Delta-Mendota Canal Recirculation Study

Executive Summary for Hydrologic and Water Quality Modeling

Prepared by

US Bureau of Reclamation
Mid-Pacific Region

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ACRONYMS – ABREVIATION

ANN	Artificial Neural Network
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta Estuary
Bay-Delta Accord	Principles for Agreement on Bay-Delta Standards between The State of California and the Federal Government
Banks Pumping Plant	Harvey O. Banks Pumping Plant
CALSIM2	California Simulation Model II
CCWD	Contra Costa Water District
CFS	cubicfoot per second
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
D-1641	Water Right Decision 1641
Delta	Sacramento – San Joaquin Delta
DFG	Department of Fish and Game
DMC	Delta-Mendota Canal
DSM2	Delta Simulation Model II
DWR	California Department of Water Resources
DWRSIM	SWP/CVP Simulation Model
EOM	End of Month
EWA	Environmental Water Account
Exchange Contractors	San Joaquin River Exchange Contractors Water Authority
JPOD	joint point of diversion
LOD	Level of Development
LP	Linear Programming
M&I	Municipal and Industrial
Merced ID	Merced Irrigation District
MID	Modesto Irrigation District
MILP	Mixed Integer Linear Programming
NMFS	National Marine Fisheries Service
NOD	North-of-Delta
OID	Oakdale Irrigation District
POA	Plan of Action
Principles for Agreement	Principles for Agreement on Bay-Delta Standards between The State of California and the Federal Government
PROSIM	Project Simulation Model
Reclamation	Bureau of Reclamation
ROD	Record of Decision
SANJASM	San Joaquin River Simulation Model
SDWA	South Delta Water Agency
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
SJR10	San Joaquin River mass balance water quality model
SJTA	San Joaquin Tributaries Association
SOD	South-of-Delta
SSJID	South San Joaquin Irrigation District
Study	Delta-Mendota Canal Recirculation Study
SWRCB	State Water Resources Control Board
TAF	thousand acre-foot
TID	Turlock Irrigation District
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Services
VAMP	Vernalis Adaptive Management Plan
WQCP	Water Quality Control Plan for San Francisco Bay/Sacramento-San Joaquin Delta Estuary May 1995

1. BACKGROUND

The Delta-Mendota Canal (DMC) Recirculation Study evaluates the benefits and impacts of recirculating water pumped from the Sacramento-San Joaquin Delta (Delta) through a series of the Central Valley Project (CVP) facilities to the San Joaquin River to meet flow objectives at Vernalis. The Study was performed to satisfy the requirements set forth by the State Water Resources Control Board (SWRCB) through its Water Right Decision 1641 (D-1641). Recirculation-related facilities include the Tracy Pumping Plant, the DMC, the Newman Wasteway, and the San Luis Reservoir. Figure 1-1 shows the study area.

The Delta Mendota Canal (DMC) Recirculation study is an appraisal level study to be conducted in two phases. The first phase includes hydrologic (water supply) modeling and water quality modeling. The second phase includes fisheries studies, water and sediment sampling, a legal analysis, an economic analysis, public involvement, and the preparation of a final study report. The scope of the modeling effort was to provide sufficient information for Reclamation management to decide whether to proceed to the second phase of the project. If at the end of the appraisal study Recirculation appears viable, then an extensive feasibility study, complete with environmental documentation, would be commenced. More detailed modeling to address unanswered questions from the appraisal study would also be conducted.

2. CONCEPT OF DMC RECIRCULATION

Recirculation uses water pumped at the CVP's Tracy Pumping Plant to augment flow in the San Joaquin River (Figure 2-1). Water is conveyed from Tracy Pumping Plant by the DMC to milepost 54.38, where a portion is diverted to the Newman Wasteway and flows to the San Joaquin River near the San Joaquin/Merced River confluence. Once in the San Joaquin River the water returns to the Delta meeting Vernalis flow and water quality targets on the way.

The initiation of recirculation requires backfilling San Luis Reservoir water into the Newman Wasteway through operation of radial gates from Check Station 13 (near O'Neill Forebay) to Check Station 10 (near the Newman Wasteway). This initiation of recirculation is termed "priming the system." Once the recirculation operation has ended, the "priming" water is returned as soon as possible to the San Luis Reservoir CVP portion.

Recirculation imposes a new demand on the system, which depending on several factors, may be recoverable. The degree to which it is recoverable is estimated in model studies reported here and is manifested primarily in change in delivery to south of delta contractors and San Luis storage at its low point.

