Delta Simulation Model Studies of Alternatives 1EX, 1A, 1C, 2B, 3X

- MASS TRACKING -

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INTRODUCTION

Mass tracking simulations simulate the movement of a tracer. A known amount of mass is inserted at a specified location for a predetermined time period. Its movement is followed through the Delta. For these studies, mass was inserted over one tidal cycle and at seven different locations within the Delta (Figure 3-1) for each of the five alternatives and for each hydrologic period. The fate of the mass from each location after 30 days was recorded.

This report documents the results of several mass tracking studies used to evaluate five different CALFED alternatives (1EX, 1A, 1C, 2B, and 3X) for four different hydrologic periods. These four periods were chosen to represent a range of Delta inflows and exports. The hydrodynamic results used to run these studies can be found in the CALFED ***Status Reports on Technical Studies for the Storage and Conveyance Refinement Process.*** These studies are:***Delta Simulation Model Studies of Alternatives 1A, 1C, 2B, 3E, 3X*** , dated January 16, 1998; with its Appendix, ***Alternative 1EX*** , dated April 24, 1998; and***Delta Simulation Model Studies of Alternatives 1C, 2B, 3X*** , dated June 1, 1998. Major flows and gate configurations from these hydrodynamic studies can be found in Appendix A of this report.

Alternative 1EX

Alternative 1EX represents the existing geometry of the Delta Channels. It assumes conditions associated with a 1995 level of development, and no temporary structures or fish control structures in the South Delta are installed. Figure 1-1 shows the existing Delta system. The hydrology for this alternative comes from DWRSIM Study 558.

Alternative 1A

Alternative 1A like 1EX represents the existing geometry of the Delta Channels. No temporary structures in the South Delta or fish control structures at the head of Old River are installed. Again, Figure 1-1 shows the existing Delta system. However, Alternative 1A assumes a 2020 level of development and uses a hydrology from DWRSIM Study 516.

Alternative 1C

Alternative 1C represents Delta changes consistent with the preferred alternative for the ***Interim South Delta Program Draft Environmental Statement / Environmental Report,*** July 1996. As shown in Figure 1-2, a new forebay intake structure with a 30000 cfs capacity is installed in the northeast section of the forebay. Old River is dredged an additional five feet from Victoria Canal to Woodward Canal. Permanent flow control structures are installed in Old River, Middle River, and Grant Line Canal. A permanent fish control structure is installed at the head of Old River. The Tracy Pumping Plant is connected to Clifton Court Forebay through an intertie.

Alternative 1C assumes a 2020 level of development and uses a hydrology from DWRSIM Study 532a.

Alternative 2B

Alternative 2B represents the development of North Delta improvements, a 10000 cfs screened Hood intake, and South Delta improvements. It represents the same changes in the South Delta as described under Alternative 1C. In addition, up to 10000 cfs of Sacramento River water is diverted from Hood to Snodgrass Slough while McCormack-Williamson Tract is flooded and channels in the Mokelumne River system are enlarged to accommodate the increased cross-Delta flow. Operation of the Hood diversion is constrained by a minimum Rio Vista average flow of 3000 cfs in July, August, and September. In addition, Hood diversion is limited to 5000 cfs in May due to migrating fish concerns.

A 10000 cfs pumping plant at Hood and a 10000 cfs open channel from Hood to Lambert Road are assumed. Snodgrass Slough is enlarged by a 1000 foot levee setback in the southwest corner of Glanville Tract. The flow down Snodgrass is then allowed to pass through a flooded McCormack-Williamson Tract at levee openings in the northwest, southwest and northeast corners of the island.

The Mokelumne River is widened 500 feet by levee setback in three reaches: from I-5 to New Hope Landing, the North Fork of the Mokelumne River from New Hope Landing to the south end of Tyler Island, and the lower Mokelumne River on the western portion of Bouldin Island. Figure 1-3 shows the areas of improvement.

Alternative 2B assumes a 2020 level of development and uses a hydrology from DWRSIM Study 532a.

