rather than waiting for subsequent months when Delta inflows might be less. DeltaSOS includes this option in the OUTQ matrix by allowing the user to select a fraction for each of the three outflow thresholds. If Delta outflow is greater than the selected fraction of the outflow threshold, the required outflow is set to the threshold value. For example, if the outflow threshold is 12,000 cfs and the threshold fraction is 0.75, Delta outflow of greater than 9,000 cfs will trigger the minimum Delta outflow of 12,000 cfs for the month, if a month remains of required outflow of 12,000 cfs.

DeltaSOS also includes a switch that allows the required Delta outflow to be applied either at Chipps Island or at Collinsville, upstream of Montezuma Slough. If the outflow standard is applied at Collinsville, the effects of Montezuma Slough diversions on satisfying the required Delta outflow standards are eliminated. If the Delta outflow standards are simulated at Collinsville, however, possible effects of the Montezuma Slough diversions on flow and salinity at Chipps Island should be carefully considered. It may be appropriate to increase the outflow requirements specified at Collinsville to ensure that the applicable salinity standards are satisfied at Chipps Island. DWR estimates, for example, that the diversion of approximately 2,000 cfs of outflow into Montezuma Slough actually requires only 300 cfs (15%) of additional Delta outflow at Collinsville to provide equivalent salinity control at Chipps Island (Russell pers. comm.).

Delta Export Pumping at Banks and Tracy

DeltaSOS represents combined CVP and SWP Delta export pumping limits in another Delta standard matrix. The CVP export pumping capacity is 4,600 cfs, but the Delta Mendota Canal capacity is limited to 4,200 cfs in December-March without deliveries for irrigation. For evaluation of D-1485 standards, SWP export capacity is assumed by DWR to be 6,680 cfs. The combined CVP and SWP export pumping capacity is therefore 11,280 cfs for April-November and 10,880 cfs for December-March.

DWR currently operates the four new pumps at the SWP Banks Pumping Plant within the general provisions of U.S. Army Corps of Engineers (Corps) regulations under

Section 10 of the River and Harbor Act of 1899. Corps public notice 5820A (amended October 13, 1981) includes a provision to allow pumping of 33% of the San Joaquin River daily inflow, if the inflow exceeds 1,000 cfs during the December 15-March 15 period, up to the SWP export capacity of 10,300 cfs. Increased water elevations in the southern Delta during periods of high San Joaquin River inflow are the basis for allowing increased SWP exports.

Estimating the net effect of daily San Joaquin River inflows and daily Clifton Court Forebay gate capacity (as currently operated) on increased monthly average export pumping is somewhat uncertain. DWR has simulated the San Joaquin River inflow provision in DWRSIM by assuming that the maximum monthly SWP pumping would increase by only 620 cfs to 7,300 cfs. However, actual pumping during periods of high San Joaquin inflow in 1993 has caused DWR to increase the estimated monthly maximum to 8,500 cfs (J. Snow pers. comm.).

In DeltaSOS, the San Joaquin River inflow provision is simulated by allowing a specified fraction of monthly San Joaquin River inflow, if greater than a specified minimum (1,000 cfs), to be exported in addition to the specified export pumping limits. In these months, DeltaSOS simulates the total allowable pumping as the specified pumping limit, plus the specified allowable export of the San Joaquin River flow, up to the maximum capacity given in the seventh column of the export pumping matrix. The November-March capacity with 8,500 cfs of SWP pumping is 12,700 cfs.

Full capacity for combined CVP and SWP export pumping could be simulated with matrix values of 14,500 cfs (December-March) and 14,900 cfs (balance of year). DeltaSOS does not allocate the Delta pumping between the CVP and SWP projects, and therefore, does not necessarily satisfy COA provisions. CCWD exports are specified as inputs and are not adjusted in DeltaSOS.

If Hood diversions are simulated with DeltaSOS, the export pumping limits apply solely to allowable direct diversions from the southern Delta. Such direct southern Delta diversions would be in addition to the exports of the Hood diversions less any required releases of Hood diversions back to the Delta. The net Hood diversions therefore increase allowable Delta exports in much the same way as the excess San Joaquin River flow. The specified pumping limits control direct exports, and net Hood diversions can augment total export, as constrained by the physical pumping limits specified in the seventh column of monthly pumping matrix values.

Delta Storage Facility

DeltaSOS simulates the possible operations of a Delta water storage facility that would be operated to divert excess Delta inflows to temporary or seasonal storage in the

Delta, and to then discharge the stored water for Delta outflow or for export during periods with available CVP or SWP pumping capacity.

DeltaSOS requires five standard matrices to simulate possible operations of a Delta storage facility. The first flow matrix specifies the maximum end-of-month storage volume (in units of thousands of acre-feet [TAF]). This matrix can be used to specify seasonal as well as year-round storage volumes for each water-year type.

A second matrix in DeltaSOS specifies the monthly assumed evaporation losses from the Delta storage facility (TAF units). A sixth column specifies the assumed monthly reductions in Delta channel depletion that result from conversion of Delta islands from agricultural production to a water storage facility. Seasonal wetland flooding or other anticipated adjustments in Delta water use patterns are also specified in this column.

DeltaSOS uses a third matrix to specify the maximum average monthly diversion rate (cfs units) when storage capacity and excess Delta inflow are available. DeltaSOS assumes that the Delta storage facility is located upstream of QWEST, so that excess Delta inflow qualifies as both excess Delta outflow and excess QWEST flow. DeltaSOS uses a separate monthly column of parameters to specify the fraction of calculated excess Delta inflow that is available for diversion to the simulated Delta storage facility, with a specified minimum excess Delta inflow that acts as a buffer for Delta storage operations.

The fourth standards matrix for Delta storage facility operations specifies the maximum monthly discharge rate. Discharge from Delta storage could be used for increasing QWEST and Delta outflow, or for increasing Delta export pumping. DeltaSOS assumes that discharge from storage will be limited to specified Delta export pumping capacity unless the user selects the option to allow export pumping of Delta storage water in addition to the specified export pumping limits. The possible exemption from specified export pumping limits can be simulated by the combination of the appropriate control switch, and the sixth column of monthly pumping limits in the export pumping standard matrix. If used, this export exemption has a similar effect as excess San Joaquin River inflow or Hood diversions for increasing allowable exports. DeltaSOS includes another switch to determine whether Delta storage exports are allowed during periods with Delta outflow deficits.

The fifth standard matrix for Delta storage facility operations specifies the required discharge for Delta outflow. If storage is available, this release is required before DeltaSOS allows any export of the water from a Delta storage facility.

Table A2-2 is a copy of an available printout from DeltaSOS that shows the control switches and standard matrices used in DeltaSOS. The values shown in Table A2-2 are representative and may not match the actual Delta standards required by current regulations and SWRCB decisions.

CALCULATED EFFECTS OF DELTA STANDARDS ON DELTA OPERATIONS

DeltaSOS tests each input standard matrix against calculated Delta channel flows for each month of the simulation period. If a specified standard is not satisfied, some action within the Delta would be required to meet the specified standard. DeltaSOS identifies several options for satisfying the specified standards if they are not met. DeltaSOS then calculates the incremental effects of each specified standard on Delta conditions.

The following sections describe the possible options in DeltaSOS for satisfying Delta standards and calculating the resulting incremental effects for each standard.

Freeport Inflows

Freeport minimum flows are used to specify required flows to assist the migration of salmon and the transport of striped bass eggs and larvae. The only realistic way to provide these flows, when they do not occur naturally from storm runoff, is to increase upstream reservoir releases. DeltaSOS calculates the increase in the initial Sacramento River inflow that would be needed to provide the specified Freeport flows.

DeltaSOS itself does not simulate upstream reservoir storage and releases and does not adjust subsequent Delta inflows. Therefore, the increased inflows calculated by DeltaSOS are, in a sense, "imaginary water". As long as the required additional inflows are relatively small, however, additional inflows to satisfy flushing flow requirements can likely be provided by modified upstream reservoir storage operations.

If DeltaSOS uses a planning model simulation that already includes these specified flushing flows as its initial Delta water budget, further adjustment in the Sacramento River inflow values will not be needed. If such a planning model simulation is not available, DeltaSOS provides a tool for estimating the possible effects of various potential flushing flow requirements.

Vernalis Inflows

The basic Vernalis flow requirement of 900 cfs (to meet the 500 mg/l TDS standard) is satisfied in almost all months of the historical record and in most planning model simulation results. Additional inflow that may be needed to satisfy additional EC standards or flushing flow requirements will have to be released from upstream reservoirs. DeltaSOS calculates the incremental increase in the initial San Joaquin River inflow necessary to provide the specified Vernalis flows.

As for Sacramento River inflows, DeltaSOS cannot simulate changes in upstream reservoir storage and cannot adjust subsequent San Joaquin River inflows. An initial Delta water budget for DeltaSOS based on a planning model simulation that already includes these flushing flows will avoid further adjustment in the San Joaquin River inflow values.

Hood Diversions and Transfer Facility Operation

In DeltaSOS simulations, potential diversions from the Sacramento River at Hood can be limited by four operational constraints. Because diversions at Hood would reduce Sacramento River flow downstream, diversions from the Sacramento River into Sutter and Steamboat Sloughs, diversions into DCC and Georgiana Slough, and Rio Vista flows would be reduced.

Because Hood diversions reduce direct Delta diversions to the CVP and SWP export pumps, QWEST flows will be increased by Hood diversions. The effect of Hood diversions on Delta outflow will depend on the quantity of direct diversions allowed and the initial and required Delta outflow. These effects of simulated Hood diversions are calculated in DeltaSOS without any further need for specified choices by the user.

DCC and Georgiana Slough Gate Operations

DeltaSOS simulates the DCC gates to be closed whenever the adjusted Sacramento River flow below Hood exceeds the specified monthly threshold, or whenever the initial Delta outflow estimate (adjusted for the Freeport inflow standard) exceeds the specified monthly threshold. The Georgiana Slough gate operation is specified in a similar manner. Although DeltaSOS simulates the status of the DCC based on these monthly flows, the DCC gates are actually operated based on daily flow estimates.