Figure 1-1. Location Map of Delta-Mendota Canal Recirculation Study Area

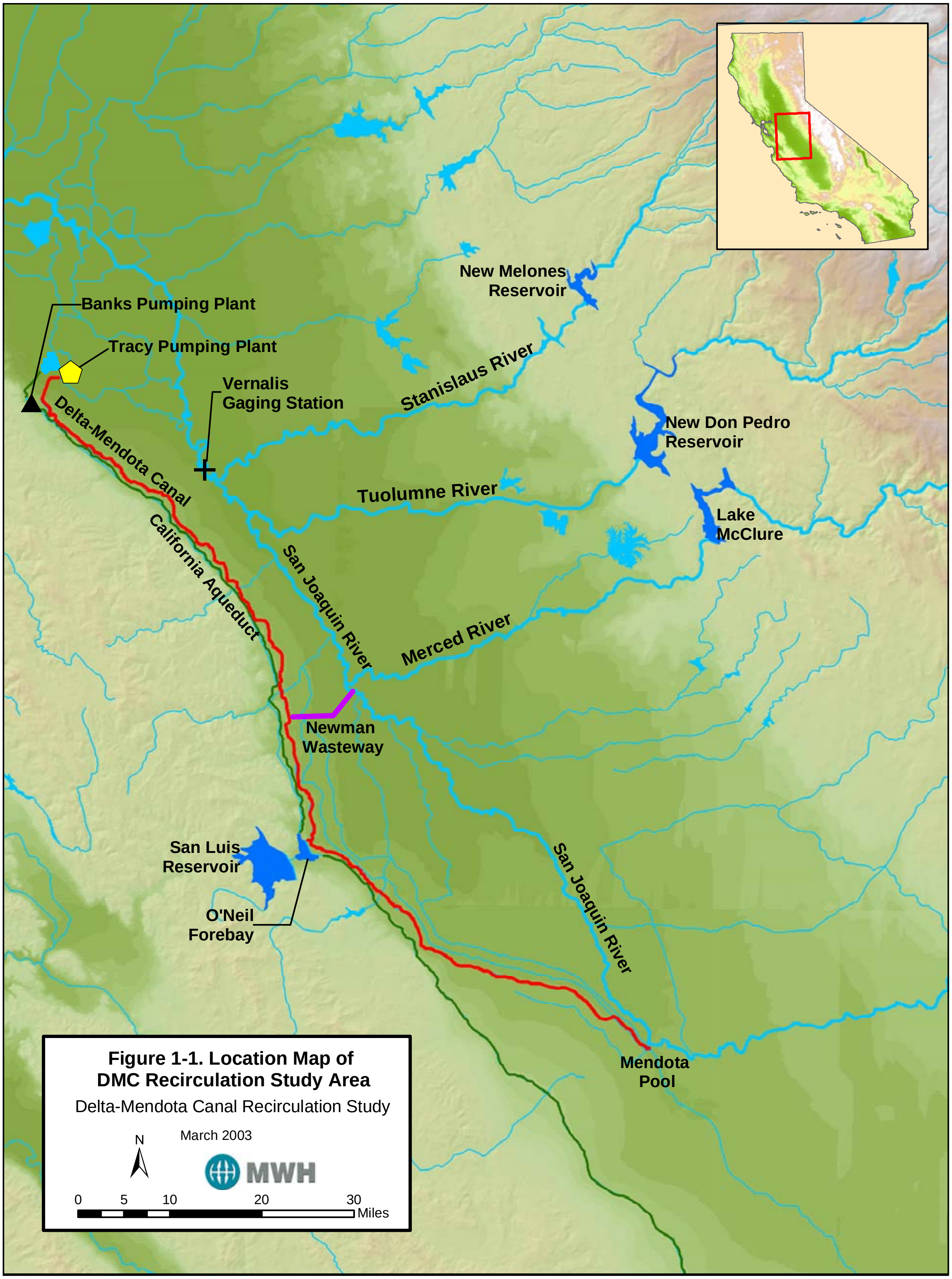

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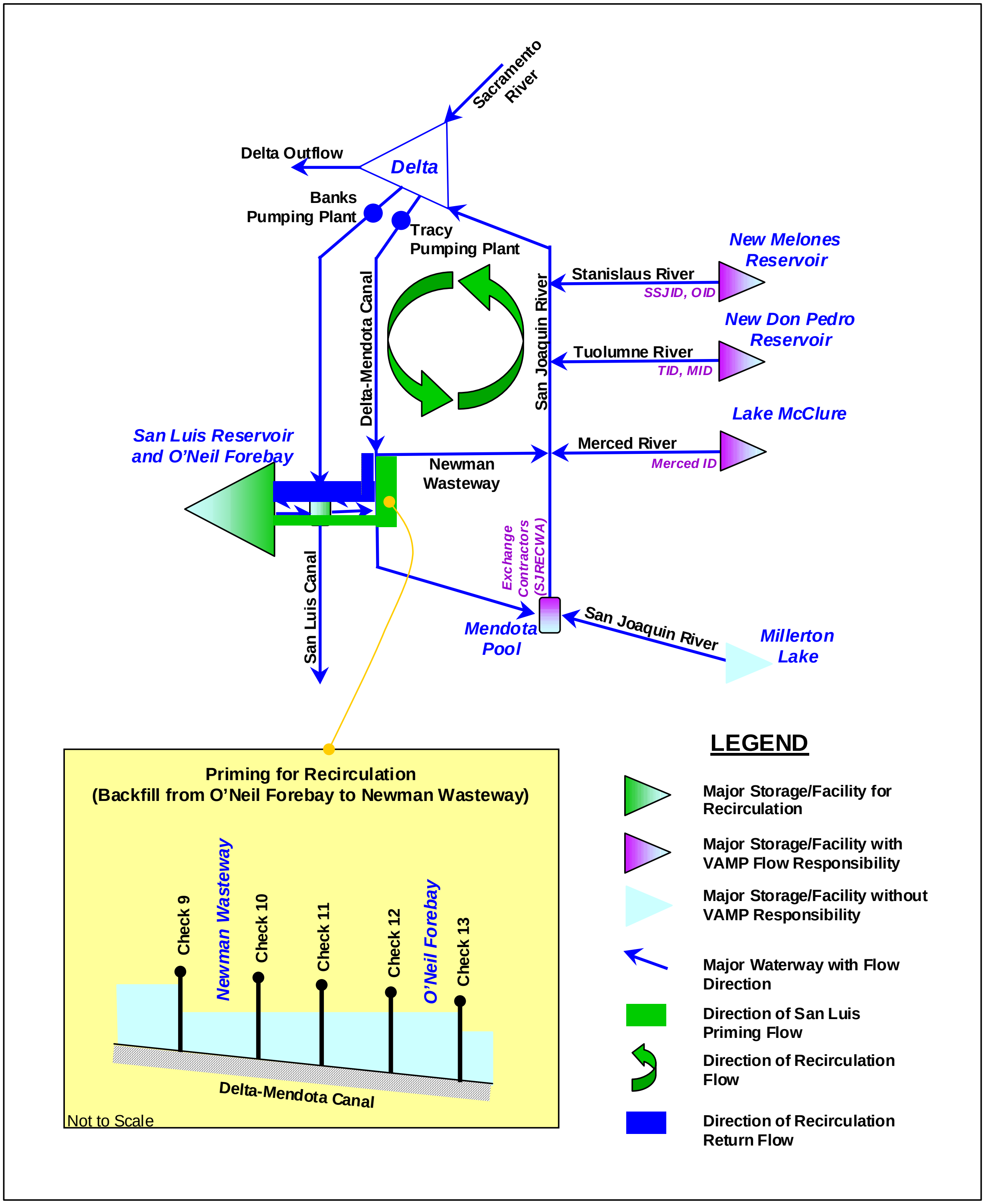
Figure 2-1. Conceptual Representation of Delta-Mendota Canal Recirculation