Alternative 3X

Alternative 3X includes a 10000 cfs isolated facility with a diversion pump on the Sacramento River near Hood (Figure 1-4). Channel enlargements in the Mokelumne system and Clifton Court Forebay improvements are the same as in Alternative 2B. Delta water is diverted into Clifton Court Forebay at a minimum of 1000 cfs through the new intake gates. Like Alternatives 1C and 2B, Alternative 3X also includes the South Delta flow control and fish control structures. However, Alternative 3X assumes a 2020 level of development and uses a hydrology from DWRSIM Study 636.

ASSUMPTIONS

Delta Boundary Conditions

The boundary of the Sacramento-San Joaquin Delta as modeled by DWRDSM2 consists of the Sacramento River at I Street, the San Joaquin River at Vernalis, and Carquinez Strait at Martinez.

Down Stream Stage

The 19-year mean tide at Martinez, Figure 2-1, is used to generate the Delta tidal action contributing to Delta hydrodynamics and water quality. This 25-hour sequence is repeated for each study period.

Delta Inflows and Exports

Delta inflows and exports are obtained from DWRSIM studies that varied for each alternative. The studies for Alternative 1EX, 1A, and 3X are 558, 516, and 636 respectively. Alternatives 1C and 2B both use study 532a. All of the studies, except for 558, assume a 2020 level of development. Study 558, assumes a 1995 level of development.

The inflows to the Delta consist of the Sacramento River, the San Joaquin River, Yolo Bypass, and Eastside Streams. The Sacramento River and San Joaquin River flows consist of inflows at I Street and Vernalis respectively. The Yolo Bypass inflow is largely Sacramento River water that is diverted from the river channel during higher flows to reduce flooding. Colusa Basin Drain, Cache Creek, and Putah Creek also contribute to the Yolo Bypass flow. The Eastside Streams inflow is the combined inflow from the tributaries on the Eastside of the Delta, between I Street and Vernalis. This flow is input to the Delta at the confluence of the Mokelumne and the Cosumnes Rivers.

The outflows from the Delta consist of Net Channel Depletion%s, Exports, and Net Delta Outflow. The Exports include the major export operations like Tracy, Banks, North Bay, and Contra Cost Canal pumping plants. Net Delta Outflow is the net flow past Martinez. It is calculated by subtracting all Delta exports and diversions from inflows.

Channel Depletion%s are estimated with the Delta Island Consumptive Use (DICU) Model. The model, on a monthly time step, keeps track of water that enters, leaves, and is stored on each of the 142 Delta subareas. Collectively, about 1,800 agricultural diversion points within the Delta are represented. It utilizes factors such as acreage, croptype, runoff, leach water, soil moisture storage, irrigation, evapotranspiration, seepage and precipitation. Calculated diversions and return flows are made for each subarea and allocated to 258 DWRDSM2 nodes. DSM2 uses the diversions, seepage and return flow at each node and calculates Channel Depletion%s; a positive value indicating a net water loss to the islands and a negative value indicating a net water gain from the islands.

Along with the inflows and exports there are two major in Delta flows, Qwest and Cross Delta flow. As shown in Figure A-1, both of these flows are a combination of flows through many channels. The Cross Delta flow is a combination of channels that divert Sacramento water to the Central Delta. Qwest flow is a combination of channels that route the water in the Central Delta out towards the bay. Qwest is a very important descriptor of what is happening to the water quality in the Central and South Delta. Low Qwest values indicate a potential problem with saline water intrusion.

Location of major inflows and outflows and their sign conventions are presented in Figure A-1, Appendix A.

Delta Facilities Operation

Clifton Court Forebay Intake Gates

The intake gates to Clifton Court Forebay for project diversion from West Canal are assumed to be operated each month according to one of three strategies or priorities (Figure 2-2). The purpose of priorities 2 and 3 are to time the diversions into the forebay to minimize impacts to low water levels in nearby channels. Priority 2 is the more protective of water levels of the two priorities. The priorities of the forebay intake gate operations for each alternative and hydrologic period are summarized in Appendix A. Alternatives which assume a CVP tie-in into the forebay (Alternatives 1C, 2B, and 3X) sometimes require changing from priority 2 to priority 3 and from priority 3 to priority 4 due to greater demands of the forebay to provide water for both projects.

Delta Cross Channel

For Alternatives 1A, 1C, and 2B, the Delta Cross Channel is assumed closed from November through June and at any other time the Sacramento River flow at I Street exceeds 20000 cfs. Otherwise, the Delta Cross Channel is open. For Alternative 3X, the Delta Cross Channel is closed in all months except July and August. Operation of the Delta Cross Channel gates for each alternative and hydrologic period is shown in Appendix A.