Once DeltaSOS determines the DCC and Georgiana Slough gate status, DeltaSOS calculates Rio Vista flows and the combined DCC plus Georgiana Slough flows to the central Delta. The DCC and Georgiana Slough channel flow calculations in DeltaSOS are based on results from the RMA Delta hydraulic model that show the splits of flow between the Sacramento River and these side channels (Figure A2-5). The flow splits used in DeltaSOS are similar but not identical to the linear estimates used in DAYFLOW.

Rio Vista Minimum Flows

DeltaSOS calculates the Sacramento River flow at Rio Vista as the Sacramento River flow not diverted at Hood (if simulated) and not diverted into DCC and Georgiana Slough, plus inflow from the Yolo Bypass. If the Rio Vista flow standard is not satisfied, and the DCC is not already closed, DeltaSOS reduces the DCC flow to increase the flow remaining in the Sacramento River. Because of the hydraulic relationship between DCC and Georgiana Slough flows, however, the DCC reduction must be greater than the required Rio Vista increase because about 25% of the DCC cutback will be diverted into Georgiana Slough (Figure A2-5).

If a flow deficit remains at Rio Vista, DeltaSOS does not increase Sacramento River inflows. The Rio Vista flow deficit is reported as a separate column in the simulation results and could be used to adjust the Sacramento River inflow. If the Rio Vista flow deficits are large, however, an initial water budget based on another planning model simulation may be required to better satisfy the specified Rio Vista flow standards.

QWEST Minimum Flows

DeltaSOS estimates initial QWEST flow after the adjusted DCC and Georgiana flows have been calculated. QWEST as estimated in DAYFLOW is equal to the sum of the flows in San Joaquin River, eastside streams, DCC, and Georgiana Slough; minus the SWP, CVP, and CCWD exports; and minus about 65% of the estimated Delta channel depletions. If DeltaSOS simulates Hood diversions, those diversions will increase QWEST, either by reducing direct exports or supplying additional channel flows in the southern Delta.

If DeltaSOS estimates the QWEST flow to exceed the minimum monthly QWEST standard, no adjustments are required. If the QWEST estimate is less than the QWEST standard, however, some adjustment of Delta flows is required.

The DeltaSOS model assumes that the most likely adjustment to increase QWEST would be reduced exports. Only a portion of the Sacramento River inflow is diverted into DCC and Georgiana Slough (less than 60% if DCC is open and less than 25% if DCC is closed). Therefore, maintaining the exports at the pumping rate in the initial water budget would require reservoir releases in the Sacramento River that are much greater than the calculated QWEST deficit. A planning model could be used to determine under what circumstances increased reservoir releases to satisfy QWEST minimum flows and maintain pumping would be feasible or likely.

DeltaSOS calculates the required export pumping cutback to satisfy the QWEST minimum flow for each month. DeltaSOS reports export reductions to satisfy the specified QWEST standards in an output column. A combination of DCC closure requirements and relatively high QWEST limits (i.e., no negative net flow) would cause large export pumping reductions.

DeltaSOS can be used to simulate the effects of QWEST limits that include Three-mile Slough net flows. To distinguish them from traditional QWEST limits, modified limits that include Threemile Slough flows should be referenced as Jersey Point (JERSEY) flows. JERSEY flows will soon be routinely measured by USGS with an acoustic velocity installation. Threemile Slough net flows are governed by the balance of Sacramento River flow at Rio Vista and net San Joaquin River flow upstream of Threemile Slough. Threemile Slough flows will also soon be routinely measured by acoustic velocity devices operated by USGS.

RMA Delta hydraulic model results indicate that Threemile Slough net flow can be calculated using the relationship between Rio Vista and QWEST flows. Figure A2-6 shows the relationship used in DeltaSOS (R^2 = 0.992):

Threemile Slough flow (cfs) =

0.2331 * Rio Vista flow (cfs) - 0.3134 * QWEST flow (cfs)

At relatively low net San Joaquin River (QWEST) flows, about 23% of the Sacramento flow at Rio Vista is diverted through Threemile Slough to the San Joaquin River. Threemile Slough therefore adds considerable flow to the San Joaquin River at Jersey Point or Antioch. Flow measurements at Jersey Point will not correspond to calculated QWEST values unless Threemile Slough flow is added to the calculations.

If JERSEY standards are specified but are not satisfied, the reduction in export pumping will need to be about 145% of the JERSEY flow deficit. With reduced exports, QWEST would increase, which would reduce Threemile Slough flow to the San Joaquin River by 31% of the QWEST increase (Figure A2-6).

DeltaSOS can be used to simulate and evaluate differences between the effects of QWEST and JERSEY standards. For either standard, DeltaSOS simulation results can be used to evaluate potential effects on fish transport and fish entrainment.

Montezuma Slough Gate Operation

Montezuma Slough Salinity Control gates were constructed to provide a net inflow to Suisun Marsh from the Sacramento River near Collinsville. The results of the RMA Delta hydraulic model suggest that the gates provide a net flow of approximately 2,200 cfs when operated. Some portion of this net flow into Montezuma Slough should be subtracted from total Delta outflow at Collinsville to appropriately estimate the effective Delta outflow at Chipps Island that provides control against salinity intrusion. Because the Montezuma Slough Salinity control gates have only been operated during the last 5 years (1989-1993), net diversion flow into Montezuma Slough has not been accounted for in DAYFLOW, and has apparently not yet been represented in MDO and DWRSIM results.

In DeltaSOS, an input matrix controls operations of the Montezuma Slough salinity control gate by months. If the gate is operated (matrix value of 1), the net effective diversion through the gate into Suisun Marsh is estimated from the total Delta outflow at Collinsville (sum of Rio Vista flow and QWEST). Remaining Delta outflow at Chipps Island is calculated as the difference. The DeltaSOS model indicates that substantial outflow deficits can be caused by operation of Montezuma Slough Salinity Control gates when the effective diversion is assumed to be 100% of the flow.

DeltaSOS includes a parameter for adjusting the effective rate of outflow diversion into Montezuma Slough. DWR estimates that only 15% of the actual diversion amount is effectively lost from Chipps Island outflow for controlling salinity intrusion.

DeltaSOS also provides an option to hold the gates open (i.e., not operate them) to satisfy outflow standards, if an outflow deficit is calculated. Not operating the gates may create higher salinity conditions in Suisun Marsh but is only required if Chipps Island is the specified location for outflow standards and an outflow deficit is calculated. DeltaSOS can be used to estimate differences in the net flows to Suisun Marsh for various specified gate operations and evaluate tradeoffs with Delta outflow past Chipps Island.

Delta Outflow

DeltaSOS calculates the total Delta outflow at Collinsville, recognizing export reductions caused by QWEST (or JERSEY) standards. DeltaSOS then compares the outflow past Collinsville or Chipps Island with the applicable minimum outflow standard. The minimum required outflow consists of a combination of the standard matrix and the calculations using the OUTQ matrix described above.

When calculated outflow is less than the required minimum value, DeltaSOS provides two options for satisfying the outflow deficits. The first option consists of modifying the operation of Montezuma Slough gates to increase Delta outflow, if the specified outflow standard is to be met at Chipps Island. The second option is to reduce exports to a specified minimum value (1,500 cfs) to provide greater Delta outflow.

After both options are selected, outflow deficits may remain, especially if the specified outflow requirements differ greatly from those used in the initial water budget for DeltaSOS (e.g., from planning model results). Any remaining outflow deficits are reported in a DeltaSOS output column.

DeltaSOS cannot determine the ability of upstream reservoirs to supply the additional releases needed to satisfy remaining outflow deficits. DeltaSOS can, however, evaluate the incremental requirements of various outflow standards, such as those proposed by EPA.

Export Pumping Limits

DeltaSOS considers four possible changes to the monthly export pumping estimate in the initial Delta water budget. First, an export reduction may be required to meet QWEST (or JERSEY) minimum flow standards. Second, export reduction (if selected as an option) may be needed to satisfy Delta outflow requirements. Third, export reduction may be needed to avoid exceeding the total export limits specified in the pumping standard matrix. If Hood diversions are simulated, the total export limits are considered to apply to direct export pumping from the southern Delta. The full specified export pumping capacity is assumed to be available for total exports, the combination of direct pumping and Hood diversions.

The fourth adjustment to export pumping considered by DeltaSOS is to increase pumping if available water can be exported within the specified pumping limits (including allowable pumping of excess San Joaquin River inflow). The possibility of increased pumping is based on assumptions that annual export demands are likely to be greater than water available for export in the future, and that south-of-Delta facilities needed to store exported water are likely to become available. Planning model simulations often have unused export capacity because they only export Delta water to meet specified monthly demands and unfilled San Luis Reservoir storage curves.

The planning models also may reduce export pumping to satisfy assumed carriage water requirements. DeltaSOS can be set to assume any specified fraction of DWR estimated carriage water. The following section of this appendix explains the DWR carriage water calculations.

DeltaSOS simulations assume that all available water within the specified export pumping limits will be exported as long as QWEST and Delta outflow standards remain satisfied. DeltaSOS reports the additional export of available water as positive values in the monthly net export change column of DeltaSOS output.

Simulating the export of all available water eliminates the possibility of a new Delta storage facility diverting water that could have been pumped by the CVP or SWP pumps, which have senior water rights. DeltaSOS simulates the maximum possible export pumping within the specified standards and choices for reducing outflow deficits prior to allowing diversions to or discharges from a Delta storage facility for export wheeling.

Carriage Water Calculations

Carriage water is a traditional concept used to represent releases of water from reservoirs to maintain acceptable chloride concentrations in export water as Delta exports are increased. Because most upstream reservoir storage is released to the Sacramento

River, Sacramento River inflow must be increased to maintain the required Delta outflow and to supply increased exports. With relatively low San Joaquin and eastside stream inflow, an increase in exports must be supplied from the Sacramento River.

DCC and Georgiana Slough have limited capacity to divert water from the Sacramento River to the central Delta. Therefore, some of the increased reservoir releases for export must flow through Threemile Slough or around Sherman Island and move in a reversed direction up the lower San Joaquin River channel from Antioch to Old and Middle Rivers (Figure A2-1). The salinity of the increased exports may thereby be increased as more of the export flow comes from the vicinity of Antioch and Emmaton; water from this vicinity may have higher salinity than the Sacramento River diversions through DCC and Georgiana. Figure A2-7 shows the terms that would be represented in a general chloride budget for the increased Delta exports.

