DRAFT

Drinking Water Quality Operations Studies

CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

916-657-2666

December 14, 1999

Integrated
Storage
Investigation

CALFED
BAY-DELTA
PROGRAM

EXECUTIVE SUMMARY

Typically, the months of April through July are most favorable with respect to the Delta as a source of drinking water. Outflow from natural runoff is usually high enough during this period to push seawater out of the Delta. This period is also outside the period of peak TOC loading from agricultural drainage. Water supply needs are greatest in these months because of direct demand requirements (which are supplemented by San Luis Reservoir releases). However, fishery concerns have resulted in a shift in exports from these higher-quality spring months to lower-quality fall months, with a corresponding degradation in delivered water quality. In particular, May and June have proven in recent years to be sensitive Delta smelt months with elevated take at the export pumps. Given these special circumstances, several operational strategies could be adopted to improve water quality delivered from the Delta for drinking water purposes, including outflow management and export management. The effectiveness of these strategies could be enhanced through the construction of additional storage facilities.

- Outflow Management – Increasing Delta outflow in fall months through reservoir releases could reduce peak bromide and salinity concentrations in south Delta drinking water diversions. (Delta outflow has less of an influence on water quality at the North Bay Aqueduct's Barker Slough intake.) Preliminary modeling studies conducted by CALFED suggest that, depending on the amount of outflow enhancement and assuming some Delta conveyance improvements, peak reduction of bromide and salinity in the south Delta in fall months could be in the range of 20 to 30 percent. Such an operation would entail a water supply risk, as the filling of San Luis Reservoir would be delayed. However, the availability of conveyance improvements (i.e. South Delta Improvements and Joint Point of Diversion) along with the ability to recover some storage losses through runoff capture could significantly reduce water supply losses. Water supply risk could be reduced further if new storage were developed to supply the additional fall outflow. Water supply risk could also be mitigated through upstream water acquisitions. With additional storage facilities north or south of the Delta, peak fall bromide concentrations could be lowered by as much as 30 to 50 percent in many years, including the driest ones. Migrating salmon may benefit from higher fall Delta outflow, although shifting export pumping into the winter months could have negative impacts on other salmon runs and Delta smelt.

- Export Management – Quality of delivered and stored water south of the Delta could be improved by shifting diversions to periods with better Delta water quality. When operating to meet water supply reliability and ecosystem objectives, the least risky operation is to begin filling San Luis Reservoir as soon as water and export capacity are available. This typically occurs in the fall of most years. However, if outflow has been low throughout the summer and fall months, seawater intrusion will occur in the south Delta and bromide and salinity concentrations will be elevated. If hydrologic conditions improve as the water year develops, outflows will increase and salinity will be pushed out of the Delta. Under these hydrologic conditions, it would be beneficial to postpone exports to fill San Luis Reservoir until Delta water quality has improved. However, there is no guarantee that fish conditions will be favorable and that surplus water will be available in the Delta for export.

Conveyance improvements such as South Delta Improvements and Joint Point of Diversion could offset the risk associated with selectively filling San Luis Reservoir. Additional storage south of the Delta could also offset the risk associated with selectively filling San Luis Reservoir. Preliminary modeling studies conducted by CALFED suggest that the most efficient role of additional south of Delta storage for drinking water quality purposes would be to make releases for direct delivery when foregone exports in the Delta are not recovered later in the winter. Filling of south of Delta storage would be restricted to the periods when conveyance and pumping capacity were available and water quality in the Delta was relatively good. These conditions would likely overlap in the late winter and spring.

While the preceding discussion has focused on export management for bromide and salinity reduction, export management strategies could also be implemented to reduce organic carbon loads in drinking water diversions. Export reductions during periods of peak organic carbon loading (typically in February and March) would benefit Delta fisheries in most years as was shown in recent CALFED Environmental Water Account gaming studies. Risk to water supply reliability would depend on which assets are available for supply recovery.

OVERVIEW

The Drinking Water Quality Operation Workgroup was formed to assist CALFED's Integrated Storage Investigation (ISI) in evaluating the relationship between various types and locations of storage and the overall role of storage in water quality improvement as part of the CALFED Water Management Strategy. The workgroup effort builds upon an earlier cooperative study lead by CALFED and several urban stakeholders which explored the potential for water quality improvements through management of water project operations. As a starting point, the original group considered the potential for water quality improvements using system flexibility provided by conveyance improvements expected during Stage 1 implementation of the CALFED Program. Details on this effort are provided in Appendix A.

The current workgroup expanded this scope to consider, refine, and analyze operational concepts for water quality improvement, with a special focus on new storage facilities under the ISI. To provide greater focus to this workgroup, multiple objectives (i.e. water supply reliability, operational flexibility, and ecosystem restoration) were not explicitly considered in the preliminary scoping studies. Tradeoffs between these objectives will be evaluated within the larger ISI analysis.

Results from this study will be used to support CALFED's Drinking Water Quality Improvement Strategy. This study can also be used to support the Water Management Development Team process.

STUDY OBJECTIVES

Specific study objectives are as follows:

1. Identify operational alternatives for improving drinking water quality.
2. Explore the potential for south Delta water quality improvements from additional north of Delta storage operated to improve drinking water quality.
3. Explore the potential for south Delta water quality improvements from additional south of Delta storage operated to improve drinking water quality.

As a preliminary effectiveness measure of operation rules and new facilities, the combined net salt load from Banks Pumping Plant, Tracy Pumping Plant, and CCWD's intakes on Old River was computed. The next step in refinement would involve segregating higher and lower-quality water south of the Delta.

STUDY SCOPE

Given the group's aggressive two-month schedule to complete this effort, only a few studies were conducted. To isolate the effect on water quality of north and south of Delta storage operations, the two were separated, with different operation rules applying to each. A study with both storage facilities was not developed because joint operation rules would be too complicated to develop within the allotted time frame. Analysis details and assumptions are provided in Appendix B.

<u>Workgroup Studies</u>

The following short list of studies was designed to assess the preliminary effects of additional storage north and south of the Delta, relative to two DWRSIM studies (Studies 809 and 822).

Study	Description
809	Preferred Alternative without Hood Diversion, Criterion B
822*	Preferred Alternative with 4,000 cfs Hood Diversion, Criterion B
809N	Study 809 + 2 MAF north of Delta storage
822N	Study 822 + 2 MAF north of Delta storage
809S	Study 809 + 1 MAF south of Delta storage
822S	Study 822 + 1 MAF south of Delta storage

* Study 822 also includes longer periods of cross channel gate closure.

The size of the additional storage was chosen to be consistent with previous CALFED studies. Possible side studies identified by the workgroup could involve timing operations to avoid diversions during periods of high organic carbon, flexing the E/I ratio constraint, and changing the baseline assumptions.

Storage Locations

Storage locations are labeled generically for simplicity. This allows a programmatic investigation of how additional storage could contribute to water quality improvement without getting into the specifics of location and type of storage. The only geographic delineation that was made was between north and south of Delta storage because the operating rules for these two geographic regions greatly differ.

OPERATION RULES

Hood Facility Operating Rules

A Hood facility with 4,000 cfs maximum capacity was considered. CALFED's Water Management Criterion B does not include a Sacramento River diversion constraint. Therefore, to be consistent with the June 1999 PEIR/EIS, no Sacramento River constraint was applied in the present studies.

North of Delta Storage Operating Rules

A brief overview of the north of Delta storage operation rule development is given below. A more detailed description and sensitivity analysis appears in Appendix E.

A spreadsheet was used to evaluate north of Delta storage operating rules because diversions to and releases from the additional north of Delta storage facility were largely independent of DWRSIM operations. That is, surplus water was diverted to storage and storage releases were only allowed to contribute to Delta outflow.

In general, operations were conducted to capture surplus Delta outflow and then make releases from storage to increase Delta outflow when seawater intrusion significantly affected south Delta water quality. The contribution of fresh through-Delta flow, another influence on south Delta salinity, was partially analyzed in this study through consideration of the Delta cross channel gate position and the influence of the Hood-Mokelumne facility. Lastly, actions to separate high and low-quality water south of the Delta were deferred to a more detailed study.

Filling operations of the north of Delta storage facility are consistent with those specified in CALFED's PEIS/EIR. Three types of triggers are combined to form the water quality release rules.

Monthly Pattern: Months are categorized based on expected salinity concentration in the Delta. For each category, there is a set of associated salinity triggers which specifies the maximum storage release rate.

Salinity Triggers: Previous month's Rock Slough chloride concentration, as calculated by the salinity-outflow relationship in DWRSIM (the G-model), is used as the salinity trigger. This is a good indicator of seawater intrusion into the Delta. The quantities of additional upstream releases are proportional to the severity of the intrusion and also vary depending on the month.

Reservoir Storage Level: This constraint reflects a conservative storage release operation by withholding water for future release during a prolonged drought. When reservoir storage is lower than the specified trigger level, only a limited percentage of the remaining storage can be released for each month.

South of Delta Storage Operating Rules

Again, a spreadsheet was used to evaluate additional storage operating rules. The south of Delta storage operation rules were based on two principles: maximize exports when quality is relatively high and make releases from previously stored water (south of the Delta) when Delta quality is relatively low. The capacities for the new south of Delta storage were assumed to be: additional storage (1 MAF), additional export capacity (3,000 cfs), and release capacity of 1,500 cfs.

The main assumption associated with the south of Delta studies is the use of a "virtual" reservoir. That is, San Luis Reservoir and the new storage facility are treated as a single reservoir and the Banks, Tracy and new pumping facility are treated as a single export pump. The virtual reservoir consists of the in/out and storage capacities of San Luis Reservoir and the new south of Delta reservoir combined. It operates in conjunction with a virtual pumping plant which is the sum of Banks, Tracy and the new pumping plant to meet the same delivery as in the base study. The capability to meet the same rule curve (south of Delta storage targets) as in the base study was added to avoid potential within-year shortages. The spreadsheet also can be used to explore the implications for water quality improvement associated with relaxing the E/I ratio.

In the spreadsheet, exports and releases from south of Delta storage are triggered on south Delta water quality. Delta exports in the spreadsheet operation are not constrained to follow exports in the DWRSIM study. If exports are foregone in a given time period, upstream operations are not modified. However, exports are recovered to the extent possible through increased export of Delta surplus later in the water year. If this water quality logic were incorporated into DWRSIM or if the spreadsheet was able to re-operate upstream facilities, reservoir releases could be reduced by some degree when exports were reduced to improve yield.

In some dry years, foregone exports (as calculated by the spreadsheet model) were not recovered. This loss to yield is overestimated for two reasons. First, a more comprehensive modeling approach would better coordinate upstream releases with exports to reduce the yield loss. Second, the "virtual" reservoir operation does not reserve storage for carryover in drier years because the south of Delta storage system collectively operates as a larger San Luis Reservoir. Yield impacts could be decreased significantly by introducing new carryover logic into the model.

The San Luis Reservoir operation is modified to selectively fill when the previous month water quality at Rock Slough is good, similar to the new south of Delta storage facility. The spreadsheet calculates available pumping per a base DWRSIM study. It also calculates salinity concentration and X2 position that result from a modified export pattern.

