

OFFICE MEMO

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| TO: Tara Smith | DATE: April 18, 2002 |
| FROM: Michael Mierzwa | SUBJECT: DSM2 Evaluation of In-Delta Storage Alternatives |

1 Introduction

DWR's Integrated Storage Investigations (ISI) is reviewing the Delta Wetlands proposal to convert two Delta islands, Bacon Island and Webb Tract, into reservoirs and to restore two other Delta islands, Bouldin Island and Holland Tract, as wetland habitats. The two reservoir islands (referred to as the "project islands") would be used to store water during surplus flow periods. This surplus water would later be released for export enhancement (i.e. increases in State Water Project pumping) or to meet Delta flow/water quality requirements. ISI has re-engineered the Delta Wetlands originally proposed project, and the new ISI proposal was the basis of these DSM2 simulations. The project will be referred to as the In-Delta Storage project to distinguish it from the original Delta Wetlands proposal.

Two 16-year daily hydrologies, one representing current operations (the base case) and one representing projected operations of the project islands, developed using CALSIM II were used as the input for DSM2-HYDRO and QUAL. CALSIM II also provided the releases and diversions to the project islands. The study period was from 1975 to 1991.

The most recent version of the DSM2 geometry was used. The physical specification for the project islands and habitat islands were provided by ISI. A complete record of stage and EC at Martinez were used by HYDRO and QUAL respectively, and dissolved organic carbon (DOC) at the Sacramento River, San Joaquin River, Eastside stream, and Yolo Bypass boundaries were developed for use in QUAL. QUAL was modified to account for DOC increases due to storage retention based on Jung (2001a), and then used to simulate EC and DOC.

This report includes the descriptions of the two scenarios and the results of these DSM2 simulations at four M&I intake locations: Contra Costa's Rock Slough intake near the Old River, Contra Costa's Los Vaqueros intake on the Old River, the State Water Project (SWP) and Central Valley Project (CVP) intakes at Banks and Tracy. Using QUAL's simulated EC and DOC, ultraviolet absorbance at 254 nm (UVA) and the formation of total trihalomethane (TTHM) and bromate at these locations were calculated. Finally, DSM2-PTM (Particle Tracking Model) was used to study the flow patterns associated with the project releases.

2 Description of Scenarios

The two different scenarios were based on CALSIM II output. The base case simulated the Delta without the operations of the proposed In-Delta Storage project. The project alternative included the proposed operations of Bacon Island and Webb Tract and the planned operation of the two habitat islands, Bouldin Island and Holland Tract. Brief summaries of both scenarios are described below in Table 2.1, followed by more detailed descriptions of these assumptions.

Table 2.1: Summary of Planning Scenarios.

| | <i>Base: No Action</i> | <i>Alternative: In-Delta Storage Operations</i> |
|-------------------------------------|--|---|
| Delta Wetlands Project Islands | No. | Yes. (Bacon Island and Webb Tract.) |
| Delta Wetlands Habitat Islands | No. | Yes. (Bouldin Island and Holland Tract.) |
| Boundary Flows | Daily CALSIM II output: base study. | Daily CALSIM II output: alternative study. |
| Boundary Stage | 15-minute planning stage. | 15-minute planning stage. |
| Ag Flows | 2020 lod DICU. ¹ | Modified 2020 lod DICU. ² |
| Martinez EC ³ | CALSIM II Net Delta Outflow & G-model. | CALSIM II Net Delta Outflow & G-model. |
| Tributary Boundary EC | CALSIM II output. ⁴ | CALSIM II output. ⁴ |
| Martinez DOC | N/A | N/A |
| Tributary Boundary DOC ⁵ | Monthly planning data. | Monthly planning data. |
| Ag Return Quality | MWQI ⁶ data. | MWQI data, w/ increases in project island DOC based on storage time. ⁷ |

1 - The Delta Island Consumptive Use (DICU) model was used to calculate diversions and return flows for all Delta islands based on a 2020 level of development (lod).

2 - The diversions and returns from the project and habitat islands were modified to better represent land use changes for these islands due to the project operation for a 2020 lod.

3 - Net Delta Outflow based on the CALSIM II flows was used with an updated G-model to calculate Martinez EC (see Ateljevich, 2001a).

4 - CALSIM II calculates monthly EC for the San Joaquin River, which was then converted to daily EC using the monthly EC and flow for the San Joaquin River. Fixed values are used at the other major tributary boundaries.

5 - Based on data collected as part of the DWR-MWQI⁶, a new set of boundary DOC data for the major tributary boundaries were calculated (see Suits, 2001a).

6 - Municipal Water Quality Investigations (MWQI).

7 - DOC concentration increases while water is stored on the project islands as discussed in Jung (2001a).

2.1 No Action (Base Case):

CALSIM II was used to provide the tributary boundary flows and exports (including CCWD's Rock Slough diversion, SWP's Banks exports, and CVP's Tracy exports).⁸ CALSIM II also provided the Delta Cross Channel (DCC) position. Normal gate and barrier configurations were based on the proposed operation schedule for the South Delta Permanent Barriers (which include Old River at Head, Old River at Tracy, Middle River, and Grant Line Canal). The Suisun Marsh Salinity Control Gate was operated according to previous DSM2 planning studies.

The Delta Island Consumptive Use (DICU) model was used to create 2020 level of demand diversions and returns. Martinez EC was calculated using Net Delta Outflow (as provided by CALSIM II) and an updated G-model (see Ateljevich, 2001a). DWR-MWQI observations were used to create synthetic time series for DOC (see Section 3.2) at the following tributary boundaries: San Joaquin River, Sacramento River, and the Eastside streams. Sacramento River data were then also applied as the boundary conditions for the Yolo Bypass. The flux of DOC from the downstream boundary at Martinez (the sea) was considered insignificant. Details on the development of agricultural return DOC data for DSM2 based on the MWQI observations are described in the report *Revision of Representative Delta Island Return Flow Quality for DSM2 and DICU Model Runs* (Dec. 2000) as prepared by Marvin Jung and Associates, Inc.

2.2 In-Delta Storage Operations (Alternative):

CALSIM II determined the diversions to and releases from the project islands, in addition to optimizing the exports at both the Banks (SWP) and Tracy (CVP) Pumping plants by using the additional system storage provided by the project islands. CALSIM II did separate the storage, diversions, and releases between the two project islands. Priority was given to Bacon Island, by filling and releasing water from Bacon Island before Webb Tract.

The total diversion to each project island is shown in Figure 2.1 (note: this is diversion for each individual island). The larger diversions are winter diversions of surplus Delta water to be released and exported by the Banks (SWP) or Tracy (CVP) Pumping plants later. The smaller off-season diversions are used to "top-off" the project islands in order to account for evaporation losses during the storage period.

⁸ CALSIM II does not model the diversion split between CCWD's Rock Slough and Los Vaqueros Reservoir intakes. The CCWD Rock Slough diversions represent both the Rock Slough and Los Vaqueros demands; however, in DSM2 this combined diversion currently is simulated only at Rock Slough.

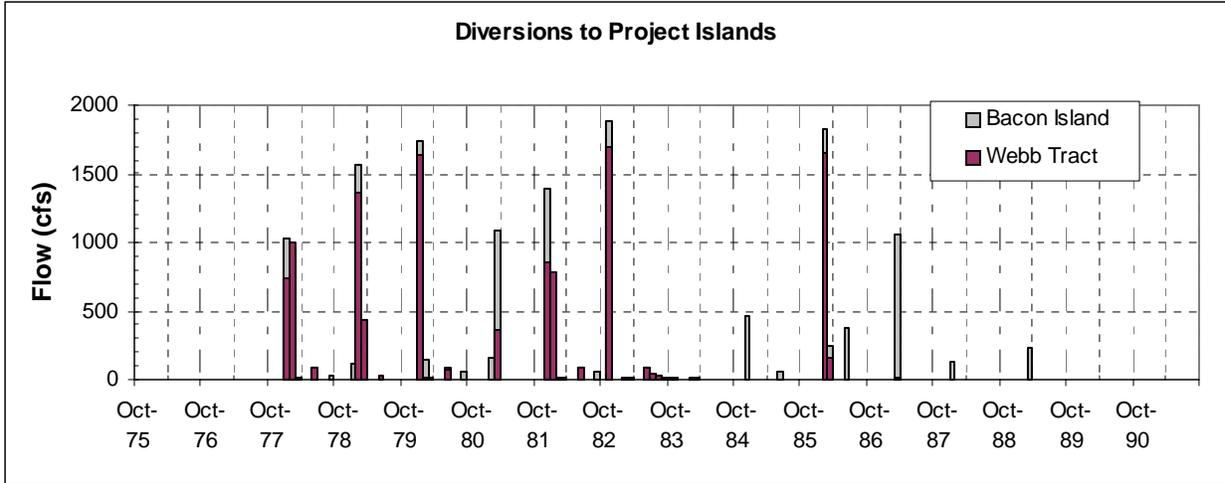


Figure 2.1: Diversions to In-Delta Storage Project Islands.

The total release from each project island is shown in Figure 2.2. Many of the summer project island releases are constrained by amount of water stored in the project islands.

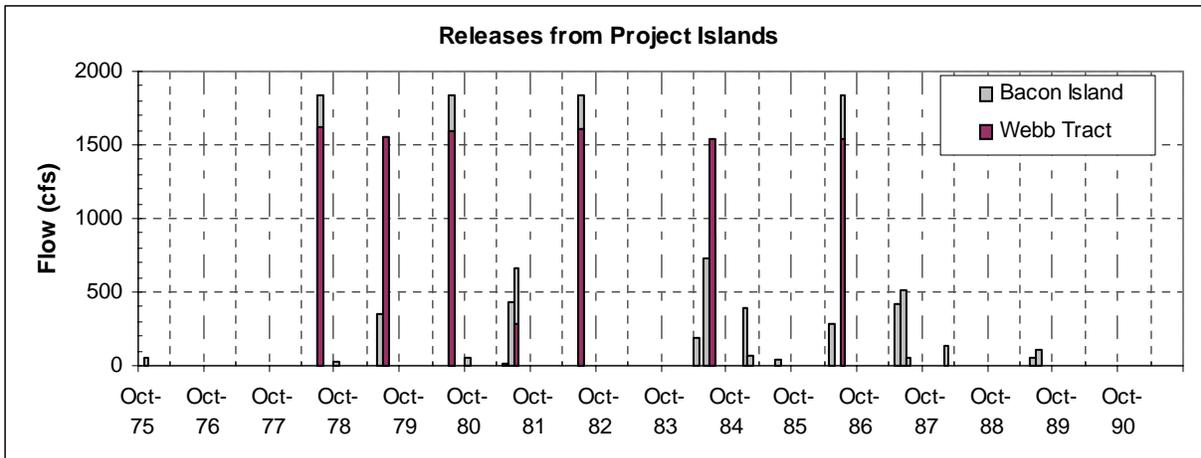


Figure 2.2: Releases from In-Delta Storage Project Islands.

2.2.1 Project Island Configuration

The configuration of the project islands as modeled by DSM2 is listed in Table 2.2. The storage capacity, surface area, discharge location, and both intake / release siphon locations for the project islands were provided by ISI. Each island is designed to use two reversible siphons to divert water onto and later off each island. The diversion and release schedules provided by CALSIM II were divided equally between each island's siphons. The location of the siphons is shown in Figures 2.3 and 2.4. The surface area of each island is fixed in DSM2. The surface area was chosen such that when full, each island would have a maximum depth of approximately 20 ft.

Table 2.2: DSM2 Configuration of Delta Wetlands Project Islands.

| <i>Island</i> | <i>Storage Capacity (TAF)</i> | <i>Surface Area (acres)</i> | <i>Siphon #1 DSM2 Node</i> | <i>Siphon #2 DSM2 Node</i> |
|---------------|-------------------------------|-----------------------------|----------------------------|----------------------------|
| Bacon Island | 120 | 5,450 | 128 | 121 |
| Webb Tract | 118 | 5,370 | 40 | 103 |

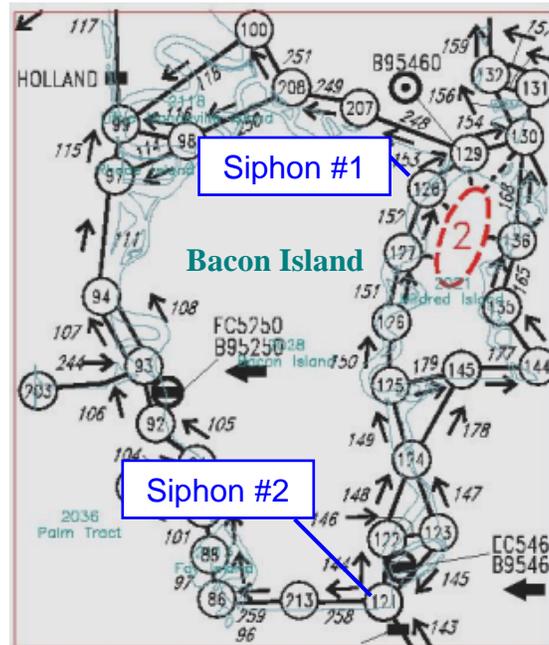


Figure 2.3: DSM2 Representation of Bacon Island.

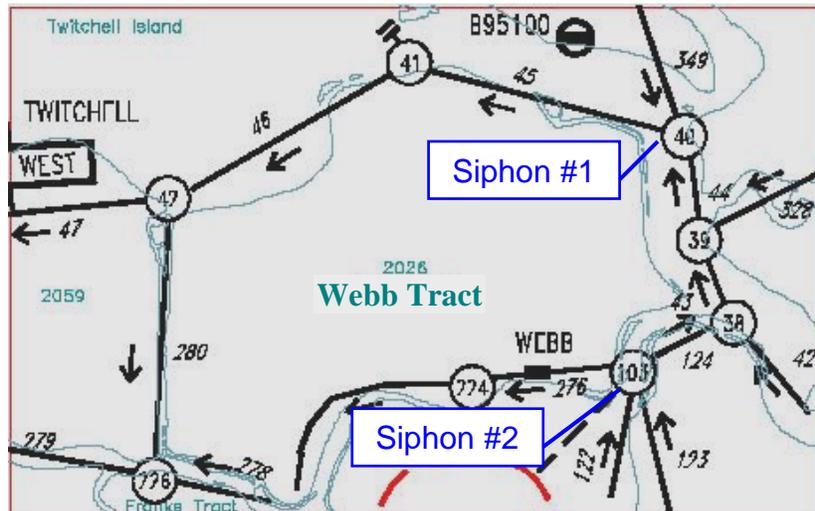


Figure 2.4: DSM2 Representation of Webb Tract.

The volume of water stored in each island reservoir is a direct function of the amount of water diverted into or released from each island. Volume of a reservoir in DSM2 is the product of the reservoir's surface area (listed above in Table 2.2 for the project islands) and its current stage

level. The project islands were isolated from the Delta channels, thus there was no limit to the stage in either reservoir. In order to prevent drying up of the island reservoirs an additional 0.2 ft of water was assumed to be present on both islands at the beginning of the simulation.⁹ This water was considered dead storage and was never released into the Delta.

2.2.2 Project Island Water Quality

Water quality from the project islands was modeled two different ways using DSM2: (1) by normal mixing in order to simulate EC, and (2) by increasing the concentration of DOC in the project reservoirs as a function of time. These two different approaches are described in detail below.

EC

For the QUAL EC simulations the reservoirs were isolated from the Delta channels as described in the previous section and flow between the surrounding channels and the project islands were regulated in DSM2 by using a direct "object-to-object" transfer. When water was diverted into the islands, this object-to-object transfer moved water from both of the siphons into or out of the reservoir. Project island diversions and releases were evenly split between the two siphons on each island.

This process allowed QUAL to automatically mix incoming EC concentrations from the nearby channels (or an adjacent non-project reservoir) with the EC already present in the reservoirs. The EC concentration of the island reservoirs only changed when water was transferred into the islands, not when water exited the islands. This process is described in greater detail in Section 4.1.

DOC

Based on work conducted by Jung (2001a), QUAL was modified for the DOC simulations such that the DOC concentration in each of the island reservoirs would increase as a function of time as described by Pandey (2001). When water was transferred into the reservoirs using the same object-to-object transfer described above, QUAL would reset the quality of the reservoir to mix with the DOC concentration of the incoming water. After this initial transfer, the DOC concentration would then increase based on Jung's growth functions (for more details see Section 3.2.2).

2.2.3 Habitat Island Configuration

In addition to modeling changes due to the operation of the project on Bacon Island and Webb Tract, changes were made in the consumptive use of Holland Tract and Bouldin Island in accordance with the plans to convert these two islands to become wetland habitats. The locations of the agricultural diversions were left unchanged for both habitat islands, but the agricultural returns on the habitat islands were moved to a single location for each island. This was done, because it was assumed that existing siphons would still be used to divert water onto the islands in order to maintain the wetland habitats, but the releases would be easier to manage

⁹ DSM2 can not run if a reservoir or channel becomes completely dry. This dead storage was added for the benefit of DSM2.

through a single discharge point. The DSM2 representation of Holland Tract and Bouldin Island is shown in Figures 2.5 and 2.6.

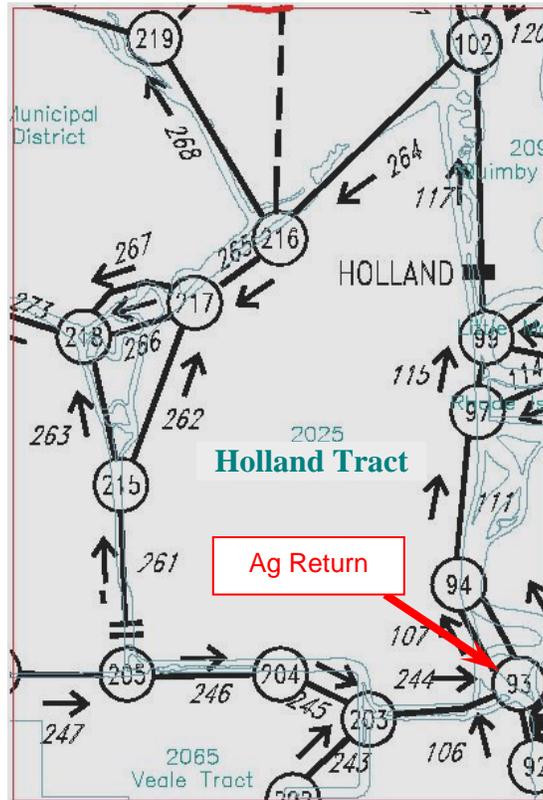


Figure 2.5: DSM2 Representation of Holland Tract.

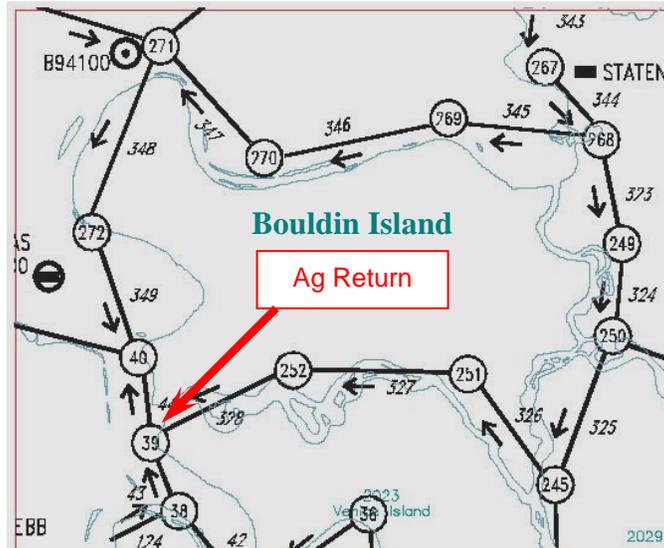


Figure 2.6: DSM2 Representation of Bouldin Island.

2.2.4 Project and Habitat Island Land Use

With changes in the land use of the project islands, the diversions and return flows for the project islands were modified using the DICU model. DICU computes the consumptive use at each node in DSM2 based on historical needs for each island or water habitat in the Delta. The diversions and return flows for each island are distributed to different nodes, such that the modeled diversions, return flows, and/or seepage at any one node frequently include the individual contributions from different islands. The diversions and return flows for the project islands were removed from all of the nodes surrounding the islands (i.e. there were no agricultural diversions or return flows associated with the project islands).

Monthly average consumptive use data taken from the Delta Wetlands EIR (see Figure 2.7) for the habitat islands were used to represent the water needs of the wetland habitats. The same monthly flow value was applied to both Holland Tract and Bouldin Island in each year of the simulation. The total diversions were divided equally among the siphons for each island, while as noted above, the return flow was discharged at a single location for each island.

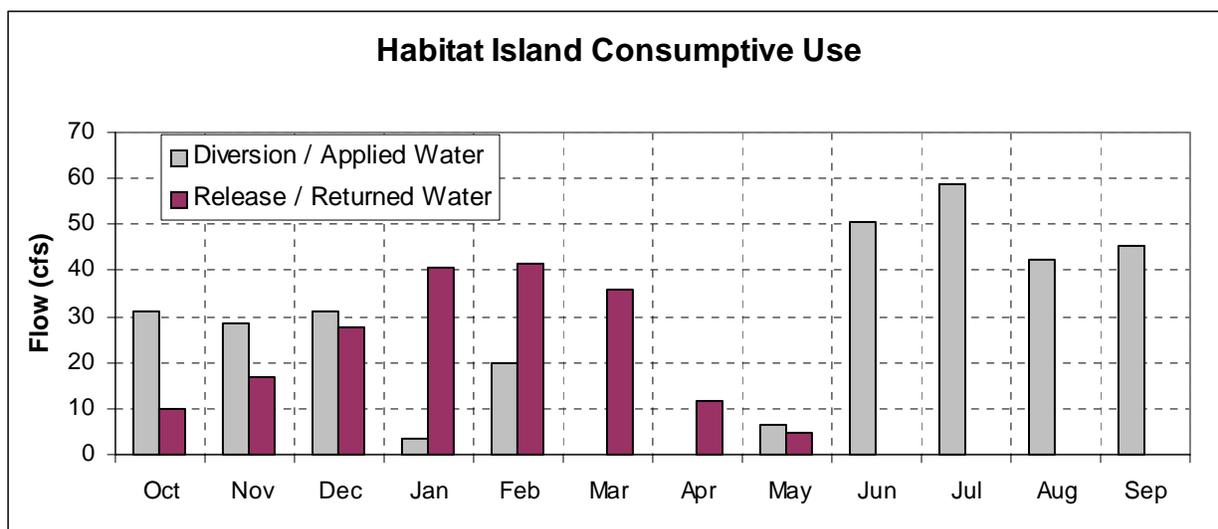


Figure 2.7: Monthly Habitat Island Consumptive Use

Even though the amount of water returning to the Delta from each habitat island changed each month (see Figure 2.7), the quality of this returned water was set to fixed concentrations as shown in Table 2.3. The DOC concentrations were based on return water quality observations taken on Holland Tract, Twitchell Island, and in similar wetland habitats (Jung, 2001b). The EC concentrations for the habitat islands are based on observations of the annual averages for each island.