3. DEFINITION OF THE BASE CONDITION AND ALTERNATIVES

Through continued consultation with the SWRCB, the Study has defined a Base Condition and two recirculation alternatives that satisfy SWRCB's requirements. In addition, fundamental guidelines for the Study are to observe current applicable water rights, laws, regulations (including CVP and SWP pumping restrictions), contracts, and other operation principles and guidelines.

Base Condition

The Base Condition is based on the CALSIM II September 2002 Benchmark Study for 2001 level of development (ANN version). The Base Condition satisfies the study requirements listed in Condition 2 of D-1641[1], and study requirements listed in SWRCB's March 21, 2000, letter[2] to the USBR.

Alternative 1 (VAMP Recirculation)

Alternative 1 includes the same assumptions as the Base Condition, except:

1. Recirculation will provide VAMP flow of up to 110 TAF per year during the April 15 to May 15 pulse flow period per the SJRA. Recirculation flows are from Delta exports of the Tracy Pumping Plant and, in some years, release from CVP San Luis Reservoir storage. This action will relieve New Melones Reservoir, New Don Pedro Reservoir, Lake McClure, and the Exchange Contractors from VAMP flow responsibility. It was assumed that fulfilling the VAMP flows had a higher priority than delivering water to CVP water contractors. Storage releases from San Luis reservoir would be required in years when Tracy export restrictions prevent the pumping of the total VAMP flow.

2. A storage release from San Luis Reservoir is required to initiate or prime the recirculation process.

Alternative 2 (Feb-Jun Vernalis Minimum Flow Recirculation)

Alternative 2 includes the same assumptions as the Base condition, except:

1. Recirculation will provide flows to supplement releases from New Melones Reservoir to meet Vernalis minimum target flows (based on X2 position) during February through June, excluding the VAMP period. New Melones Reservoir will release for X2 minimum target flows of up to 75 TAF when storage and inflow conditions permit. Generally, the recirculation flow will be Delta export water from the Tracy Pumping Plant. In some years, Tracy export restrictions may prevent the pumping of the full X2 augmentation flow in which case CVP storage will be released from San Luis Reservoir.

[1] SWRCB(2000), *Revised Water Right Decision 1641*, March 15, 2000, pg 153.
[2] SWRCB(2001), *Letter of Acceptance of the Delta Mendota Canal Recirculation Study Plan of Action*, addressed to Lester Snow, Bureau of Reclamation, Mid-Pacific Region, March 21, 2000, pg 153.

4. MODELING TOOLS USED

The tools for hydrologic (water supply) and water quality evaluation are the California Simulation Model (CALSIM) and the Delta Simulation Model 2 (DSM2), respectively. The outputs of CALSIM will be used as the hydrologic inputs of DSM2 for planning purposes. These two models have very distinct model characteristics such as simulation time step and resolution in geographical representation.

4.1 The CALSIM II Model

The water supply analysis for the Study was accomplished using the California Simulation Model II (CALSIM II). CALSIM II is a general-purpose planning simulation model under development by Reclamation and DWR to simulate operations of California's water resources system, specifically the CVP and SWP. On a monthly time-step, CALSIM II utilizes optimization techniques to route water through a network. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period with a given set of weights and system constraints.

CALSIM II's geographic coverage includes the valley floor drainage area of the Sacramento and San Joaquin Rivers, the upper Trinity River, San Joaquin Valley, Tulare Basin, and southern California areas served by CVP and SWP. Although the focus of CALSIM II is on major CVP and SWP facilities, operations of many other facilities are included to varying degrees.

4.2 The DSM2 Model

DSM2, developed by DWR, is a one-dimensional deterministic hydrodynamic and salt transport model for the Sacramento-San Joaquin Delta. DSM2 is comprised of a network of nodes and arcs, for which the channel geometry are specified. DSM2 has two modules: DSM2-HYDRO for hydrodynamics, and DSM2-QUAL for water quality. Electrical conductivity is used as a surrogate in salt transport calculation. The modeling area of DSM2 covers the entire legal Delta: Sacramento River downstream of the City of Sacramento, San Joaquin River downstream of Vernalis, and Sacramento-San Joaquin Delta east of the Benicia Bridge. The simulation time step is 15 minutes.

An extension of DSM2 along the mainstem of the San Joaquin River (DSM2-SJR) was developed by DWR in year 2000 because many Delta water supply, water quality, and fishery issues are closely linked to conditions in the San Joaquin River. The modeling area of DSM2-SJR is along the San Joaquin River mainstem from the Bear Creek confluence to Vernalis. The outputs of DSM2 include the flow, stage, and water quality at selective reporting locations. The model linkage developed in this Study is limited to DSM2-SJR's modeling area.

5. FINDINGS OF THE HYDROLOGIC (WATER SUPPLY) MODELING

The findings of the water supply modeling are presented in the following paragraphs and tables. Before describing the findings, it is important to distinguish the actual impacts to the system caused by an alternative from changes that are beyond the resolution of the model to calculate. Therefore, a 1-percent or 5.0 TAF threshold has been designated for this study. Changes between an alternative and the base condition that are less than 1-percent or 5.0 TAF are **not** considered impacts due to recirculation.