South Delta Flow Control Structures

Flow control structures on Old River, Middle River, and Grant Line Canal are installed and operated for Alternatives 1C, 2B, and 3X. For these alternatives, the structures are operated at the times shown in Figure 2-3, as long as San Joaquin River flow at Vernalis is below 20000 cfs. When all three flow control structures are simultaneously operating, downstream flow through the structures is at times allowed to promote better circulation. The strategy of this special operation of the structures for Alternatives 1C and 2B is shown in Figure 2-4.

Fish Control Structure at the head of Old River

The fish control structure at the head of Old River is assumed installed and operating for Alternatives 1C, 2B, and 3X according to the schedule in Figure 2-5, as long as the San Joaquin River flow at Vernalis did not exceed 8600 cfs. For higher flows, the flow control structure was assumed to be open causing no restriction to flow.

Study Periods

The study was composed of four monthly periods incorporating average to more extreme dry hydrologic periods between the years 1976 and 1991. These periods and description of inflow and export characteristics are listed in Table 2-1. Note: October of 1989 is actually part of water year 1990. A summary of the major flows and operation of major structures is provided for each study period in Appendix A.

Table 2-1: Classification of Hydrologic Periods.

Hydrologic Period	Delta Inflow	Exports
February, 1979	High	High
April, 1981	Medium	Low
October, 1989	Low	High
July, 1991	Low	Low

Mass Tracking

The mass tracking, modeled by DSM2-Qual, assumes the mass to be a non-reactive conservative constituent. The fate and distribution of the mass in the Delta is driven by the hydrodynamics, modeled by DSM2-Hydro, and the dispersion coefficient. A known amount of mass is inserted at each of seven locations over one tidal cycle. After a simulated period of 30 days the amount of mass in each of the 5 sinks is calculated.

Note that this study did not include the effects of the screens described by Alternatives 2B and 3X. The intake screen of the Hood Diversion and Isolated facility, has no effect on the mass fate. Mass is allowed to move through the screen freely.

METHODOLOGY

The studies were performed using DSM2-Qual. Mass was injected at seven discrete locations within the Delta system, shown in Figure 3-1. The mass tracking simulation was executed for a simulation time of 33 days.

The results of the simulation are presented in two forms, the **fate** of the constituent and the **distribution** of the constituent in the Delta. The fate of the constituent is an indication of where the mass is likely to end up. The mass injected at the seven discrete locations is tracked, and after 30 days the percentage of the mass in each of 5 sinks is determined. These sinks include areas like *In Delta* and *Islands*, and locations like *Exports*, *Contra Costa Canal* and *Chipps Island*. These sinks are shown in Figure 3-2.

In Delta is not really a sink, but refers to the Delta waterways from Sacramento at I Street to San Joaquin at Vernalis to Chipps Island. Mass left in the delta will eventually, given enough time, end up in one of the other 4 sinks.

Islands refer to the irrigated agricultural lands. Mass diverted to these islands by way of irrigation diversions is assumed not to return to the Delta.

Exports refer to the mass that is diverted by the exports of CVP and SWP. Mass diverted to this sink is assumed not to return to the Delta.

Contra Costa Canal (CCC), refers to the mass diverted by the Contra Costa Canal. Mass diverted to this sink is assumed not to return to the Delta.

Chipps Island, refer to the location nearing the entrance to Suisun Bay. Mass that passes *Chipps Island* is assumed to escape the Delta system.

The Distribution of the mass left in the Delta is further broken down into Delta regions, as shown in Figure 3-3. These regions 1 through 11 break the delta into sections so that the general area of the remaining mass in the Delta can be shown.

However, the distribution portion of the study, consists of a slightly different area of the Delta than does the fate portion. Regions 5 and 6 which cover the Suisun Bay and Montezuma Slough area, is not incorporated in the fate portion of the study. These areas are downstream of *Chipps Island* and are considered part of that location in the fate study. In addition, the distribution study does not include the upper portions of the Sacramento River, San Joaquin River, or the Sacramento Deep Water Ship Channel. For these reasons, the *In Delta* mass from the fate study and the total mass from the distribution study, will be inconsistent.