Table 2.3: Habitat Island Return Water Quality Concentrations.

| Habitat Island | Return EC Concentration (umhos/cm) | Return DOC Concentration (mg/l) |
|----------------|---------------------------------------|------------------------------------|
| Bouldin Island | 750 | 50 |
| Holland Tract | 1100 | 40 |

Since seepage in DSM2 represents the amount of water that comes from the Delta channels to the islands, it was not modified for either scenario.

3 Simulation Inputs

3.1 Hydrodynamics

3.1.1 Flow

Tributary flows, exports, and diversions were provided by CALSIM II for both the base and alternate case simulations. Similar CALSIM II studies that were used in previous DSM2 In-Delta Storage simulations are described by Easton (2001). The tributary flows include the Sacramento River, San Joaquin River, and the Yolo Bypass and one combined parameter representing the eastside flows into the Delta. Exports include the State Water Project (SWP), the Central Valley Project (CVP), Vallejo diversions, North Bay Aqueduct diversions, and Contra Costa Canal diversions from Rock Slough. Contra Costa operations on the Old River for the Los Vaqueros reservoir intake were not available for this particular CALSIM II study.

The CALSIM II studies assumed a 2020 level of development for the Delta Island Consumptive Use (DICU). The DICU model was run to create two different sets of agricultural irrigation and drainage representations of the Delta for 2020 water demands. The base case consumptive use represented only a factoring upward of the historical Delta water demands to meet the 2020 level of use. The changes to the alternative consumptive use patterns accounted for the change in land use of the project islands and habitat islands. These changes were first made to the historical consumptive use patterns, and then the altered consumptive use data were adjusted to the 2020 level of demand. It is important to note that when the DICU model adjusts the historical consumptive use levels, that it increases all of the Delta flows upward or downward based on an estimate of total Delta consumptive use for the new demand level. The DICU model can not change the level of future demand, hence the base and alternative 2020 DICU results have the same total Delta consumptive use value. However, the changes made to the land use of the project and habitat islands mean that the amount of diversions and returns from all of the Delta islands are slightly different between the two consumptive use patterns.

3.1.2 Stage

A new planning tide developed by Ateljevich (2001b) was applied at the Martinez downstream boundary. This 15-minute tide incorporates historical data and includes two primary components:

- An astronomical tide that includes Spring-Neap variation and accurate harmonic components; and
- A residual tide with long-period fluctuations due to barometric changes and other nonlinear interactions.

3.1.3 Gates

Delta Cross Channel

Unlike previous planning studies where monthly operations were used for the Delta Cross Channel (DCC) position, CALSIM II provided daily operations of the DCC. The DCC was opened and closed by CALSIM II in accordance with State Water Resources Control Board (SWRCB) D-1641 standards.¹⁰

South Delta Permanent Gates

The proposed future operation of the three South Delta agricultural permanent gates (Old River at Tracy, Middle River, and Grant Line Canal) and the fish protection barrier at Old River at Head was used in this study. When operating, the gates only allowed flow in the upstream direction. Each structure may be either installed or removed during the 13 planning periods, see Figure 3.1 below. Each month represents one planning period, with the exception of April, which is divided into two planning periods. This was done so the gates could be installed in the middle of the month, per the proposed future operation of the gates.

| <i>Barrier</i> | <i>Oct</i> | <i>Nov</i> | <i>Dec</i> | <i>Jan</i> | <i>Feb</i> | <i>Mar</i> | <i>Apr</i> | <i>May</i> | <i>Jun</i> | <i>Jul</i> | <i>Aug</i> | <i>Sep</i> |
|-------------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Old River @ Head | | | | | | | | | | | | |
| Old River @ Tracy | | | | | | | | | | | | |
| Middle River | | | | | | | | | | | | |
| Grant Line Canal | | | | | | | | | | | | |

Figure 3.1: Schedule of Permanent Barrier Operations.

Other Gates

The Suisun Marsh Salinity Control Gate was operated October through May of each year. The Clifton Court Forebay Gates allowed water into the Forebay from the Old River when a difference in stage occurred between the river and the Forebay. This was referred to as a priority four operation in previous DSM2 planning studies.¹¹ Water was not allowed to leave the Forebay.

3.2 Quality

Water quality inputs were applied both at the external boundaries and at the Delta interior locations through use of the Delta Island Consumptive Use (DICU) model. Furthermore, QUAL was modified to account for increases in DOC stored in the project reservoirs based on research conducted by Jung (2001a). The sources and nature of these data are discussed below.

¹⁰ The SWRCB D-1641 standards for the DCC stipulate that the DCC must be closed when: (1) flow in the Sacramento River is greater than 23,000 cfs, (2) for 45 days in Nov. - Jan., and (3) Feb. - May.

¹¹ There are four different typical schedules of operation of the Clifton Court Forebay Gates that were used in previous DSM2 planning studies. These schedules were designed to optimize the amount of water entering the Forebay, while minimizing the impact on South Delta stage. The work to create these different priority operations in DSM2 with the new historical-based tide used at Martinez is not yet completed.

3.2.1 EC

As discussed above in Section 2.1, Martinez EC was generated using Net Delta Outflow (calculated from the CALSIM II results) and an updated G-model, based on work done by Ateljevich (2001a).

CALSIM II provided monthly EC values for the San Joaquin River. Using the daily San Joaquin River flow and the monthly EC values, daily EC values were derived.

The EC concentration at the remaining tributary boundaries, the Sacramento River, the Yolo Bypass, and the eastside streams, was fixed at 200 umhos/cm.

Standard DICU data developed from the DICU model were used to represent the quality of water draining off the Delta islands. For the base case all of the standard DICU node locations and EC concentrations were used. For the alternative case the standard DICU node EC concentrations were used, but as discussed above in Section 2.2.4, the diversions and return flows were altered.

3.2.2 DOC

Jung (2001a) reports that flooding Delta islands may result in increases in the DOC, due in part to peat soil DOC releases. A series of experiments were conducted to find the rate of DOC growth on Delta islands, and then a conceptual model was created to simulate this DOC growth. QUAL was modified to account for increases in DOC due to storage, using Equation 1 (see Jung 2001a).

$$DOC(t) = \frac{A}{1 + Be^{-kt}} \quad \text{[Eqn. 1]}$$

where

- A = maximum island DOC concentration (mg/l),
- B = initial DOC concentration of diversion into island,
- k = growth rate of DOC (days⁻¹), and
- t = time relative to initial diversion into island (days).

Two different bookend simulations were run, to represent low and high ranges of DOC released from the islands. A summary of the coefficients used in Equation 1 and the range of DOC releases as modeled in QUAL is shown in Table 3.1. The initial DOC concentration was calculated within QUAL and takes the depth of the reservoir into account. This term is hardwired into QUAL. For most of the releases the DOC coming off the islands was less than the maximum values listed below.

Table 3.1: QUAL DOC Bookends.

| Bookend | A (mg/l) | k (days ⁻¹) | Range of Released DOC |
|---------|-------------|----------------------------|--------------------------|
| Low | 70 | 0.022 | 6 - 10 mg/l |
| High | 215 | 0.022 | 13 - 22 mg/l |

Another area that would affect DOC growth in the project islands is bioproductivity. This was not considered in these simulations.

The DOC concentrations for the San Joaquin River, Sacramento River, and eastside streams were developed based on MWQI observations taken from 1987 through 1998 (Suits, 2001a). The summer DOC concentrations were based on monthly averages of the June through October observations. The winter DOC concentrations were generated using relationships relating DOC to flow. These relations were then used to create DOC concentrations for the three tributary boundary locations for the entire 16-year simulation period. The Sacramento River DOC concentrations were also applied to the Yolo Bypass flows. The range of the DOC concentrations at the rim boundaries is summarized in Table 3.2 below.

Table 3.2: Range of Tributary Boundary DOC (mg/l) Concentrations.

| | San Joaquin | Sacramento | Eastside Streams |
|-----------|--------------|-------------|------------------|
| DOC Range | 2.40 - 11.40 | 1.81 - 5.65 | 1.66 - 3.95 |

DICU data developed as part of the DWR MWQI studies were used to represent the DOC (mg/l) draining off the Delta islands (see Jung, 2000). Three different ranges of DOC returns were used to represent return water DOC concentrations in the Delta. Figure 3.2 represents the DOC values used in QUAL. In DSM2 each island in the Delta was assigned either the high, middle, or low range DOC release concentrations. The high range DOC is associated with DOC releases from the Delta islands that peak out above 30 mg/l. The islands with high range DOC releases were located in the central Delta, and include the islands neighboring both the project and habitat islands. The low range DOC is used for islands that were found to have low DOC releases.

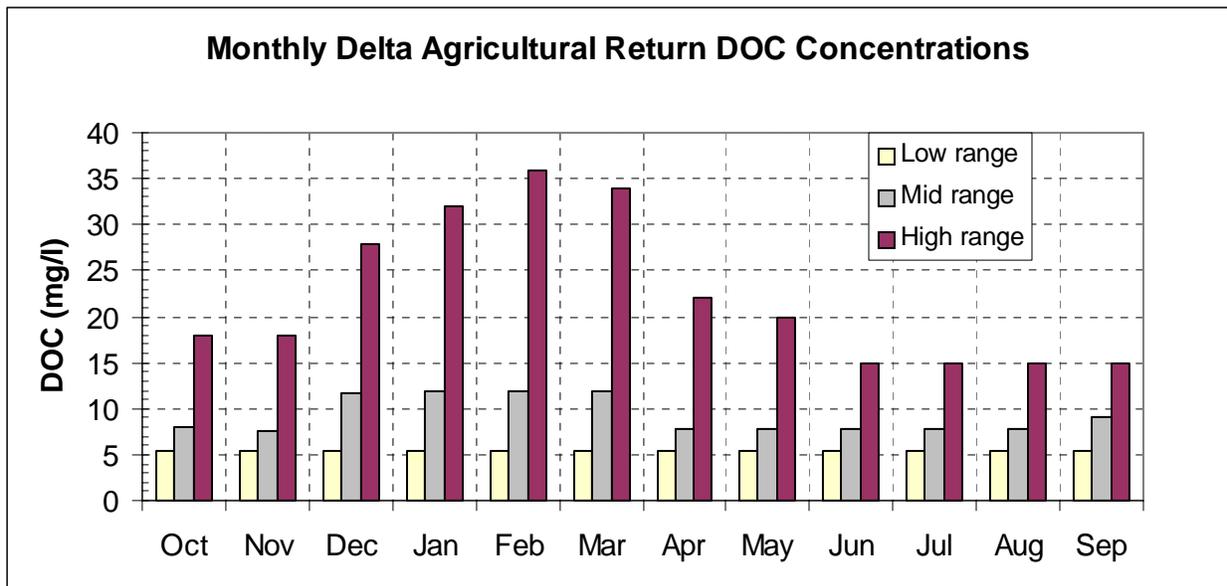


Figure 3.2: Monthly Averaged DOC Concentrations from Agricultural Returns.

3.3 Initial Conditions

DSM2 planning studies cover a 16-year period from Oct. 1975 to Sep. 1991. Unlike HYDRO, QUAL requires a much longer start-up period. In the case of planning studies, no assumption is made about the initial water quality conditions in the Delta; thus an extra year is run in order to simulate the mixing of the Delta. This is called a cold start routine. Both HYDRO and QUAL are run for this extra year, but the results are disregarded during this cold start period.

4 Results

This report discusses five water quality constituents, chloride, dissolved organic carbon (DOC), ultraviolet absorbance at 254 nm (UVA), total trihalomethane (TTHM), and bromate. The long-term impacts on chloride and DOC are also discussed. QUAL was used to simulate EC and DOC, and then these constituents were used to calculate chloride, UVA, TTHM and bromate formation potentials.

Modeled water quality at the following locations are shown below in Figure 4.1 for the entire planning period (1975 - 1991): Contra Costa's Rock Slough intake near the Old River, Contra Costa's Los Vaqueros intake on the Old River, the SWP and CVP intakes at Banks and Tracy Pumping Plants. These DSM2 output locations correspond with field sampling locations. This report focuses only on water quality at these locations.

For the alternative simulation, the percentage of the time of year water was diverted to and later released from the project islands for the entire study period is shown in Figures 4.2 and 4.3. Generally the islands were filled in the winter months (Nov., Dec., Jan., Feb. and Mar.) and emptied in the summer months (Jun. and Jul.). Webb Tract is filled and emptied after Bacon Island has reached capacity; hence 100% of its releases are in July. During the summer months, CALSIM II frequently diverted small amounts of water to the project islands to account for evaporation losses.

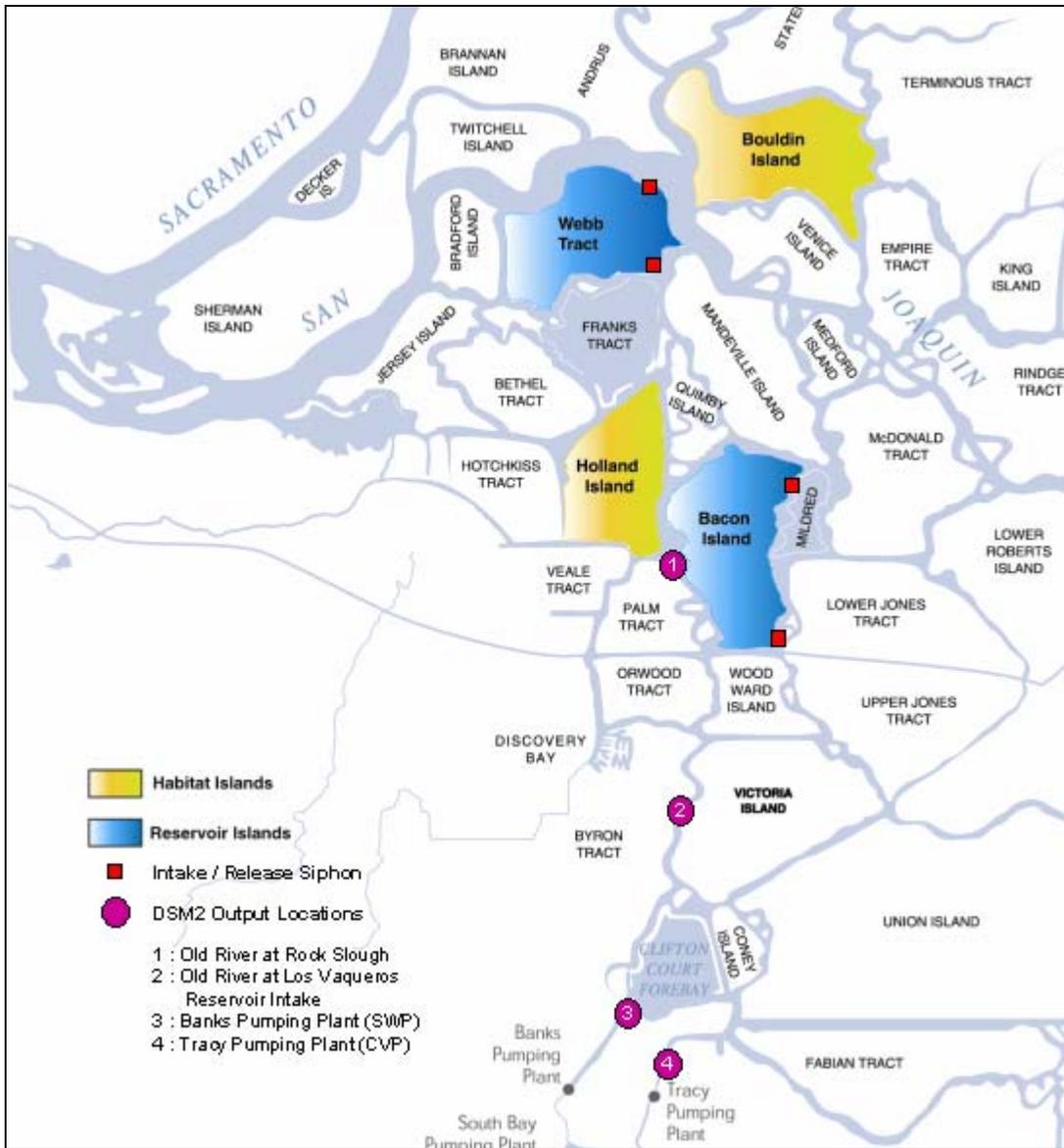


Figure 4.1: Location of In-Delta Storage Project Islands and DSM2 Output Locations.

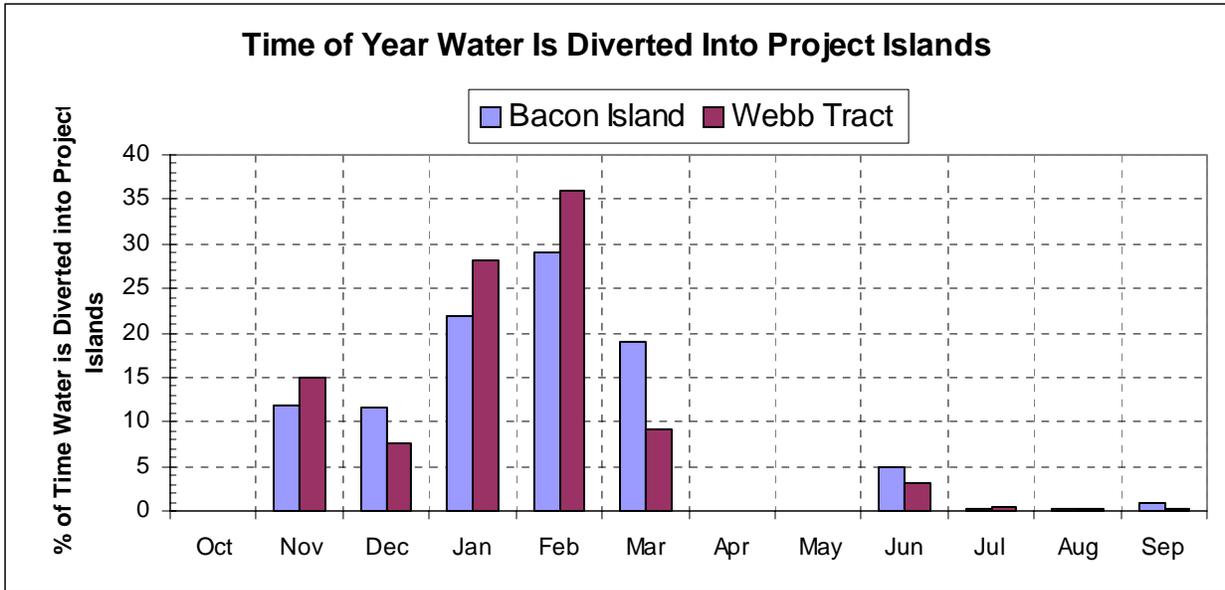


Figure 4.2: Time of Year Water is Diverted to Project Islands.

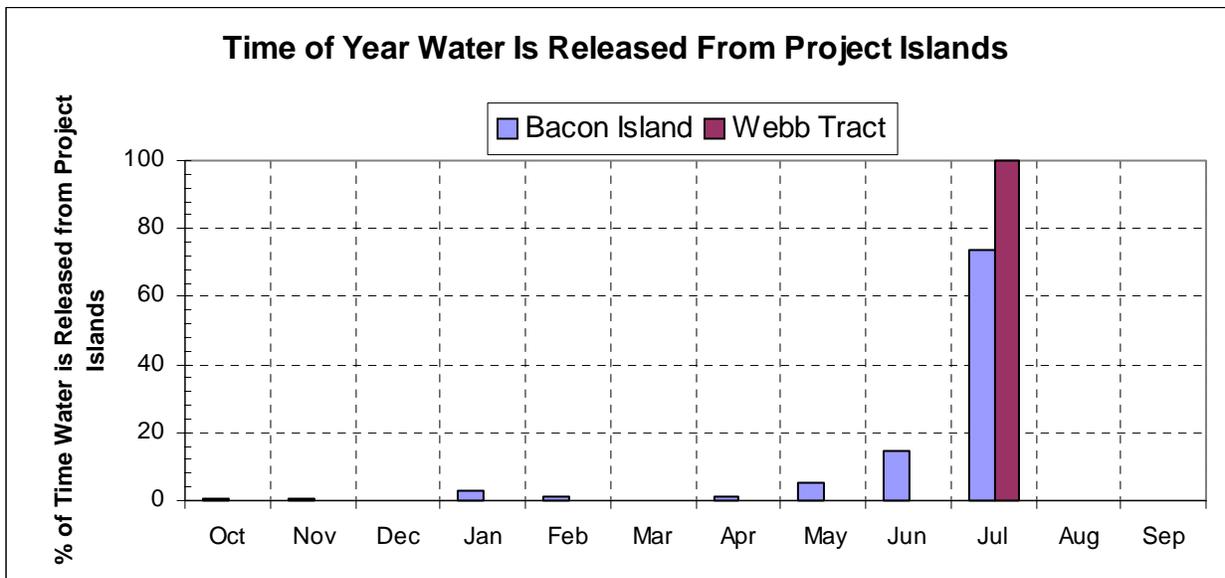


Figure 4.3: Time of Year Water is Released from Project Islands.