Initial studies focus on the south of Delta salt balances, with no explicit consideration to routing water of differing salinity to specific users. Additional refinements may consider conveyance issues to improve drinking water quality. Different trigger levels can be set to explore different optimizations depending on if the goal is to minimize average salinity in exports or to reduce the peak salinity.

Integration of Operating Rules to Maximize Multiple Objectives

The group did not develop a process for resolving competing operation rules in the initial phase of this study.

Technical Issues Not Directly Addressed Within This Study

The intent of this study was to investigate the potential water quality improvements associated with new and existing storage facilities. This preliminary assessment was purposely kept simple, opting to quantify the possible improvements from newly developed operating rules first before addressing secondary measures in detail. There are several actions involving new or existing storage facilities that could potentially contribute to improved water quality that were not covered within this preliminary study. Because of the group's limited schedule, these actions were not directly analyzed although the group believes there is enough potential to warrant further investigation. These actions are listed in Appendix F.

RESULTS AND DISCUSSION

The workgroup examined the effect of new storage, north and south of the Delta, under operating rules designed specifically for water quality improvement. The new studies were developed from CALFED's DWRSIM Studies 809 and 822. Study 822 includes a 4,000 cfs Hood-Mokelumne canal and more frequent closure of the Delta Cross Channel, otherwise the assumptions are similar to Study 809. Comparison of these two base studies is useful; however, they do not isolate the water quality effect of the Hood facility or the effect of the Delta Cross Channel because the two actions were not individually varied.

Bromide, a constituent of seawater and in some cases agricultural drainage, was chosen as the primary water quality indicator for these studies. Organic carbon is another significant constituent of concern for drinking water suppliers. However, bromide tends to be more strongly related to operations (e.g., reservoir releases and Delta exports), while organic carbon concentration in the Delta is linked to the collective operations of many individual land owners and dischargers.

The intent of the new operation rules was to lower salinity in the south Delta through enhanced outflow and to lower exports when seawater intrusion had increased salinity concentration in the south Delta. As the simulation results show, the actions lowered peak average monthly bromide concentration in the south Delta (see Tables 1A-1D) and also lowered flow weighted long-term average monthly bromide concentration (see Tables 2A-2B). Peak average monthly bromide concentration was lowered by 30-50% in the fall months of many years, including the driest ones.

The good water quality periods (typically April through July) were not influenced by the operation rules or new facilities in this study (i.e., concentrations were not lowered further). However, salinity levels during these conditions are relatively low. When Delta outflow is high (greater than 30,000 cfs) bromide contributions from seawater intrusion do not influence concentration in the south Delta as much as local agricultural drainage and by the San Joaquin River.

Table 1A: Bromide concentration cumulative exceedance at Clifton Court Forebay (expressed as percentage reduction)

Exceedance	STUDY						Comparison of 822 studies to 809***		
	*DWRSIM Study 809**			*DWRSIM Study 822***					
%	809	809N	809S	822	822N	822S	822	822N	822S
99	-	0.0	-118.2	-	-0.3	-94.5	-15.9	-0.3	-42.4
90	-	0.0	-4.8	-	0.0	-3.7	0.0	0.5	-0.3
80	-	0.0	0.0	-	0.0	0.0	1.2	2.3	3.5
75	-	0.0	0.7	-	0.0	0.3	2.1	3.1	6.3
70	-	0.0	1.3	-	0.0	1.2	3.1	4.9	8.6
60	-	2.0	4.4	-	0.7	3.7	6.9	14.4	16.7
50	-	10.6	8.8	-	9.1	10.5	16.0	34.3	27.9
40	-	19.9	16.0	-	18.0	16.6	25.4	49.8	42.3
30	-	30.2	23.7	-	30.6	24.4	35.6	57.9	56.3
25	-	32.5	31.7	-	35.7	30.3	40.3	60.8	60.2
20	-	36.0	39.3	-	38.7	37.0	49.7	64.6	65.0
10	-	43.3	60.5	-	45.1	58.8	56.3	71.0	76.2
1	-	55.5	88.0	-	55.7	85.2	64.5	75.9	88.9
average	-	17.0	16.5	-	17.0	16.4	21.8	33.1	32.4

Table 1B: Bromide concentration cumulative exceedance at Tracy Pumping Plant (expressed as percentage reduction)

Exceedance	STUDY						Comparison of 822 studies to 809***		
	*DWRSIM Study 809**			*DWRSIM Study 822***					
%	809	809N	809S	822	822N	822S	822	822N	822S
99	-	0.0	-57.5	-	0.0	-61.1	-14.8	-1.2	-60.3
90	-	0.0	-3.6	-	0.0	-4.2	0.0	0.0	-0.1
80	-	0.0	-0.5	-	0.0	-0.1	0.5	1.0	0.0
75	-	0.0	0.0	-	0.0	0.0	1.1	1.8	0.8
70	-	0.0	0.0	-	0.0	0.0	1.9	2.7	2.1
60	-	1.2	0.6	-	0.7	0.5	3.5	7.1	5.4
50	-	5.1	3.0	-	4.2	2.0	7.4	15.6	12.3
40	-	11.8	8.0	-	9.4	5.5	15.1	31.0	22.9
30	-	22.9	18.4	-	23.3	13.4	22.5	42.7	40.1
25	-	28.3	22.3	-	27.8	20.1	33.2	50.6	48.3
20	-	31.2	27.5	-	32.3	26.1	36.6	55.7	56.3
10	-	41.2	56.3	-	39.9	50.4	51.2	66.0	70.9
1	-	52.3	84.5	-	52.3	72.4	55.9	71.9	86.9
average	-	13.9	13.1	-	13.4	11.1	16.6	25.9	23.5

* Studies 809N and 809S are compared to Study 809
** Studies 822N and 822S are compared to Study 822
*** Studies 822, 822N, and 822S are compared to Study 809

Table 1C: Bromide concentration cumulative exceedance at Rock Slough (expressed as percentage reduction)

Exceedance	STUDY						Comparison of 822 studies to 809***		
	DWRSIM Study 809*			DWRSIM Study 822**					
%	809	809N	809S	822	822N	822S	822	822N	822S
99	-	-0.5	-102.6	-	-0.9	-117.2	-6.8	-0.9	-98.9
90	-	0.0	-5.3	-	0.0	-46.5	0.4	0.6	-27.6
80	-	0.0	-0.8	-	0.0	-20.7	2.2	2.5	-4.0
75	-	0.0	0.0	-	0.0	-10.5	3.0	3.5	8.3
70	-	0.0	0.9	-	0.0	-0.5	4.4	5.2	24.0
60	-	1.8	3.1	-	1.4	23.7	9.0	19.1	33.2
50	-	13.3	7.1	-	13.3	36.6	19.2	34.3	45.0
40	-	20.1	14.7	-	20.3	51.9	26.6	51.7	64.1
30	-	29.9	32.0	-	32.0	56.2	35.5	59.9	70.3
25	-	32.0	36.3	-	38.8	60.5	38.3	63.0	74.7
20	-	36.8	43.1	-	41.1	64.2	45.3	65.5	77.2
10	-	45.0	70.6	-	47.4	72.6	53.1	69.3	84.2
1	-	61.3	91.9	-	60.0	86.6	60.5	74.5	92.8
average	-	17.7	18.5	-	18.2	23.5	22.0	34.1	36.9

Table 1D: Bromide concentration cumulative exceedance at North Bay Aqueduct (expressed as percentage reduction)

Exceedance	STUDY						Comparison of 822 studies to 809***		
	DWRSIM Study 809*			DWRSIM Study 822**					
%	809	809N	809S	822	822N	822S	822	822N	822S
99	-	-1.5	-7.5	-	-2.7	-5.4	-32.6	-16.8	-27.1
90	-	0.0	-3.2	-	0.0	-2.9	-12.3	-6.6	-9.3
80	-	0.0	0.0	-	0.0	0.0	-6.8	-5.3	-6.8
75	-	0.0	0.0	-	0.0	0.0	-6.6	-4.2	-6.4
70	-	0.0	0.0	-	0.0	0.0	-6.2	-3.6	-6.1
60	-	0.0	0.0	-	0.0	0.0	-4.9	-3.4	-5.1
50	-	0.0	0.0	-	0.0	0.0	-3.5	-3.2	-3.5
40	-	0.0	0.0	-	2.5	0.0	-3.1	-2.8	-3.2
30	-	2.4	0.0	-	3.0	0.0	-2.7	0.0	-2.8
25	-	2.8	0.0	-	3.2	0.0	-1.1	0.0	-1.2
20	-	3.1	0.0	-	3.3	0.4	0.0	0.0	0.0
10	-	3.6	2.0	-	8.5	4.4	0.0	3.2	0.9
1	-	19.9	10.7	-	22.7	13.2	9.5	17.5	13.0
average	-	1.6	0.0	-	2.5	0.6	-4.9	-2.2	-4.2

* Studies 809N and 809S are compared to Study 809

** Studies 822N and 822S are compared to Study 822

*** Studies 822, 822N, and 822S are compared to Study 809

Table 2A: Flow weighted bromide concentration, long-term average (1976-1991) (Expressed as percentage reduction)

	Compared to Study 809	
Location	Study 822	
North Bay Aqueduct	-2	
Rock Slough	32	
Clifton Court Forebay	17	
Tracy Pumping Plant	33	

Table 2B: Flow weighted bromide concentration, long-term average (1976-1991) (Expressed as a percentage reduction)

	Compared to Study 809		*Compared to Study 822*	
Location	Study 809N	Study 809S	Study 822N	Study 822S
North Bay Aqueduct	1	0	1	0
Rock Slough	33	44	34	42
Clifton Court Forebay	25	15	30	38
Tracy Pumping Plant	27	35	25	31

<u>South of Delta and North of Delta Storage Results</u>

Additional storage facilities can have a significant effect on bromide concentrations in the water exported from the south Delta (particularly when bromide levels are high) under the operating rules that were developed. The primary reason for water quality improvement in the south of Delta storage studies relates to the selective pumping criteria that were introduced. Had this selective export logic been utilized in the north of Delta studies, the water quality improvement in those studies may have also increased. The presence of additional south of Delta storage simply increased the benefits that had accrued from the selective export operations while also acting to preserve supply under this selective pumping regime. In some cases though, yield was not fully recovered. The spreadsheet logic could be refined in subsequent studies to force the model to hold portions of storage in reserve for dry periods to prevent this from occurring. For simplicity, the current spreadsheet logic combines new south of Delta storage with existing San Luis Reservoir. This "virtual" storage concept is simple but limiting because the new, larger reservoir is too responsive to delivery needs in the current water year. Consequently, a portion of the "virtual" storage cannot be reserved for yield recovery if exports in subsequent years are selectively deferred based on water quality.

North of Delta storage operations, as simulated, are relatively simple and effective. Surplus flows are captured and then released based on south Delta water quality; releases are typically made in the fall under balanced conditions. The same amount of water is exported from the Delta but with higher Delta outflow. This causes the export operation, basically a north to south water transfer, to occur with lower salinity.

In the south of Delta storage studies, collective exports (Banks, Tracy, and the new export capacity) were all triggered off of water quality in the south Delta. This operation risks supply because forgone exports in the fall, when salinity is higher, may not be made up in the winter and spring if the hydrology is not wet enough. However, in many years, the losses are recovered while export water quality significantly improves.