5.1 Alternative 1 (VAMP Recirculation)

DMC recirculation could be used to supplement San Joaquin River flow during the 31-day pulse flow period (April 15 through May 15), in lieu of the releases from tributary reservoirs (New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure). The major impact would be to SOD CVP delivery, which would be reduced to facilitate recirculation flow. Recirculation would have limited impacts on reservoir operation, CVP/SWP deliveries north of Delta, and reservoir storage in San Luis Reservoir. Results of the Alternative 1 modeling are summarized in Table 5-1.

The following are key findings regarding Alternative 1 hydrologic and water supply impacts:

1) Annual average recirculation flows are about 44 TAF, ranging from zero to 110 TAF. For the 73 years used in the simulation, recirculation flow would have been required in 54 years (Figure 5-1).

2) Average required flow for recirculation purposes is 10, 60, 80, 69, and 27 TAF for wet, above normal, below normal, dry, and critical years, respectively. This flow directly reduces south of delta CVP deliveries.

3) Annual average SOD CVP deliveries were reduced by 43.5 TAF, which is equivalent to the average annual volume required for DMC recirculation. The majority of the reductions occur during April and May (VAMP period) with a decrease in deliveries of 13.6 TAF (-8.4%) and 19.6 TAF (-8.0%) respectively.

4) Average end-of-August (San Luis low-point) storage for CVP San Luis would decrease by 6.8 TAF (-3.5 %).

5) Changes to NOD CVP deliveries and SOD SWP deliveries were both below the 1% threshold and were not considered significantly impacted.

6) Impacts to NOD CVP and NOD SWP reservoir storage, and SWP San Luis Reservoir all fell within the 1% or 5.0 TAF threshold and were not considered significant.

7) Changes to CVP and SWP exports, including CVP wheeling, all fell within the 1% or 5.0 TAF threshold and were not considered significant.

8) Average end-of-September storage in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure would increase by 27.6 TAF, 15.5 TAF, and 57.2 TAF, respectively.

9) Releases from eastside tributary reservoirs during the VAMP pulse flow period were reduced. Note that in this Study, no alternative uses of this saved water were identified. As a result, these unused flows could be released outside of the VAMP pulse flow period; for example, pre-releases prior to the flood control season or to meet instream flows.

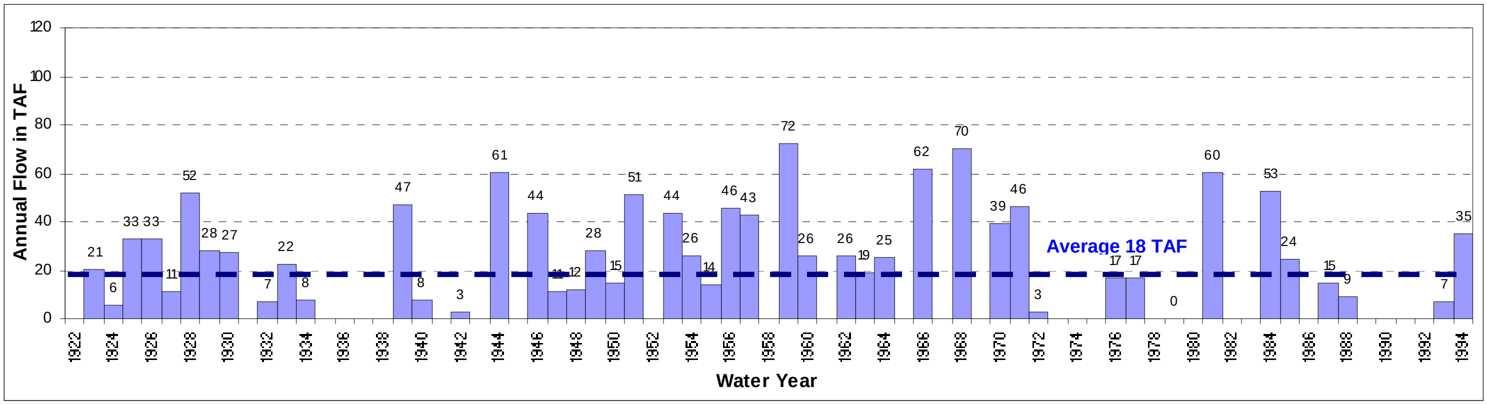
Table 5-1 (Alternative 1 Results)

Result	Average[1] Base (TAF)	Average[1] Alt. 1 (TAF)	Average[1] Diff[2] (TAF)	%Diff (%)
SOD CVP Total Deliveries	2,442	2,399	-43.5	-1.8
SOD CVP April Deliveries	165	151	-13.6	-8.4
SOD CVP May Deliveries	253	234	-19.6	-8.0
SOD SWP Total Deliveries	2,906	2,912	5.1	0.3
NOD CVP Total Deliveries	2,206	2,204	-1.8	-0.1
CVP (Tracy) Total Exports	2,256	2,263	7.1	0.3
SWP (Banks) Total Exports	3,251	3,256	5.2	0.1
SWP (Banks) Exports for SWP	3,021	2,028	7.7	0.2
SWP (Banks) Exports for CVP	132	130	-2.5	-1.8
CVP San Luis EOM Aug Storage	200	193	-6.8	-3.5
SWP San Luis EOM Aug Storage	301	304	2.6	1.3
CVP NOD Reservoirs[3] EOM Sep Storage	3,257	3,252	-4.1	-0.2
SWP NOD Reservoirs[4] EOM Sep Storage	1,989	1,989	-0.2	0.0
New Melones EOM Sep Storage	1,323	1,351	27.6	2.7
Don Pedro EOM Sep Storage	1,355	1,370	15.5	1.4
Lake McClure EOM Sep Storage	468	525	57.2	24.0