The diversions and releases compared to the storage of both Bacon Island and Webb Tract as modeled in HYDRO are shown in Figures 4.4 and 4.5. Though the maximum design storage for Bacon Island and Webb Tract were listed as 120 and 118 TAF respectively, the CALSIM operations never reached these two capacities in DSM2. Figures 4.4 and 4.5 show the maximum modeled storage to be 115 and 102 TAF for Bacon Island and Webb Tract. The small loss of storage between each major diversion and release is due to evaporation, which was provided by CALSIM.

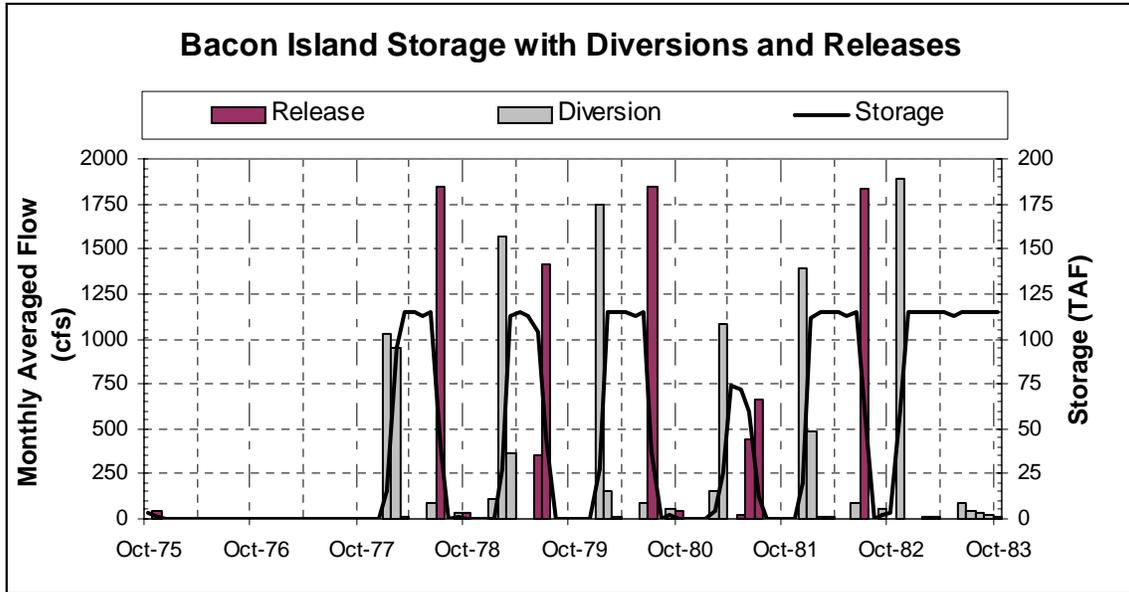


Figure 4.4a: Bacon Island Storage with Diversions and Releases 1975 - 1983.

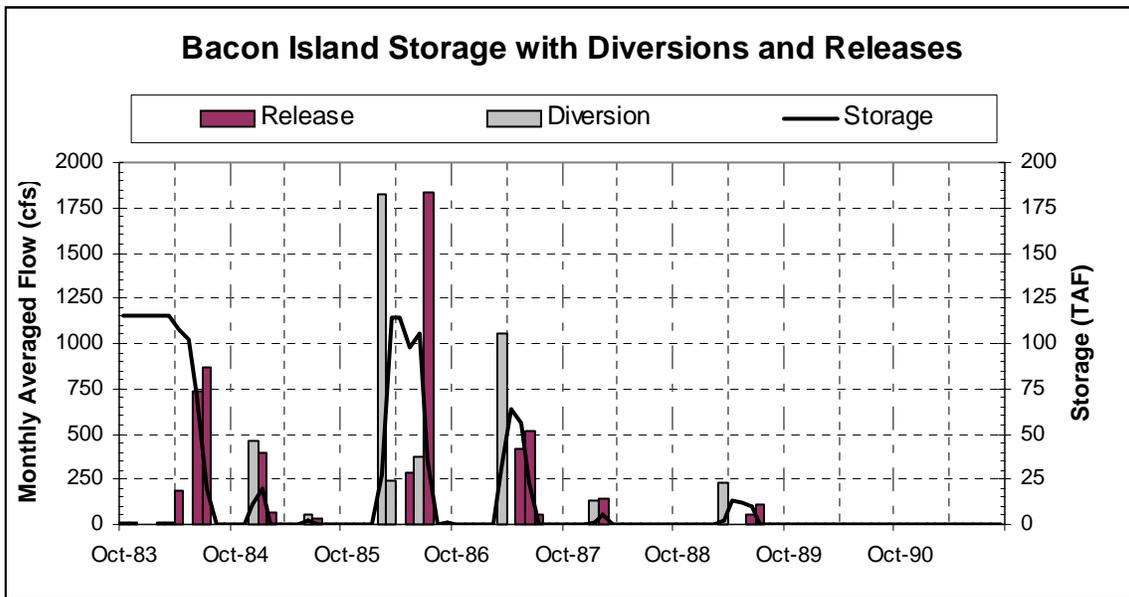


Figure 4.4b: Bacon Island Storage with Diversions and Releases 1983 - 1991.

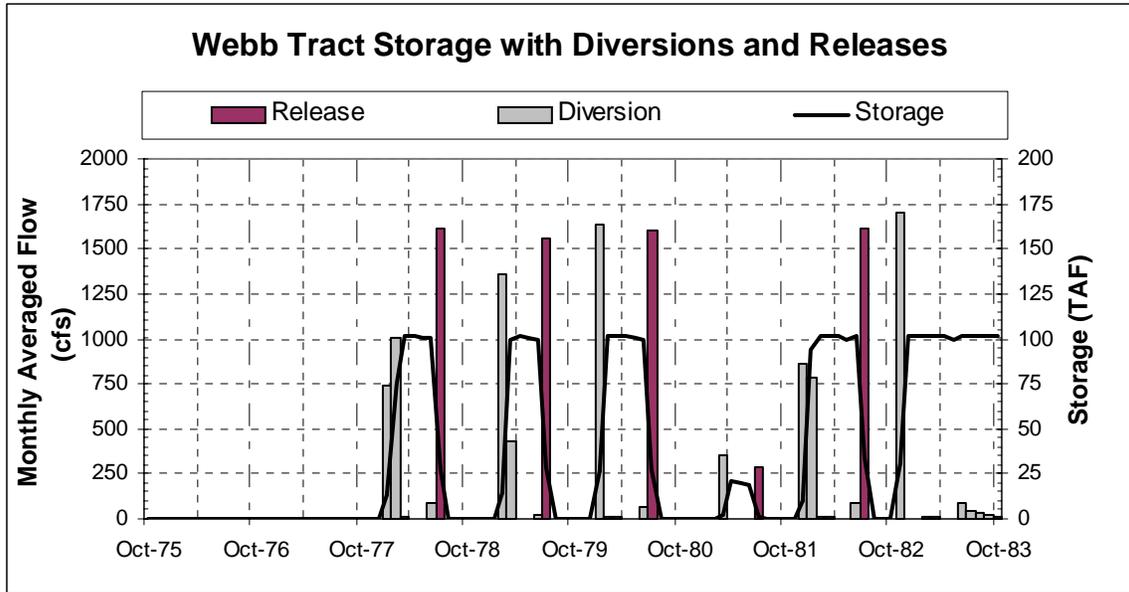


Figure 4.5a: Webb Tract Storage with Diversions and Releases 1975 - 1983.

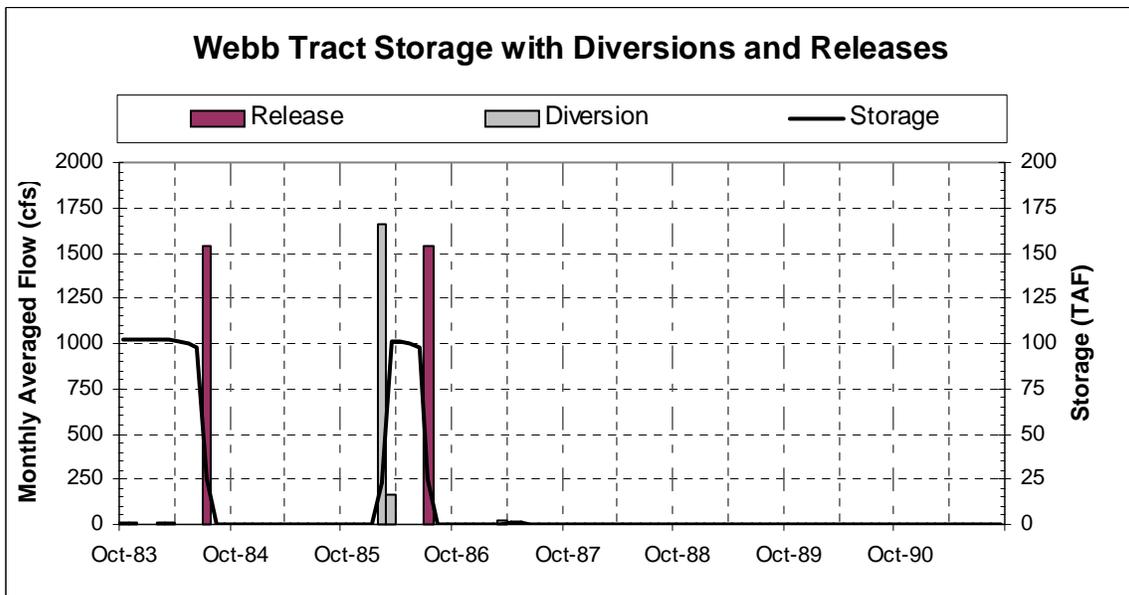


Figure 4.5b: Webb Tract Storage with Diversions and Releases 1983 - 1991.

4.1 Chloride

As described above in Table 2.2.1 (see Section 2.2), two reservoirs were created in DSM2 to simulate chloride (modeled as EC in QUAL) coming from the two project islands: Bacon Island and Webb Tract. These reservoirs were connected to the Delta in DSM2 by using object-to-object transfers. This technique controlled when water would be added to or removed from the reservoirs.

Since the chloride concentration of the reservoir islands is a function of the chloride around the intakes and the current chloride concentration in each island reservoir, QUAL was able to store the water and account for changes in water quality due to mixing, as shown in Equation 2 where concentrations are represented by C and volumes are represented by V. The only time chloride concentration in the islands would change was when water was diverted into the islands, which can be seen in Figures 4.6 and 4.7.

$$C_{new} = \frac{C_{inf\ lows} V_{inf\ lows} + C_{island} V_{island}}{V_{inf\ lows} + V_{island}} \quad [\text{Eqn. 2}]$$

If the EC concentration of the water at the intakes were lower than the EC levels inside the island reservoir, then the inflows would reduce the island EC concentration. If the EC concentration of the water at the intakes were higher than the EC levels inside the island, then the inflows would increase the island EC concentration. Discharges from the islands did not change the water quality of the reservoirs and had little impact on the EC concentration in the Delta itself.

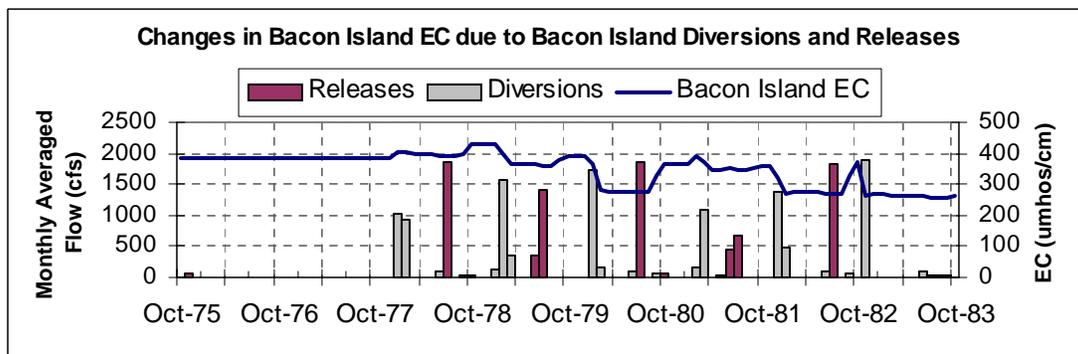


Figure 4.6a: Changes in Bacon Island EC due to Project Diversions and Releases 1976-1983.

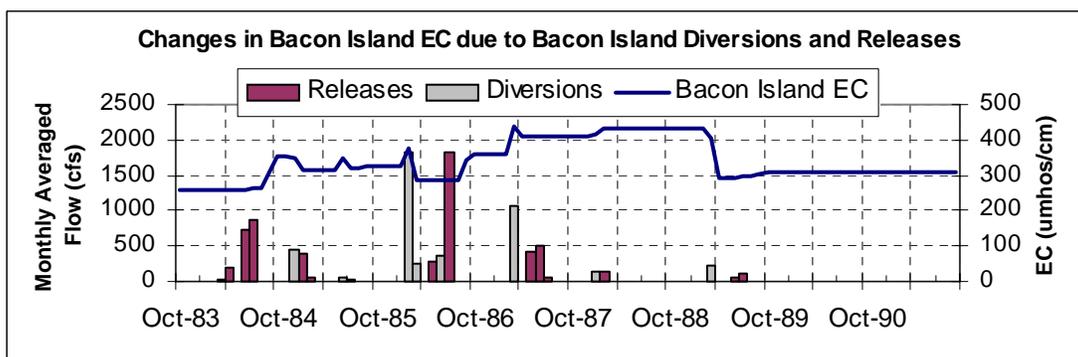


Figure 4.6b: Changes in Bacon Island EC due to Project Diversions and Releases 1983-1991.

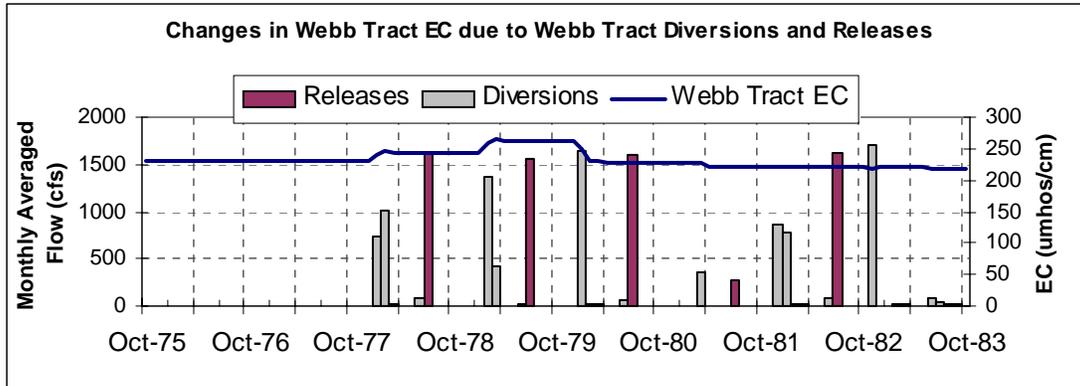


Figure 4.7a: Changes in Webb Tract EC due to Project Diversions and Releases 1976-1983.

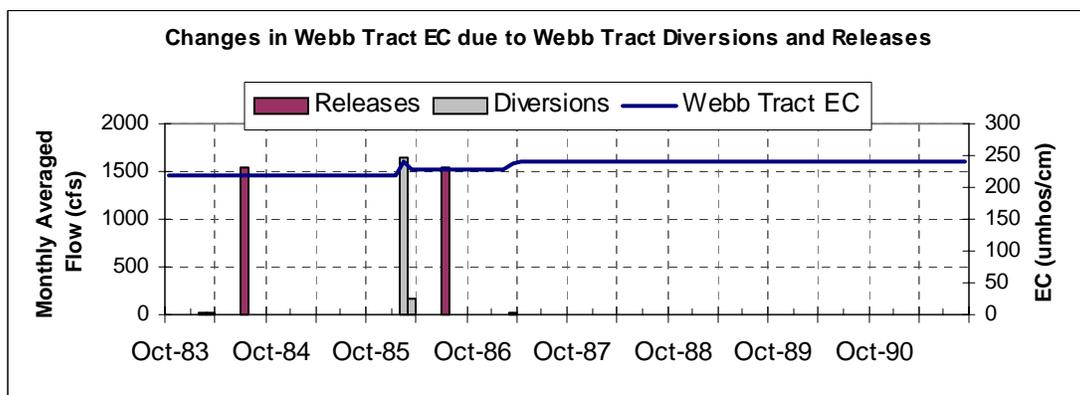


Figure 4.7b: Changes in Webb Tract EC due to Project Diversions and Releases 1983-1991.

EC (umhos/cm) was converted to chloride (mg/l) using the following relationships (Suits, 2001b):

$$Chloride_{Contra\ Costa\ Pumping\ Plant\ \#1} = \frac{EC_{Old\ River\ at\ Rock\ Slough} - 89.6}{3.73} \quad [Eqn. 3]$$

$$Chloride = \frac{EC - 160.6}{3.66} \quad [Eqn. 4]$$

Equation 3 is used to convert modeled EC to chloride concentration for Contra Costa Water District's Rock Slough diversion location (Contra Costa Pumping Plant #1). Equation 4 is used to convert modeled EC to chloride at all of the other intake locations. The relationships developed by Suits were based on field observations. However, during a few periods QUAL's EC concentrations were so low that using these field conversions resulted in chloride concentrations that were too low. A minimum chloride concentration of 10 mg/l was assumed during these periods.

The impacts of the project releases are compared to the base case scenario in Figures 4.8 - 4.19. Figures 4.8, 4.11, 4.14, and 4.17 illustrate the time series of monthly averaged chloride concentration at the four intake locations for the entire 16-year study period. The Water Quality

Management Plan (WQMP, 2000) 225 mg/l chloride constraint is shown on these figures. The WQMP limited this constraint to be 90% of existing D-1641 salinity standards (Hutton, 2001).

The 225 mg/l WQMP chloride constraint was exceeded at the Old River at Rock Slough and Tracy (CVP) intake locations for both the base and alternative studies in 1977. The WQMP constraint was not exceeded in either scenario at the Los Vaqueros or Banks (SWP) intake locations. The maximum monthly averaged chloride for the four intake locations is listed in Table 4.1. All of these maximums occurred in 1977. The maximum monthly averaged chloride concentration was larger in the alternative than in the base study at all four locations.

Table 4.1: Maximum Monthly Averaged Cl (mg/l).

| <i>Location</i> | <i>Base</i> | <i>Alternative</i> |
|----------------------------------|-------------|--------------------|
| Old River at Rock Slough | 235 | 243 |
| Old River at Los Vaqueros Intake | 191 | 197 |
| Banks Pumping Plant (SWP) | 222 | 223 |
| Tracy Pumping Plant (CVP) | 246 | 247 |

The WQMP stipulated that the maximum increase in chloride concentration due to operation of the project is 10 mg/l when the base case chloride concentration is less than the 225 mg/l constraint, otherwise no increase is allowed (Hutton, 2001). Time series of the difference between the alternative and base case chloride results for the four intake locations and change in chloride concentration constraint for the 16-year period are illustrated in Figures 4.9, 4.12, 4.15, and 4.18. The maximum increase in monthly averaged chloride when this incremental 10 mg/l constraint applies is listed in Table 4.2. The WQMP incremental chloride constraint is exceeded at all four urban intake locations during the 16-year simulation.

**Table 4.2: Maximum Increase in Monthly Averaged Cl (mg/l)
When Base Chloride is Less Than 225 mg/l.**

| <i>Location</i> | <i>Alt. - Base</i> |
|----------------------------------|--------------------|
| Old River at Rock Slough | 32 |
| Old River at Los Vaqueros Intake | 25 |
| Banks Pumping Plant (SWP) | 18 |
| Tracy Pumping Plant (CVP) | 18 |

The Cumulative Distribution Function (cdf) for the change (measured as alternative - base case) in chloride concentration at each location is shown in Figures 4.10, 4.13, 4.16, and 4.19. These cdfs were calculated based on a frequency histogram of the difference in chloride concentration (alternative - base) for every month of the entire 16-year simulation. Each cdf curve represents the amount of time that the chloride concentration is equal to or less than a corresponding chloride level. These figures illustrate that over the study period that the overall changes in chloride tended to be between -20 and 20 mg/l. These plots are useful in measuring the impact of the In-Delta Storage project operations on the four urban intake locations.

A summary of the percent of time that this increase in salinity (alternative - base) exceeded the WQMP constraint is shown below in Table 4.3. The largest increase in chloride was at Old

River at Rock Slough, where the WQMP chloride constraint was exceeded approximately 5.7% of the time.

Table 4.3: Percent of time that the change in Cl is larger than 10 mg/l.

| <i>Location</i> | <i>% Exceedance</i> |
|----------------------------------|---------------------|
| Old River at Rock Slough | 5.7 |
| Old River at Los Vaqueros Intake | 5.2 |
| Banks Pumping Plant (SWP) | 3.6 |
| Tracy Pumping Plant (CVP) | 3.6 |

The number of months that the two WQMP Cl constraints were exceeded for both the base and alternative simulations is shown below in Table 4.4. The values in Table 4.4 were taken from the entire 16-year (192 month) period, however the project only diverted or released water during 75 of these months.¹² The last column in Table 4.4 shows the total number of months the WQMP Cl constraints were violated. If the 225 mg/l constraint was violated in the alternative, but not in the base case during a month that when the 10 mg/l change in Cl constraint was also exceeded, that month was not double counted.

Table 4.4: Number of Months of Exceedance of the WQMP Cl Standards.

| <i>Location</i> | 225 mg/l Cl Constraint | | 10 mg/l Change in Cl Constraint | Total Number of Months in Violation |
|----------------------------------|-------------------------------|------------|--|--|
| | <i>Base</i> | <i>Alt</i> | <i>Alt - Base</i> | <i>Alt - Base</i> |
| Old River at Rock Slough | 3 | 3 | 11 | 11 |
| Old River at Los Vaqueros Intake | 0 | 0 | 10 | 10 |
| Banks Pumping Plant (SWP) | 0 | 0 | 7 | 7 |
| Tracy Pumping Plant (CVP) | 1 | 1 | 7 | 7 |

The number of months in which the 225 mg/l Cl standard was violated was the same in both the base and alternative simulations. The largest number of total WQMP violations was at Rock Slough.