Excess Delta Exports

Excess Delta exports are calculated as total Delta exports plus 65% of Delta channel depletion minus water supplied from the San Joaquin River and eastside streams. Excess Delta exports are therefore those supplied from the Sacramento River.

Three pathways transport flow from the Sacramento River to supply the excess export. Some of the excess export flow is diverted into DCC and Georgiana Slough. For example, the DWR DAYFLOW equation with DCC open is:

$$\text{DCC and Georgiana flow (cfs)} = 2090 + 0.293 * \text{Sacramento flow (cfs)}$$

The remaining Sacramento River flow at Rio Vista is therefore:

$$\text{Rio Vista flow (cfs)} = 0.707 * \text{Sacramento flow (cfs)} - 2090$$

Similar equations are used by DWR when DCC is closed; less water is diverted from the Sacramento River when DCC is closed.

Excess QWEST and Threemile Slough Flows

Excess export that is not supplied from DCC and Georgiana Slough must enter the central Delta from the Sacramento River through Threemile Slough or from the lower San Joaquin River channel as reversed flow from Antioch. This required additional flow can be considered as reverse QWEST flow needed to supply the excess exports. DWR carriage water calculations assume that 80% of the required reverse QWEST flow comes from Antioch while 20% of the required reverse QWEST flow comes through Threemile Slough.

The RMA Delta hydraulic model results indicate, however, that Threemile Slough flow is more accurately described by:

$$\text{Threemile Slough flow (cfs)} = 0.23 * \text{Rio Vista flow} - 0.31 * \text{QWEST}$$

The assumed hydraulic behavior of Threemile Slough flow is an important aspect of the carriage water calculations. The effort by USGS to install an acoustic flow meter in Threemile Slough will soon provide a continuous record of tidal flows, so that net flow can be estimated directly. In the meantime, available results from the RMA Delta hydraulic model are considered reliable because they are based on measured channel geometry and friction coefficients that have generally accepted values. Similar results are obtained from the Fischer Delta Model (Denton pers. comm.).

The remaining fraction of reverse QWEST not supplied by Threemile Slough moves upstream from Antioch and past Jersey Point as reversed flow in the lower San Joaquin River. The RMA Delta hydraulic model results indicate that Threemile Slough flow usually supplies much greater than 20% of reverse QWEST. A greater contribution to reverse QWEST by Threemile Slough means that a much smaller reversed flow from Antioch is required to supply the excess exports than has been assumed in DWR carriage water calculations.

Antioch Reverse Flows

Table A2-3 gives estimated Antioch flow as a percentage of total excess export. Negative percentages indicate reversed flow. Use of the DWR method for calculating carriage water shows large percentages of reversed flow from Antioch for a wide range of Delta outflows and excess exports. The maximum percentage of excess exports from reversed Antioch flow using the DWR calculations is about 40%. The RMA hydraulic model results suggest that much smaller percentages of excess export come from Antioch as reversed flow. The maximum reversed Antioch flow percentage using the RMA results is about 20%.

Antioch and Excess Export Chloride Concentrations

Table A2-4 indicates the estimated chloride concentration of the excess export, using the DWR assumption that chloride concentrations from DCC and Georgiana and Threemile Sloughs are constant at 15 mg/l. In this case, the effective chloride concentration of the reversed flow from Antioch is the only variable required to calculate the chloride concentration excess exports (Figure A2-7). The effective chloride concentration of the reversed flow from Antioch can be estimated as a function of Delta outflow because seawater intrusion is thought to be the major factor governing Antioch chloride concentration.

The DWR carriage water calculations use a "negative exponential" relationship between Antioch chloride and Delta outflow obtained from results of a steady-state salinity model called SALDIF. Similar results from the RMA Delta salinity model can be approximated as:

$$\text{Antioch Cl (mg/l)} = 7900 * \exp\{-0.00035 * \text{Outflow (cfs)}\}$$

The estimated Antioch chloride concentrations for given values of Delta outflow are shown in the second column of Table A2-4.

The DWR method assumes that Antioch chloride is the effective chloride concentration for the reversed flow from Antioch. Tidal mixing produces a chloride concentration gradient between Antioch and Jersey Point, however, so that the effective chloride concentration for the reversed flow from Antioch is better represented by Jersey Point chloride. Based on available EC data at Antioch and Jersey Point, the effective chloride concentration for the reversed flow from Antioch should be less than 50% of the chloride concentration at Antioch. The carriage water calculations shown in Table A2-4 based on RMA model results use 50% of the Antioch chloride as the effective Jersey Point chloride concentration.

As indicated in Table A2-4, estimated chloride concentration in the excess exports is much less using the method based on RMA model results because reversed flow from Antioch is estimated to be less and because the chloride concentration of the reversed flow is estimated to be about half of Antioch chloride concentration used in the DWR carriage water calculations.

Carriage Water Estimates

Carriage water is operationally defined as the additional outflow required to maintain the excess export chloride concentration below an acceptable level. The acceptable chloride concentration threshold used by DWR corresponds to the Rock Slough chloride standard of 150 mg/l or 250 mg/l, depending on the month and water year type.

For example, assume that 150 mg/l chloride is to be maintained as the Rock Slough chloride standard. Using the DWR method for an excess export of 8,000 cfs with an outflow of 6,000 cfs, the resulting excess export chloride concentration would be 150 mg/l (Table A2-4). If the export was increased to 10,000 cfs, the required outflow needed to maintain an export chloride concentration of 150 mg/l would increase from 6,000 cfs to 7,000 cfs. Under this scenario, the required carriage water needed to allow an increased export of 2,000 cfs would be 1,000 cfs. The required reservoir release necessary to supply 2,000 cfs of additional export would be 3,000 cfs. Estimated carriage water is calculated to be much less based on the RMA model results.

Based on this comparison of estimates using the DWR carriage water calculation method and estimates using results of the RMA Delta model, carriage water may actually be required only for extreme combinations of low Delta outflow and high excess exports. As Table A2-4 indicates, estimated chloride concentration of the excess exports based on RMA model results will exceed 150 mg/l only for low Delta outflows of less than 3,000 cfs in combination with high excess exports of greater than 11,000 cfs. This combination of low Delta outflow and high excess exports is unlikely to occur with D-1485 or more restrictive Delta standards.

DeltaSOS can incorporate any specified fraction of DWR estimated carriage water in the required outflow calculations. The specified fraction of the monthly DWR carriage water estimate (required as DeltaSOS input) is added to the required Delta outflow. DeltaSOS does not make independent calculations of estimated carriage water requirements.

DELTASOS MATRICES VALUES FOR D-1485 DELTA STANDARDS

The only information required to simulate likely future Delta conditions with DeltaSOS is an appropriate set of Delta standard matrices. This section describes the D-1485 standard matrices as a reference point for initial DeltaSOS analyses.

- **Sacramento River at Freeport Flow** - D-1485 standards do not contain Freeport flushing flow requirements, so the Freeport matrix values are set to zero.

- **Hood Diversions** - D-1485 reference standards do not apply to possible Hood diversions, so the three required matrices for this control location are each set to zero.

- **Sacramento River at Rio Vista Flow** - The currently applicable D-1485 standards at Rio Vista to protect salmon migration are shown in Table A2-2.

- **DCC and Georgiana Slough Gate Operation** - The D-1485 DCC closure criteria are shown in the two DCC matrices in Table A2-2. Georgiana Slough remains open under D-1485, so the standard matrix values for that control point are set to 80,000 cfs.

- **San Joaquin River at Vernalis** - The D-1485 reference standards matrices include the D-1422-derived, 900-cfs minimum flow for all months of all year types.

- **Old River Gate** - The temporary barrier at the head of Old River is assumed to be closed to assist fish migration during the September to November period and the April to June period, with a maximum controllable floodflow of 8,000 cfs.

- **QWEST Flow Minimums** - D-1485 does not contain standards for QWEST.

- **Montezuma Slough Gate Operation** - The Montezuma Slough salinity control gates have been operated for several months each year beginning with water year 1989. The standards matrix for the Montezuma gate specifies whether the gate is operating (1=operate) each month of each year type. The assumed D-1485 operation period is from October through May of each water year type.

- **Delta Outflow** - The matrix for D-1485 Delta outflow standards is shown in Table A2-2. The basis for these D-1485-derived outflow values is identified in Table A2-1. SWRCB staff have determined these values represent the combination of all applicable D-1485 Delta standards for flow or salinity control.

  D-1485 Delta standards do not directly address possible effects of the Montezuma Slough salinity control gate. Nevertheless, DeltaSOS can calculate the effects of the Montezuma Slough diversions on salinity at Chipps Island in several ways as described above.

  D-1485 Suisun Marsh standards include a 5-month (February-June) requirement of 6,600 cfs for all year types and a requirement for 2 months out of the January-April period of 12,000 cfs for above-normal and below-normal year types. These requirements are approximated in the OUTQ matrix values.

- **Export Pumping Limits** - The D-1485 export limits are 6,000 cfs in May and June and 9,200 cfs in July. The D-1485 reference matrix assumes increased SWP exports of 33% of the monthly average San Joaquin River inflow (if greater than 1,000 cfs) to a maximum export of 8,500 cfs during the months of December to March as the current SWP operational limits (Johns pers. comm.).

- **Delta Storage Operations** - The D-1485 reference standards do not apply to possible Delta storage facilities, so the values in the five required matrices for such a facility are set to zero.

CITATIONS

Personal Communications

Denton, Richard. Water resources engineer. Contra Costa Water District, Concord, CA. August 18, 1993 - letter and CCWD internal memorandum to Austin Nelson on "Fischer Model Relationship for Threemile Slough".

Johns, Gerald E. Assistant division chief. California State Water Resources Control Board, Division of Water Rights, Sacramento, CA. December 16, 1993 - letter to Jordan Lang regarding analysis of alternative scenarios for the DW project.

Russell, Dwight. Senior engineer. California Department of Water Resources, Division of Planning, Modeling Support Branch, Delta Modeling, Sacramento, CA. December 1993 - telephone conversation.