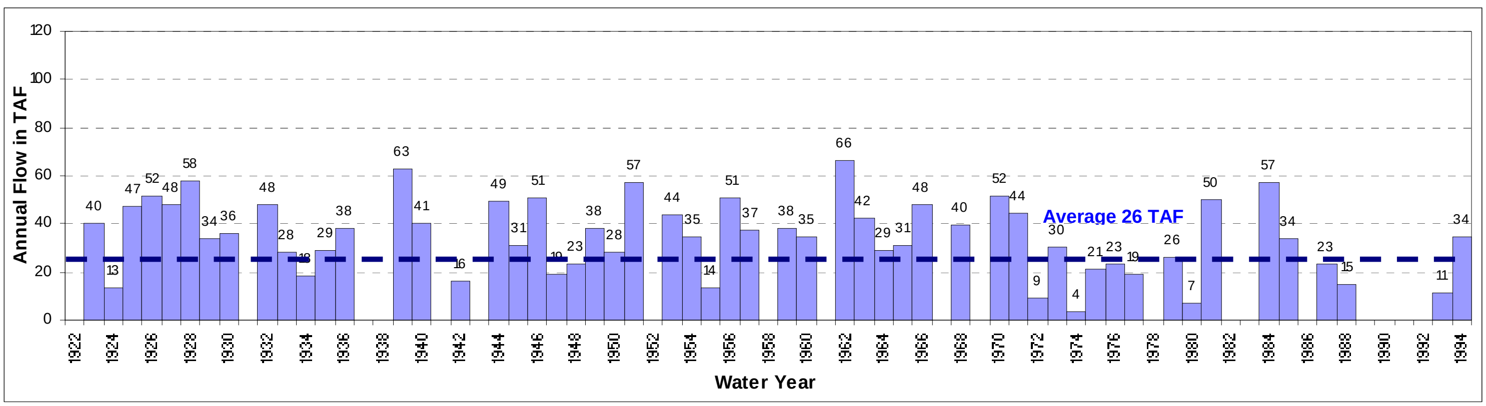
Notes:
[1] Average for all water year types (1922-1994)
[2] Average difference (Recirculation – Base) for all water year types, (1922-1994)
[3] Wiskeytown Lake, Shasta Lake, Keswick Reservoir, Folsom Lake, Lake Natomas
[4] Lake Oroville, Themalito Forebay

Figure 5-1. Recirculation Flow of Alternative 1 in TAF

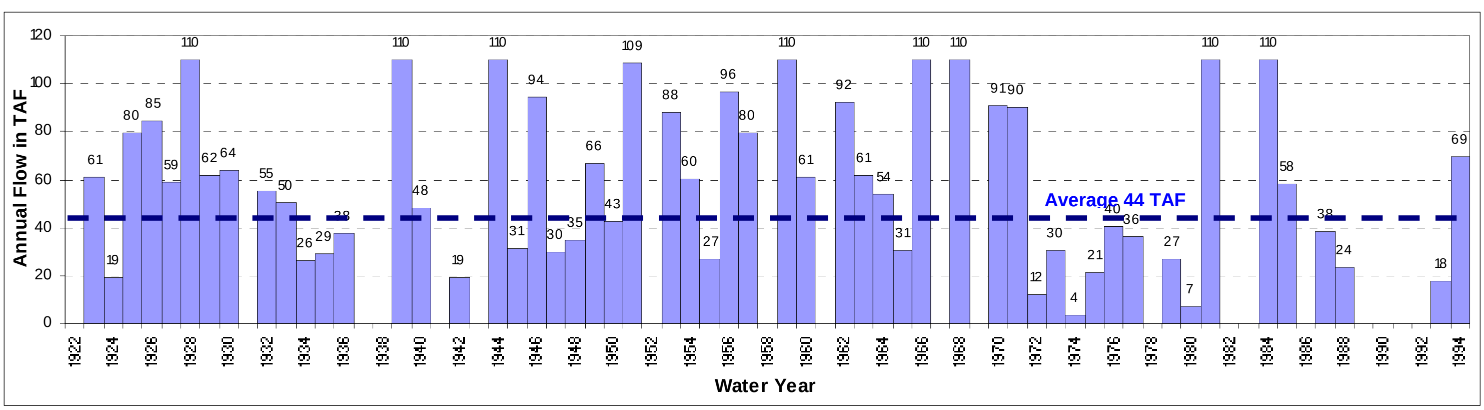
(a) April 15-31



(b) May 1-15



(c) Annual Total



5.2 Alternative 2 (Feb –Jun Vernalis Minimum Flow Recirculation)

DMC recirculation could be used to supplement San Joaquin River flow in addition to the releases from New Melones Reservoir during February through June, excluding the 31-day pulse flow period (April 15 through May 15). Also, application of recirculation for October pulse/attraction flows was also investigated. The overall water supply impact from recirculation is minimal because the required recirculation flow is small. A summary of results for Alternative 2 is given in Table 5-2. The following are key findings regarding Alternative 2 hydrologic and water supply impacts:

1) The annual average recirculation flow was about 5.1 TAF, ranging from zero to 76.6 TAF. For the 73 years of simulation used in the model, recirculation flow would have been required in 22 years (Figure 5-2).

2) Average required flow for recirculation purposes was 1, 10, 1, 17, and 1 TAF for wet, above normal, below normal, dry, and critical years, respectively. However, recirculation flow is consistently provided by withdrawals from San Luis Reservoir and increases in Delta pumping.

3) The average end-of-August storage (San Luis Low Point) for CVP San Luis would decrease by 3.0 TAF (-1.3%).

4) Impacts to SWP deliveries and SWP San Luis were both below the 1% threshold and were not considered significant.

5) On an annual average basis, there would be insignificant impacts to CVP delivery and storage (both NOD and SOD), Delta pump operation, and releases from the tributary reservoirs (New Melones, New Don Pedro, and Lake McClure).

6) The October minimum flow of 1,000 cfs was always achieved through pulse/attraction flows; thus recirculation was never required for this month.