RESULTS

Fate of Injected Mass

Fate results for all seven injection locations are summarized for each hydrologic period in Appendix B. Three locations were selected for a more in-depth analysis; Vernalis, Freeport, and Prisoners Point. Note: For the purpose of simplifying figures, Contra Costa Canal was added to the *Exports*. Results shown reflect the fate of mass after 30 days.

February 1979

February 1979 was considered a period of high inflow to the delta and high exports. The mass injected at Vernalis (Figure 4-1), resulted in a situation where the large flows of the San Joaquin River were routed to the export pumps. For Alternatives 1EX, 1A, 1C, and 2B, at least 80 percent of the mass went to the exports. This was caused by the large extraction of water from the South Delta and large San Joaquin River inflow. Alternative 3X only exported approximately 40 percent of the mass, due to the majority of the export flow, 10000 cfs, taken from the northern Delta through the isolated facility.

The mass injected at Freeport (Figure 4-2), confirmed the results of Vernalis. It showed very little mass in the exports indicating the export demand was largely satisfied by the San Joaquin inflows. However, Alternatives 1C and 2B showed an increase in mass over 1A and 1EX. The elevated Sacramento River flow to the South Delta for 1C and 2B were due respectively to Old River Dredging and the Hood Diversion. Alternative 3X, diverted 10000 cfs to the exports and as a result approximately 27 percent of the mass was exported.

The mass injected at Prisoners Point (Figure 4-3), showed the effect of channel dredging at Old River and Mokelumne River. Alternative 1C showed a definite increase in exported mass from Prisoners Point, resulting from the dredging at Old River and increased SWP exports of 4000 cfs over that of Alternative 1A. This situation resulted in a greater demand on the water in the Central Delta. This demand can be shown in Table A-1, where Qwest for 1C is nearly 1/9*th* the flow of 1A, and 1/18*th* the flow of 2B. Consequently, Alternative 2B resulted in less exported mass from Prisoners Point. This can be attributed to the increase in water to the Central Delta from the Hood diversion that mixed with the water from Prisoners Point and allowed a greater percentage to move toward Chipps Island.

April 1981

April 1981 was considered a period in which there was medium inflow to the delta and Low exports. The mass injected at Vernalis (Figure 4-4), resulted in a relationship similar to the February period, where a large amount of the mass was drawn to the exports for Alternatives 1EX, 1A, 1C, and 2B. Alternatives 1C and 2B resulted in slightly less mass in exports and more in the Delta than Alternative 1A and 1EX. This was a result of the flow control structures placed in the South Delta for 1C and 2B. The gates increased the residence time and aided in circulation. Alternative 3X decreased the mass into the exports because of the additional inflow to the exports from the isolated facility, resulting in less demand on the San Joaquin River.

The mass injected at Freeport (Figure 4-5), resulted in only a small amount of mass drawn to the exports for Alternatives 1EX, 1A, 1C, and 2B. Again, Alternative 2B showed an increase in Sacramento River water in the exports, over 1EX, 1A, and 1C, due to additional flow through the Central Delta. Alternative 3X showed a larger amount of mass drawn to the exports because of the isolated facility. In the April 1981 period, it is diverting more than half the Sacramento flow and therefore diverts more than 50% of the mass.

The mass injected at Prisoners Point (Figure 4-6), resulted in a comparison similar to the February period between Alternatives 1C and 2B. During the April period Qwest for 1C is approximately 1/6*th* the flow of 2B. Again the additional water from the Hood Diversion helps reduce the burden of exports on the Central Delta.

October 1989

October 1989 (water year 1990) was considered a period of low inflow to the delta and high exports. The mass injected at Vernalis for October (Figure 4-7), and April, had similar results in that most of the mass was drawn to the exports for Alternatives 1EX, 1A, 1C, and 2B. However, because there were lower inflows and higher exports, the amount of mass lost to exports for October was greater than that for April. Alternatives 1C and 2B resulted in a reduction of mass in exports and an increase in islands due to the South Delta barriers and an increased residence time. Alternative 3X decreased the mass into the exports due to the minimum intake operation of 1000 cfs at the Clifton Court Forebay South Delta Intake. After 30 days, for 3X, most of the mass remained in the Delta.