The most sensitive feature of south of Delta operations for water quality appears to be selectively exporting. Additional storage in the south Delta will further improve the ability of these flexible operations to improve delivered and exported quality while also preserving yield relative to the base study. Considering this, the logical and possibly most efficient role of additional south of Delta storage for water quality purposes would be to make releases for direct delivery when foregone exports in the Delta are not recovered later in the winter. Filling of south of Delta storage would be restricted to the periods when conveyance and pumping capacity were available and quality in the Delta was relatively high. These conditions would likely overlap in the late winter and spring.

The influence of the Hood facility seems to be significant from the data in Tables 1A-1D, and Tables 2A-2B. However, because the Delta Cross Channel was closed more often in Study 822 than in Study 809, the effectiveness of the Hood facility may be linked to gate closure. More study is needed to isolate the effect of the two actions individually.

There are only small changes in bromide concentration at the North Bay Aqueduct after additional storage is added. This is not surprising considering that the Sacramento River flows and Delta Cross Channel gate position were not altered significantly. There is a slight increase in salinity at the North Bay Aqueduct between Studies 809 and 822, reflecting the increased diversions into the central Delta from the Hood facility and the corresponding reduction in Sacramento River flow past Rio Vista.

Operating rules to reduce total organic carbon loading were not developed within this study. However, considering the regularity in which organic carbon concentration peaks in the Delta, rules could easily be developed to reduce diversion of this constituent.

Comparison of South And North Of Delta Storage Within This Study

The present studies were not designed to directly compare additional storage north of the Delta to additional storage south of the Delta. In fact, a side-by-side comparison is impossible despite the tempting format of the output tables because of differences in storage size and the level of operation rule design and refinement. The reader should limit the interpretation of the results to a simple and preliminary investigation of general operation rule concepts.

APPENDIX A. ASSESSMENT OF INITIAL WATER QUALITY OPERATION RULES FOR STAGE 1

Introduction

Water quality operation measures are an important part of the overall assessment of water quality in Stage 1 of the CALFED Bay-Delta Program. Along with operational rules that are specifically designed to improve water quality, the cost effectiveness of the CALFED water quality common program elements such as source control and watershed management need to be considered. Additionally, the indirect effect from other CALFED measures (or measures beyond CALFED) that are not necessarily related to quality (e.g., increased capacity at the Banks Pumping Plant or operation of the environmental water account, etc.) must be factored in to the analysis to determine the net effect on water quality and the incremental contribution from operating rules.

These initial studies will begin to answer questions related to the water quality improvements that are possible in Stage 1 and the associated tradeoffs. These studies are the first formal efforts in this area (but probably will not be the last) and are intended to provide technical substantiation for the revised Phase II Report in an effort to assist that document's comprehensive examination of water quality improvement. Many operations and facilities were directly analyzed in this study, others were indirectly examined. In both cases, recommendations are made for further study. The qualitative assessment made in this report is provided to CALFED for review.

Purpose and scope of this study and report

The main purpose of this water quality enhancement study is to explore the range of improvements in Stage 1 that are possible for specific water users through the alteration of operating rules and to describe the corresponding tradeoffs (expressed as cost, water supply, and ecosystem impacts). From a pre-determined basecase, operating rules were changed and water quality, water supply, and ecosystem parameters were evaluated. However, practical limits were placed on the altered operating regime to keep impacts reasonable.

The studies used in this analysis are founded on CALFED's existing conditions assessment. New operation measures to enhance delivered quality (designed mainly for urban contractors) were incorporated. Newly developed water supply measures (e.g., joint point of diversion (JPOD), expanded Banks Pumping Plant, groundwater, etc..) were used to offset impacts to supply. The present CVP and SWP delivery capability and existing prescriptive fish protection measures related to the Accord, AFRP, and ESA are preserved in all studies.

These new studies do not necessarily represent a preferred alternative. Rather, the studies attempt to further identify the limits to water quality improvement within Stage 1 and the associated tradeoffs when system operations more strongly emphasize water quality.

Knowledge gained through this exercise will contribute to a more fully integrated alternative.

Reduction of TDS and bromide concentration will be the main focus of the adapted operating rules. TOC reduction will be deferred to recommended actions of the CALFED Water Quality Workgroup because TOC concentration in the south Delta is not necessarily related to SWP and CVP operations. (The TOC concentration peak that occurs in the Delta annually in the winter from agricultural drainage is recognized. Project exports could, in theory, be operated to minimize the export of high TOC water. However, this operation could increase bromide loading.)

Study methodology

This group initially intended to perform sensitivity studies on the preferred alternative range outlined by CALFED in the revised draft EIS/EIR. However, this technical group subsequently agreed to begin with CALFED's existing conditions assessment and then conduct water quality studies from this base to better study the possibilities and tradeoffs associated with "Day 1" implementation. The approaches are slightly different but both work to provide answers to the fundamental questions. The present studies are built from DWRSIM Study 771, CALFED's existing conditions simulation, which includes the in-Delta CVPIA (b)(2) measures and Trinity River minimum fish flows below Lewiston (340 TAF/year in all years).

Inclusion of the in-Delta CVPIA (b)(2) actions in the basecase and in the subsequent cases may reduce flexibility of the system and will likely result in fewer opportunities to improve quality without risk to supply. However, the studies show the relative difference in quality before and after the water quality operation rules have been applied.

The group developed a water supply study (Study 771WS) built upon DWRSIM Study 771, and various water quality studies that utilize the water generated from Study 771WS to offset supply losses caused by implementation of water quality operation rules (Studies 771WQ-1,2,3,...). These studies are not designed to identify a preferred alternative. They are designed to evaluate the effectiveness of water quality operation rules and the associated tradeoffs that could occur in Stage 1. The group used the FDM (version 8) for the initial water quality assessment of the Delta. DSM2 studies were performed by DWR staff to confirm the results.

Water quality at Delta export locations is not always indicative of delivered water quality because of the blending that occurs in conveyance and storage facilities south of the Delta. Quantifying blending for deliveries south of the Delta is an exercise that is beyond the scope of Delta water quality hydrodynamics simulations so alternative assessment tools are required. Assumptions involving the O'Neill bypass routing (using both the existing configuration and a new idealistic bypass network[1]) as well as other assumptions related to south of Delta incidental blending are listed in Appendix A-1.

[1] An idealistic routing network refers to new conveyance facilities in and near the existing O'Neill Forebay that would allow any source of water (Banks PP, Tracy PP, and San Luis Reservoir) to be delivered to any

Initial operating rules refined by the group for assessment

The group acknowledges that the first implementation of these rules may not be optimum. Adjustments will be made as experience is gained. Operating rules and study assumptions are listed in detail in Appendix A-2.

Effectiveness and tradeoffs of initial actions

There are many actions that could be used to reduce export salinity caused by seawater intrusion into the south Delta and improve water quality available to urban contractors. Among these are increasing outflow, shifting exports to periods of lower salinity, increasing the percentage of Sacramento River water reaching the south Delta, and maintaining better separation of conveyed water when quality from different sources is variable (reduce mixing).

Four specific actions to improve water quality were examined during this initial study. Two of the actions (a Hood-Mokelumne channel and an O'Neill bypass) are not directly related to operations. However, water operations designed to meet the Rio Vista flow requirement could be affected by the operation of the Hood-Mokelumne channel. The other two actions (increase to Delta outflow in the fall and selective filling of San Luis Reservoir) were directly related to operations. Reducing seawater intrusion reduces TDS, chloride and bromide concentrations. The hydrodynamics studies performed with the Fischer Delta Model quantified the TDS and bromide concentration in the south Delta. Effectiveness of the water quality actions were measured as reduced average concentrations of these quantities. A summary of the results is shown in Tables A1 and A2.

---

demand location (joint reach or the lower DMC). However, this network cannot fully isolate sources because often more than one source is needed to meet a given demand.

Table A1. Monthly Average Bromide Cumulative Exceedance, 1922-92 (ug/l)

Rock Slough

	8C	8M	2M	3M	5M
Max	1285	2009	1913	1388	1316
99%	1112	1661	1704	1167	1000
90%	900	1180	1208	836	724
75%	513	670	759	537	489
50%	183	209	219	212	211
25%	115	138	144	147	141
10%	94	112	113	121	112
1%	68	83	83	93	83
Min	47	64	66	68	64
Average	338	446	474	362	331

Banks Pumping Plant

	8C	8M	2M	3M	5M
Max	724	1310	1209	791	822
99%	611	1020	1044	661	622
90%	485	692	724	478	448
75%	298	410	440	332	303
50%	135	160	171	167	159
25%	106	120	125	130	123
10%	81	91	96	102	93
1%	59	66	68	75	66
Min	42	52	57	65	57
Average	215	288	303	236	224

Tracy Pumping Plant

	8C	8M	2M	3M	5M
Max	644	1239	1147	764	785
99%	593	958	977	630	586
90%	475	623	645	467	452
75%	324	406	423	356	337
50%	197	214	229	225	213
25%	159	165	170	174	168
10%	132	143	142	147	142
1%	82	83	83	83	83
Min	64	65	65	65	65
Average	252	308	321	271	260

Table A2. Monthly Average TDS Cumulative Exceedance, 1922-92 (mg/l)

Rock Slough

	8C	8M	2M	3M	5M
Max	782	1159	1104	826	788
99%	693	977	996	714	636
90%	584	726	746	540	489
75%	394	467	514	392	377
50%	226	240	248	237	238
25%	178	190	193	187	190
10%	160	166	170	168	169
1%	137	142	141	140	141
Min	98	116	117	117	117
Average	299	350	365	300	290

Banks Pumping Plant

	8C	8M	2M	3M	5M
Max	489	808	757	522	541
99%	452	652	664	465	450
90%	384	485	500	362	364
75%	286	342	354	291	290
50%	198	210	215	207	208
25%	168	177	181	176	179
10%	149	149	152	149	150
1%	101	105	105	105	105
Min	79	82	82	82	82
Average	234	269	277	234	237

Tracy Pumping Plant

	8C	8M	2M	3M	5M
Max	580	799	753	537	622
99%	496	647	652	493	499
90%	426	499	508	405	417
75%	346	383	397	350	343
50%	262	272	278	269	267
25%	221	223	226	223	225
10%	190	199	199	197	198
1%	104	104	104	104	104
Min	82	82	82	82	82
Average	285	310	318	286	287

8C – Study 469 (SWRCB 1995 WQCP base added for reference)
8M -- Study 771 (CALFED base)
2M – Study 771 + water supply measures
3M – Study 771 + water supply measures + 2000 cfs Hood diversion
5M – Study 771 + water supply measures + increased outflow in summer and fall months

Increasing Delta Outflow

One of the water quality studies featured an increase in minimum required outflow as a method of forcing a reduction in seawater intrusion. In all year types, minimum required outflow was increased by 1,300 cfs in August through October and by 1,000 cfs in November and December. In many DWRSIM studies minimum required outflow tends to govern (as opposed to an interior Delta salinity or X2 requirement) in dry summer and fall periods. Even in wetter years if runoff occurs early enough in the water year, the Delta can be in a balanced condition in the summer and fall. The increase to minimum outflow was therefore applied to all water year types.