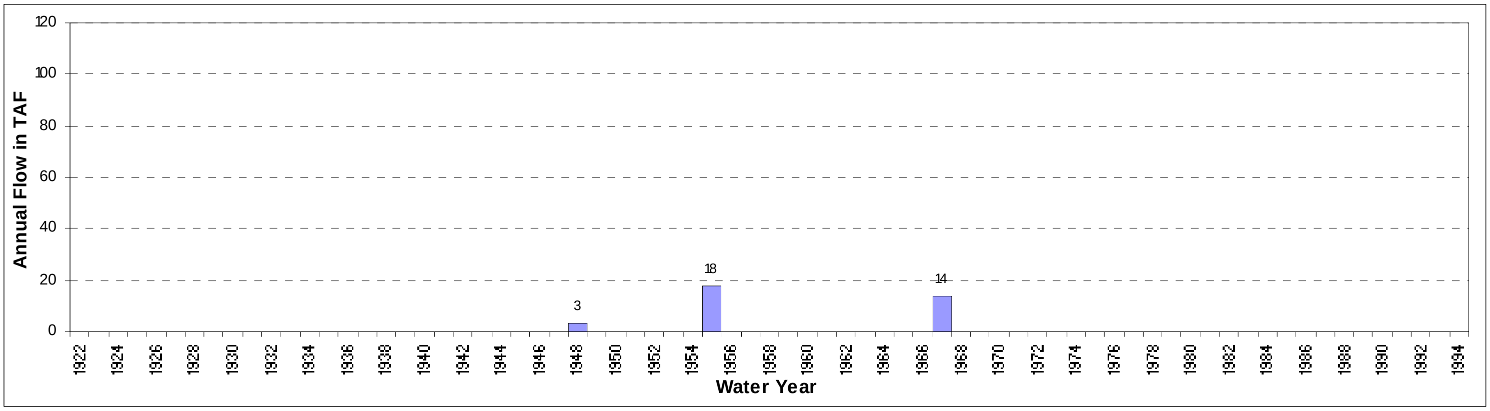
Table 5-2 (Alternative 2 Results)

Result	Average[1] Base (TAF)	Average[1] Alt. 1 (TAF)	Average[1] Diff[2] (TAF)	%Diff (%)
SOD CVP Total Deliveries	2,442	2,442	-0.1	0.0
SOD SWP Total Deliveries	2,906	2,909	2.7	0.1
NOD CVP Total Deliveries	2,206	2,206	-0.2	0.0
CVP (Tracy) Total Exports	2,256	2,260	4.1	0.2
SWP (Banks) Total Exports	3,251	3,257	5.6	0.1
SWP (Banks) Exports for SWP	3,021	3,026	5.7	0.1
SWP (Banks) Exports for CVP	132	132	0.1	0.8
CVP San Luis EOM Aug Storage	200	197	-3.0	-1.3
SWP San Luis EOM Aug Storage	301	303	2.0	0.6
CVP NOD Reservoirs[3] EOM Sep Storage	3,257	3,255	-1.6	-0.1
SWP NOD Reservoirs[4] EOM Sep Storage	1,989	1,989	-0.6	0.1
New Melones EOM Sep Storage	1,323	1,323	-0.2	0.0

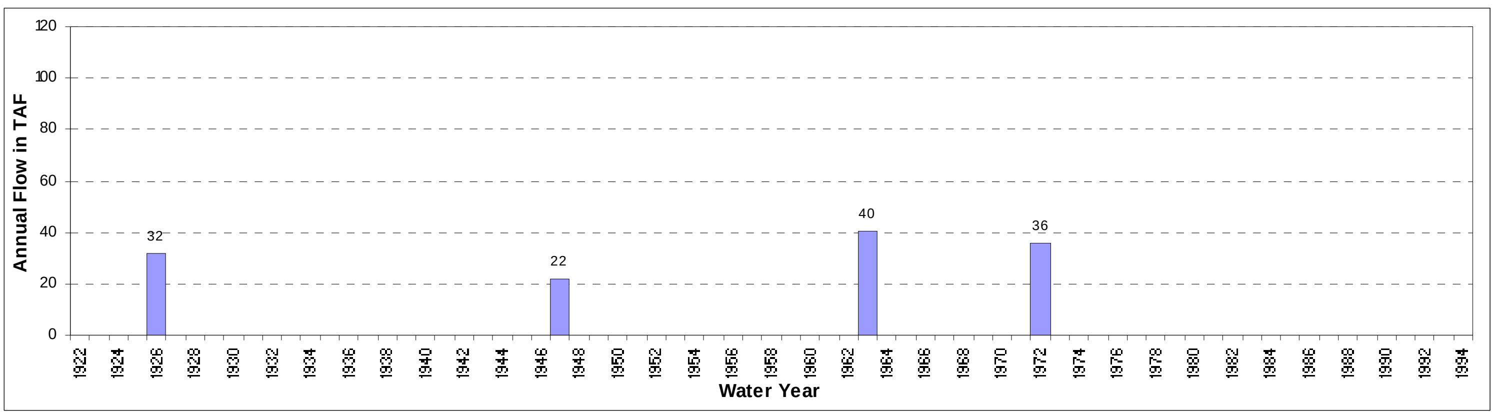
Notes:
[1] Average for all water year types (1922-1994)
[2] Average difference (Recirculation – Base) for all water year types, (1922-1994)
[3] Wiskeytown Lake, Shasta Lake, Keswick Reservoir, Folsom Lake, Lake Natomas
[4] Lake Oroville, Themalito Forebay