Table A2-1. Delta Outflow (D-1485) Reference Standard Matrix for DeltaSOS

	Standards by Hydrological Year Types															
Month	Wet	Std	AN	Std	BN	Std	Dry	Std	Critical	Std	W/SS	Std	AN/SS	Std	BN/SS	Std
October	4,800	A	4,800	A	4,800	A	4,800*	A	4,800*	A	4,800	A	4,800	A	4,800	A
November	4,800	A	4,800	A	4,800	A	4,800*	A	4,800*	A	4,800	A	4,800	A	4,800	A
December	4,800	A	4,800	A	4,800	A	4,800*	A	4,800*	A	4,800	A	4,800	A	4,800	A
January	4,800	A	4,800	A, C	4,800	A, C	4,800	A	4,800	A	4,800	A	4,800	A, C	4,800	A, C
February	10,000	B	4,800	A, C	4,800	A, C	4,800	A	4,800	A	10,000	B	4,800	A, C	4,800	A, C
March	10,000	B	7,210	C, D	7,210	C, D	7,210	D	4,800	E	10,000	B	7,210	C, D	7,210	C, D
April	10,000	B	7,580	C, F	7,580	C, F	7,580	F	6,700	G	10,000	B	7,580	C, F	7,580	C, F
May	13,350	H	12,960	I	10,780	J	7,580	F	4,850	K	7,580	F	7,580	F	7,580	F
June	14,000	L	10,700	L	9,500	L	6,120	M	3,850	N	7,580	F	7,580	F	6,620	O
July	10,000	L	7,700	L	6,500	L	4,650	P	3,850	N	7,580	F	6,720	Q	5,370	R
August	4,960	S	4,530	T	3,890	U	3,540	V	3,150	W	4,960	S	4,530	T	3,890	U
September	2,500	X	2,500	X	2,500	X	2,500	X	2,500	X	2,500	X	2,500	X	2,500	X

Headers:

Std = Standard (see sources of standards identified below).
AN = Above normal.
BN = Below normal.
W/SS = Wet/subnormal snowmelt.
AN/SS = Above normal/subnormal snowmelt.
BN/SS = Below normal/subnormal snowmelt.

Standards:

A = D-1485 Suisun Marsh 12.5 μmhos/cm EC (=4,500 cfs) + 300 cfs (=15% of 2,000 cfs average outflow diverted through Montezuma Slough when gates are operated); * = standard drops to 15.6 μmhos/cm EC (=3,500 cfs outflow) + 300 cfs control gate correction (total = 3,800 cfs) when projects are taking deficiencies.

B = D-1485 Suisun Marsh Delta outflow standards; SS (subnormal snowmelt; 10,000 cfs February-April) standard applies only to wet years, not to above-normal or below-normal years.

C = D-1485 Suisun Marsh 60 consecutive days at 12,000 cfs handled by OUTQ function.

Table A2-1. Continued

D = Average of D-1485 Suisun Marsh 6,600 cfs base flow (=17 days at 6,600 cfs + 300 cfs control gate correction), and ramping up for Emmaton 0.45 µmhos/cm EC (=14 days at 7,580 cfs) agricultural standard starting April 1 (see also note under G, "OUTQ").

E = D-1485 Suisun Marsh 12.5 µmhos/cm EC (=4,500 cfs) + 300 cfs control gate correction; no Emmaton agricultural standard in critical years.

F = D-1485 Emmaton 0.45 µmhos/cm EC (=7,580 cfs) agricultural standard.

G = D-1485 striped bass spawning protection; 14 days at 6,700 cfs outflow and 16 days at 1.5 µmhos/cm EC at Antioch (=16 days at 6,700 cfs outflow); may be reduced to as low as 4,500 cfs (Suisun Marsh 12.5 µmhos/cm EC standard) when projects are taking deficiencies.

H = Average of D-1485 Suisun Marsh (=5 days at 10,000 cfs) and striped bass outflow (=26 days at 14,000 cfs) standards.

I = Average of D-1485 Emmaton 0.45 µmhos/cm EC (=5 days at 7,580 cfs) agricultural and striped bass outflow (=26 days at 14,000 cfs) standards.

J = Average of D-1485 Emmaton 0.45 µmhos/cm EC (=5 days at 7,580 cfs) agricultural and striped bass outflow (=26 days at 11,400 cfs) standards.

K = Average of D-1485 Antioch striped bass salinity (=5 days at 6,700 cfs) and Suisun Marsh 12.5 µmhos/cm EC (=26 days at 4,500 cfs) standards; Antioch standard may be reduced to as low as 4,500 cfs when projects are taking deficiencies.

L = D-1485 striped bass outflow standard.

M = Average of D-1485 Emmaton 0.45 µmhos/cm EC (=15 days at 7,580 cfs) and 1.67 µmhos/cm EC (=15 days at 4,650 cfs) agricultural standards.

N = D-1485 Emmaton 2.78 µmhos/cm EC (=3,850 cfs) agricultural standard.

O = Average of D-1485 Emmaton 0.45 µmhos/cm EC (=20 days at 7,580 cfs) and 1.14 µmhos/cm EC (=10 days at 6,690 cfs) agricultural standards.

P = D-1485 Emmaton 1.67 µmhos/cm EC (=4,650 cfs) agricultural standard.

Q = Average of D-1485 0.45 µmhos/cm EC (=1 day at 7,580 cfs) and 0.63 µmhos/cm EC (=30 days at 6,690 cfs) agricultural standards.

R = D-1485 Emmaton 1.14 µmhos/cm EC (=5,370 cfs) agricultural standard.

S = Average of D-1485 Emmaton 0.45 µmhos/cm EC (=15 days at 7,580 cfs) and 16 days at 2,500 cfs minimum Delta outflow (MDO); MDO is not in D-1485 but is needed to maintain salinity stability in Delta.

T = Average of D-1485 Emmaton 0.63 µmhos/cm EC (=15 days at 6,690 cfs) and 16 days at 2,500 cfs MDO.

U = Average of D-1485 Emmaton 1.14 µmhos/cm EC (=15 days at 5,370 cfs) and 16 days at 2,500 cfs MDO.

V = Average of D-1485 Emmaton 1.67 µmhos/cm EC (=15 days at 4,650 cfs) and 16 days at 2,500 cfs MDO.

W = Average of D-1485 Emmaton 2.78 µmhos/cm EC (=15 days at 3,850 cfs) and 16 days at 2,500 cfs MDO.

X = MDO; D-1485 salmon standards at Rio Vista do not have concurrent outflow standards.

Table A2-1. Continued

Notes:
1. All year types designated according to D-1485 criteria.
2. Salinity standard conversions to Delta outflow from DWRSIM formulas.
3. These outflow standards do not compensate for net movement of water through Montezuma Slough when the control gates are operating. For example, the D-1485 February Suisun Marsh wet-year standard of 10,000 cfs Delta outflow at Chipps Island is not increased by 2,000 cfs to account for water moving through Montezuma Slough rather than flowing past Chipps Island directly. For purposes of this analysis, Delta outflow and Suisun Marsh standards are assumed to apply at Collinsville, just upstream of Montezuma Slough. The 300-cfs control gate correction is applied for salinity standards for internal Suisun Marsh stations; the control gate correction is not applied for Delta outflow standards. DeltaSOS is capable of analyzing the flow standards specified either for Collinsville or for Chipps Island; it can also vary the value of the correction factor.
4. Controlling standards only shown; in certain months, higher OUTQ outflow values may control.
5. Values shown in this table were developed by SWRCB staff member Jim Sutton (version 20 12/09/93 JESUTTON).

DeltaSOS

Minimum required Sacramento River flow at Freeport (cfs)

02-Jan-94

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Maximum permitted Hood Diversion capacity (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Maximum permitted fraction of Sacramento River flow available for Hood Diversion (%)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0%	0%	0%	0%	0%
Nov	0%	0%	0%	0%	0%
Dec	0%	0%	0%	0%	0%
Jan	0%	0%	0%	0%	0%
Feb	0%	0%	0%	0%	0%
Mar	0%	0%	0%	0%	0%
Apr	0%	0%	0%	0%	0%
May	0%	0%	0%	0%	0%
Jun	0%	0%	0%	0%	0%
Jul	0%	0%	0%	0%	0%
Aug	0%	0%	0%	0%	0%
Sep	0%	0%	0%	0%	0%

Minimum releases from Hood Diversion to QWEST (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Sacramento River trigger for Delta Cross Channel (cfs) (Closed if Sac flow below Hood>value)

DeltaSOS 02-Jan-94

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	25,000	25,000	25,000	25,000	25,000
Nov	25,000	25,000	25,000	25,000	25,000
Dec	25,000	25,000	25,000	25,000	25,000
Jan	25,000	25,000	25,000	25,000	25,000
Feb	25,000	25,000	25,000	25,000	25,000
Mar	25,000	25,000	25,000	25,000	25,000
Apr	25,000	25,000	25,000	25,000	25,000
May	25,000	25,000	25,000	25,000	25,000
Jun	25,000	25,000	25,000	25,000	25,000
Jul	25,000	25,000	25,000	25,000	25,000
Aug	25,000	25,000	25,000	25,000	25,000
Sep	25,000	25,000	25,000	25,000	25,000

Delta outflow trigger for Delta Cross Channel (cfs) (Closed if Delta outflow>value)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	75,000	75,000	75,000	75,000	75,000
Nov	75,000	75,000	75,000	75,000	75,000
Dec	75,000	75,000	75,000	75,000	75,000
Jan	12,000	12,000	12,000	12,000	12,000
Feb	12,000	12,000	12,000	12,000	12,000
Mar	12,000	12,000	12,000	12,000	12,000
Apr	12,000	12,000	12,000	12,000	12,000
May	75,000	75,000	75,000	75,000	75,000
Jun	75,000	75,000	75,000	75,000	75,000
Jul	75,000	75,000	75,000	75,000	75,000
Aug	75,000	75,000	75,000	75,000	75,000
Sep	75,000	75,000	75,000	75,000	75,000