¹² Out of the 192 months simulated, water was diverted into or released from the project islands during 75 months. These diversions include the smaller flows that were taken by the project in order to account for evaporation losses. Many of these smaller diversions were less than 25 cfs, which is significantly smaller than many of the Delta island consumptive use diversions and return flows.

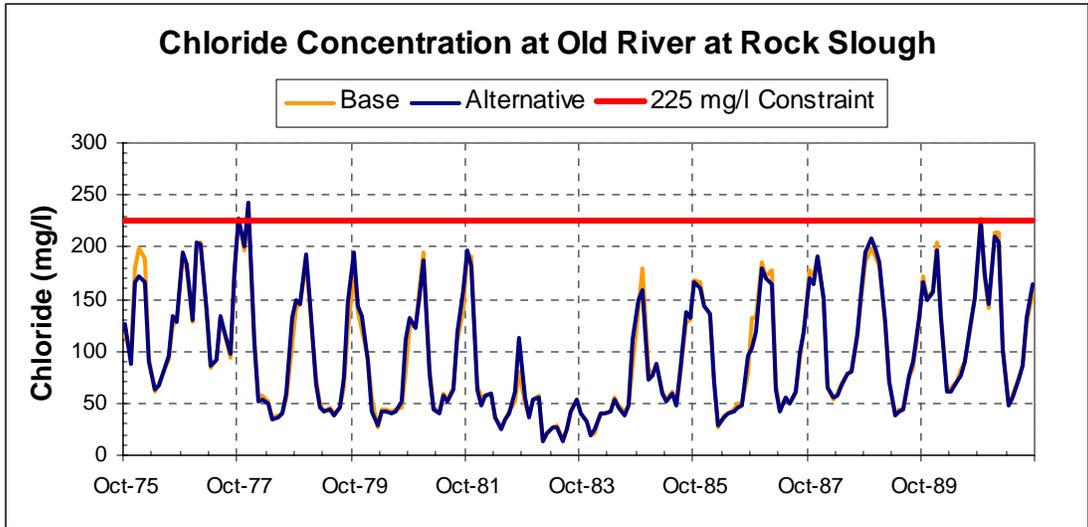


Figure 4.8: Chloride Concentration at Old River at Rock Slough.

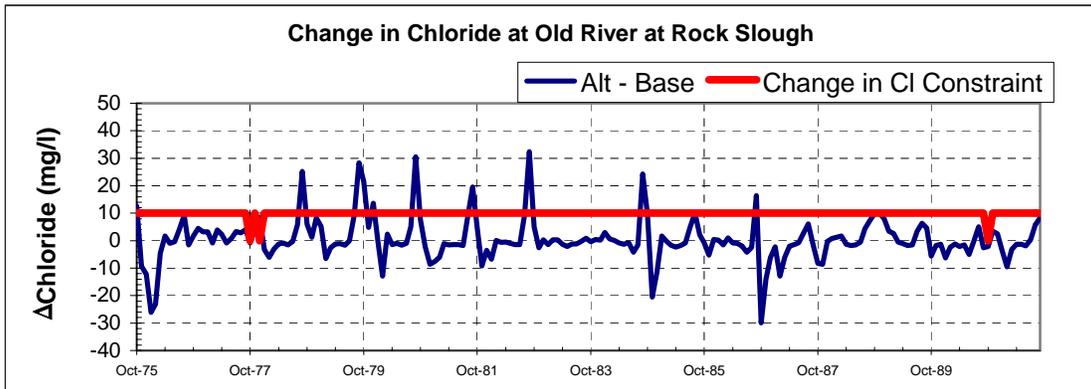


Figure 4.9: Change in Chloride at Old River at Rock Slough.

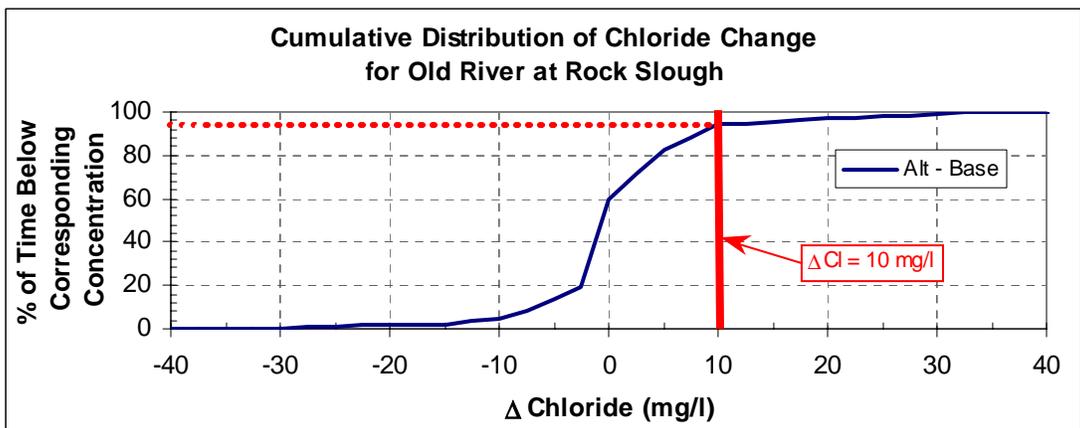


Figure 4.10: Cumulative Distribution of Chloride Change at Old River at Rock Slough.

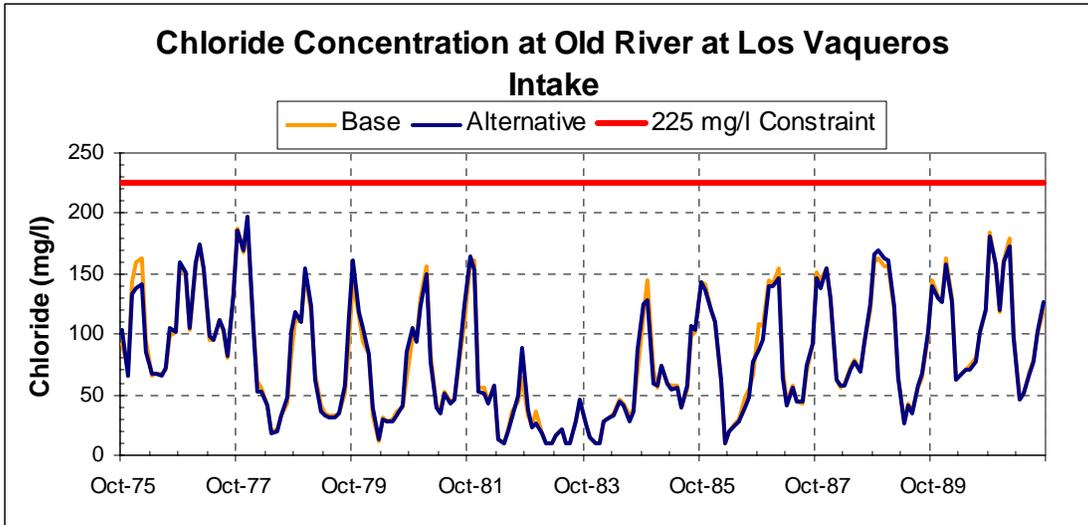


Figure 4.11: Chloride Concentration at Old River at Los Vaqueros Intake.

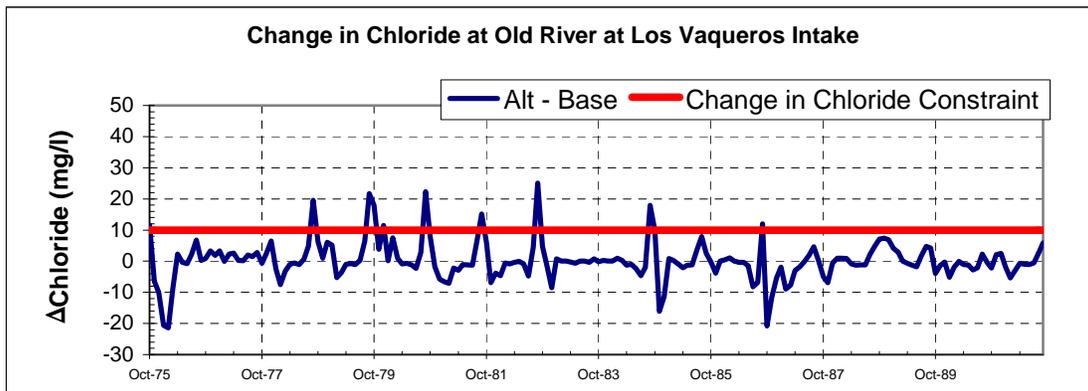


Figure 4.12: Change in Chloride at Old River at Los Vaqueros Intake.

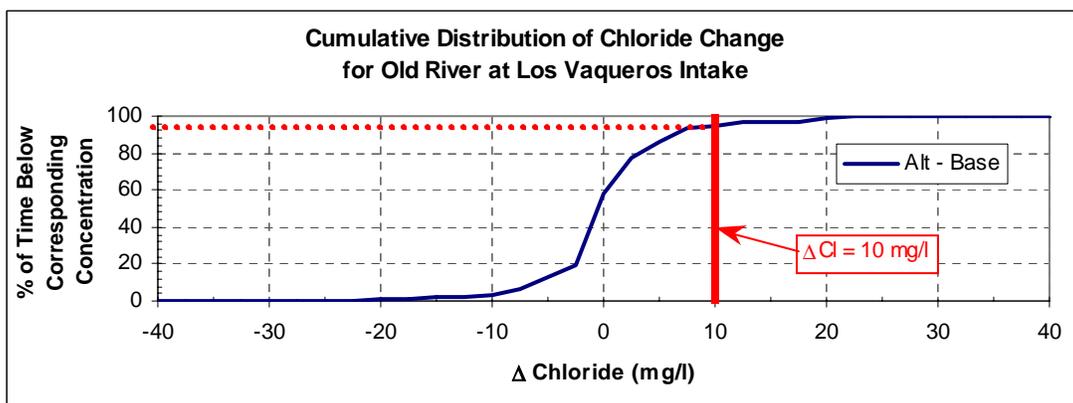


Figure 4.13: Cumulative Distribution of Chloride Change at Old River at Los Vaqueros Intake.

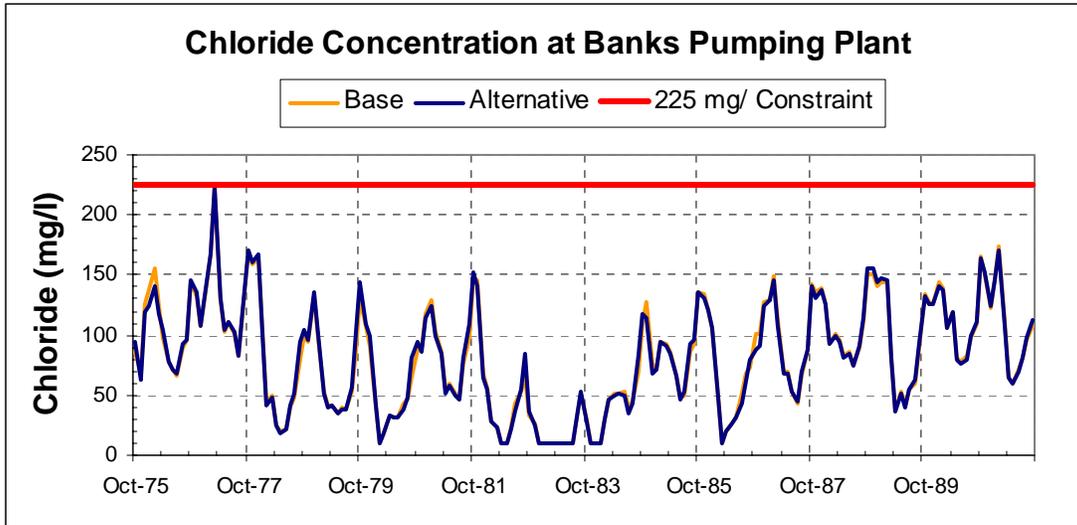


Figure 4.14: Chloride Concentration at Banks Pumping Plant.

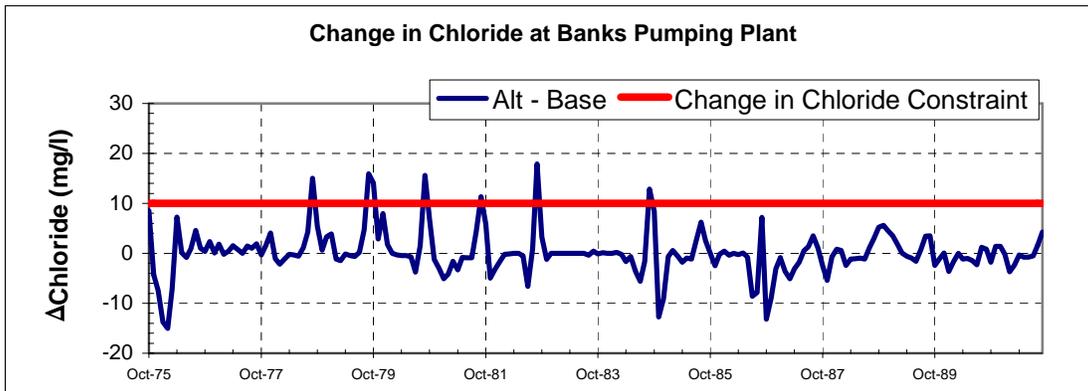


Figure 4.15: Change in Chloride at Banks Pumping Plant.

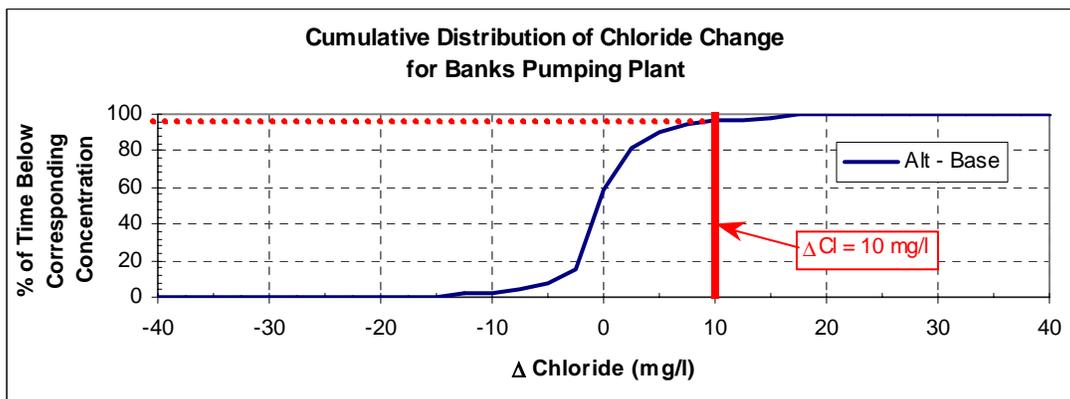


Figure 4.16: Cumulative Distribution of Chloride Change at Banks Pumping Plant.

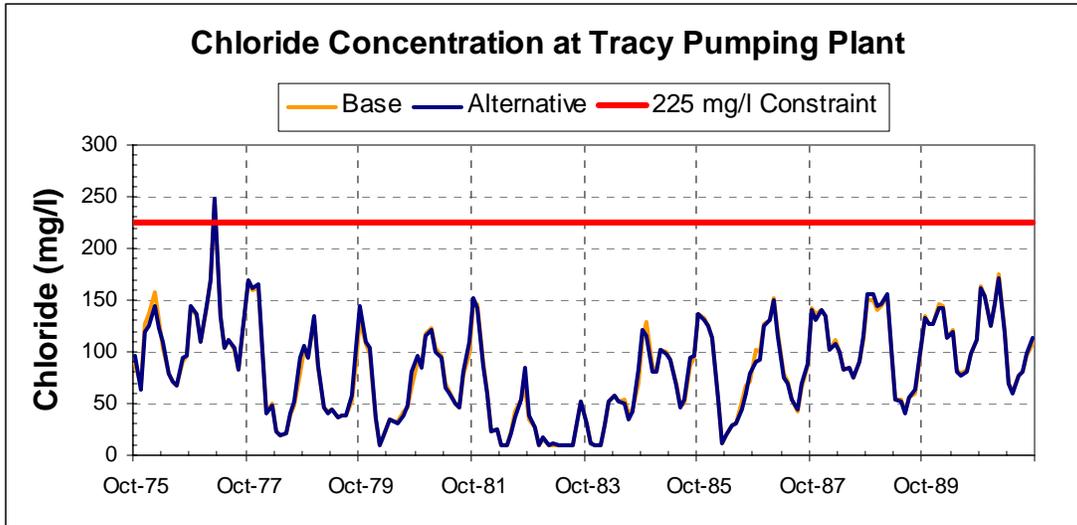


Figure 4.17: Chloride Concentration at Tracy Pumping Plant.

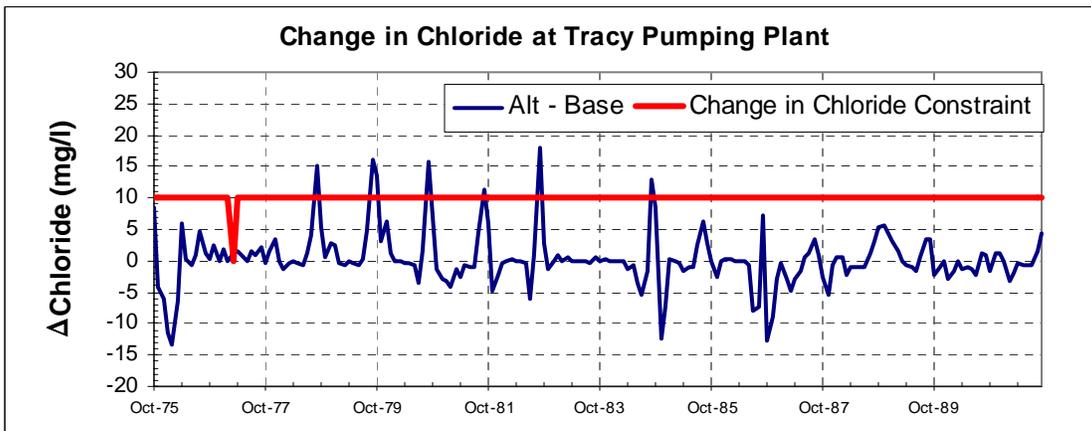


Figure 4.18: Change in Chloride at Tracy Pumping Plant.

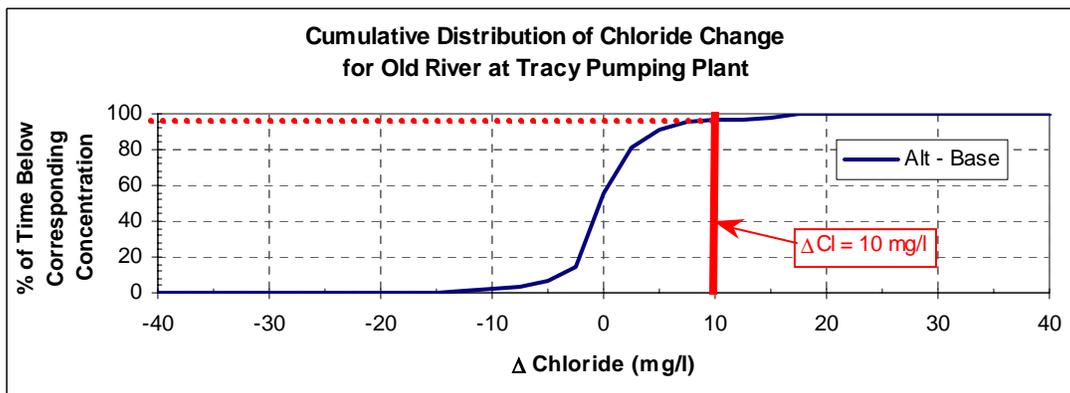


Figure 4.19: Cumulative Distribution of Chloride Change at Tracy Pumping Plant.

4.2 Long-Term Chloride

Long-term increases due to the operation of the project were calculated as the 3-year running average of monthly average chloride mass loading (see Hutton, 2001). Time series plots of the long-term monthly averaged chloride mass loading (expressed in 1000 metric tons / month) at Old River at Rock Slough and the State Water Project and the Central Valley Project intakes are shown in Figures 4.20, 4.23, and 4.26.¹³ The long-term impact of the project operations was calculated using Equation 5.

$$\% \text{Chloride}_{\text{Increase w/ Project}} = \frac{\text{Chloride}_{\text{w/ Project}} - \text{Chloride}_{\text{w/o project}}}{\text{Chloride}_{\text{w/o project}}} \times 100\% \quad [\text{Eqn. 5}]$$

The WQMP limits the long-term chloride mass loading increases at the intake locations due to the project operation to 5%. This 5% limit is shown on the time series plots (Figures 4.21, 4.24, and 4.27) of the long-term percent increase of chloride mass loading. The maximum percent increase in the long-term monthly averaged chloride mass loading is shown in Table 4.5. The alternative simulation exceeded the WQMP 5% increase constraint at Old River at Rock Slough and the Banks Pumping Plant, but the operation of the project only met the 5% increase constraint at the Tracy Pumping Plant.

Table 4.5: Maximum Percent Increase in Long-Term Monthly Averaged Chloride Mass Loading.

| <i>Location</i> | <i>Percent Increase</i> |
|---------------------------|-------------------------|
| Old River at Rock Slough | 6.6 |
| Banks Pumping Plant (SWP) | 6.5 |
| Tracy Pumping Plant (CVP) | 5.0 |

Frequency histograms of the percent increase in long-term chloride mass loading for the entire simulation period were used to create cumulative distribution functions (cdfs) to represent the long-term impact of the project operations. These cdfs are shown in Figures 4.22, 4.25, and 4.28. The WQMP maximum 5% increase in long-term chloride mass loading constraint is shown on each figure. The percent of the time that each scenario was equal to or below the WQMP maximum 5% increase constraint is listed in Table 4.6.

¹³ Normally Contra Costa Water District (CCWD) diversions are divided between the Rock Slough and Los Vaqueros Reservoir intakes. Long-term chloride mass loading was not calculated for Old River at Los Vaqueros Reservoir intake because CALSIM II did not separate the CCWD diversions. Similarly, the mass loading calculated for Rock Slough is based on the assumption that 100% of CCWD's diversions would be taken at the Rock Slough location.