Figure 5-2. Recirculation Flow of Alternative 2 in TAF

(a) February



(b) March



(c) April 1-14

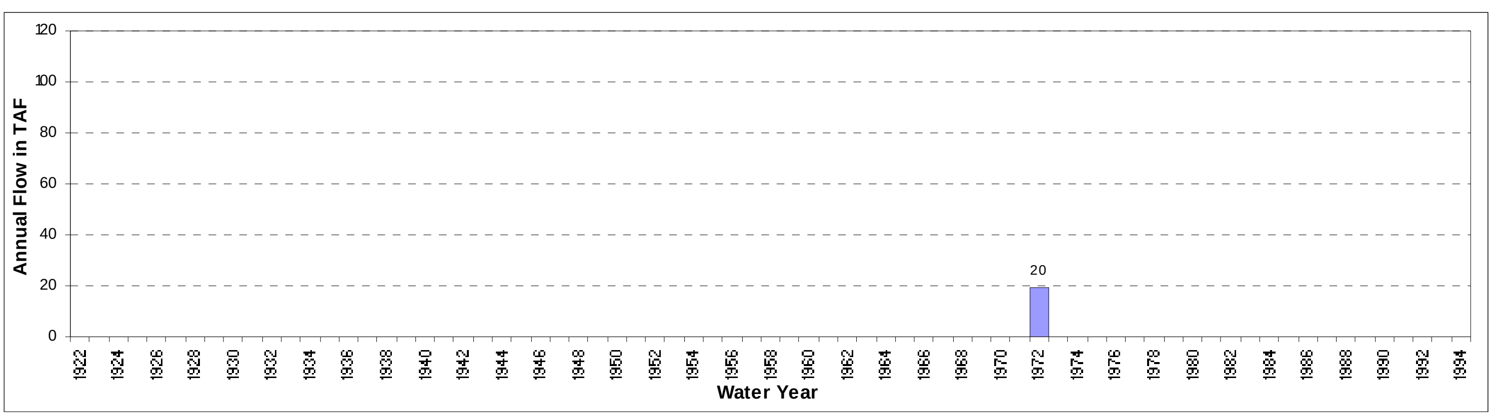
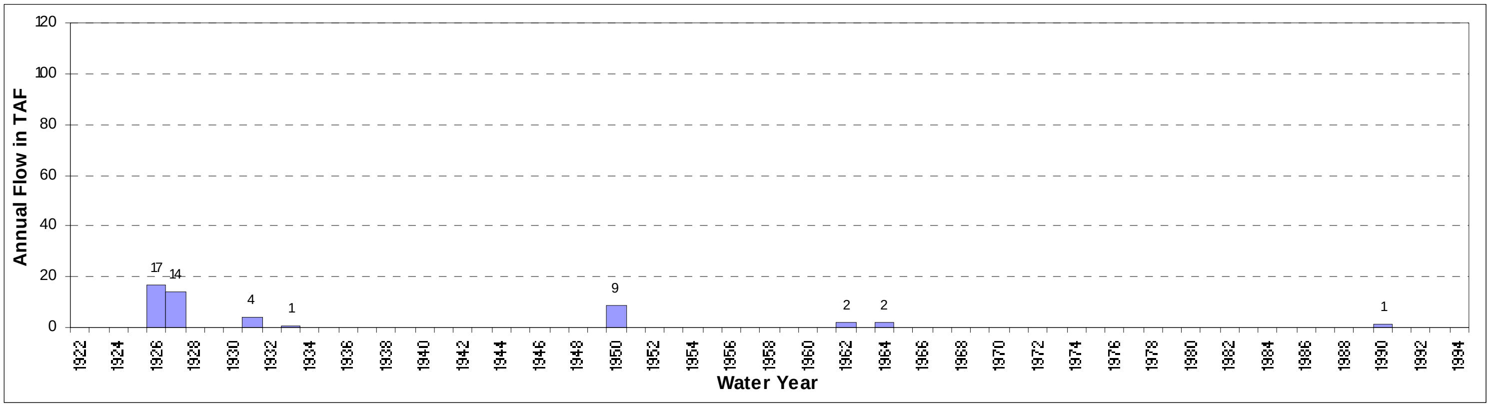
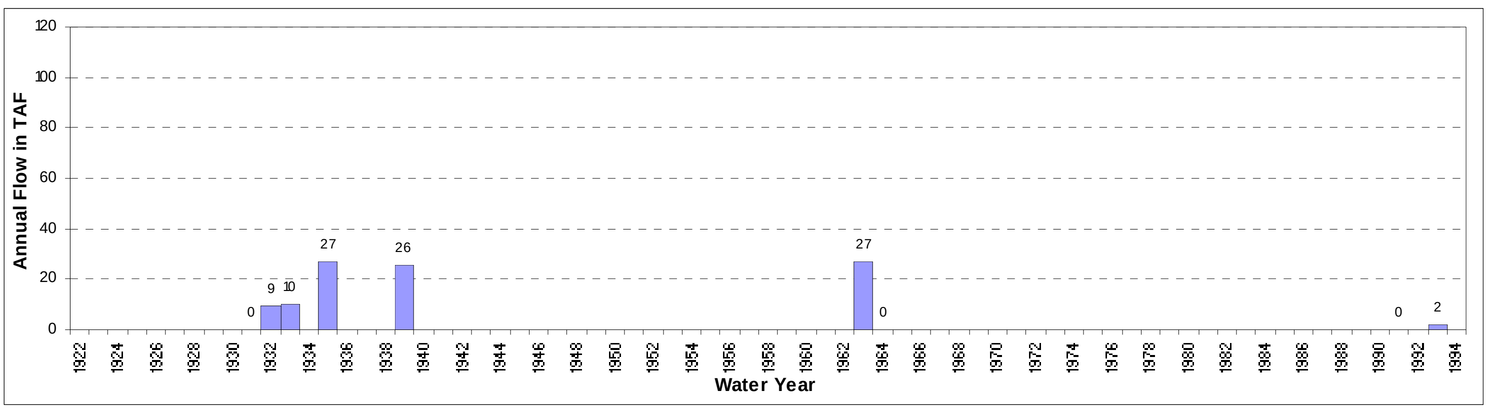