Sacramento River trigger for Georgiana Slough Gates (cfs) (Closed if Sac flow below DCC>value)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	80,000	80,000	80,000	80,000	80,000
Nov	80,000	80,000	80,000	80,000	80,000
Dec	80,000	80,000	80,000	80,000	80,000
Jan	80,000	80,000	80,000	80,000	80,000
Feb	80,000	80,000	80,000	80,000	80,000
Mar	80,000	80,000	80,000	80,000	80,000
Apr	80,000	80,000	80,000	80,000	80,000
May	80,000	80,000	80,000	80,000	80,000
Jun	80,000	80,000	80,000	80,000	80,000
Jul	80,000	80,000	80,000	80,000	80,000
Aug	80,000	80,000	80,000	80,000	80,000
Sep	80,000	80,000	80,000	80,000	80,000

Minimum Rio Vista flow (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	5,000	2,500	2,500	1,500	1,500
Nov	5,000	2,500	2,500	1,500	1,500
Dec	5,000	2,500	2,500	1,500	1,500
Jan	2,500	2,500	2,500	1,500	1,500
Feb	3,000	2,000	2,000	1,000	1,000
Mar	4,000	2,500	2,500	1,500	1,500
Apr	4,000	4,000	4,000	4,000	4,000
May	4,000	4,000	4,000	4,000	4,000
Jun	4,000	4,000	4,000	4,000	4,000
Jul	3,000	2,000	2,000	1,000	1,000
Aug	1,000	1,000	1,000	1,000	1,000
Sep	5,000	2,500	2,500	1,500	1,500

DeltaSOS

Minimum QWEST flow (cfs)

02-Jan-94

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Nov	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Dec	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jan	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Feb	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Mar	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Apr	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
May	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jun	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jul	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Aug	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Sep	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)

Minimum San Joaquin River flow at Vernalis (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	900	900	900	900	900
Nov	900	900	900	900	900
Dec	900	900	900	900	900
Jan	900	900	900	900	900
Feb	900	900	900	900	900
Mar	900	900	900	900	900
Apr	900	900	900	900	900
May	900	900	900	900	900
Jun	900	900	900	900	900
Jul	900	900	900	900	900
Aug	900	900	900	900	900
Sep	900	900	900	900	900

Maximum fraction of San Joaquin River flow available for export (%)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0%	0%	0%	0%	0%
Nov	0%	0%	0%	0%	0%
Dec	33%	33%	33%	33%	33%
Jan	33%	33%	33%	33%	33%
Feb	33%	33%	33%	33%	33%
Mar	33%	33%	33%	33%	33%
Apr	0%	0%	0%	0%	0%
May	0%	0%	0%	0%	0%
Jun	0%	0%	0%	0%	0%
Jul	0%	0%	0%	0%	0%
Aug	0%	0%	0%	0%	0%
Sep	0%	0%	0%	0%	0%

San Joaquin River trigger for Old River Gates (cfs) (Open if SJR flow at Vernalis>value)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	10,000	10,000	10,000	10,000	10,000
Nov	10,000	10,000	10,000	10,000	10,000
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	10,000	10,000	10,000	10,000	10,000
May	10,000	10,000	10,000	10,000	10,000
Jun	10,000	10,000	10,000	10,000	10,000
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	10,000	10,000	10,000	10,000	10,000

DeltaSOS Number of months where tiered Delta outflow standards (cfs) must be met if triggered 02-Jan-94

Outflow Threshold	Wet	Above Normal	Below Normal	Dry	Critical	Threshold Fraction
6,600	5	5	5	5	5	1.00
12,000	0	2	2	0	0	1.00
28,000	0	0	0	0	0	1.00

Minimum Delta outflow (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	Wet Sub-Snowmelt	Above Normal Sub-Snowmelt	Below Normal Sub-Snowmelt
Oct	4,500	4,500	4,500	3,400	3,400	4,500	4,500	4,500
Nov	4,500	4,500	4,500	3,400	3,400	4,500	4,500	4,500
Dec	4,500	4,500	4,500	3,400	3,400	4,500	4,500	4,500
Jan	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Feb	10,000	4,500	4,500	4,500	4,500	10,000	4,500	4,500
Mar	10,000	6,910	6,910	6,910	4,500	10,000	6,910	6,910
Apr	10,000	7,580	7,580	7,580	6,700	10,000	7,580	7,580
May	13,350	12,960	10,780	7,580	4,850	7,580	7,580	7,580
Jun	14,000	10,700	9,500	6,120	3,850	7,580	7,580	6,620
Jul	10,000	7,700	6,500	4,650	3,850	7,580	6,720	5,370
Aug	4,960	4,530	3,890	3,540	3,150	4,960	4,530	3,890
Sep	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500

Maximum Delta export (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	DW Exemption	Assumed Capacity
Oct	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Nov	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Dec	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Jan	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Feb	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Mar	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Apr	10,880	10,880	10,880	10,880	10,880	10,880	11,280
May	6,000	6,000	6,000	6,000	6,000	6,000	11,280
Jun	6,000	6,000	6,000	6,000	6,000	6,000	11,280
Jul	9,200	9,200	9,200	9,200	9,200	9,200	11,280
Aug	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Sep	11,280	11,280	11,280	11,280	11,280	11,280	11,280

Status of Montezuma Slough Salinity Gates (0 = open,1 = operating)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	1	1	1	1	1
Nov	1	1	1	1	1
Dec	1	1	1	1	1
Jan	1	1	1	1	1
Feb	1	1	1	1	1
Mar	1	1	1	1	1
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Maximum Delta Wetlands storage capacity (TAF)

DeltaSOS 02-Jan-94

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Delta Wetlands evaporation (TAF)

	Wet	Above Normal	Below Normal	Dry	Critical	DW-Net CU Reductions	2-Island	4-Island
Oct	2.8	2.8	2.8	2.8	2.8	0.0	2.8	5.5
Nov	1.3	1.3	1.3	1.3	1.3	0.0	1.3	2.5
Dec	0.8	0.8	0.8	0.8	0.8	0.0	0.8	1.5
Jan	0.8	0.8	0.8	0.8	0.8	0.0	0.8	1.5
Feb	1.4	1.4	1.4	1.4	1.4	0.0	1.4	2.8
Mar	2.6	2.6	2.6	2.6	2.6	0.0	2.6	5.1
Apr	3.8	3.8	3.8	3.8	3.8	0.0	3.8	7.6
May	5.2	5.2	5.2	5.2	5.2	0.0	5.2	10.3
Jun	6.0	6.0	6.0	6.0	6.0	0.0	6.0	12.0
Jul	6.8	6.8	6.8	6.8	6.8	0.0	6.8	13.5
Aug	6.0	6.0	6.0	6.0	6.0	0.0	6.0	12.0
Sep	4.4	4.4	4.4	4.4	4.4	0.0	4.4	8.8

Maximum Delta Wetlands diversion (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Maximum Delta Wetlands discharge (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

DeltaSOS — Delta Wetlands outflow (cfs) — 02-Jan-94

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

USER DEFINED INPUTS FOR DELTA OPERATIONS:

		Range Names	Fraction of Available Water Diversion = Fract*(Avail−Minimum)	FRACT	MINIMUM
Hood Diversions to Exports? (0 = No, 1 = Yes)	0	HOOD			
Delta standards outflow point (0=Collinsville, 1=Chipps Island)	0	OUTPT			
Add Carriage Water to Required Outflow? (0=No, 1=Yes)	1	CARRY	OCT	1.0	0
Open Montezuma Gates to Meet Outflow? (0= No, 1= Yes)	0	MSSG	NOV	1.0	0
Cut Pumping to Meet Outflow? (0= No, 1= Yes)	1	EPA	DEC	1.0	0
Outflow Deficit Limits Delta Storage Export? (0= No, 1= Yes)	0	WHEEL	JAN	1.0	0
Delta Storage Export Limit Exemption? (0= No, 1= Yes)	1	FULL	FEB	1.0	0
SWP/CVP Export All Available (0= No ,1= Yes)	1	TAKE	MAR	1.0	0
Effective Montezuma Diversion Factor	1.00	MDF	APR	1.0	0
Starting Month for Delta Outflow Restrictions (1= Oct)	5	SDO	MAY	1.0	0
Ending Month for Delta Outflow Restrictions (1= Oct)	9	EDO	JUN	1.0	0
QWEST Estimated with Threemile Included? (0= No, 1= Yes)	0	TMS	JUL	1.0	0
Minimum SJR for Extra SWP Pumping	1,000	MINSJR	AUG	1.0	0
Minimum Pumping During Cutbacks	1,500	MINPUMP	SEP	1.0	0