Table 4.6: Percent Time that the Percent Increase of Long-Term Chloride Mass Loading Exceeds the WQMP Maximum 5% Increase Constraint.

| <i>Location</i> | <i>% Exceedance</i> |
|---------------------------|---------------------|
| Old River at Rock Slough | 9 |
| Banks Pumping Plant (SWP) | 5 |
| Tracy Pumping Plant (CVP) | 0 |

The number of months out of the 156 months that the long-term chloride mass loading increase exceeds the WQMP 5% increase constraint is shown below in Table 4.7.¹⁴ Old River at Rock Slough experienced the largest number of violations (14 months) of the constraint.

Table 4.7: Number of Months the Long-Term Chloride Mass Loading Increase Exceeds the WQMP 5% Increase Constraint.

| Location | 5% Increase Constraint |
|---------------------------|-------------------------------|
| Old River at Rock Slough | 14 |
| Banks Pumping Plant (SWP) | 8 |
| Tracy Pumping Plant (CVP) | 0 |

¹⁴ Instead of 192 months, the long-term mass loading calculations used the first 36 months to calculate the running average, thus long-term violations come from a sample of only 156 months.

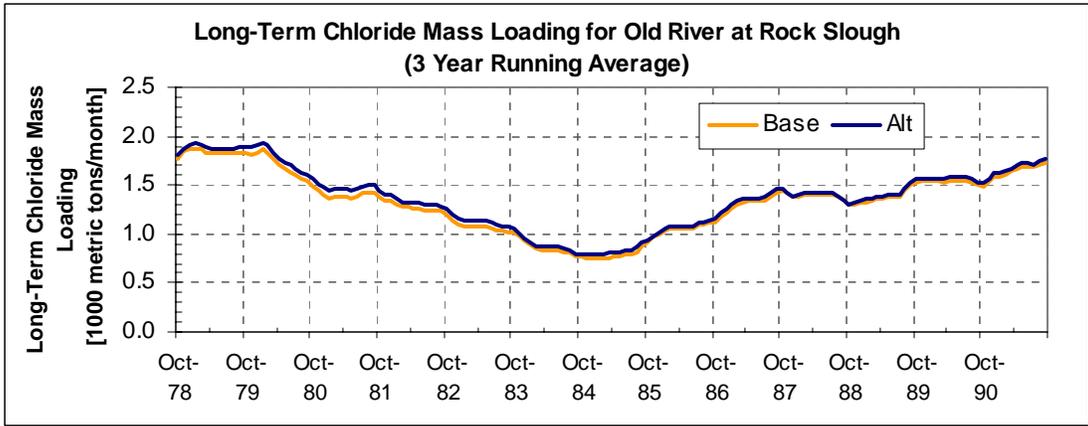


Figure 4.20: Long-Term Chloride Mass Loading for Old River at Rock Slough.

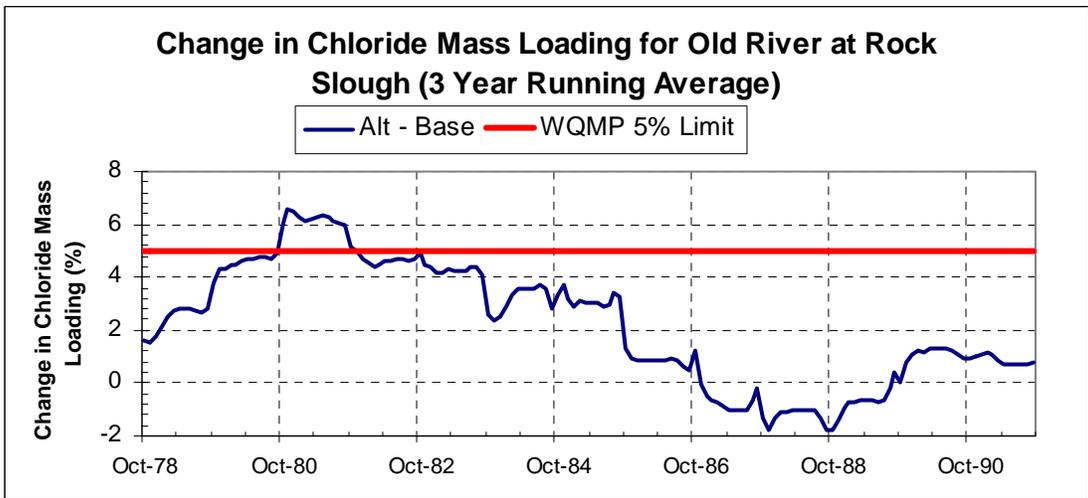


Figure 4.21: Change in Long-Term Chloride Mass Loading for Old River at Rock Slough.

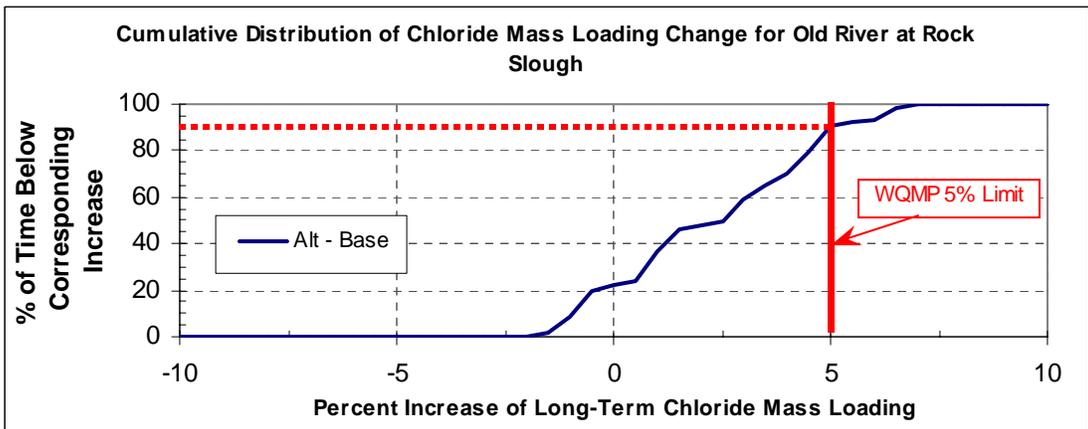


Figure 4.22: Cumulative Distribution of Long-Term Chloride Mass Loading Change for Old River at Rock Slough.

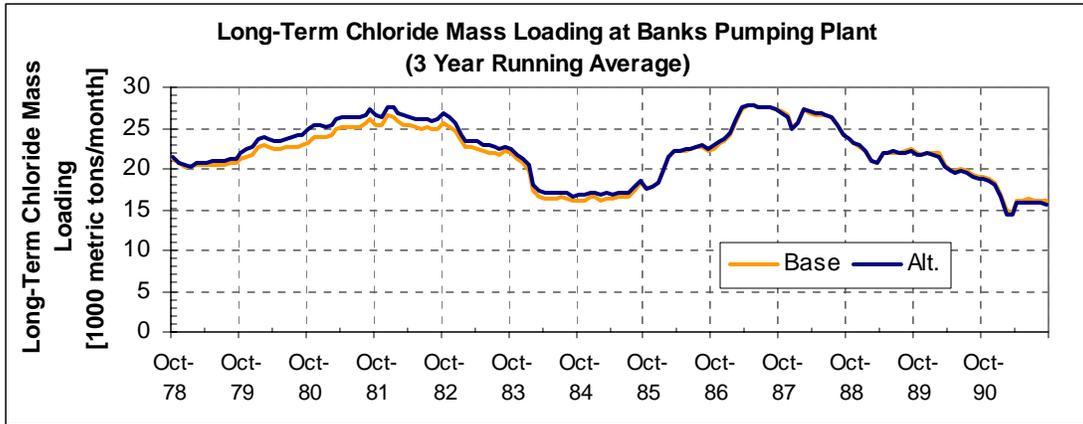


Figure 4.23: Long-Term Chloride Mass Loading for Banks Pumping Plant.

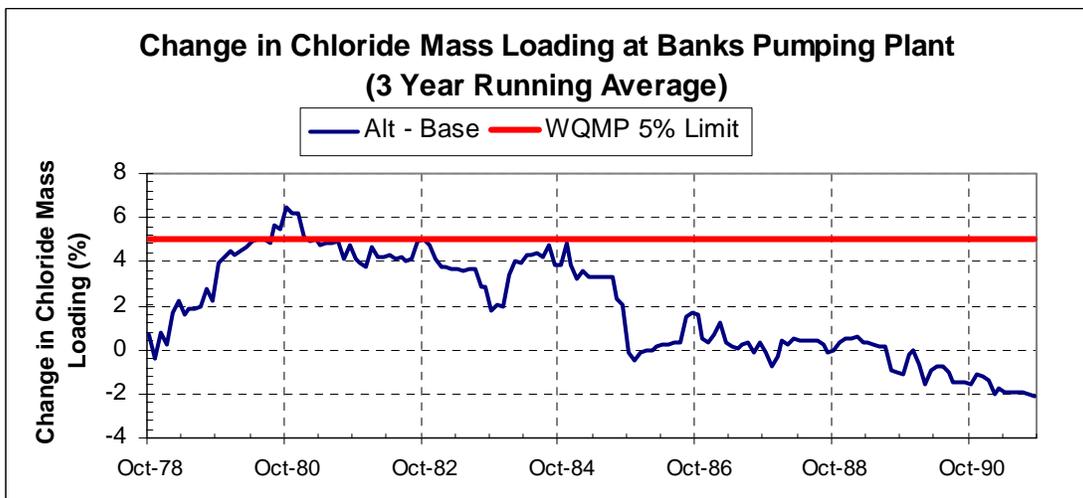


Figure 4.24: Change in Long-Term Chloride Mass Loading for Banks Pumping Plant.

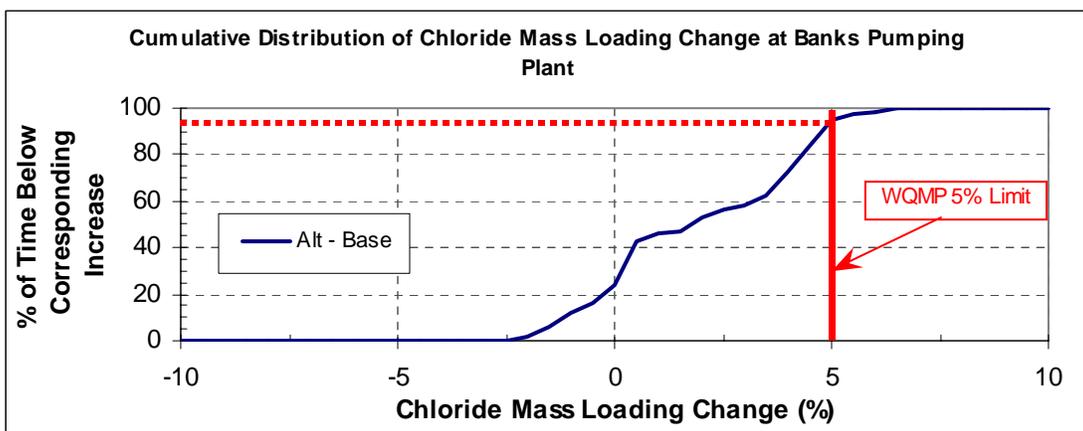


Figure 4.25: Cumulative Distribution of Long-Term Chloride Mass Loading Change for Banks Pumping Plant.

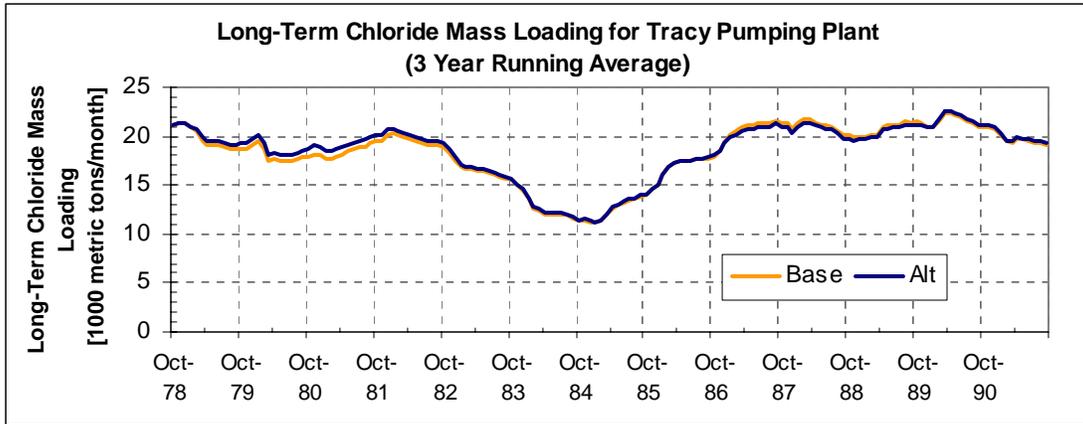


Figure 4.26: Long-Term Chloride Mass Loading for Tracy Pumping Plant.

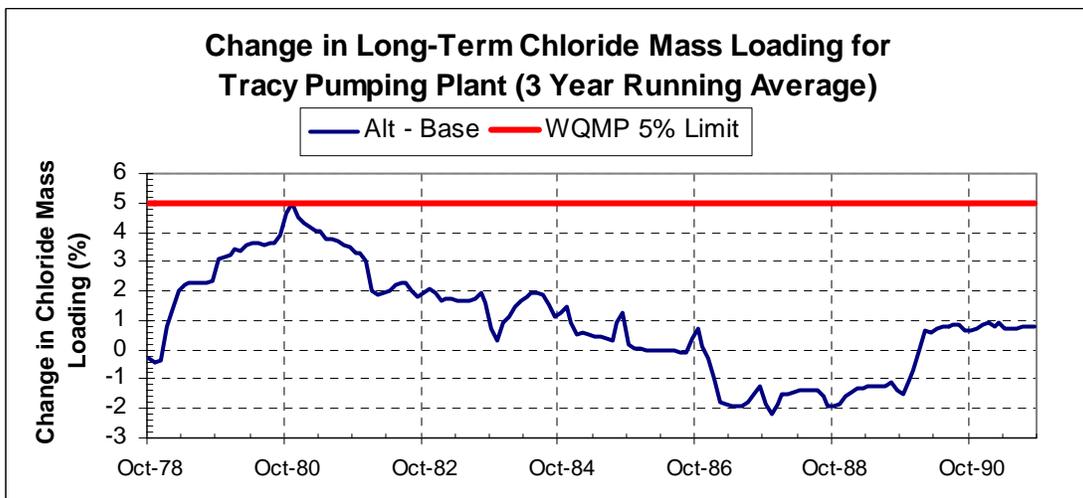


Figure 4.27: Change in Long-Term Chloride Mass Loading for Tracy Pumping Plant.

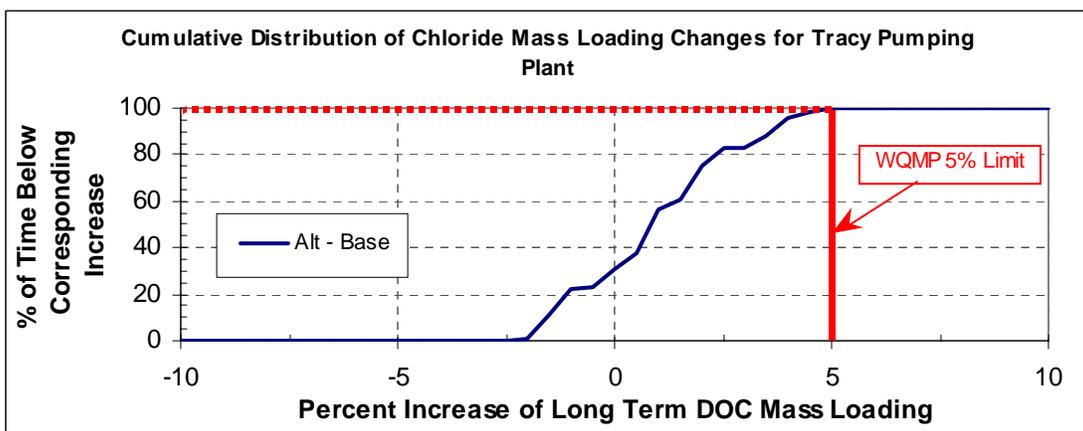


Figure 4.28: Cumulative Distribution of Long-Term Chloride Mass Loading Change for Tracy Pumping Plant.

4.3 DOC

As discussed in Section 3.2.2, QUAL was modified to simulate increases in DOC related to the use of the project islands as reservoirs. Two bookend values were chosen to represent realistic upper and lower bounds of reservoir based growth in DOC. The impact of these modifications on DOC in both Bacon Island and Webb Tract are shown in Figures 4.29 and 4.30. The maximum-modeled DOC in the project islands was 10 and 22 mg/l for the low and high bookend conditions respectively.

When water was diverted into the reservoirs, the DOC in the reservoirs was recalculated using Equation 1 with new initial conditions (the current stage in the reservoir and the DOC concentration of the incoming diversion). The DOC in the reservoirs continued to grow at a rate specified by Equation 1 until the next diversion. This can be best seen in Figure 4.29a, where each drop in Bacon Island DOC corresponds with a diversion into the reservoir.

In some cases the incoming DOC from neighboring channels was higher than the asymptotic (theoretical maximum) value for the low-bookend. The parameters used in Equation 1 could result in the DOC growth formulation effectively removing or lowering the DOC concentration in an island reservoir if the concentration of an incoming diversion was higher than the theoretical maximum. For example, it is shown in Figure 4.29a that the low-bookend DOC tends to flatten out around 6.3 mg/l. Based on the parameters chosen for the low-bookend (see Section 3.2.2) and the depth of Bacon Island during a typical diversion period, the maximum low-bookend should be around 6.3 mg/l. However, there are a few periods in which the low-bookend DOC shown in Figure 4.29a exceeds 8 mg/l. The incoming DOC at these times was greater than 6.3 mg/l. In the original post-processing (these results are not shown) of the DSM2 results, the low-bookend application of Equation 1 then slowly lowered the DOC concentration in Bacon Island until it once again reached the theoretical maximum of 6.3 mg/l. Instead of DOC growing, the DOC in Bacon Island appeared to decrease over time.

Since the purpose of Jung's DOC growth function was to account for increases in DOC concentration due to interactions between water and the peat soil of the island reservoirs, a third simulation where no DOC growth was accounted for was also run. In this third QUAL simulation, the DOC concentration in the island reservoirs would only be a function of the DOC concentration of incoming diversions and the DOC concentration already present in the island reservoirs. This simple mixing formulation is consistent with conservative water quality constituents, and was described by Equation 2 in Section 4.1.

The time series of low-bookend DOC was then compared with the no growth DOC time series. For the few times that the no growth DOC time series was greater than the low-bookend DOC time series (and this would only happen when the implementation of Equation 1 resulted in reductions of island DOC concentrations), the no growth DOC time series data were used instead of the low-bookend data.

The concentration of any release from either island can be found by simply looking at the reservoir concentration at the time of the release. It is important to note that the majority of the

releases did not occur when either island's DOC had yet reached its maximum values. The operations provided by CALSIM II resulted in carry-over storage in 1983 (i.e. water was stored in Bacon Island and Webb Tract for more than one year). The summer releases in 1984 from both islands were at the maximum DOC levels described above (NOTE: these 1984 releases did exceed the DOC standards, however, they do not represent the maximum violations of the WQMP standards, as will be described below).

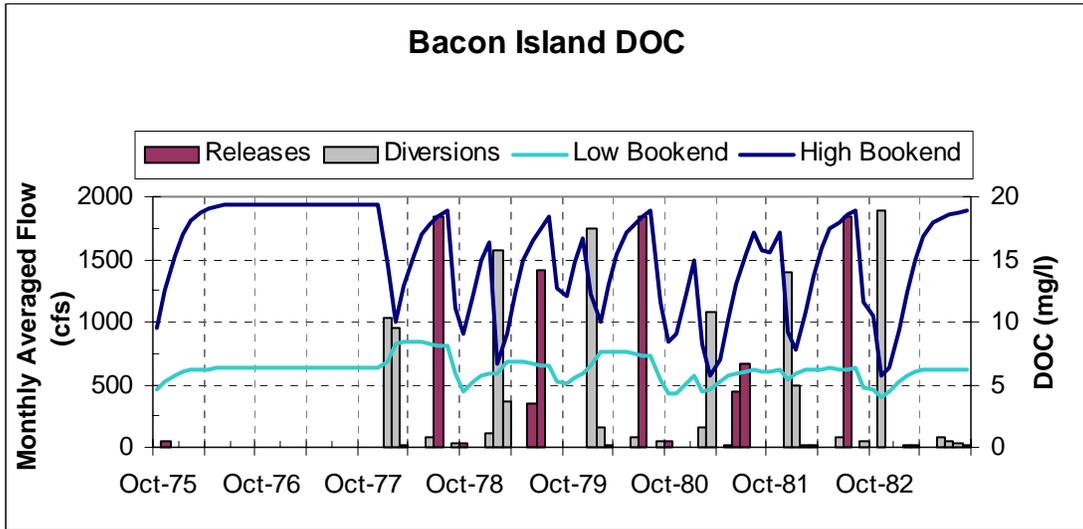


Figure 4.29a: Bacon Island DOC 1975 – 1983.