Adding this requirement to the DWRSIM model forced outflow to increase and reduced seawater intrusion in the south Delta. Salinity reductions (in terms of 71-year averaged bromide concentration) in the south Delta were **22%** at Banks Pumping Plant, **16%** at Tracy Pumping Plant and **26%** at Rock Slough measured relative to the CALFED basecase (Study 771). Tradeoffs between dry year supplies and increased outflow used for salinity reduction must also be considered.

Water supply was not impacted relative to the base because of the use of larger Banks Pumping Plant capacity and the use of JPOD. Results indicate that when exports were curtailed as a method of increasing outflow, the reduction in water supply was temporary, as exports were increased later in the water year via the water supply tools. If upstream releases were increased to raise outflow (while exports were held constant, relative to the basecase) the storage loss was substantially recovered through runoff or by capturing spills that occurred in the base case.

The effect of this operation on Delta fisheries could be positive for out-migrating spring run to the extent that Delta outflow was increased. Shifting export pumping into the winter months could have negative impacts on other salmon runs and Delta smelt.

Hood-Mokelumne Diversion

This action tends to increase the amount of Sacramento River water in the south Delta when outflow is low or when the cross channel gates are closed. In the current studies, a 2,000 cfs intake was implemented in DWRSIM and in the hydrodynamic studies. Salinity reductions (in terms of 71-year averaged bromide concentration) in the south Delta were **18%** at Banks, **12%** at Tracy and **19%** at Rock Slough measured relative to the CALFED base (Study 771). The benefits of this facility may not be as large if the cross channel is open more often or if make-up pumping in the fall is less frequent because of smaller export restrictions in the spring, such conditions could occur under a different base case (i.e., one without the in-Delta AFRP actions).

Water supply effects are minimal because Hood diversions are reduced if water is needed to meet the Rio Vista flow standard. Although, with a diversion capacity of 2,000 cfs, this condition rarely occurs. If flows through the intake are held constant, regardless of

Sacramento River hydrology, then there could be a water supply impact. This is apparent from earlier CALFED studies which considered much larger diversion capacities.

Effects on fish could be negative depending on the design of the Hood fish screens (on the Sacramento River side of the intake) and the fish ladder or bypass channel (for up-migrating Sacramento salmon).

O'Neill Bypass

Implementation of an O'Neill bypass could improve water quality for some contractors by selectively routing higher quality source water into the joint reach of the California Aqueduct. The effectiveness of this action increases as the water quality difference between the San Luis Reservoir and the Delta increases. However, when demands are high in the California Aqueduct, selective routing is limited because both Delta exports and releases from San Luis Reservoir are required to meet the demand.

Preliminary results indicate that if ideal routing is assumed to occur through the O'Neill Forebay, the 71-year averaged reduction to salinity (bromide) is about **5-10%**. Most of this salinity reduction is caused by direct routing of Delta exports to the joint reach when demands are relatively low and Delta water quality is substantially better than supplies previously stored in San Luis Reservoir.

An obvious drawback of this action is the accompanying shift of the salt load from the California Aqueduct to the lower Delta-Mendota Canal. The reduction to salinity in the California Aqueduct would necessarily correspond to an increase in salinity to contractors of the lower Delta-Mendota Canal and Mendota Pool. The cost of the new bypass network would also need to be considered on a cost/benefit basis.

There would be no effect on water supply or Delta fisheries with this action.

Selective Filling of San Luis Reservoir

Water quality in San Luis Reservoir could improve if export pumping was shifted to periods with higher Delta water quality. When operating for water supply, the most prudent operation is to begin filling San Luis Reservoir as soon as water and export capacity are available. This typically occurs in the fall of most years. However, if outflow has been low throughout the summer and fall, seawater intrusion may be prevalent in the south Delta. If the water year becomes wetter as winter approaches, water quality could be substantially better (lower salinity). Delayed exports to fill San Luis Reservoir could improve water quality under these conditions. Water supply tools such as JPOD and larger Banks capacity could offset the risk to filling if exports are deferred. However, there is no guarantee that fish conditions will be favorable and that surplus water in the Delta will be available as the water year develops.

During this round of studies, the group did not have time to fully explore the potential associated with this measure. However, the effects of this action can be estimated by observing the changes in exports that have resulted from other actions. For example, when outflow is increased in the fall, exports are often reduced as a way of achieving the increased outflow. This action shifts export pumping into the winter when outflow is typically higher and salinity lower. This is an indirect way of selectively filling San Luis Reservoir but may not be the most efficient way. (Additionally, exports that are pumped during the fall benefit from the outflow increase in that period).

DWRSIM code has been developed to allow a study of San Luis Reservoir filling based on this water quality-triggered operation. The primary variable associated with this trigger is south Delta salinity as determined internally by DWRSIM through the G-model. The model will defer pumping to storage if it detects poor south Delta water quality in the fall (based on seawater intrusion only). As the water year develops, the criteria are relaxed to reduce the risk of not filling San Luis Reservoir.

The group also considered a secondary trigger for San Luis Reservoir filling based on agricultural drainage in the south Delta. In wetter years, drainage and runoff contribute more salinity than seawater intrusion and also contribute to TOC loading. However, there are two difficulties with operating to avoid TOC and agricultural drainage: (1) there is a larger risk of not filling San Luis Reservoir if exports are limited during significant drainage events (salinity and TOC peaks from drainage could last 2 months) because these drainage events usually occur in winter months close to the start of the pulse flow, and (2) drainage events may be harder to parameterize in DWRSIM but some generalizations regarding the timing of events are possible. For example, drainage could be correlated with Delta precipitation or with DWRSIM Delta consumptive use data. Triggering based on San Joaquin River salinity is also a possibility.

The effect of this operation on Delta fisheries could be positive for out-migrating spring run to the extent that Delta outflow was increased. Shifting export pumping into the winter months could have negative impacts on other salmon runs and Delta smelt.

Recommendations

There were many actions which have potential to improve delivered water quality that were not analyzed in this initial assessment. The group recommends that CALFED consider these actions in the future to more comprehensively examine the potential for water quality improvement. These actions include:

- Additional study of selective San Luis Reservoir filling
- Regional exchanges
- Higher emphasis on exports during the highest quality months (typically April-June).
- As part of an impact analysis, more studies can and should be made regarding the relationship between operations and water quality. These include: water quality optimization under different levels of fish protection and demand (CALFED's Water Management Criteria A and B) and the incremental benefits provided by new facilities (e.g., the Hood-Mokelumne River diversion and additional surface storage).

- Use of in-Delta barriers to channel agricultural drainage water away from M&I diversion and export locations when Delta water quality is degraded by these sources.

Future studies should quantify the quality results in extended dry periods.

Group participation and outreach

Technical support was provided by Bill Smith of Surface Water Resources, Inc. with respect to the development of a version of DWRSIM which incorporated the operating rules for water quality enhancement. Chuching Wang (MWD) and Dave Briggs (CCWD) completed most of the other technical work. Paul Hutton, Mark Cowin, Rick Woodard, and Gary Bardini provided CALFED-related oversight. Others providing guidance to the technical work were Grace Chan (MWD), Terry Erlewine (SWC), Richard Denton (CCWD), and Bruce Herbold (EPA).

Appendix A-1 Assumptions associated with south of Delta blending using DWRSIM output

General

1. All routing is assumed to occur instantaneously in a given month and is assumed to be constant for the entire month.
2. Blending in storage and conveyance facilities (in a given reach) is assumed to be 100%.
3. Control points (CP) refer to the DWRSIM network diagram.

Existing O'Neill Forebay operations

1. O'Neill Forebay has 3 sources of water: Banks (via the California Aqueduct), Tracy (via the upper Delta Mendota Canal), and San Luis Reservoir releases.

2. Banks inflow is CP 804 (flow downstream). This includes CVP wheeling which passes through O'Neill Forebay (whether the water goes to San Luis, Cross Valley contractors, joint reach, or to the lower DMC).

3. Tracy inflow to O'Neill is CP 703 (flow downstream) less water delivered to the lower DMC (CP 720, flow downstream). In certain months this quantity can be zero because the CVP is releasing from San Luis and pumping at Tracy to meet lower DMC demands.

4. San Luis releases into the O'Neill Forebay by the CVP and SWP are standard outputs from DWRSIM (CP 11 and CP 12, flow downstream).

5. Quality from Banks and Tracy are inputs from the FDM.

6. Quality in San Luis is assumed for the first month (initial condition).

7. In any given month, O'Neill quality is computed first, then San Luis quality is updated based on fills from O'Neill and evaporation. Releases from San Luis are assumed to be homogeneous and do not affect quality in San Luis (but do affect the quality in O'Neill Forebay).

8. Pump-generation actions which occur at O'Neill on a daily basis for power generation could affect quality in San Luis and O'Neill but are not included in the spreadsheet calculation.

Idealistic routing scenario in place of existing O'Neill Forebay

1. San Luis is filled directly from the Delta. Inflow quality is computed from Banks and Tracy using the FDM results. Flows are obtained from CP 814 and CP 710

(diversion-actual). Mixing occurs in a small forebay at the foot of San Luis Reservoir.

2. Water available from the Delta for delivery to the joint reach and lower DMC is water pumped at Banks and Tracy less water used to fill San Luis and less deliveries made to the San Felipe Unit, South Bay Aqueduct and upper DMC contractors.

3. Demand in the joint reach of the California Aqueduct south of San Luis Reservoir is met with the best of three sources of water (Banks, Tracy, and San Luis). If the supply from the highest quality source is not enough to meet demand in the joint reach, supply from the next highest source is used as a supplement, etc.., until the balance is reached. The remaining supplies are used to meet the demand in the lower DMC.

4. No mixing is assumed in O'Neill Forebay because of the assumed ideal routing.

5. The SWP and CVP are assumed to not individually fill and release from San Luis in a given month (although this is common for power generation).

Note that the DWRSIM and deliveries are not changed by the routing operations. The same amount of water is being pumped and released. The routing simply separates the water by quality.

Appendix A-2 Details and assumptions for the water quality operations studies

Base Case: CALFED Study 771 (existing conditions)

- 1995-level of hydrology and upstream depletions are based on DWR land use projections
- South of Delta SWP demands are varied between 3,529 TAF in drier years down to 2,644 TAF in the wetter years based on local wetness indices
- South of Delta CVP demands, including wildlife refuges, are set at 3,433 TAF/year
- Operation of CVP and SWP export facilities in the Delta are coordinated with the upstream SWP and CVP reservoirs to meet the SWRCB May 1995 Water Quality Control Plan for the Bay-Delta (WQCP)
- The CVPIA (b)(2) Delta Actions are included
- Trinity River minimum fish flows below Lewiston Dam are maintained at 340 TAF/year for all years

Base water supply study

Add to Study 771 the following:

- Unlimited JPOD (maximum wheeling)
- Expanded Banks capacity to 8,500 cfs
- Alternative upstream reservoir operations (intended to affect carryover and balancing not flood control)[2]
- Groundwater south of the Delta (300 TAF with 20 TAF/month recharge and extraction capability).