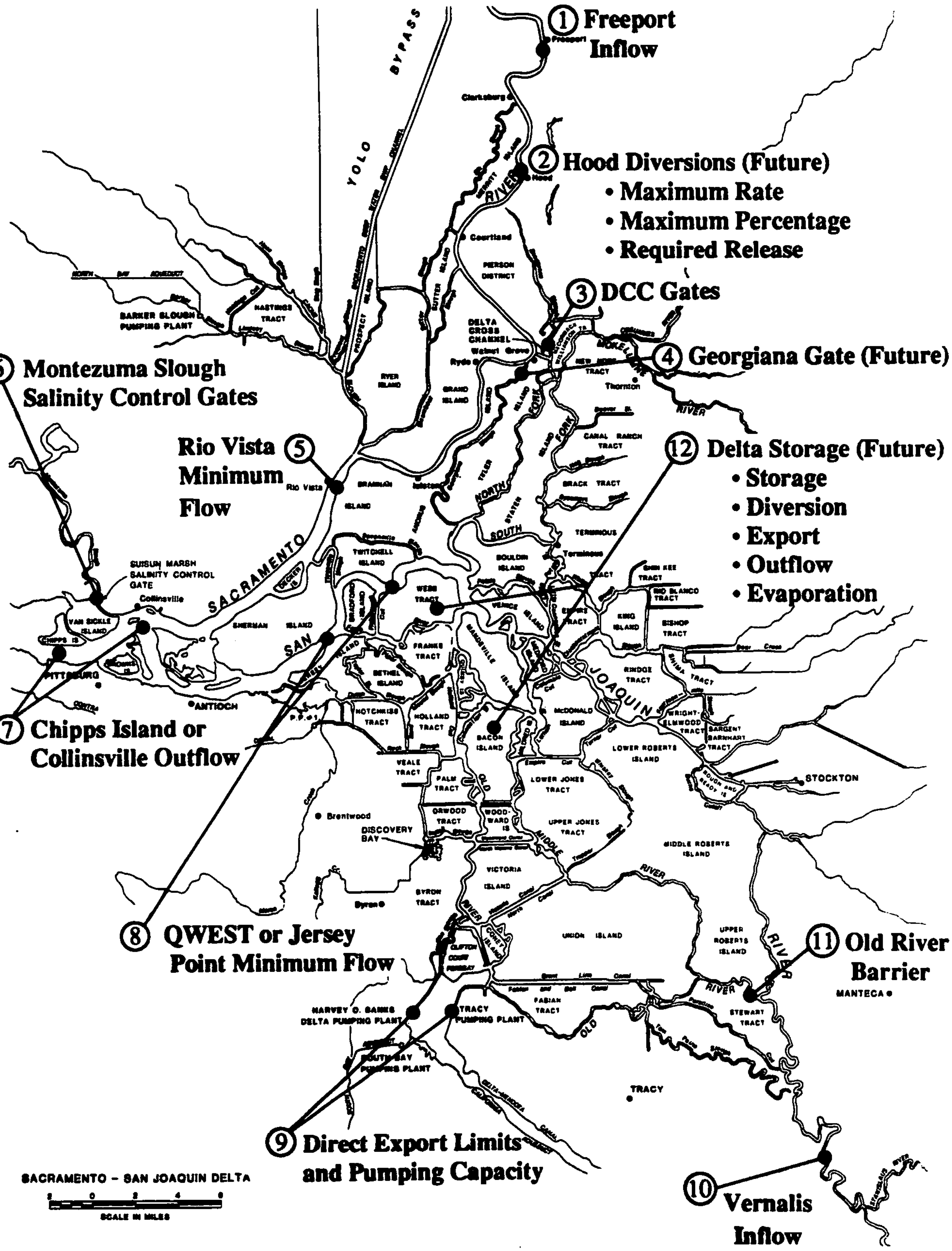
Table A2-3. Percent of Excess Export from Antioch for Different Combinations of Excess Export and Delta Ouflow
(Negative Percent Indicates Reversed Flow from Antioch)

Delta Outflow (cfs)	Excess Export (thousands of cfs)													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DWR Carriage Water Method (Threemile = -0.2 * Excess QWEST)														
10,000	160	88	52	30	16	5	-3	-9	-13	-17	-21	-23	-26	-28
9,000	148	80	46	25	12	2	-5	-11	-16	-19	-22	-25	-27	-29
8,000	136	72	40	21	8	-1	-8	-14	-18	-22	-24	-27	-29	-31
7,000	125	64	34	16	4	-5	-11	-16	-20	-24	-26	-29	-31	-32
6,000	113	56	28	11	0	-8	-14	-19	-23	-26	-28	-30	-32	-34
5,000	101	49	22	7	-4	-11	-17	-22	-25	-28	-30	-32	-34	-36
4,000	89	41	16	2	-8	-15	-20	-24	-27	-30	-32	-34	-36	-37
3,000	78	33	11	-3	-12	-18	-23	-27	-30	-32	-34	-36	-37	-39
2,000	66	25	5	-8	-16	-22	-26	-29	-32	-34	-36	-38	-39	-40
1,000	54	17	-1	-12	-20	-25	-29	-32	-34	-36	-38	-39	-41	-42
Based on RMA Delta Model Results (Threemile = 0.23 * Rio Vista - 0.31 * Excess QWEST)														
10,000	222	137	95	69	52	40	31	24	18	14	10	7	4	1
9,000	204	125	86	62	46	35	27	20	15	11	7	4	1	-1
8,000	186	113	77	55	40	30	22	16	11	7	4	1	-1	-3
7,000	168	101	68	48	34	25	18	12	8	4	1	-2	-4	-6
6,000	149	89	58	40	28	19	13	8	4	1	-2	-5	-7	-8
5,000	131	77	49	33	22	14	8	4	0	-3	-5	-7	-9	-11
4,000	113	64	40	26	16	9	4	0	-3	-6	-8	-10	-12	-13
3,000	95	52	31	18	10	4	-1	-4	-7	-9	-11	-13	-14	-16
2,000	76	40	22	11	4	-1	-5	-8	-11	-13	-14	-16	-17	-18
1,000	58	28	13	4	-2	-7	-10	-12	-14	-16	-17	-19	-20	-20

Table A2-4. Estimated Chloride Concentration (mg/l) of Excess Export for Different Combinations of Excess Export and Delta Outflow

Delta Outflow (cfs)	Reversed Flow Chloride Concentration (mg/l)	Excess Export (thousands of cfs)												
		3	4	5	6	7	8	9	10	11	12	13	14	15
DWR Carriage Water Method (Antioch Chloride = 7,900 * exp [-0.00035 * Outflow])														
10,000	239	15	15	15	15	15	21	34	45	54	61	67	72	77
9,000	339	15	15	15	15	15	33	51	66	78	88	96	103	110
8,000	480	15	15	15	15	22	54	79	99	115	129	140	150	159
7,000	682	15	15	15	15	47	90	124	151	173	191	206	220	231
6,000	967	15	15	15	16	93	150	195	231	260	285	305	323	339
5,000	1,373	15	15	15	69	171	248	307	355	394	426	454	477	497
4,000	1,948	15	15	15	167	302	403	481	544	595	638	674	705	732
3,000	2,765	15	15	93	339	515	647	749	831	899	955	1,002	1,043	1,078
2,000	3,923	15	15	308	628	856	1,027	1,160	1,267	1,354	1,427	1,488	1,541	1,586
1,000	5,567	15	76	692	1,102	1,396	1,616	1,787	1,924	2,035	2,129	2,208	2,275	2,334
Based on RMA Delta Model Results (Jersey Chloride = 0.5 * Antioch Chloride)														
10,000	119	15	15	15	15	15	15	15	15	15	15	15	15	15
9,000	169	15	15	15	15	15	15	15	15	15	15	15	15	16
8,000	240	15	15	15	15	15	15	15	15	15	15	15	18	23
7,000	341	15	15	15	15	15	15	15	15	15	15	21	28	34
6,000	484	15	15	15	15	15	15	15	15	15	25	36	46	54
5,000	686	15	15	15	15	15	15	15	15	33	50	64	76	87
4,000	974	15	15	15	15	15	15	17	48	73	94	112	128	141
3,000	1,382	15	15	15	15	15	25	73	112	143	170	192	211	228
2,000	1,962	15	15	15	15	42	118	177	224	262	294	322	345	365
1,000	2,784	15	15	15	78	198	287	357	413	459	497	529	556	580

Note: Sacramento River chloride concentration assumed to be 15 mg/l.



Source: Adapted from California Department of Water Resources 1993

Figure A2-1.
Locations Where Delta Standards Can Be
Specified in DeltaSOS Model

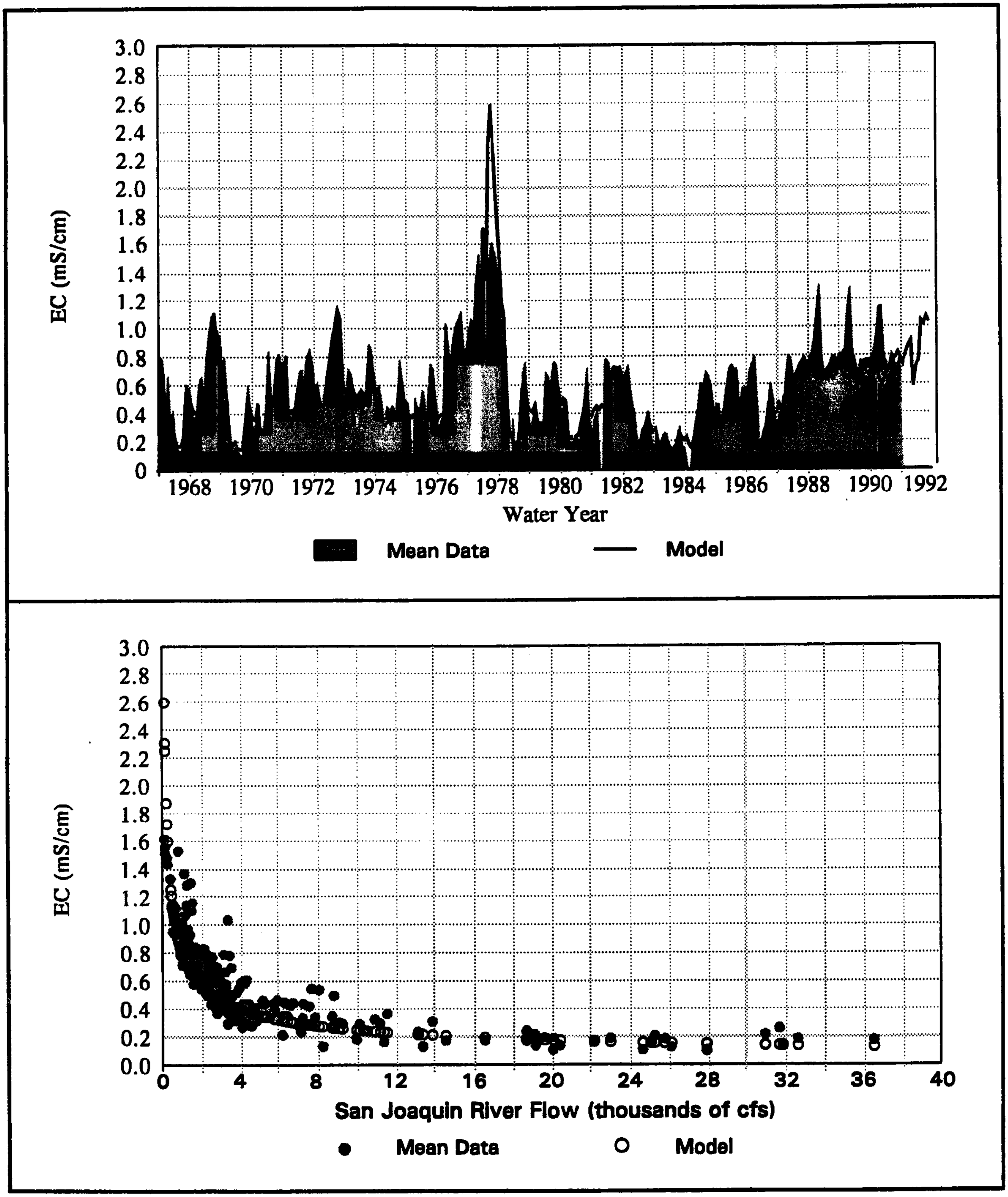


Figure A2-2. Simulated and Observed Relationship between Monthly EC at Vernalis and San Joaquin River Flow for 1967-1991