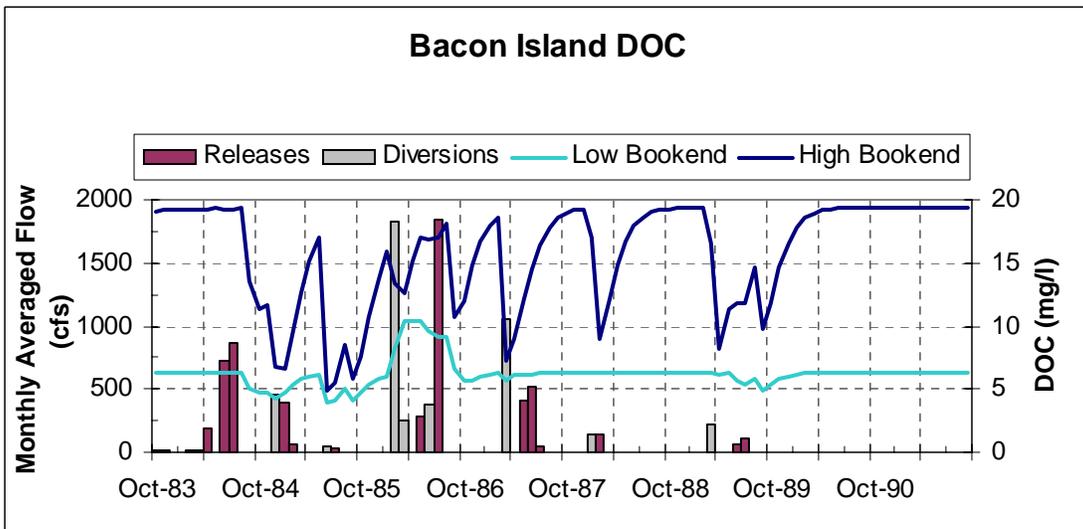


Figure 4.29b: Bacon Island DOC 1983 – 1991.

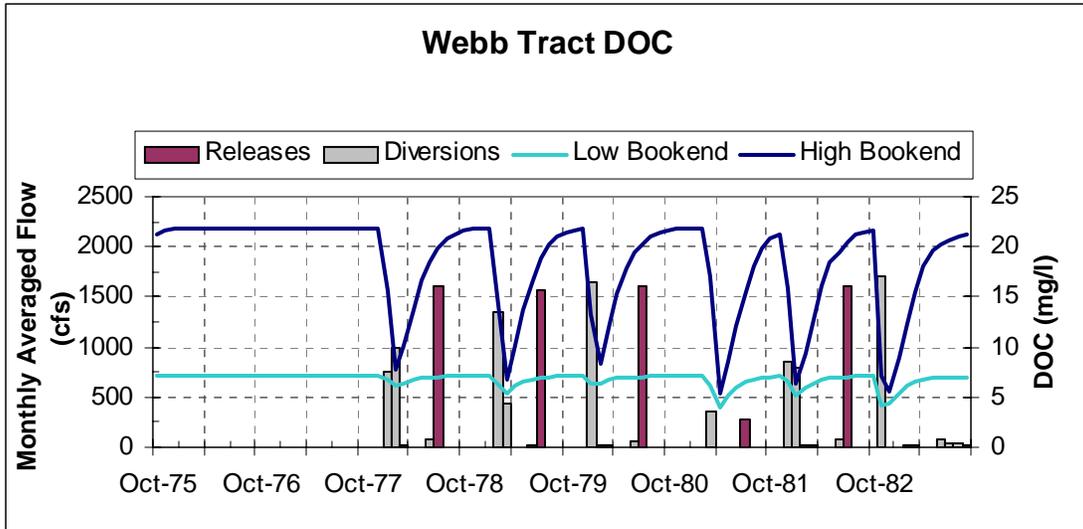


Figure 4.30a: Webb Tract DOC 1975 – 1983.

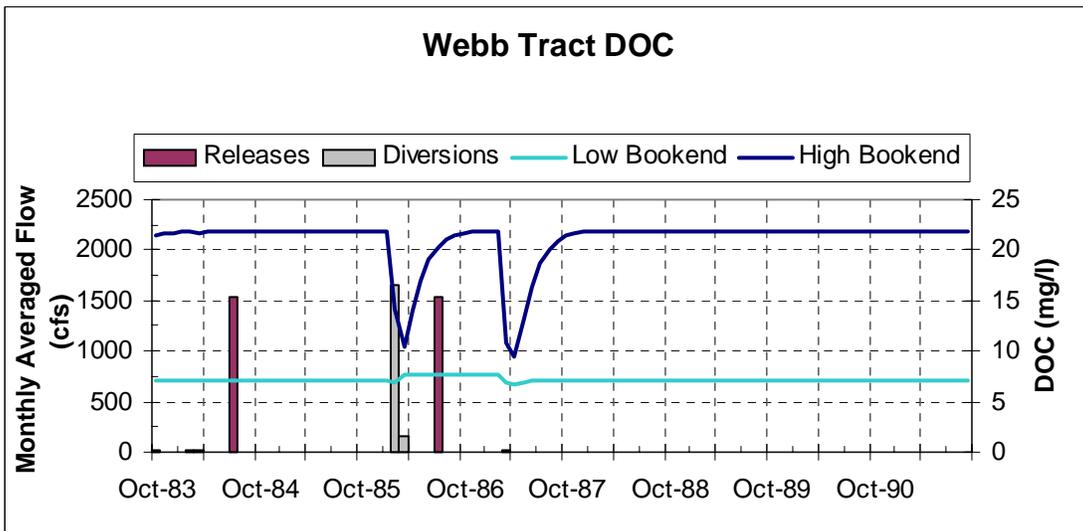


Figure 4.30b: Webb Tract DOC 1983 – 1991.

As discussed in Section 2.2, the consumptive use of both the project and habitat islands was modified to account for local changes in land use. These changes did not decrease the overall consumptive use in the Delta, but instead redirected water use from the project and habitat islands to other locations (see Section 2.2.4 for more details). Clearly these changes will have some impact on both hydrodynamics and water quality. However, the impact of similar changes to consumptive use on just the project islands was found to have a relatively small benefit (Mierzwa, 2001).¹⁵

Figures 4.32, 4.35, 4.38, and 4.41 illustrate the sensitivity to DOC release concentrations at each of the four urban intake locations: Old River at Rock Slough, Old River at the Los Vaqueros

¹⁵ It is recommended that future studies be conducted without operation of the project, but accounting for changes in land use associated with the project. These studies could quantify the actual ag credit associated with changing the consumptive use of both the project and habitat islands.

Intake, the State Water Project intake at Banks Pumping Plant, and the Central Valley Project intake at Tracy. A 4 mg/l DOC concentration is shown, which was later used to calculate the WQMP change in DOC constraint.

The base case monthly averaged DOC concentration at Rock Slough ranged between 2.08 and 8.42 mg/l. Further south at the other three intake locations, the base case monthly averaged DOC concentrations increased slightly. The base case DOC frequently exceeded the 4 mg/l concentration level at all four locations. During the times when the base case DOC exceeded the 4 mg/l concentration level, both the low- and high-bookend simulations also exceeded 4 mg/l. However, releases from the project also resulted in additional times when the alternative simulations exceeded 4 mg/l. The maximum monthly averaged DOC at all four export locations over the entire 16-year planning study is summarized in Table 4.8.

Table 4.8: Maximum Monthly Averaged DOC (mg/l).

| <i>Location</i> | <i>Base</i> | <i>Low Bookend</i> | <i>High Bookend</i> |
|----------------------------------|-------------|--------------------|---------------------|
| Old River at Rock Slough | 8.42 | 7.73 | 7.73 |
| Old River at Los Vaqueros Intake | 8.81 | 8.19 | 8.19 |
| Banks Pumping Plant (SWP) | 10.01 | 9.50 | 9.50 |
| Tracy Pumping Plant (CVP) | 10.39 | 10.10 | 10.10 |

In all three simulations, the periods of maximum DOC for all of the locations coincided with the high runoff periods that start in the late winter and last through the spring. These periods of high DOC did not coincide with the major (summer) release periods associated with the operation of the project. Though summer project releases from the two alternative simulations did result in additional DOC spikes that approached the winter DOC maximums listed above, the concentration from the project releases did not exceed the maximums for either bookend. However, previous DSM2 studies have shown that other Delta Wetlands configurations can result in conditions where the summer project releases for both bookends can exceed the winter DOC concentrations (Mierzwa, 2001).

Table 4.9: Maximum Monthly Averaged Increase in DOC (mg/l).

| <i>Location</i> | <i>Low - Base</i> | <i>High - Base</i> |
|----------------------------------|-------------------|--------------------|
| Old River at Rock Slough | 0.63 | 2.92 |
| Old River at Los Vaqueros Intake | 0.98 | 3.60 |
| Banks Pumping Plant (SWP) | 1.37 | 4.30 |
| Tracy Pumping Plant (CVP) | 1.36 | 4.21 |

As shown in Figures 4.29 and 4.30, the quality of the water released from the project islands typically ranged between 5 and 20 mg/l, which frequently is higher than the DOC concentration of the water already present in the channels around the project islands. The maximum monthly increase in DOC for each of the bookend scenarios is shown in Table 4.9. At all four intake locations, these increases were directly related to project releases. The largest increases occurred at the Banks Pumping Plant (SWP). Particle Tracking Model (PTM) simulations have shown that when high quantities of water is released from the island reservoirs, and the export capacity of Banks is increased to match this release, a large portion of this additional water ends up at the

project pumps. This additional water typically has DOC concentrations equal to or higher than the concentration of the water coming from other sources, thus the largest increases in DOC concentrations were associated with the regions that also had the largest increases in exports. In other words, increased pumping at Banks would pull the water with higher DOC concentrations to both the Banks and Tracy Pumping Plants.

The impact of the project operations is better illustrated in Figures 4.32, 4.35, 4.38, and 4.41 as a time series of the change in monthly averaged DOC (alternative - base). The WQMP limits the maximum increase in DOC due to project operations based on the modeled base case DOC concentration. When the base case DOC is either less than 3 mg/l or greater than 4 mg/l, the maximum increase in DOC is 1 mg/l. When the base case DOC is between 3 mg/l and 4 mg/l, then the alternative DOC can not exceed 4 mg/l (in other words, the maximum allowed increase is the difference between 4 mg/l and the base case). This constraint is shown below in Figure 4.31 and is illustrated in Figures 4.33, 4.36, 4.39, and 4.42 as a changing DOC constraint time series with values between 0 to 1 mg/l.

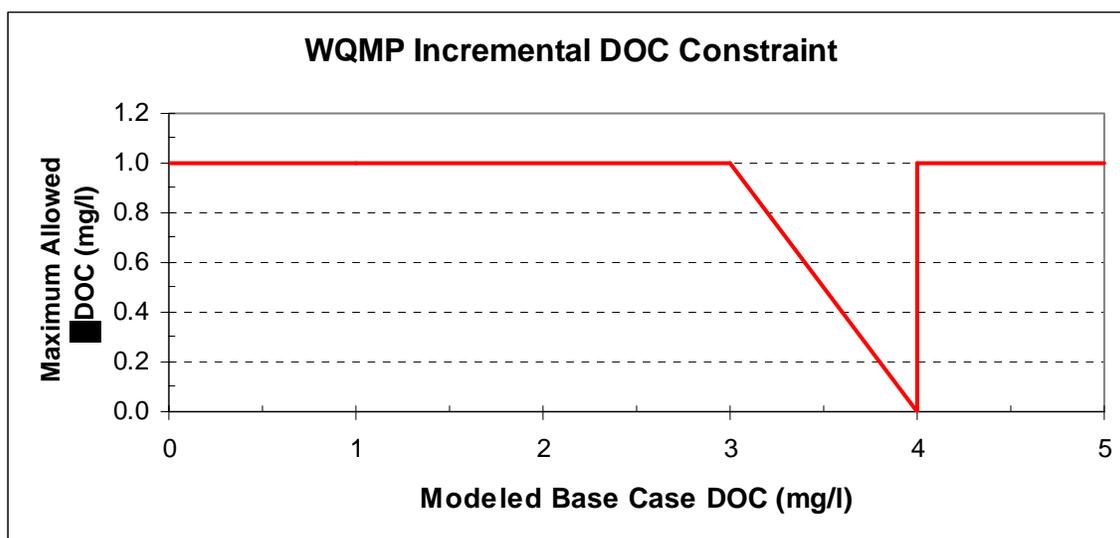


Figure 4.31: WQMP Incremental DOC Constraint.

Both the low- and high-bookend simulations exceeded the WQMP's incremental increase constraint. The low-bookend simulation exceeded the incremental constraint at Banks and Tracy for 4 of the 8 major release periods.¹⁶ The high-bookend simulation exceeded the incremental constraint at all four intake locations for 6 of the 8 major project releases during the 16-year simulation.¹⁷ Typical summer releases were made in July and averaged above 3000 cfs for the

¹⁶ Though during the entire 16-year (192 month) simulation water was released from the project island reservoirs 25 months, the combined flow released from the two project islands exceeded 500 cfs only 9 months or 8 different years (1978, 1979, 1980, 1981, 1982, 1984, 1986, and 1987). In 1979, 1981, 1984 and 1987 water was released in both June and July. June 1984 was the only time when a June release was larger than 500 cfs. These 8 different years are referred to as the major project releases or release periods.

¹⁷ The State Water Project and Central Valley Project exceeded the WQMP constraint for the high-bookend simulation for two months in the same release period (June and July in 1984), bringing the total number of months of violation to 7 for each location.

month. The project releases were less than 1500 cfs, during the two release periods (1981 and 1987) that did not exceed the constraint in the high-bookend simulation.

Frequency histograms of the change in DOC for the entire simulation period were used to create cumulative distribution functions (cdfs) representing the relative change in DOC for each location. These cdfs are shown in Figures 4.34, 4.37, 4.40, and 4.43. On each cdf, a 1 mg/l limit is shown. The point where this limit intersects either of the curves represents the percentage of time that the change in DOC due to the project operations will be equal to or less than the WQMP limit.

For example, according to Figure 4.34, high DOC releases from the project islands will result in changes in DOC at Rock Slough that is equal to or less than 1 mg/l approximately 97% of the time. Similarly, this means that approximately 3% of the time the operation of the project will result in increases in DOC at Rock Slough that are greater than the 1 mg/l WQMP constraint. A summary of the percent of time increases in monthly averaged DOC exceeds the WQMP constraint for the entire simulation period is shown below in Table 4.10. However, as illustrated above in Figure 4.31, sometimes the incremental constraint is less than 1 mg/l, which means that the values shown in Table 4.10 are equal to or less than the percent time that the change in DOC exceeds the WQMP constraint.

Table 4.10: Percent of Time that the Change in DOC is Larger than 1 mg/l.

| <i>Location</i> | <i>% Exceedance Low - Base</i> | <i>% Exceedance High - Base</i> |
|----------------------------------|------------------------------------|-------------------------------------|
| Old River at Rock Slough | 0.0 | 3.1 |
| Old River at Los Vaqueros Intake | < 0.1 | 3.1 |
| Banks Pumping Plant (SWP) | 0.5 | 3.6 |
| Tracy Pumping Plant (CVP) | 0.5 | 3.6 |

The total number of months, out of the 192 months simulated, that exceed the WQMP change in DOC constraint is shown below in Table 4.11. This includes periods when the WQMP change in DOC constraint was less than 1 mg/l. For Banks and Tracy, two of the months this constraint was exceeded occurred in consecutive months of the same year (1984). The number of months that the simulations exceeded 4 mg/l is not shown.

Table 4.11: Number of Months of Exceedance of the WQMP Change in DOC Constraint.

| <i>Location</i> | <i># Months Low - Base</i> | <i># Months High - Base</i> |
|----------------------------------|--------------------------------|---------------------------------|
| Old River at Rock Slough | 0 | 6 |
| Old River at Los Vaqueros Intake | 1 | 6 |
| Banks Pumping Plant (SWP) | 4 | 7 |
| Tracy Pumping Plant (CVP) | 4 | 7 |

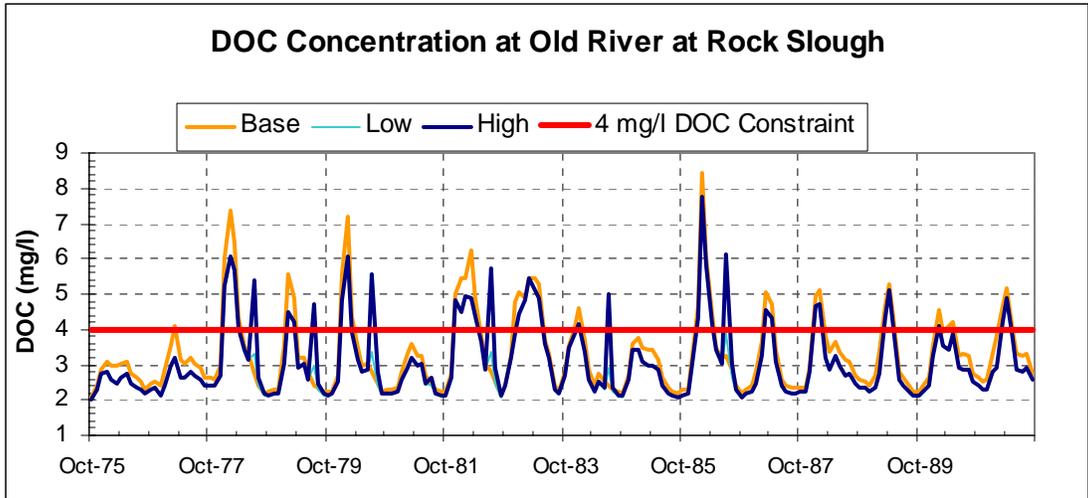


Figure 4.32: DOC Concentration for Old River at Rock Slough.

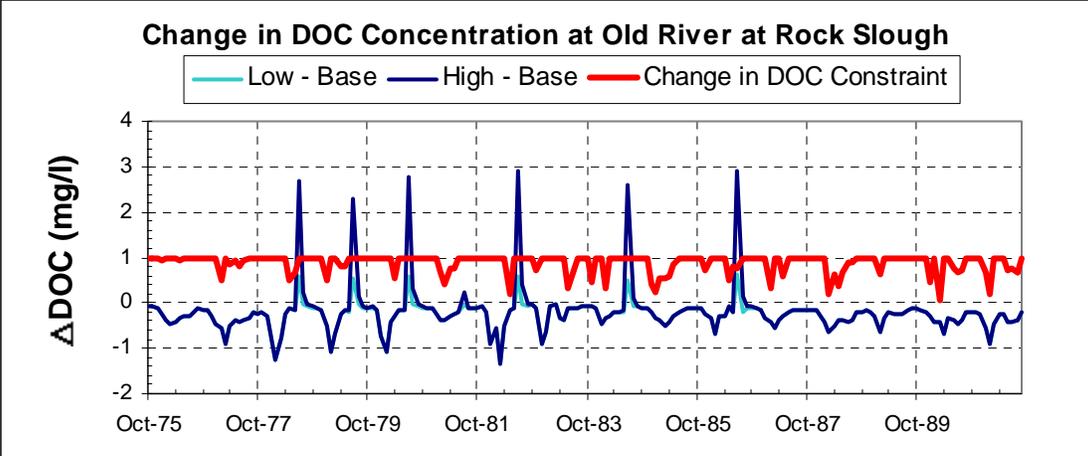


Figure 4.33: Change in DOC for Old River at Rock Slough.

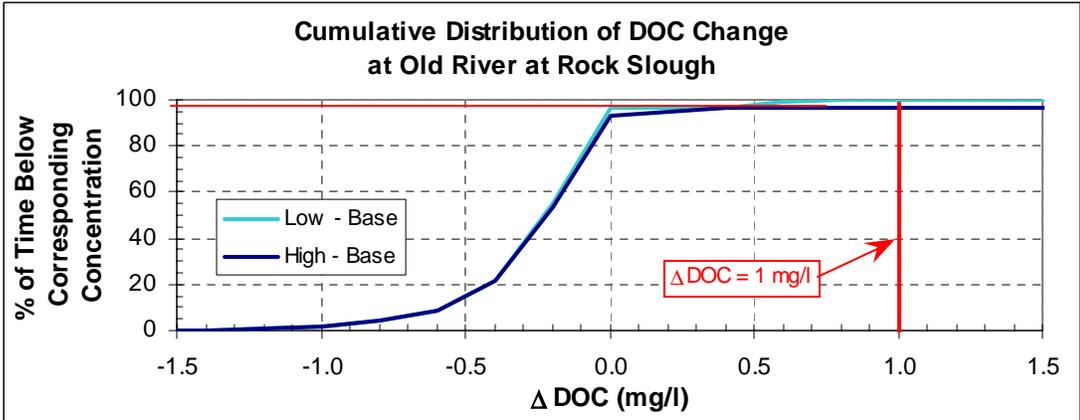


Figure 4.34: Cumulative Distribution DOC Change for Old River at Rock Slough.

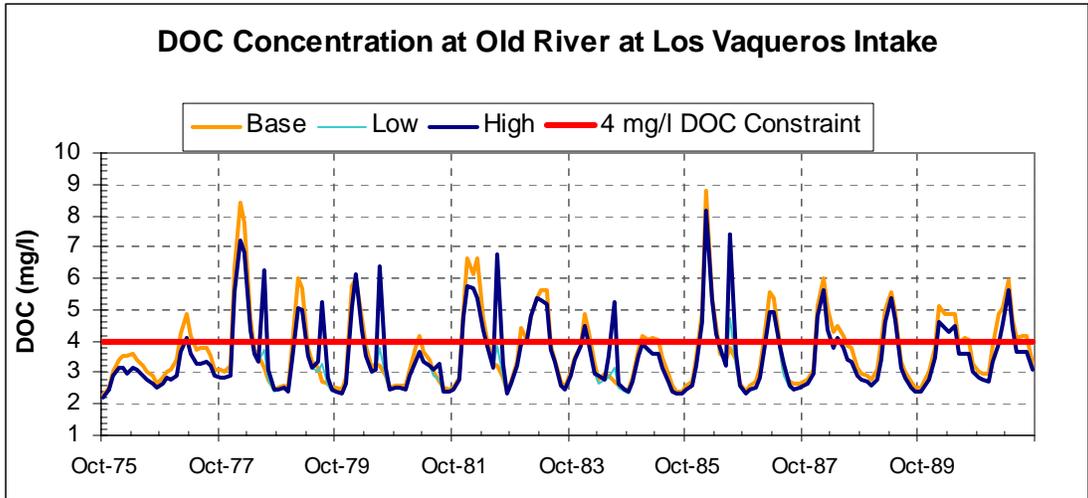


Figure 4.35: DOC Concentration for Old River at Los Vaqueros Intake.