Figure 5-2. (Continued)

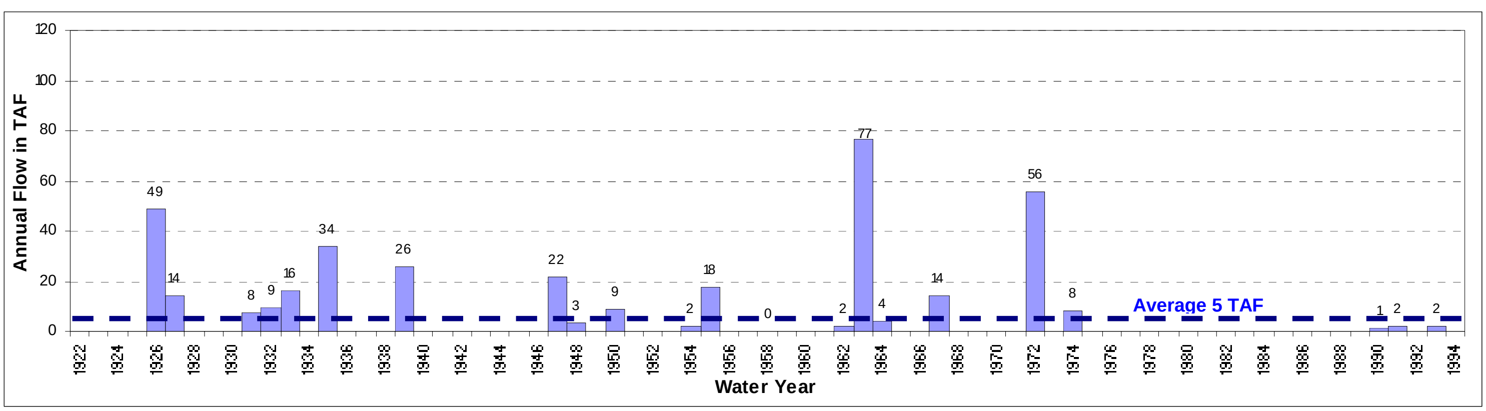
(d) May 16-31



(e) June



(f) Annual Total



6. FINDINGS OF THE WATER QUALITY MODELING

The California Department of Water Resources, Delta Modeling Group of the Modeling Support Branch conducted a DSM2 water quality analysis on DMC Recirculation. The water quality analysis evaluated the impacts of recirculation on Lower San Joaquin water quality as well as analyze the ability of recirculation to help meet flow objectives in the South Delta and at Vernalis. For this study, the water quality analysis was limited to the evaluation of salt transport using electrical-conductivity (EC) as a surrogate. The cases analyzed included the Base Condition and Alternatives 1 and 2.

Electrical-conductivity was computed on the San Joaquin River at Vernalis and also immediately upstream and downstream of the Merced/San Joaquin River confluence (see Figure 1-1 in Section 1). In the Delta region, EC was computed at the CVP export facility and also at Twitchell Island. In addition, flows were analyzed at Turner Cut, Columbia Cut, and the Old River at Highway 4 (see Figure 6-1) at the request of the California Department of Fish and Game. South Delta Barriers were modeled as determined by the DWR Delta Modeling and South Delta Improvements Group. The barriers in the Old River near Tracy, Middle River, and Grantline Canal were assumed to be temporary rock structures with weir and culvert flow as per 2002 installation. The base and two alternatives assumed identical barrier operations. Water quality simulations were conducted for the 16-year period 1976-1991, which is typical of DWR model runs using DSM2.

6.1 Alternative 1 (VAMP Recirculation)

Alternative 1 recirculates water during the VAMP period, and replaces some of the SJR tributary and exchange contractor water to meet Vernalis flow standards. The following are key findings regarding Alternative 1 flow and water quality impacts:

1) There was little change in flows at Turner Cut, Columbia Cut, and Old River at Highway 4 between the base case and Alternative 1.

2) Recirculation can affect the local San Joaquin River salinity where the Newman Wasteway flows into the main stem. Modeling illustrated a substantial decrease in San Joaquin River EC just below the inflow of the wasteway. The Newman Wasteway flow diluted the saline water upstream of the Newman Wasteway. A few miles downstream, however, the salinity improvement decreased with recirculation and an increase in EC was shown. This was due to a decrease in Merced River inflow in Alternative 1 and a subsequent higher salinity release from the Merced River into the San Joaquin River.

3) Changes in salinity at Vernalis, are a direct consequence of change in San Joaquin River tributary flow and the recirculation flow down the Newman Wasteway. When water is recirculated, the EC at Vernalis increases especially when tributary flow is decreased. Vernalis EC correspondingly decreases when tributary inflow is increased.

4) Alternative 1 tends to cause either little or moderate increase in CVP Export EC during the April - May period. Changes in salinity at the Tracy Pumping Plant was a direct consequence of changes in Vernalis EC and changes in combined CVP and State Water Project exports.

5) Period averaged EC at Twitchell Island changes little under Alternative 1, with the exception of some winter months in water years 1979, 1980, and 1991. The changes in EC seen at these times correspond to changes in Delta outflow.

6.2 Alternative 2 (Feb-Jun Vernalis Minimum Flow Recirculation)

Alternative 2 recirculates water from February through June (excluding the VAMP period) to meet 1995 Water Quality Control Plan minimum flow requirements at Vernalis. DSM2 simulations cover the time period 1976-1991, and it was found that recirculation for X2 flow augmentation would only occur in one month. Because of having only one occurence, a general salinity trend for Alternative 2 recirculation cannot be determined. However, there was a small increase in EC of 18 μS/cm during the one period of recirculation; May 16-31 of 1990. The EC values for this period indicate that the trend for recirculation in Alternative 2 would follow Alternative 1 with a small to moderate increase in salinity during recirculation.

Figure 6-1, DSM2 Sacramento/San Joaquin Delta Output Location