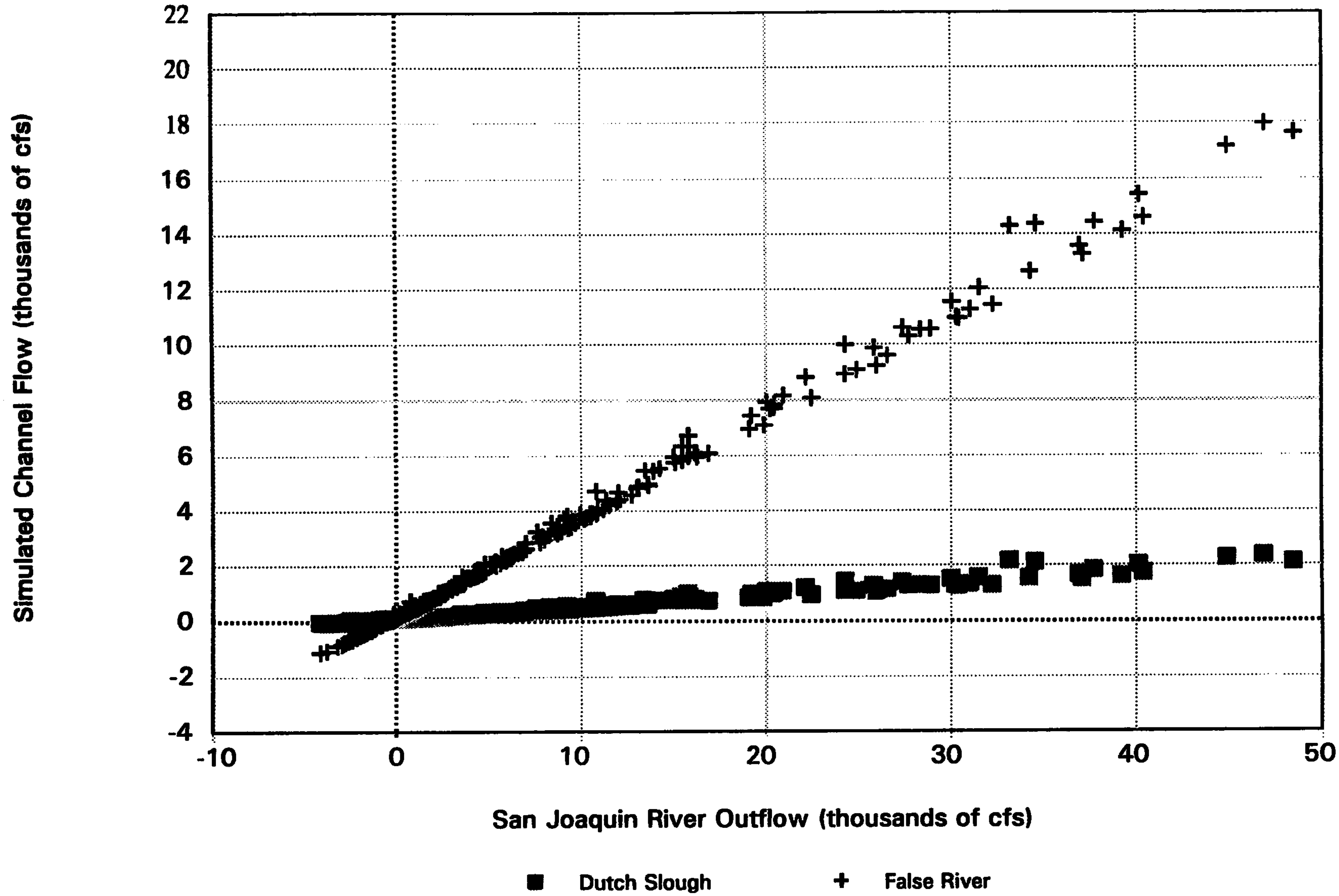


Figure A2-3. Simulated Relationship between Monthly Average Franks Tract Channel and San Joaquin River Outflow (QWEST) for 1967-1991

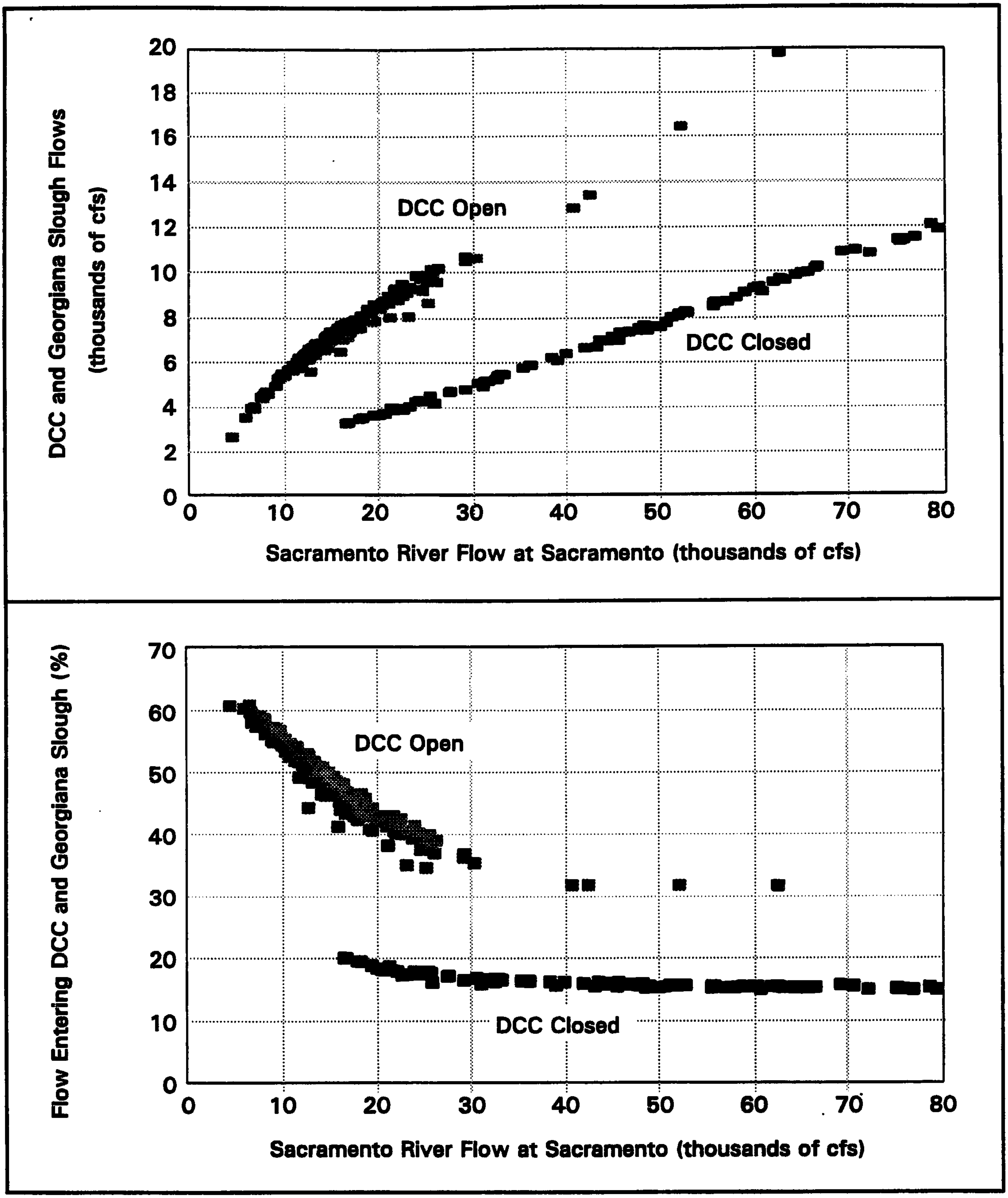


Figure A2-5. Simulated Relationship between Monthly Average DCC and Georgiana Slough Diversions and Sacramento River Inflow for 1967-1991