Primary water quality actions (Study 771WQ-x)

- Fill San Luis Reservoir based (to some degree) on water quality in the south Delta (first cut at this operation rule is to trigger San Luis Reservoir filling on anticipated water quality, if quality is good, fill is much as possible, if quality is relatively poor defer filling, this rule will begin in September and as the water year develops should be phased out to reflect the increasing risk of not filling San Luis Reservoir),
- O'Neill bypass (allowing the joint reach to be supplied by the Delta or San Luis Reservoir, which ever has better quality). This action would not affect quality available to SCVWD (negatively or positively); however the action would increase more salt to the lower DMC and Mendota Pool (a tradeoff).
- Allow Tracy to divert from Clifton Court and the south Delta,
- 2,000 cfs Hood diversion (diversions are limited in the spring based on CALFED's operations rules, but not limited if Rio Vista flow standard is controlling)

---

[2] Direct re-operation of upstream storage for water quality purposes (or any purpose) is difficult because upstream releases are often linked to fish protection actions and re-operation could affect carryover-delivery operations significantly.

- Increase Delta outflow in fall months when the Delta is in balance (a simple surrogate is to lower the Rock Slough chloride standard from 250 to 220 mg/l, or increase minimum required Delta outflow).

Level 2 water quality study (not completed to date)

Add to the following to the Level 1 water quality study:

- Regional exchange: Friant-MWD, dry year options only.
- Regional exchange: Assume CCWD can receive Mokelumne water to Los Vaqueros Reservoir (5 TAF/year would improve CCWD's blending capability). These deliveries would represent surplus Mokelumne flows that EBMUD could wheel.
- Release water from San Luis Reservoir and route through the O'Neill Forebay and the lower Delta Mendota Canal to the San Joaquin River in wetter years if better quality water in the Delta can be used to refill the evacuated storage space. This action will be limited by the fill/release capacity and risk to not re-filling. Simple calculations could quantify the possible benefits.

Note: The water supply study is designed to provide a measure of water supply tradeoffs associated with implementing the water quality measures. Effects on the ecosystem outside of the prescriptive standards which are implemented in each run are considered.

APPENDIX B. ANALYSIS DETAILS AND ASSUMPTIONS

Analysis methodology

CALFED's Preferred Alternative, as defined in the June 1999 PEIS/EIR provided the baseline for evaluating drinking water quality operating rules. The group considered Delta configurations with and without a demonstration facility at Hood. Some key baseline assumptions include:

- Flow/fish control structures at Old River, Middle River, and Head of Old River
- Unlimited joint point of diversion
- Full Banks pumping capacity (10,300 cfs) with channel modifications
- Preferred Alternative without Hood Diversion, Criterion B (DWRSIM Study 809)
- Preferred Alternative with 4,000 cfs Hood Diversion, Criterion B (DWRSIM Study 822)

New Storage Facilities

To limit the number of studies, new storage facilities were limited to 2 MAF north of the Delta and 1 MAF south of the Delta. It was assumed that the information derived from the modeling results could be applied to both new surface and groundwater storage. In-Delta storage was not directly evaluated.

Inflow and release criteria were investigated to improve water quality. In some cases the yield from new facilities was dedicated to maintaining higher fall outflows, thereby reducing salinity intrusion during those months.

Operation of Delta and conveyance facilities were also considered. These facilities included (but are not necessarily limited to) the Delta Cross Channel, expanded Banks capacity, access to joint point of diversion, and a demonstration facility at Hood.

Modeling tools

Spreadsheets were developed to evaluate north and south of Delta storage operations. Details regarding these spreadsheets are provided in Appendix C.

Fischer Delta Model studies were run with output from DWRSIM and the spreadsheet models. The FDM studies computed bromide at critical locations in the Delta and also included "fingerprinting" which allowed for the evaluation of any conservative constituent. Barrier operations, Delta bathymetry, and boundary conditions for the San Joaquin River (flow and salinity) were consistent with other CALFED studies. Details of the FDM studies are in Appendix D.

Limitations on Analysis

Operating rules were developed to control bromide at the larger drinking water intakes in the Delta: Clifton Court Forebay, Tracy Pumping Plant, CCWD's intakes at Rock Slough and Old River near Highway 4, and the North Bay Aqueduct. Operating rules to reduce total organic carbon loading were not developed within this study. However, considering the regularity in which organic carbon concentration peaks in the Delta, rules could easily be developed to reduce diversion of this constituent.

Operating rules do not explicitly consider tradeoffs with other ISI objectives such as water supply reliability and operational flexibility. Consideration of these objectives are implicit in formulating reasonable operating rules, however.

Water treatment options were not be evaluated in the development of operating rules. The workgroup used the CALFED Program's water quality targets as goals. Tradeoffs between treatment and project operations will be considered within the larger ISI evaluation.

D-013787

APPENDIX C. DETAILS OF SPREADSHEET STUDIES

North of Delta Storage Water Quality Operation Spreadsheet

The model is an Excel 97 spreadsheet that uses data from a DWRSIM simulation as a base condition to operate a north of Delta reservoir for water quality purposes. The user has control over several operation rules through a user editable input worksheet. Final operation and salinity outputs are available in tabular or graphical formats.

Major assumptions

The major assumptions implemented are:
- Operates for water quality purposes only by augmenting Delta outflow during periods of high salinity
- Does NOT impact project operations, uses output from a DWRSIM simulation to provide base-line operations
- Uses forward G-Model @ Antioch, Chipps, Collinsville, Emmaton, Jersey Point, and Rock Slough as implemented in DWRSIM to compute salinities at each station

General Operation Rules

Fill from "surplus" Sacramento River flows
Release for Delta Outflow purposes only
Release computed based on
- Type of month (typical good or bad salinity)
- Rock Slough Salinity "triggers"
- Storage Protection Level

User Input

Active Storage	TAF	Total useable storage in the reservoir
Initial Storage	TAF	Reservoir storage at start of simulation
Intake Capacity	CFS	Maximum rate water can be put into the reservoir
Outlet Capacity	CFS	Maximum rate water can be released from the reservoir
NDO Release Limit	CFS	Largest Net Delta Outflow that release will create
Release Operation Code(s)	N/A	Type of release operation each month
Release Salinity Triggers	CL	Rock Slough Salinity trigger and release for each release code
Carryover Factor	N/A	Maximum % of storage in the reservoir that can be released in any one month
G-model coefficients	N/A	Used to compute salinities with G-model
X2 coefficients	N/A	Used to compute X2 position
Geomorphologic Criteria	CFS	Minimum Sacramento River flow at diversion location before diversion can be made.

Model Usage

1. Copy the data for the desired study from the sheet Data 809 or Data 822 to the main DWRSIM input data sheet Database. All computations get DWRSIM output data from the sheet Database. Do NOT delete the Database sheet and rename the Data 809 or Data 822 sheets as this will destroy the references.
2. Go to the sheet User Input and set parameters.
3. Verify that the spreadsheet has re-calculated.

Detailed Operation

1. Reservoir fill operations happen whenever there is water and capacity available. The amount of fill is computed as the minimum of:

    - Minimum of surplus @ Navigation Control Point, Freeport, Rio Vista, E/I Ratio, Delta Outflow
    - Sacramento River Flow @ diversion point minus geomorphologic flow
    - Available Storage Capacity
    - Physical Fill Capacity

2. Reservoir release operations are based on several user input factors.
    - Release Operation Codes:
        1. Code 0: Other months
        2. Code 1: Fall and winter bad salinity months (e.g. Oct, Nov, Dec).
        3. Code 2: Months with potential initial sea water intrusion (e.g. Jul, Aug, Sep).
    - Rock Slough Salinity Trigger – These specify the release for Delta Outflow each month based on the Release Operation Code and computed Rock Slough salinity the previous month.
    - Carryover Factor – This is a user specified storage level and percentage. If the computed reservoir storage falls below this level then the release is limited to the specified percentage of the storage.

South of Delta Storage Water Quality Operation Spreadsheet

The model is an Excel 97 spreadsheet that uses data from a DWRSIM simulation as a base condition to operate a new south of Delta reservoir for water quality purposes. The user has control over several operation rules through a user editable input worksheet. Final operation and salinity outputs are available in tabular or graphical formats.

Major Assumptions

The major assumptions implemented are:

- Facilities are assumed to be a new south of Delta reservoir and new export facilities in the Delta
- Should NOT impact project operations, uses output from a DWRSIM simulation to provide baseline operations

- Uses forward G-Model @ Antioch, Chipps, Collinsville, Emmaton, Jersey Point, and Rock Slough as implemented in DWRSIM to compute salinities at each station
- Will re-operate San Luis Reservoir as well as new reservoir
- Any reservoirs can serve any demand
- Any export pumping plant can serve any reservoir
- Year to year carryover is OK
- Upstream inflows are assumed NOT to change; that is, pumping reductions result in additional Delta outflow

These assumptions mean that the San Luis Reservoir and New storage can be treated as a single reservoir and the Banks, Tracy and New pumping facilities as a single export pump. This is implemented as a new "Virtual" reservoir south of the Delta. The virtual reservoir consists of the in/out and storage capacities of San Luis Reservoir and the New south of Delta Reservoir combined. It operate in conjunction with a virtual export pumping plant which is the sum of Banks, Tracy and the New pumping plant.

General Operation Rules

There are three potential modes of operation for each period. *Only one can happen in a period*:

A. Fill - when salinity at the export pumps is very good export as MUCH as possible so will compute export to meet all demand and fill up virtual storage as much as possible within physical and operational constraints.

B. Release - when salinity at the export pumps is very bad export as LITTLE as possible. Will release as much as possible from virtual storage and then increase exports to cover the remaining delivery.

C. Normal Operation – When salinity at the export pumps is just OK export just enough to leave the "Virtual" reservoir at rule curve, a desired level of storage, and meet the delivery for the period. These months give the project flexibility to meet demands and provide the best water quality possible. The desired level of storage is included here to ensure that there is enough export capacity plus storage to meet the delivery every month. If the desired level of storage is not enough then it is possible that the deliveries from the DWRSIM base study will not be met. This needs to be checked in the final results and the rule curve parameters adjusted as required.

Note: This approach does not allow segregation of water between the two reservoirs based on water quality. The results are only applicable to looking at changes in total salt load from the export pumps. There may be additional water quality benefits possible from operating the facilities independently.