The mass injected at Freeport (Figure 4-8), resulted in minor differences between the alternatives. Alternative 2B showed the most difference over Alternatives 1EX, 1A, and 1C. It resulted in a reduction of mass at Chipps Island and an increase in the Delta, possibly resulting from an increased residence time.

The mass injected at Prisoners Point (Figure 4-9), resulted in most drawn to the exports, for Alternatives 1EX, 1A, 1C, and 2B. Alternative 2B had the least exported mass because of additional water to the Central Delta which increased the Qwest flow. Alternative 3X, again, due to minimum Clifton Court South Delta Intake rate of 1000 cfs, showed very little mass drawn to the exports.

July 1991

July 1991 was considered a period of low inflow to the delta and low exports. The mass injected at Vernalis (Figure 4-10), showed a dramatic effect of low San Joaquin flows on the mass fate. For all alternatives, irrigation claimed the greater portion of the mass. Alternatives 1C, 2B and 3X decreased the percentage of mass drawn to the exports and islands by up to 15 percent because of the South Delta barriers. Instead of mass being routed through Old River (at head) and toward the exports, it traveled down the San Joaquin River and into Turner and Columbia Cut. This path increased the residence time of the mass and resulted in more mass in the Delta.

The mass injected at Freeport (Figure 4-11), resulted in minor changes between the alternatives. Alternatives 1A,1C, and 2B showed an increased irrigation demand on the Sacramento River. Alternative 3X indicated an increase of mass in the exports and a reduction of mass in the Delta resulting from the Isolated Facility.

The mass injected at Prisoners Point (Figure 4-12), resulted in very little difference between Alternatives 1C, 2B, and 3X. These alternatives decreased the mass to exports over Alternative 1A. However, this difference could be a result of the different hydrologies provided by DWRSIM studies.

Distribution of Mass In Delta

The Distribution of mass in the Delta is a very important aspect to investigate when determining the effect of alternatives on the mass transport in the Delta. Looking at the location of greatest mass concentration, the fate of remaining in Delta mass can be estimated. If the remaining mass in the Delta has a greater concentration in regions 1, 2, 3, 9, 10 or 11, the fate of the mass is most likely the exports or the islands. For regions 10 and 11 a fate to the exports increases. Mass remaining in regions 4, 5, 6, 7, and 8 have a good chance of escaping the Delta system. Refer to Appendix C for tables of mass distribution in the Delta.

CONCLUSIONS

The mass tracking studies were performed on 5 alternatives and 4 hydrologic periods. From these studies a general trend appeared for each hydrologic period; the injection location of greatest impact from the three locations, was Vernalis. For the 4 hydrologic periods very little, if any mass was transported to Chipps Island. The Prisoners Point injection location was also heavily affected by the exports.

There were small differences in the impacts of Alternatives 1A, 1C, and 2B on the mass injected at Vernalis, after 30 days. The greatest difference was associated with Alternative 3X. It reduced the demand on San Joaquin River and reduced mass from Vernalis to the exports.

Two comparisons of the Alternatives for mass fate to the exports and islands are summarized in Table 5-1 and Table 5-2 for the four hydrologic periods. There are four basic comparisons labeled with a reference number and explained below:

1. Compares Alternative 1A and 1EX, and represents the changes due to the increase in the level of development.

2. Compares Alternative 1C and 1A, and represents the changes due to the South Delta barriers.

3. Compares Alternative 2B and 1C, and represents the changes due to the through Delta flow.

4. Compares Alternative 3X and 2B, and represents the changes due to constructing the Isolated Facility.

For each reference number there is a specific comparison as stated above. Listed in the table is the alternative with the largest percentage of mass in each sink. However, to help eliminate the effects resulting from different DWRSIM studies. The difference between alternatives listed in Table 5-1 is five percent.

The difference between alternatives listed in Table 5-2 is ten percent. Notice that these are the major changes due to particular characteristics of the different alternatives.

Possible additional studies:

- Investigate the dynamics of the mass transport. Look at different time period results (5 days, 10 days ...) or a time series.
- Investigate the fate of *In Delta* mass; running the simulations until there is minimal amounts of mass left in the Delta.
- Investigate the effects of the Hood Diversion and Isolated Facility screen efficiency on the mass fate and mass distribution.

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