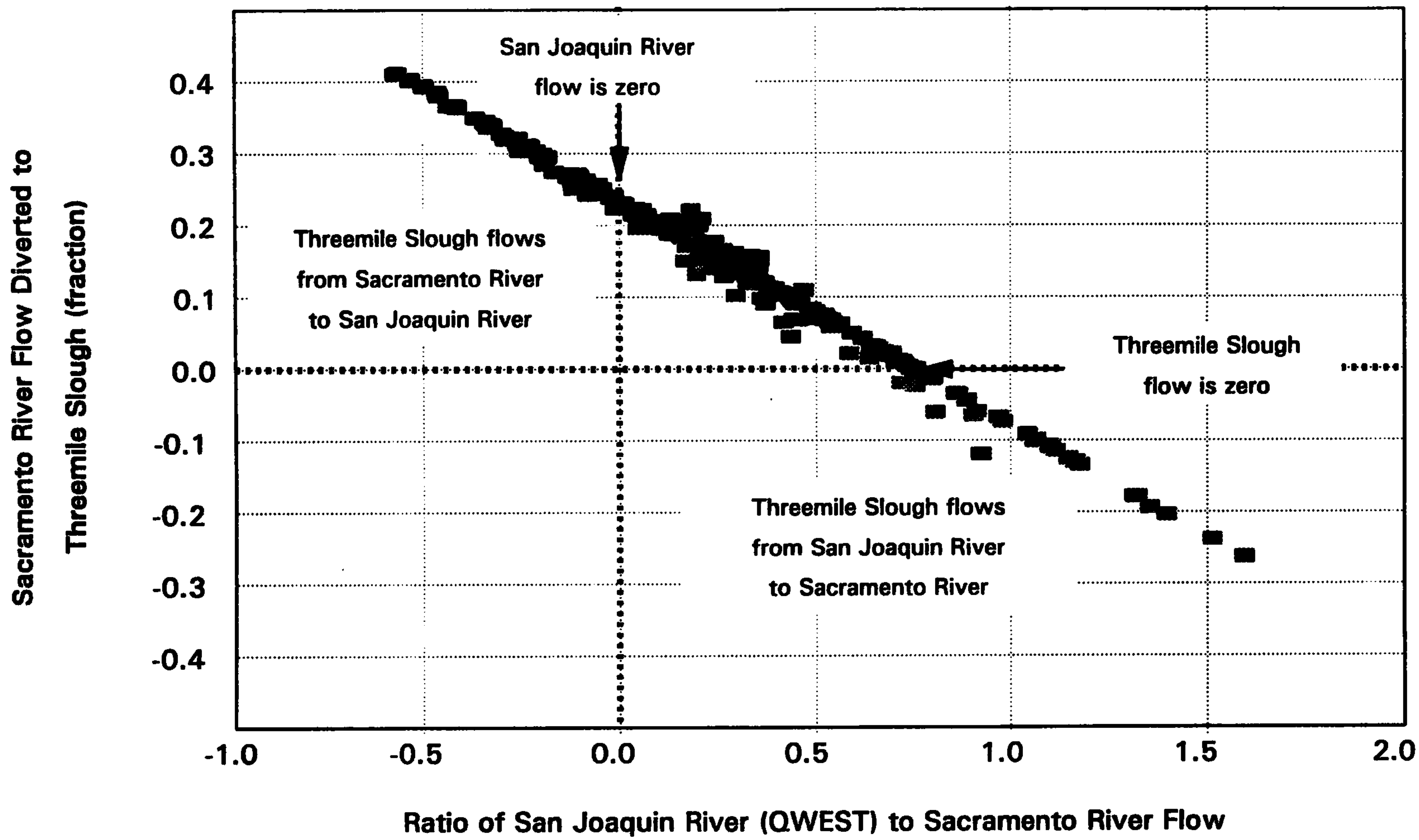


Figure A2-6. Simulated Relationship between Monthly Average Flows in Threemile Slough and Sacramento and San Joaquin River Flows for 1967-1991

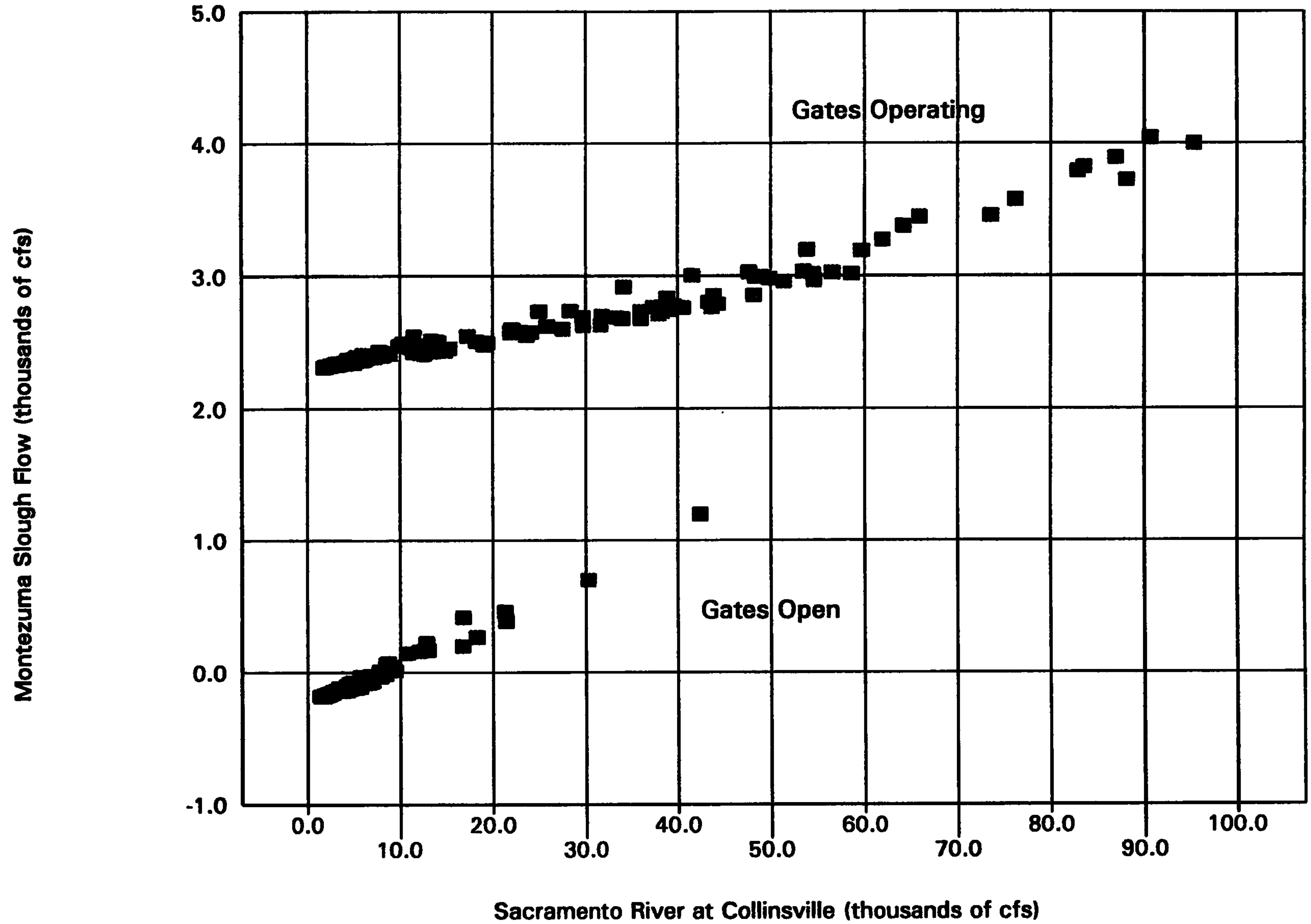
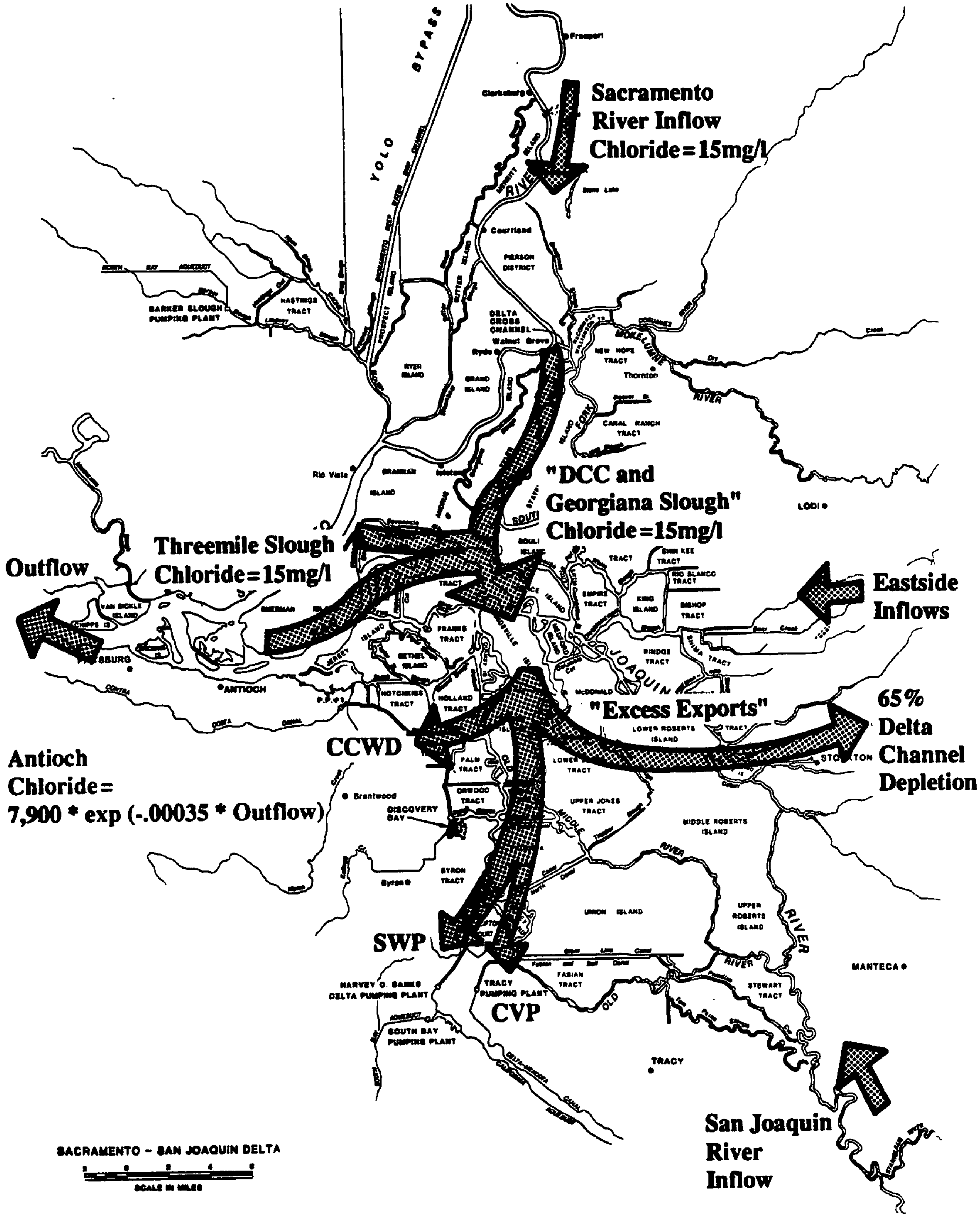


Figure A2-4. Simulated Relationship between Monthly Average Flows in Montezuma Slough and Sacramento River at Collinsville for 1967-1991



Source: Adapted from California Department of Water Resources 1993

Figure A2-7.
Chloride Budget Terms for
Carriage Water Calculations