User Input

Storage for Release	N/A	Switch to set level of rule curve, higher gives more protection against shortages
Tracy Constrained by 4200 CFS DMC	N/A	Switch to constrain Tracy operation to the 4200 CFS DMC capacity instead of the 4600 CFS pumps
Dec 15 – Mar 15 Banks Limit	CFS	Corp permit limit as in DWRSIM
DA1 Days	N/A	Sets 30 or 60 day pulse flow period as in DWRSIM
Top Dead Storage	TAF	Reservoir storage that can not be used
Top Cons Storage	TAF	Maximum storage at top of conservation pool. Active, or useable, storage is this minus Dead storage.
Max Fill	CFS	Maximum rate water can be put into the reservoir
Max Release	CFS	Maximum rate water can be released from the reservoir
Initial Storage	TAF	Reservoir storage at start of simulation
Banks Capacity	CFS	Physical export capacity at Banks
Tracy Capacity	CFS	Physical export capacity at Banks
New Pump Capacity	CFS	Physical export capacity at Banks
Virtual Reservoir Flags	N/A	For each month set allowed operation and salinity trigger. Both must be met for operation to occur that month.
E/I Relaxation Limits	N/A	New E/I ratio to be used if higher than ratio from DWRSIM run.
G-model coefficients	N/A	Used to compute salinities with G-model

Model Usage

1. Go to the sheet User Input and set parameters.
2. Verify that the spreadsheet has re-calculated.

Detailed Operation

1. Since the upstream operations are assumed fixed, compute the maximum export pumping that could occur given export and water supply limits. This computation considers Delta outflow requirements, export limits including E/I ratio limits, physical capacities, Delta (b) (2) requirements, and VAMP.
2. Compute the total delivery required this month. This includes all losses, changes in storage in SWP reservoirs (other than San Luis), on the aqueduct, evaporation etc.
3. Operate the virtual reservoir.
   A. Determine type of operation for the month based on the user input operation flags and the computed Rock Slough salinity the previous month.
   B. If Fill operation, then will export the entire total delivery if possible, then release any remaining unmet delivery from storage.
   C. If Release operation, then release the entire delivery from storage is possible, then export any remaining unmet delivery.
   D. If other operations, then compare the actual storage, to the desired or rule curve storage.
      1) If the actual storage is above the rule curve storage, then release to the rule curve and export the rest. If can not export the rest, then make additional release from storage to meet the remaining unmet delivery.
      2) If the actual storage is below the rule curve, then first export the full delivery then release from storage to meet the remaining unmet delivery. After the full delivery is met, if there is still export capacity and water supply available, then export to full storage to the rule curve level.

APPENDIX D. DETAILS OF FISCHER DELTA MODEL STUDIES

The Fischer Delta Model (FDM) has been used to study the effects of flow diversions and flow storage. A total of six scenarios are studied: Scenarios 809, 822, 809N, 822N, 809S, and 822S. CALFED's Preferred Alternative, as defined in the June 1999 PEIS/EIR, provides the baseline for the evaluation of drinking water quality operating rules. Delta inflow data taken from DWRSIM outputs of CALFED Studies 809 and 822 are used in FDM Scenarios 809 and 822. Study 809 is a preferred alternative without a Hood diversion, criterion B. Study 822 is a preferred alternative with a 4,000 cfs Hood diversion, criterion B. Scenarios 809N and 822N include Sacramento Valley storage (2 MAF) north of the Delta. Scenarios 809S and 822S include off-aqueduct storage (1 MAF) south of the Delta. Changes in Sacramento River inflow (for the "N" studies) and changes in Delta exports (for the "S") studies were formulated by the CALFED Drinking Water Quality Operations Workgroup. This report addresses the simulated bromide concentrations at selected monitoring stations in the sixteen-year period from water year 1976 to 1991.

This appendix was prepared by Flow Science Incorporated of Pasadena, California, acting under agreement with CALFED. It begins with a general discussion of the model applied in this study. This is followed by a description of the input data and the model output.

Fischer Delta Model

The Fischer Delta Model (FDM)[3] consists of two linked models, a hydrodynamic model and a water quality model. The hydrodynamic model utilizes the fixed grid method of characteristics to simulate the hydrodynamics in the Delta. The water quality model uses a Lagrangian method, in which the motion of parcels of water is followed through the Delta. The Lagrangian method uses no grid points, but the computational effort required is equivalent to the use of approximately 2,500 grid points in a conventional numerical model. The model extends from the downstream boundary in Carquinez Strait, upstream to Sacramento on the Sacramento River, and to Vernalis on the San Joaquin River. It also includes tidally-influenced sloughs. The hydrodynamic model is called DELFLO and the water quality model is called DELSAL.

The purpose of these models is to describe changes in the water quality of the Delta as affected by changes in geometry and hydrology and Delta operations. Changes in hydrology include changes in riverine flows and diversions within the Delta and to the south of the Delta. The models are also designed to allow prediction of the effect of changes in agricultural discharges and changes in municipal discharges. The model is capable of simulating a partial year, a full year, or multiple years of hydrology. It is not intended for water quality prediction during floods, or during periods of rapidly changing high flows. The hydrodynamic model is not expected to be accurate at extremely high discharges because of the use of a constant channel width.

[3] The model is operated by Flow Science Incorporated for Hugo B. Fischer, Inc.

DELFLO was calibrated by comparing model output at 40 stations to observations in the field and to water surface elevations in the physical model operated by the U. S. Army Corps of Engineers at Sausalito, California. Two conditions were studied: the tide of August 27-28, 1968, with a net Delta outflow of 2,500 cfs; and the tide of September 14-15, 1968, with a net Delta outflow of 17,200 cfs. The values of Manning's "n" (the friction factor for each channel) were varied until a satisfactory agreement was obtained between the numerical model and water surface elevations measured in the field and in the physical model. In most cases, the field and physical model elevations agree within 0.2-foot water surface elevation.

DELSAL, the water quality model, was calibrated primarily by comparing model output for salinity to field data. The Lagrangian method adopted in the model eliminates numerical dispersion, which is inherent in finite difference and finite element models. The model was designed to simulate salinity changes in the Delta as affected by physical and hydrologic changes in the Delta, but it can also be used to determine the movement and dispersion of pollutants (or any mass conserving, neutrally buoyant particles) released from point sources.

Version 10.32 of the FDM was used in this study. Suisun Marsh was modeled as simple channels with reservoirs, and Duck Club operations (which are slight modifications of conditions in Suisun Marsh) were not considered. The geometry data file consists of 163 channels, 125 nodes, 10 gates, and 13 reservoirs. A general layout of the network is depicted in Figure D-1[4]. At Eckley, the 19-year mean tide is applied as the downstream boundary condition. The salinity changes due to return flow from San Francisco Bay are considered as described below.

Input data

The input data include geometry data, hydraulic data, and salinity data. The basic geometry data are those used in FDM Versions 5 to 9. Channel dimension modifications, if any, are not considered. Three of the simulations (822, 822N, and 822S) included a structural change to allow the diversion of up to 4,000 cfs from the Sacramento River at Hood to the North Fork of the Mokelumne River.

The fish control barrier at the head of Old River and flow control barriers on Middle River north of Union Island and on Old River near Tracy are included in the model. The fish control structure at the head of Old River is assumed installed and operating in May, October, November, and half of April, as long as the San Joaquin River flow at Vernalis did not exceed 8,600 cfs. For higher flows, the flow control structure was assumed to be open causing no restriction to flow. Flow control structures on Old River near Tracy and on Middle River are installed and operated in April through October, as long as the San Joaquin River flow at Vernalis is below 20,000 cfs.

[4] A few additional nodes, channels, and reservoirs specific to this study are not shown in this figure.

For Scenarios 809, 809N, and 809S, Delta Cross Channel Gates are open July through September and for almost all of June. For Scenarios 822, 822N, and 822S, they are open in July and August only.

The hydraulic data used in this study include: (a) the monthly inflow for the Sacramento River, Yolo Bypass, San Joaquin River, Mokelumne River, and Calaveras River at the upstream boundary of the model; (b) monthly export and diversion rates at the Tracy Pumping Plant, State Delta Pumping Plant, Contra Costa Canal, North Bay Aqueduct, and City of Vallejo Diversions, and (c) monthly Delta consumptive use rates. These data are taken from DWRSIM outputs. The flows are monthly averaged flows and are held constant for each month.

The bromide concentrations at the locations of interest were modeled by first estimating the concentration of total dissolved solids (TDS), then converting TDS values to bromide concentrations as discussed below. The TDS concentration files for the major inflows to the Delta were identical for all model runs. For the Sacramento River and Yolo Bypass flows, a constant value of 100 mg/l TDS was used. For the Eastside streams, a constant value of 72 mg/l was used. The salinity of the San Joaquin River at Vernalis was estimated using the following formulae (derived by the DWR Central District):

$$EC = 29249 \times Q^{-0.514139}$$

for April – September (irrigation season), and

$$EC = 19039 \times Q^{-0.44950}$$

for October – March (non-irrigation season) to convert the flow rate, Q, in cfs, to electrical conductivity, EC, in microsiemens/cm or micromho/cm. In both seasons, the electrical conductivity is converted to the total dissolved solid of the San Joaquin River, TDS, in ppm, using the following conversion:

$$TDS = 0.58379 \times EC - 2.67$$

where TDS is constrained to fall between 94 and 1100 ppm.

There are relatively few data on agricultural returns in the Delta. The first available reliable source of data was developed by the California Department of Water Resources (DWR) in 1967 (Bulletin 123-67). These data were used during the initial development of the FDM as the basis of the formulation of agricultural diversions and return flows. In developing these data, the Delta was divided into three primary regions (the north, central, and south Delta) and flow and salinity estimates were apportioned appropriately. These data are reproduced in the table below.

D-013794

Table D-1 Estimates of agricultural returns, fraction of total returns by region, salinity of agricultural returns, and rainfall and consumptive used estimates. (From DWR Bulletin 1967, and based upon 1964 data.)

Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Monthly agricultural returns: flows in cfs												
North	140	220	340	330	190	160	180	230	340	460	380	190
Central	100	130	240	260	120	120	160	120	160	180	160	110
South	270	420	840	1000	380	260	280	470	660	700	660	410
Total	510	770	1420	1590	690	540	620	820	1160	1340	1200	710
Fraction of total monthly agricultural return flows												
North	.274	.285	.239	.207	.275	.296	.290	.280	.293	.343	.316	.267
Central	.196	.168	.169	.163	.173	.222	.258	.146	.137	.134	.133	.154
South	.529	.545	.591	.628	.550	.481	.451	.573	.569	.522	.550	.577
Monthly salinity of agricultural returns: TDS in ppm												
North	609	599	829	860	908	788	618	419	180	198	244	332
Central	575	485	796	892	1051	1051	962	649	452	556	672	540
South	1209	1413	835	861	957	1006	1020	860	680	673	857	1004
Average	920	1024	827	866	960	951	889	706	502	494	638	752

The model set the downstream boundary at Eckley, where the 19-year mean tide is applied as the boundary condition. The salinity of the water at the boundary was determined by applying the bay-return-salinity option in the model to consider the mixture of water from upstream and water returned from inside the bay. The probability of water particle returns from the bay to the downstream boundary, depending on the delta net outflow, was determined from a previous computer run of the combined Bay-Delta model.

After TDS was computed for interior Delta stations, TDS values were converted to bromide concentrations. The conversion factors, given below, were constant for each source of water to the Delta for all times of the year.

Results

All six scenarios were run for sixteen years from water year 1976 to water year 1991. In addition to the total TDS, the TDS at each station due to the contribution from five sources were also calculated. These five source components are (1) Sacramento River and Yolo Bypass inflows, (2) San Joaquin River inflow, (3) Bay water, (4) Eastside stream inflows, and (5) agricultural returns. Results were collected for eleven selected stations. The station codes and locations for these

Table D-2. Locations of monitoring stations.

Station Code	Location (see Figure D-2)
CVP	CVP Tracy Pumping Plant Intake
Rock	West end of Rock Slough
LVin	Los Vaqueros Intake
NBA	North Bay Aqueduct
JP	Jersey Point
Emma	Sacramento River at Emmaton
SAL	San Andreas Landing
Moss	San Joaquin River at Mossdale
BB	San Joaquin River at Brandt Bridge
Anti	Antioch
Clif	Clifton Court Forebay

eleven monitoring stations are listed in Table D-2.