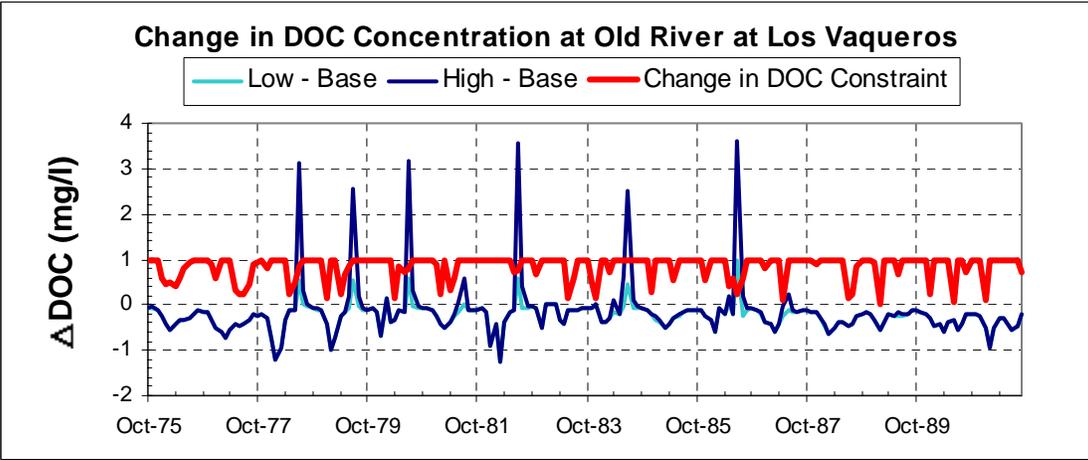


Figure 4.36: Change in DOC for Old River at Los Vaqueros Intake.

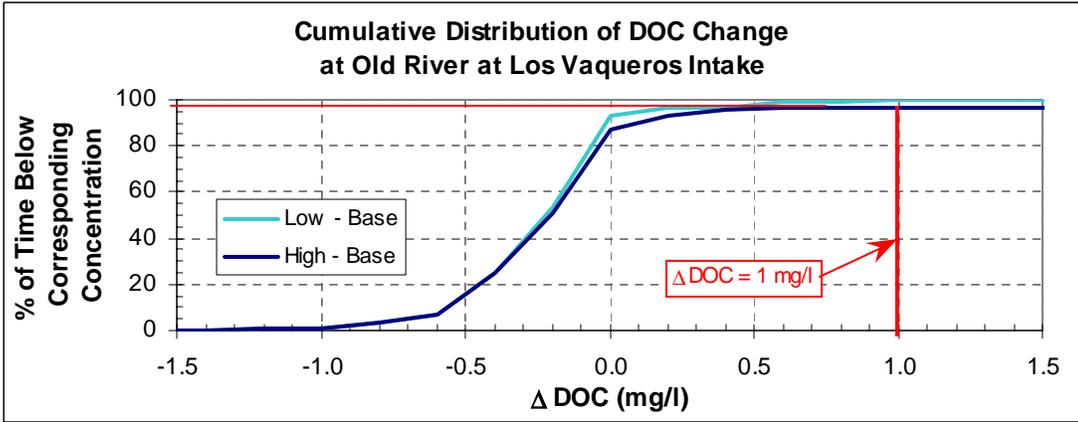


Figure 4.37: Cumulative Distribution DOC Change for Old River at Los Vaqueros Intake.

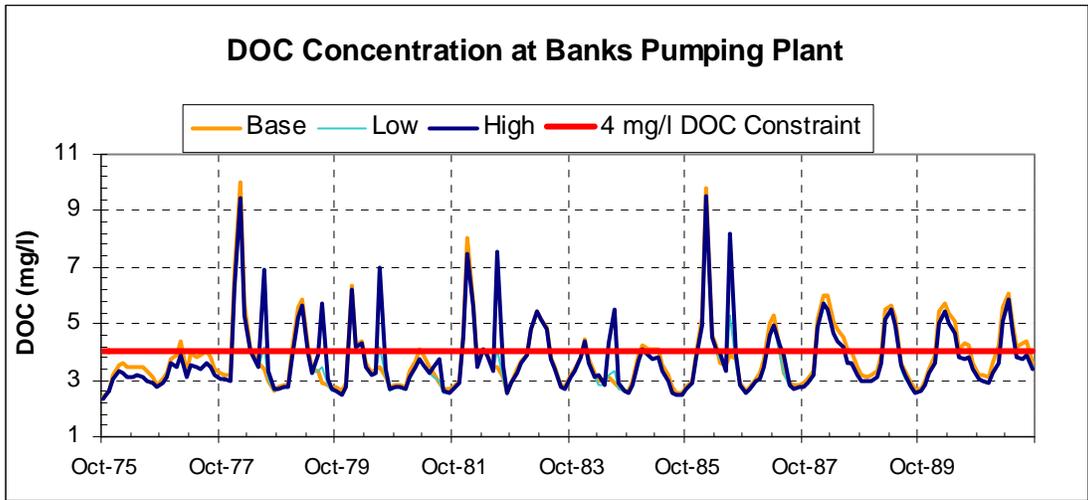


Figure 4.38: DOC Concentration for Banks Pumping Plant.

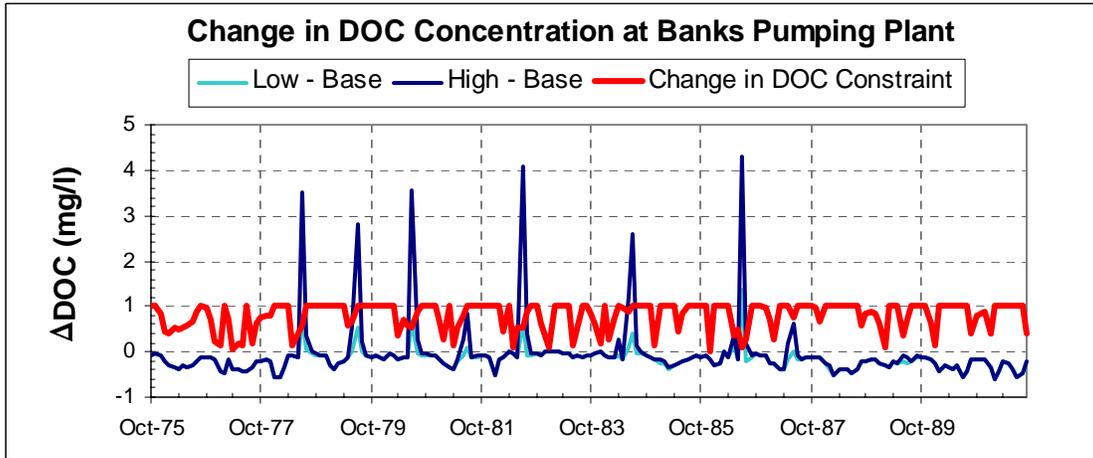


Figure 4.39: Change in DOC for Banks Pumping Plant.

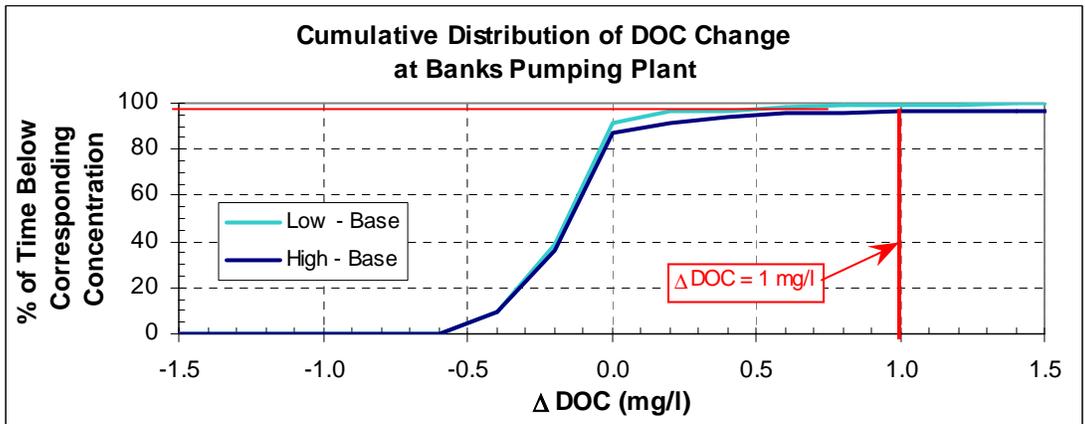


Figure 4.40: Cumulative Distribution DOC Change for Banks Pumping Plant.

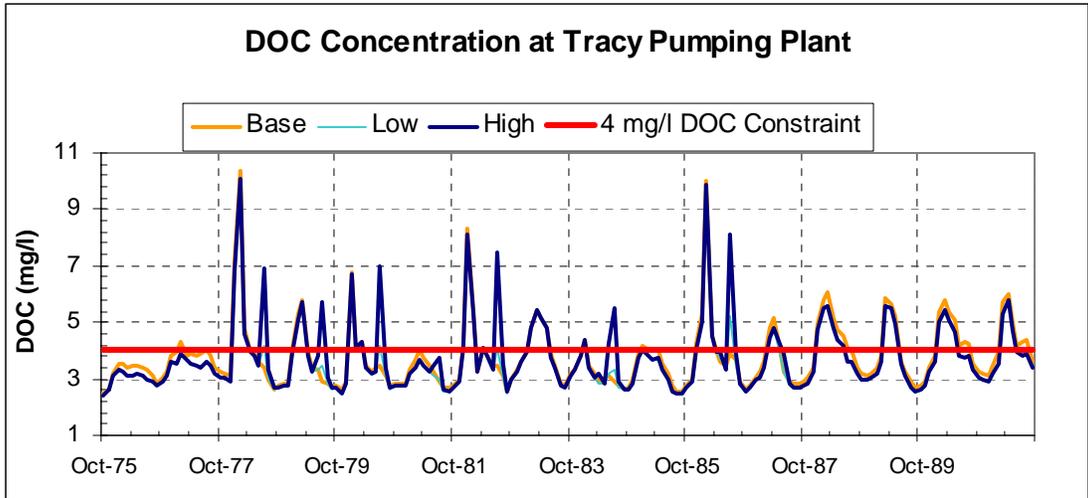


Figure 4.41: DOC Concentration for Tracy Pumping Plant.

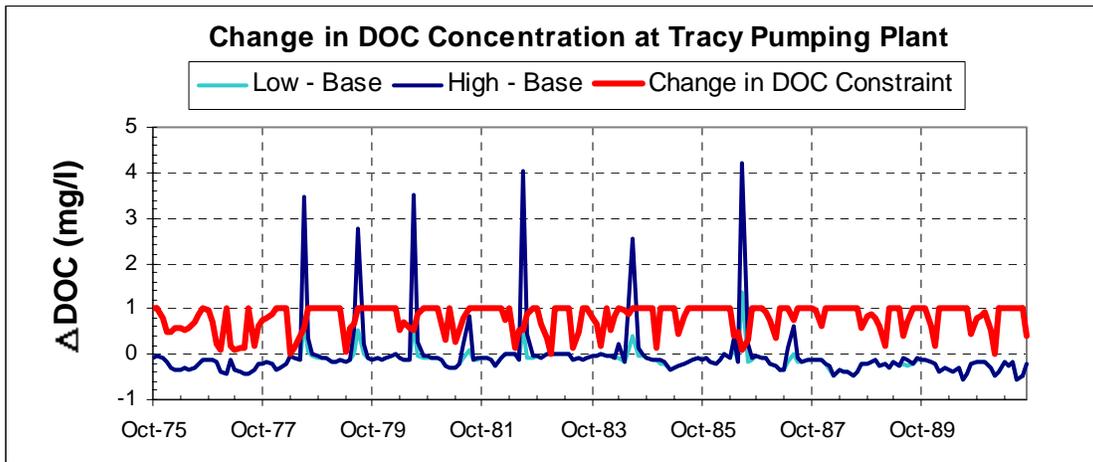


Figure 4.42: Change in DOC for Tracy Pumping Plant.

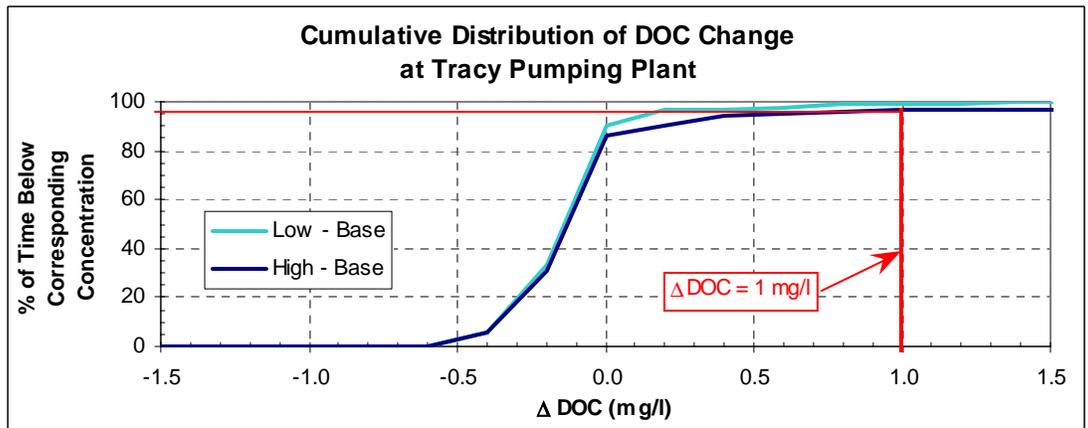


Figure 4.43: Cumulative Distribution DOC Change for Tracy Pumping Plant.

4.4 Long-Term DOC

Long-term increases due to the operation of the project were calculated as the 3-year running average of monthly average DOC mass loading (see Hutton, 2001). Time series plots of the long-term monthly averaged DOC mass loading (expressed in 1000 metric tons / month) at Old River at Rock Slough and the State Water Project and the Central Valley Project intakes are shown in Figures 4.44, 4.47, and 4.50.¹⁸ The long-term impact of the project operations was calculated using Equation 6.

$$\% DOC_{Increase w/ Project} = \frac{DOC_{w/ Project} - DOC_{w/o project}}{DOC_{w/o project}} \times 100\% \quad [Eqn. 6]$$

The WQMP limits the long-term DOC mass loading increases at the intake locations due to the project operation to 5%. This 5% limit is shown on the time series plots (Figures 4.45, 4.48, and 4.51) of the long-term percent increase of DOC mass loading. The maximum percent increases in the long-term monthly averaged DOC mass loading is shown in Table 4.12. Only the high-bookend simulations exceeded the WQMP 5% increase constraint for all three locations. The change in long-term monthly averaged DOC mass loading at the Old River at Rock Slough and Tracy Pumping Plant intakes was consistently lower in the low-bookend simulation than in the base case, as is shown by negative maximum increases in Table 4.12.

Table 4.12: Maximum Percent Increase in Long-Term Monthly Averaged DOC Mass Loading.

| <i>Location</i> | <i>Low - Base</i> | <i>High - Base</i> |
|---------------------------|-------------------|--------------------|
| Old River at Rock Slough | -2.5 | 9.5 |
| Banks Pumping Plant (SWP) | 3.3 | 12.0 |
| Tracy Pumping Plant (CVP) | -0.5 | 7.6 |

Frequency histograms of the percent increase in long-term DOC mass loading for the entire simulation period were used to create cumulative distribution functions (cdfs) to represent the long-term impact of the project operations. These cdfs are shown in Figures 4.46, 4.49, and 4.52. The WQMP maximum 5% increase in long-term DOC mass loading constraint is shown on each figure. The percent of the time that each scenario was equal to or below the WQMP maximum 5% increase constraint is listed in Table 4.13.

¹⁸ Normally Contra Costa Water District (CCWD) diversions are divided between the Rock Slough and Los Vaqueros Reservoir intakes. Long-term DOC mass loading was not calculated for Old River at Los Vaqueros Reservoir intake because CALSIM II did not separate the CCWD diversions. Similarly, the mass loading calculated for Rock Slough is based on the assumption that 100% of CCWD's diversions would be taken at the Rock Slough location.

Table 4.13: Percent Time that the Percent Increase of Long-Term DOC Mass Loading Exceeds the WQMP Maximum 5% Increase Constraint.

| <i>Location</i> | <i>% Exceedance Low - Base</i> | <i>% Exceedance High - Base</i> |
|---------------------------|------------------------------------|-------------------------------------|
| Old River at Rock Slough | 0 | 8 |
| Banks Pumping Plant (SWP) | 0 | 50 |
| Tracy Pumping Plant (CVP) | 0 | 25 |

The total number of months, out of the 156 months simulated, that the long-term increase in DOC mass loading exceeds the WQMP 5% maximum increase constraint is shown below in Table 4.14.¹⁹ None of the three intake locations exceeded the 5% increase constraint for the low-bookend. For the high-bookend, all three locations exceeded the 5% increase constraint. The Banks Pumping Plant exceeded the constraint 50 months, the most for any intake location.

Table 4.14: Number of Months that the Increase in Long-Term DOC Mass Loading Exceeds the WQMP 5% Increase.

| <i>Location</i> | <i># Months Low - Base</i> | <i># Months High - Base</i> |
|---------------------------|--------------------------------|---------------------------------|
| Old River at Rock Slough | 0 | 12 |
| Banks Pumping Plant (SWP) | 0 | 78 |
| Tracy Pumping Plant (CVP) | 0 | 39 |

¹⁹ Instead of 192 months, the long-term mass loading calculations used the first 36 months to calculate the running average, thus long-term violations come from a sample of only 156 months.

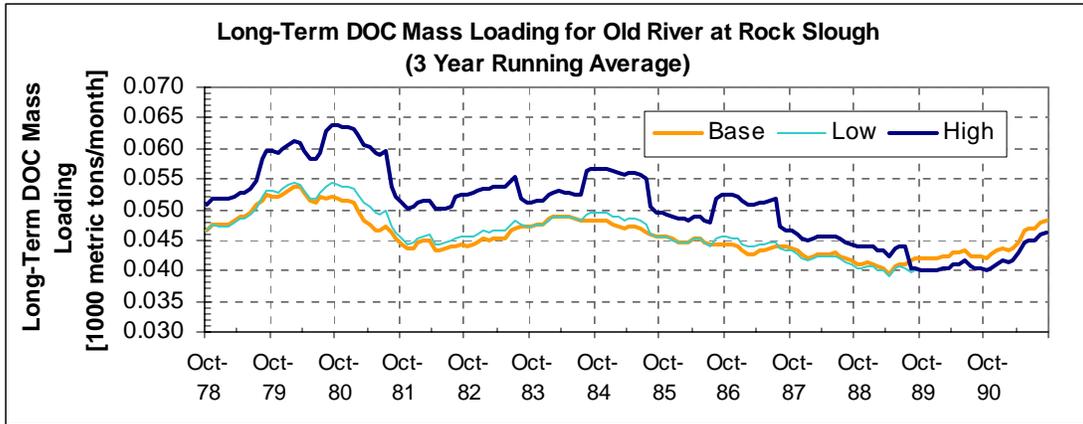


Figure 4.44: Long-Term DOC Mass Loading for Old River at Rock Slough.

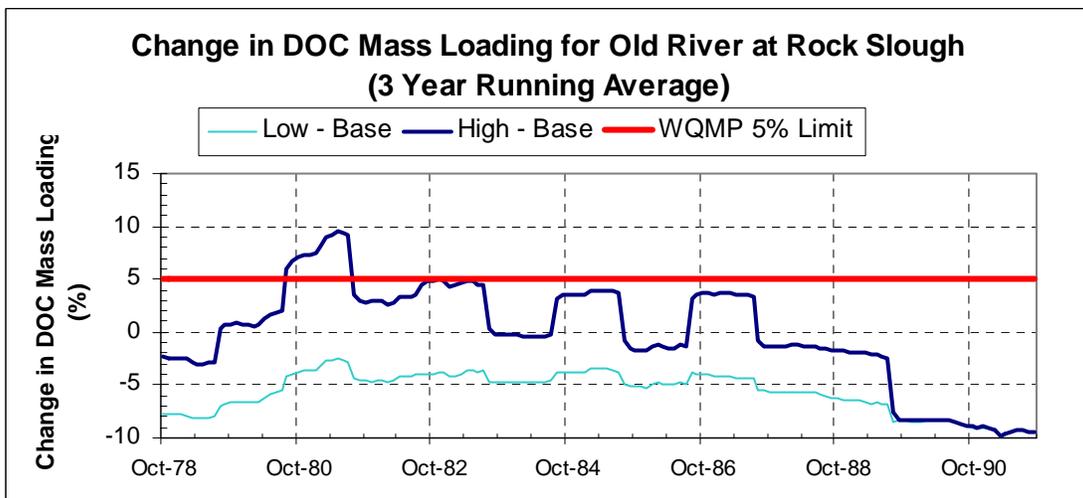


Figure 4.45: Change in Long-Term DOC Mass Loading for Old River at Rock Slough.

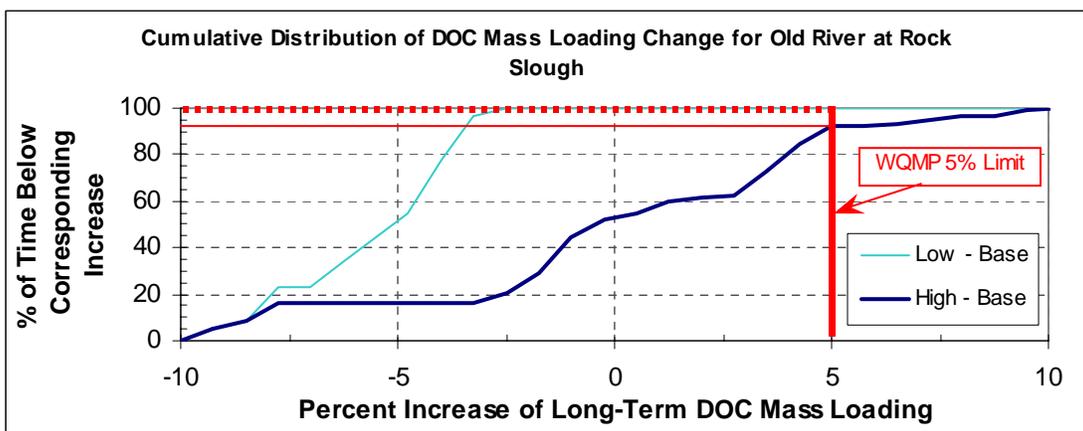


Figure 4.46: Cumulative Distribution of Long-Term DOC Mass Loading Change for Old River at Rock Slough.