Results are presented in this report for four locations: North Bay Aqueduct, Rock Slough, Clifton Court Forebay, and Tracy Pumping Plant. For each of the six studies and each of the four reporting locations, the flow-weighted bromide concentration was calculated as follows:

$$\textit{Flow - weighted average bromide concentration} = \frac{1}{\sum_{i=1}^{N} Q_i} \sum_{i=1}^{N} Q_i C_i$$

where N is the number of months in the sixteen-year simulation period, Q is the export (or diversion) flow rate, and C is the monthly average simulated bromide concentration.

$$Bromide\,[\mu g/l]_{Bay} = TDS\,[mg/l]_{Bay} \times \frac{65{,}000\,[\mu g/l]\,Bromide}{33{,}000\,[mg/l]\,TDS}$$

$$Bromide\,[\mu g/l]_{Sacramento\ River} = TDS\,[mg/l]_{Sacramento\ River} \times \frac{20\,[\mu g/l]\,Bromide}{100\,[mg/l]\,TDS}$$

$$Bromide\,[\mu g/l]_{Eastside\ Streams} = TDS\,[mg/l]_{Eastside\ Streams} \times \frac{20\,[\mu g/l]\,Bromide}{100\,[mg/l]\,TDS}$$

$$Bromide\,[\mu g/l]_{San\ Joaquin\ River} = TDS\,[mg/l]_{San\ Joaquin\ River} \times \frac{76\,[\mu g/l]\,Bromide}{100\,[mg/l]\,TDS}$$

$$Bromide\,[\mu g/l]_{Agricultural\ Returns} = TDS\,[mg/l]_{Agricultural\ Returns} \times \frac{113\,[\mu g/l]\,Bromide}{100\,[mg/l]\,TDS}$$

APPENDIX E. DETAILS OF WATER QUALITY OPERATION RULES FOR NORTH OF DELTA STORAGE

This appendix describes the development of operation rules associated with an additional north of Delta storage facility for the purpose of improving export water quality. In developing the operation rules, the following factors have been considered.

1. Operation rules should follow or implement the general water quality improvement principles/guidelines (described in the main report).
2. Rules should be simple to allow application to a wide range of conditions.
3. Triggers should be capable of being measured or estimated so that they can be potentially implemented in real operations.

North Of Delta Storage Water Quality Operation Rules

Three types of triggers are combined to form water quality storage release rules.

Monthly Pattern: Monthly-Code

This trigger is designed to take advantage of the expected Delta salinity patterns. Each month is classified as one of three categories:

Code 2: Potential early seawater intrusion months (e.g. Jul, Aug, Sep).
Code 1: Fall and winter high salinity months (e.g. Oct, Nov, Dec).
Code 0: Other months

For each category, there is a set of associated salinity triggers to govern the release operation. The monthly code should be modified if the salinity pattern changes due to future significant changes in the system configuration or operation.

Salinity Triggers

Previous month Rock Slough chloride concentrations are used as the salinity triggers. This is a good indicator for seawater intrusion into the south Delta. The quantities of additional upstream releases are tied to the severity of the intrusion. These trigger levels and associated release quantities can be refined further.

The following is an example of trigger set for a 2 MAF reservoir. These salinity triggers were developed through trial-and-error with a spreadsheet model.

Code 0		**Code 1**		**Code 2**	
Chloride (mg/L)	**Release (cfs)**	**Chloride (mg/L)**	**Release (cfs)**	**Chloride (mg/L)**	**Release (cfs)**
0 – 100	0	0-25	0	0-23	0
> 100	0	25-50	0	23-50	1,500
		50-100	750	> 50	1,500
		> 100	1,000		

Reservoir Storage Level

This constraint reflects a conservative release operation because water is retained for future release to reduce seawater intrusion during prolonged droughts. When reservoir storage is lower than the specified trigger level, only a limited percentage of the remaining storage can be released for each month.

Storage Trigger (TAF)	Allowed Percentage
1,000	10%

For example, when August storage is reduced to 800 TAF, the maximum release would be 80 (or 1,340 cfs) for September. This is lower than the 1,500 cfs called for by the water quality triggers. This constraint was added so that storage would not be reduced prematurely by the water quality trigger release rules.

For modeling implementation, the storage trigger and allowed percentage are user inputs. The parameter values used in this study resulted from a trial-and-error process which attempted to sustain storage through the 1928-1934 dry period, leaving no storage in the additional north of Delta storage facility by the end of the drought.

Sensitivity Analysis For Triggered Releases

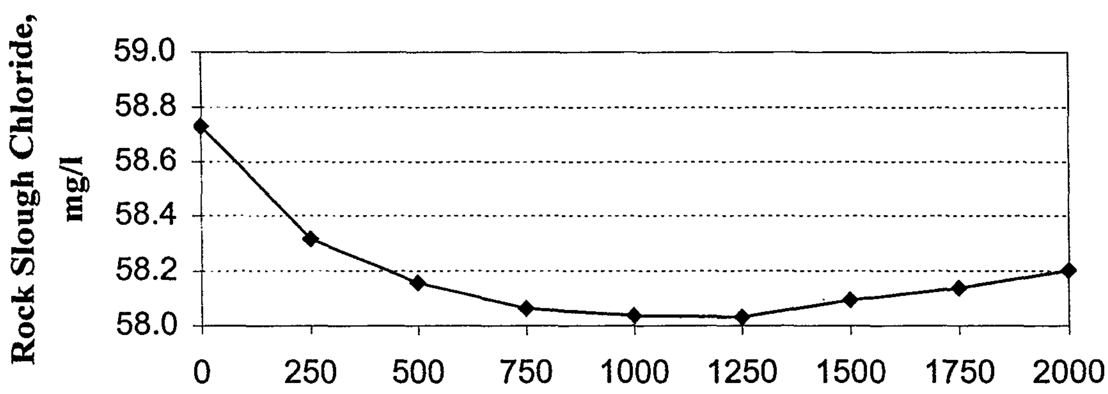
For Study 809, a sensitivity analysis was conducted to evaluate the relative water quality improvement by varying NDSS release triggers associated with Code-1 and Code-2. Two criteria are used to evaluate the sensitivity of a parameter: the long-term average and peak chloride concentration at Rock Slough. Chloride concentrations at the 75%, 90%, 95% and 100% exceedance level are good measures of peak concentration.

In this study only single-variable sensitivity analyses were conducted. That is, the trigger values presented in the previous section are used as the base values for those parameters. When conducting the sensitivity runs, only the parameter of interest is varied in a wide range. Other parameters are kept at their base values. Figure E-1 shows the effectiveness of Code-1 releases on the mean chloride. Figure E-2 compares the concentration at various exceedance levels. From Figure E-1, we can conclude that the best Code-1 release amount is between 1,000 cfs and 1,250 cfs to reduce the long-term mean chloride. From Figure E-2 we learned that very low Code-1 release amounts such as 250 cfs, could actually achieve better 99% and 100% exceedance values. This indicated that a normal "optimal" operation would deplete the new storage before the end of a prolonged drought.

Figures E-3 and E-4 contain sensitivity curves for the Code-2 release quantities. From Figure E-3, it appeared that the 2,500 cfs release gave the best long-term mean performance. But Figure E-4 indicates that the 2,500 cfs release would have worse 90% and higher exceedance performance than the 1,500 cfs release.

Some caution should be exercised with the interpretation of this sensitivity analysis considering that it was conducted with single variables and considering that the Code-1 and Code-2 triggers have different base values. Therefore, a direct comparison between the effectiveness of Code-1 and Code-2 from figures E-1 and E-3 is difficult. Figure E-5 is a sensitivity study on Code-1 releases by changing the Code-2 base value to match the Code-1 base value. By comparing the relatively unbiased results of Figures E-3 and E-5, one may conclude that by releasing an equal quantity of flow, the Code-2 months may produce relatively more water quality improvement.

Figure E-1: Sensitivity of Code-1 Release on Long-Term Monthly Mean Chloride, mg/l



D-013799

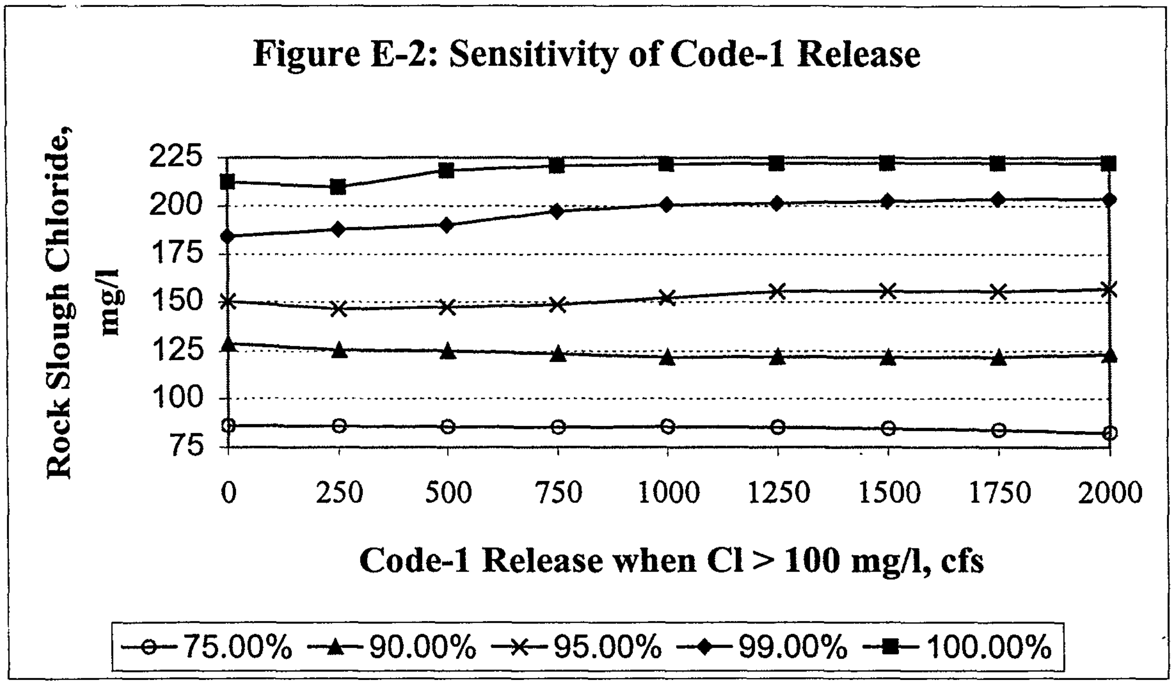


Figure E-2: Sensitivity of Code-1 Release
Rock Slough Chloride, mg/l
225
200
175
150
125
100
75
0
250
500
750
1000
1250
1500
1750
2000
Code-1 Release when Cl > 100 mg/l, cfs
75.00%
90.00%
95.00%
99.00%
100.00%

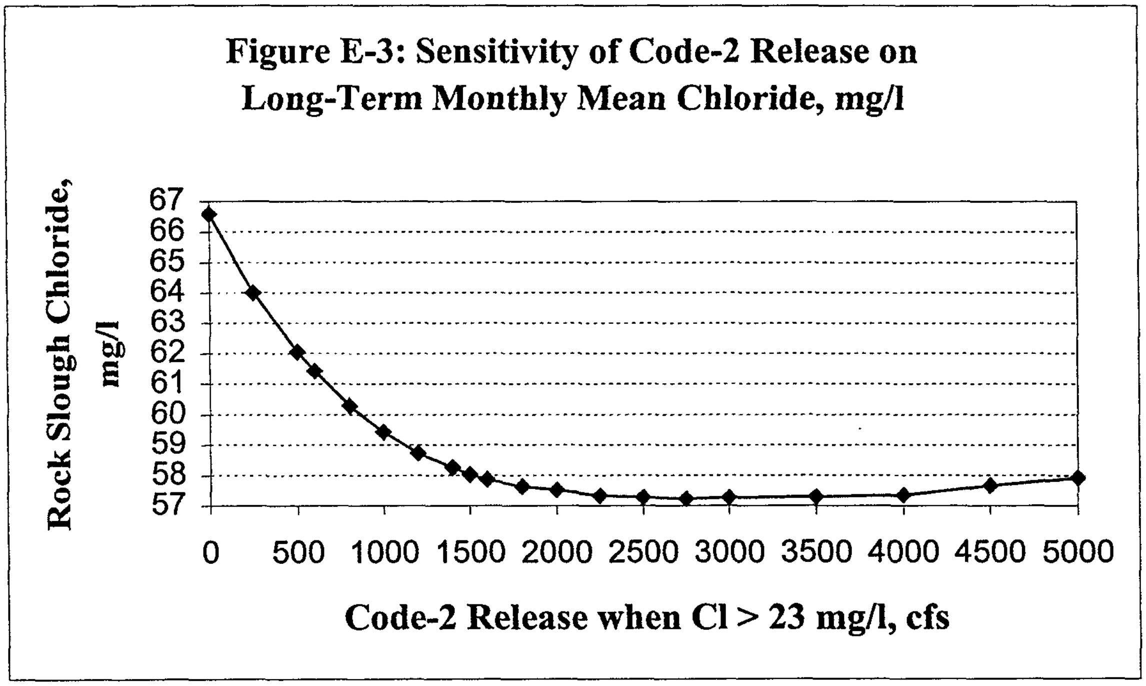


Figure E-3: Sensitivity of Code-2 Release on Long-Term Monthly Mean Chloride, mg/l
Rock Slough Chloride, mg/l
67
66
65
64
63
62
61
60
59
58
57
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Code-2 Release when Cl > 23 mg/l, cfs

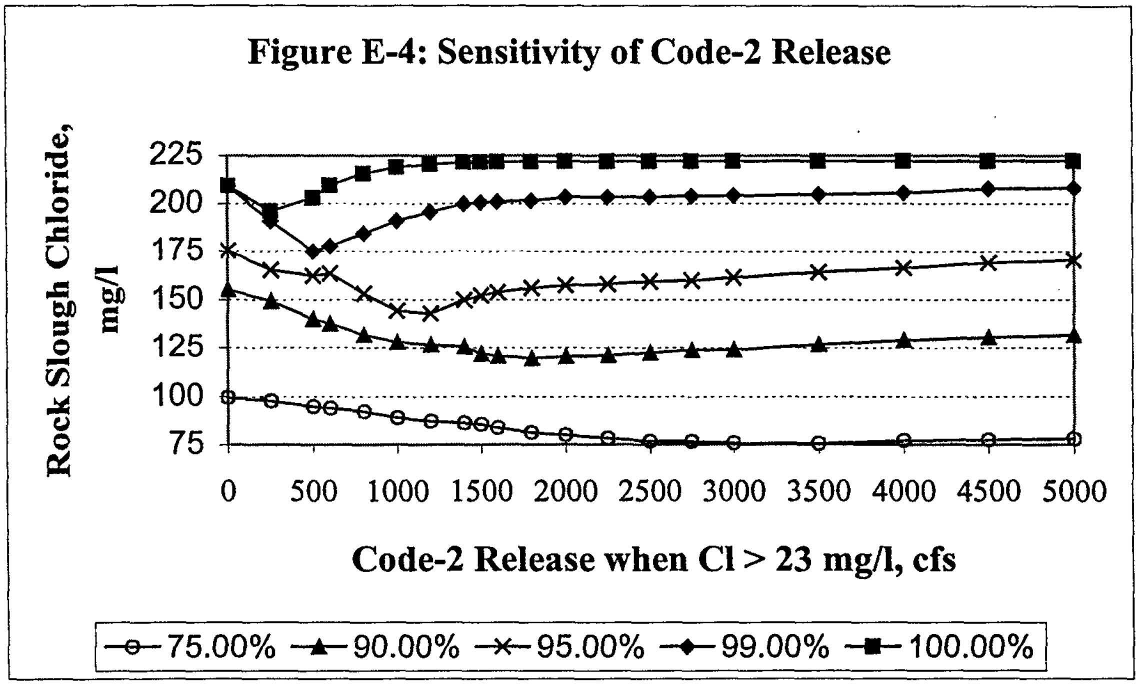


Figure E-4: Sensitivity of Code-2 Release
Rock Slough Chloride, mg/l
225
200
175
150
125
100
75
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
Code-2 Release when Cl > 23 mg/l, cfs
75.00% 90.00% 95.00% 99.00% 100.00%

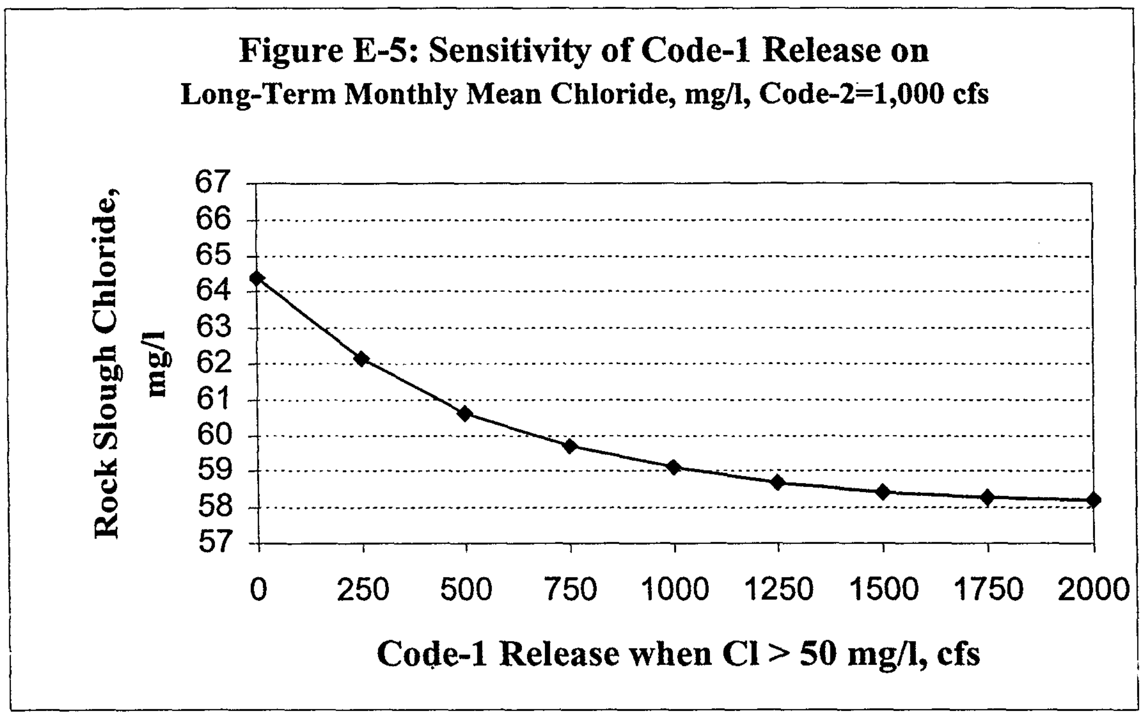


Figure E-5: Sensitivity of Code-1 Release on
Long-Term Monthly Mean Chloride, mg/l, Code-2=1,000 cfs
Rock Slough Chloride, mg/l
67
66
65
64
63
62
61
60
59
58
57
0 250 500 750 1000 1250 1500 1750 2000
Code-1 Release when Cl > 50 mg/l, cfs

D-013801

APPENDIX F. OTHER WATER QUALITY ACTIONS

For completeness and for reference, the group developed a list of supplemental actions which could improve delivered drinking water quality. These supplemental actions are actions that were not included in this study and actions that are more appropriately addressed as part of the Delta Drinking Water Council process as they do not directly involve storage facilities (both existing and new).

- Isolation of south of Delta deliveries. After water is exported from the Delta through Banks Pumping Plant and Tracy Pumping Plant, there are opportunities for the water to be blended with water previously exported which may be of significantly different quality. Separation of high- and low-quality supplies can help achieve delivered water quality goals.

- Isolation of the effect of the Delta Cross Channel closure on south Delta water quality and the effect of the Hood-Mokelumne facility

- Re-operation of potential near-term facilities (see Appendix A for preliminary work)
  - Existing storage reoperation, south and north of the Delta
  - Selective exports with increased Banks Pumping Plant capacity and joint point of diversion
  - O'Neill bypass for water quality isolation

- Within-Delta facility operations and source control
  - Active operation of the Delta Cross Channel to improve quality when the Rio Vista flow requirement does not control operations.
  - Active operation of flow-control barriers.
  - Possibilities for the consolidation of Delta agricultural drains should also be explored. This drainage could be treated and/or moved away from urban Delta intakes.
  - Land use management within the Delta (to reduce or dynamically vary organic carbon loads)
  - In-Delta storage (divert only low saline and low TOC water, use for outflow enhancement or delivery to agriculture)
  - Filling of Clifton Court Forebay based on tides and water quality
  - Joint point of diversion for water quality (if possible)

- Modifications in Delta environmental requirements (e.g., varying E/I ratio to increase exports if water quality is favorable)

- Water exchanges from surplus or agricultural higher-quality supplies
  - North Bay Aqueduct-Lake Berryessa exchanges
  - Bay Area exchanges
  - Friant-Tulare-MWD exchanges
  - New Don Pedro-San Joaquin exchanges

- California Aqueduct in plug flow pulses of different water qualities

- Conveyance facilities
  - Mid-Valley canal
  - Isolated conveyance facility for the Delta

- Advances in drinking water treatment

APPENDIX G. PARTICIPATION

The following individuals participated in the CALFED Drinking Water Quality Operations Workgroup:

Elaine Archibald (CUWA), Dave Briggs (CCWD), Brian Campbell (EBMUD), Grace Chan (MWD), Francis Chung (DWR), Mark Cowin (CALFED), Richard Denton (CCWD), Terry Erlewine (SWC), Amy Fowler (SCVWD), Paul Hutton (CALFED), Jay Lund (UC Davis), Bruce Macler (EPA), Susan Paulsen (Flow Science), Paul Sandhu (DWR), Sanjaya Seneviratne (DWR, Bill Smith (Surface Water Resources Inc.), Lynda Smith (MWD), Chuching Wang (MWD), and Phil Wendt (DWR).

Printed by
Department of Water Resources
Reprographics

D-013805