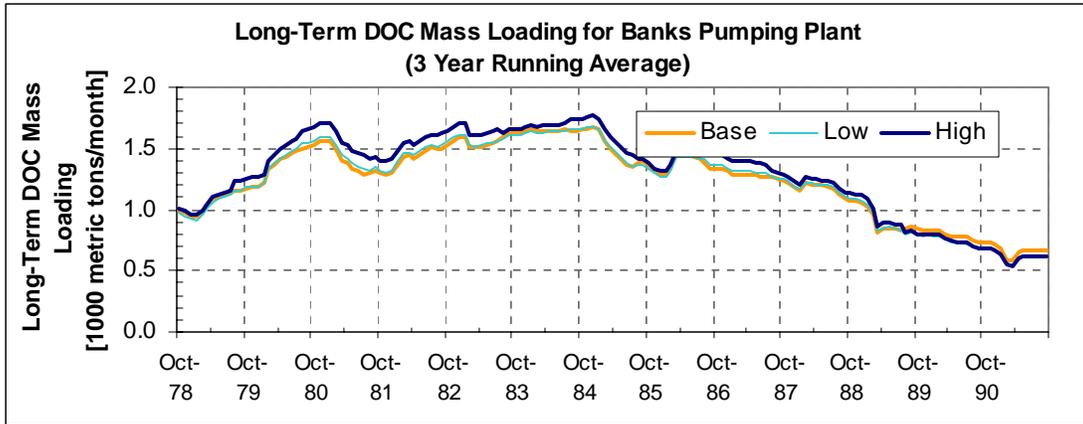


Figure 4.47: Long-Term DOC Mass Loading for Banks Pumping Plant.

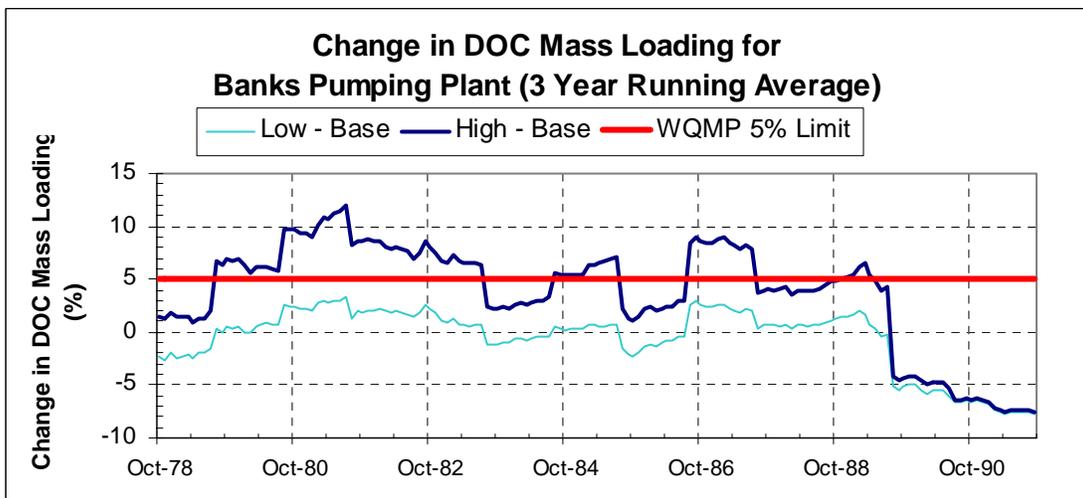


Figure 4.48: Change in Long-Term DOC Mass Loading for Banks Pumping Plant.

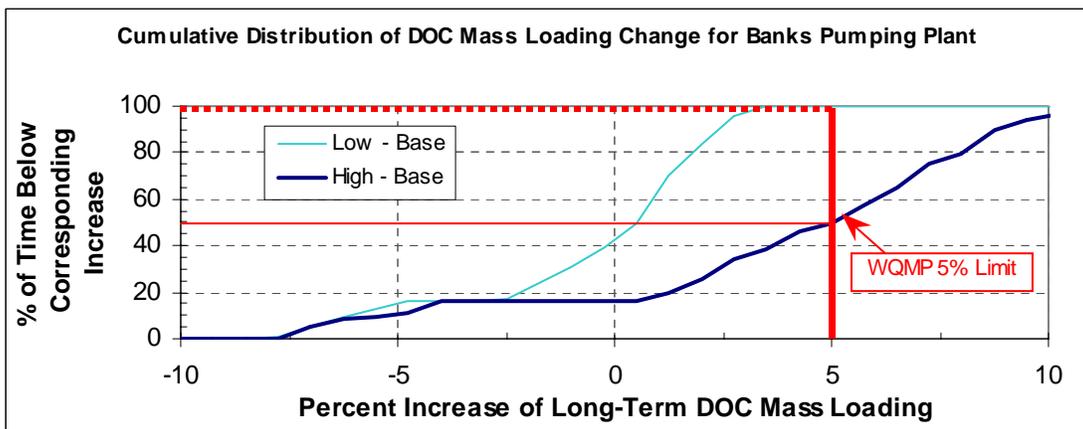


Figure 4.49: Cumulative Distribution of Long-Term DOC Mass Loading Change for Banks Pumping Plant.

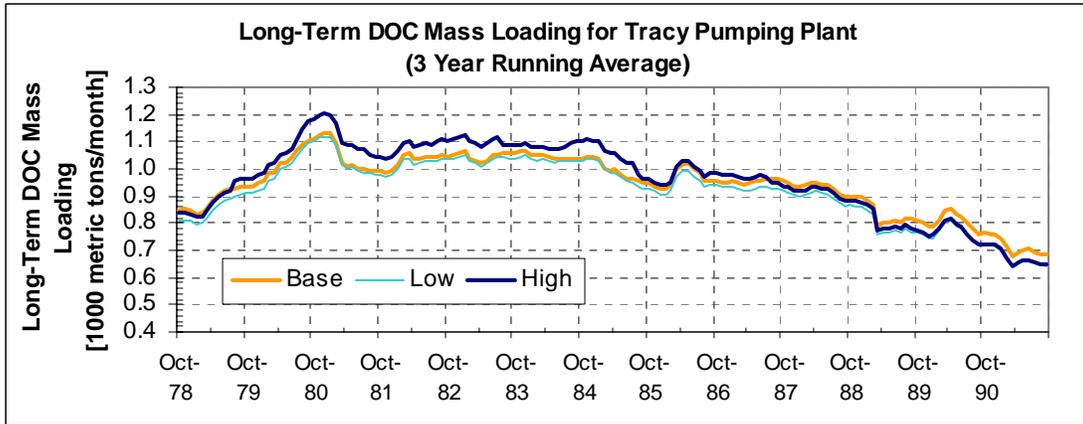


Figure 4.50: Long-Term DOC Mass Loading for Tracy Pumping Plant.

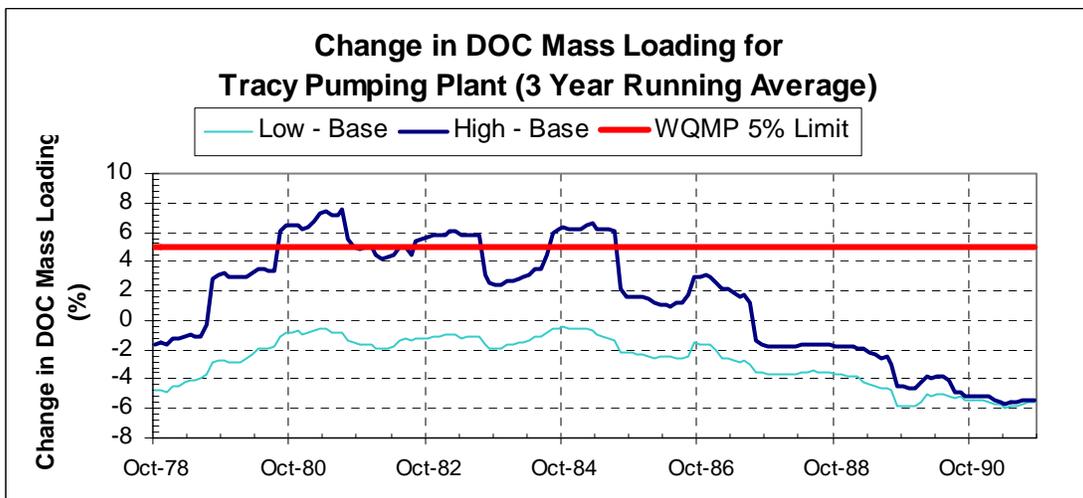


Figure 4.51: Change in Long-Term DOC Mass Loading for Tracy Pumping Plant.

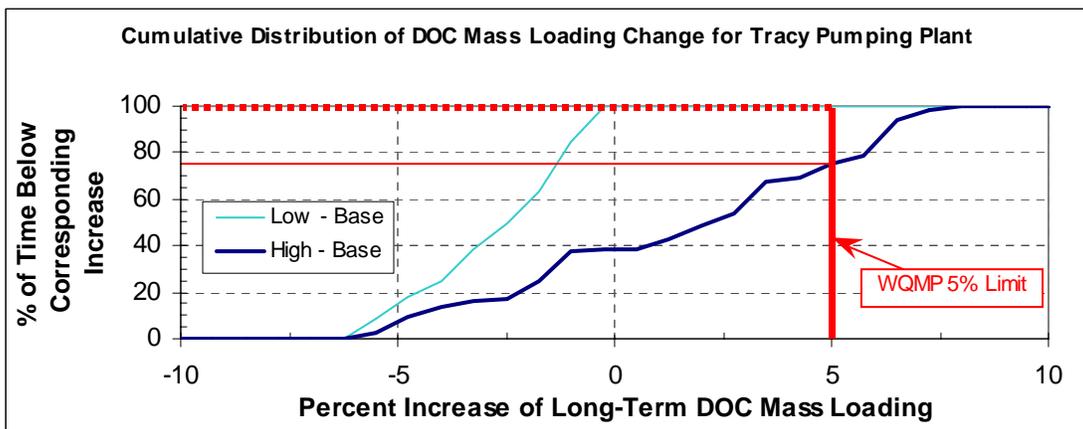


Figure 4.52: Cumulative Distribution of Long-Term DOC Mass Loading Change for Tracy Pumping Plant.

4.5 UVA

Like DOC, storage in a Delta reservoir for several months should increase the UVA measurements. Since the growth formulation modifications made to QUAL only applied to DOC, the UVA results presented here were calculated from the QUAL DOC simulations (see Section 4.3), which accounted for the growth of DOC due to long storage times. Previous work relating DSM2 DOC to UVA results has shown that there is a strong relationship between modeled DOC and UVA at the four intake locations (Anderson, 2001). Anderson developed a linear regression (Equation 7) that was used in this report to convert both the low- and high-bookend DOC results at the four urban intakes to equivalent UVA values.

$$UVA = 0.0435 \times DOC - 0.0347 \quad [\text{Eqn. 7}]$$

Figures 4.53, 4.55, 4.57, and 4.59 illustrate the sensitivity to UVA release at each of the four urban intake locations: Old River at Rock Slough, Old River at the Los Vaqueros Intake, the State Water Project intake at Banks Pumping Plant, and the Central Valley Project intake at Tracy. In the base case, the periods of high UVA for all of the locations coincided with the high runoff periods that start in the late winter and last through the spring. The maximum monthly averaged UVA for each location is shown in Table 4.15. Both the time series plots and Table 4.15 show that the operation of the project resulted in lower maximum monthly averaged UVA values at the intake locations for the low- and high-bookend simulations.

Table 4.15: Maximum Monthly Averaged UVA (cm^{-1}).

| <i>Location</i> | <i>Base</i> | <i>Low Bookend</i> | <i>High Bookend</i> |
|----------------------------------|-------------|--------------------|---------------------|
| Old River at Rock Slough | 0.33 | 0.30 | 0.30 |
| Old River at Los Vaqueros Intake | 0.35 | 0.32 | 0.32 |
| Banks Pumping Plant (SWP) | 0.40 | 0.38 | 0.38 |
| Tracy Pumping Plant (CVP) | 0.42 | 0.40 | 0.40 |

Figures 4.54, 4.56, 4.58, and 4.60 allow a closer look at the changes between the alternative simulation and the base case simulations. In addition to showing the time series of change between the alternative and base case, the combined project releases and diversions are also plotted. Summer time releases from the project increased the UVA concentration by more than 0.1 cm^{-1} for the high-bookend simulation during 6 of the 8 release periods at all four intake locations. The two remaining periods (summers of 1981 and 1987) had substantially lower project releases.

The maximum monthly averaged increase in UVA at each of the intake locations is shown in Table 4.16. The smallest increase in UVA due to project operation occurred at Old River at Rock Slough. The largest increases in UVA were at Banks and Tracy.

Table 4.16: Maximum Monthly Averaged Increase in UVA (cm^{-1}).

| <i>Location</i> | <i>Low - Base</i> | <i>High - Base</i> |
|----------------------------------|-------------------|--------------------|
| Old River at Rock Slough | 0.03 | 0.13 |
| Old River at Los Vaqueros Intake | 0.04 | 0.16 |
| State Water Project | 0.06 | 0.19 |
| Central Valley Project | 0.06 | 0.18 |

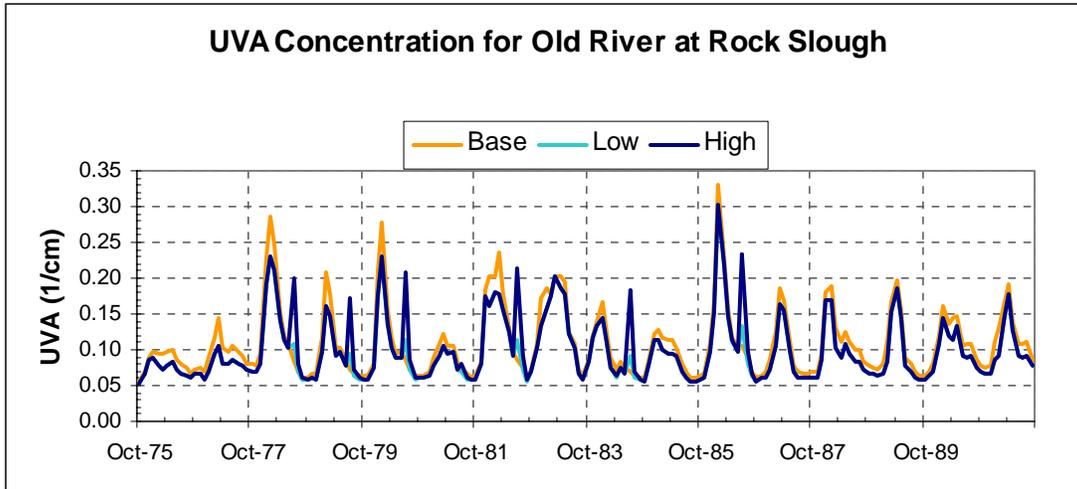


Figure 4.53: UVA Concentration for Old River at Rock Slough.

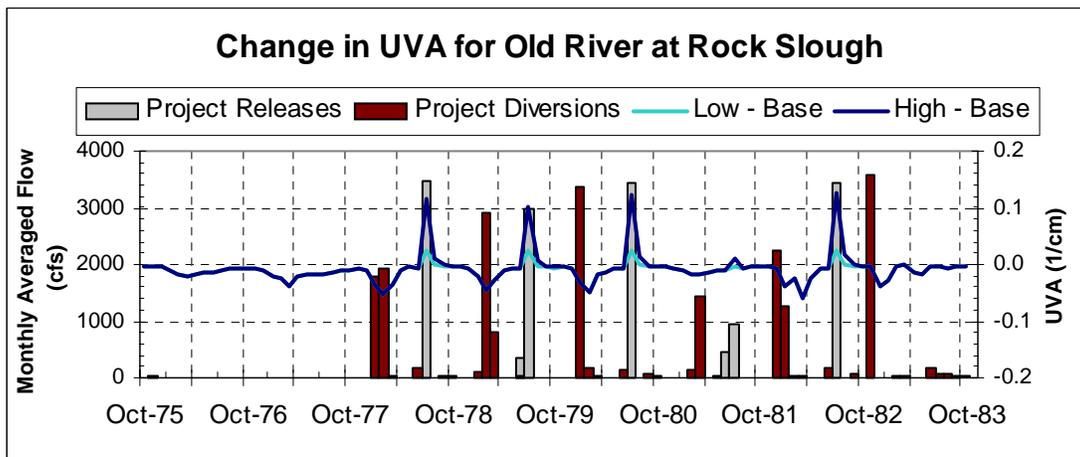


Figure 4.54a: Change in UVA for Old River at Rock Slough for 1975-1983.

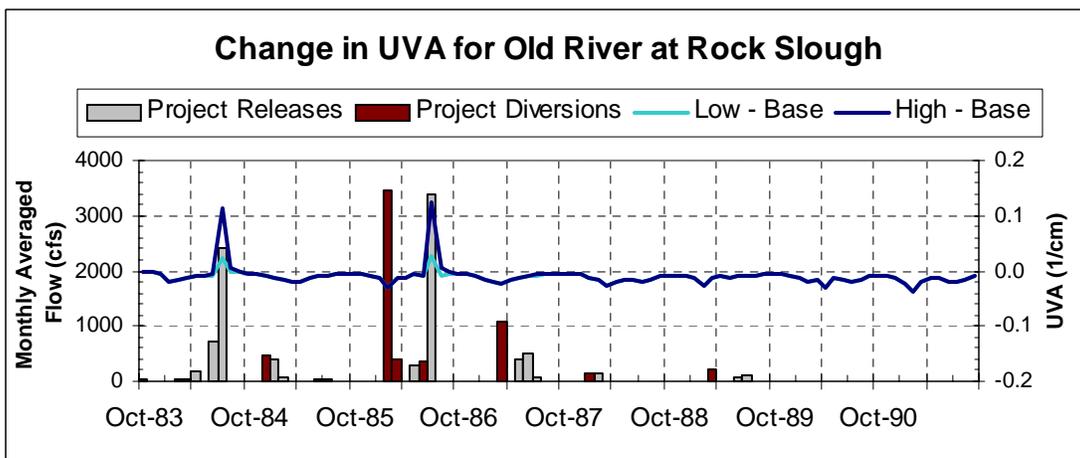


Figure 4.54b: Change in UVA for Old River at Rock Slough for 1983-1991.

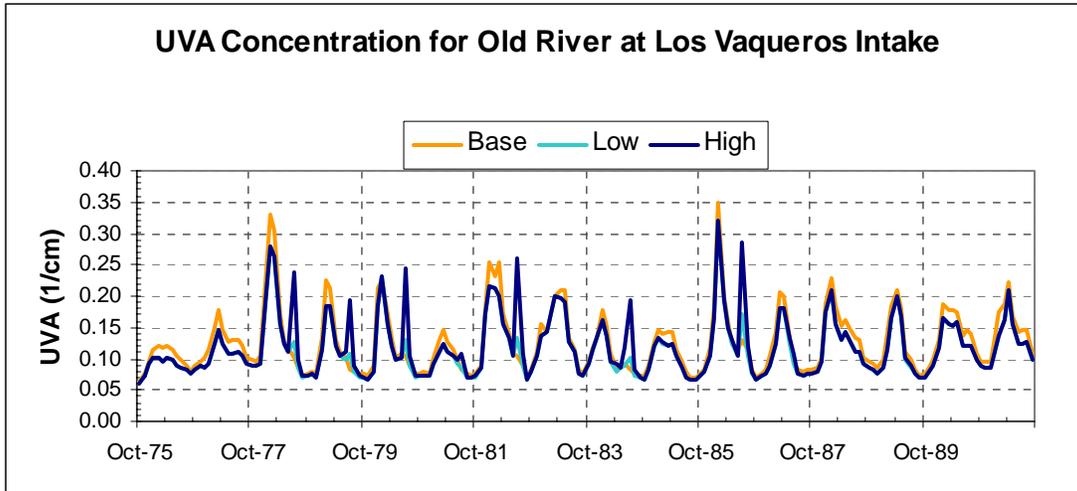


Figure 4.55: UVA Concentration for Old River at Los Vaqueros Intake.

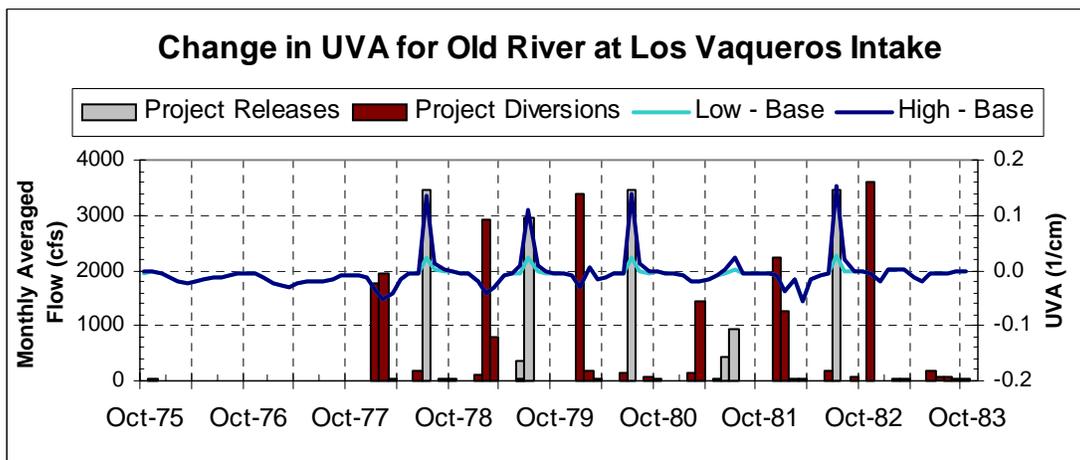


Figure 4.56a: Change in UVA for Old River at Los Vaqueros Intake for 1975-1983.

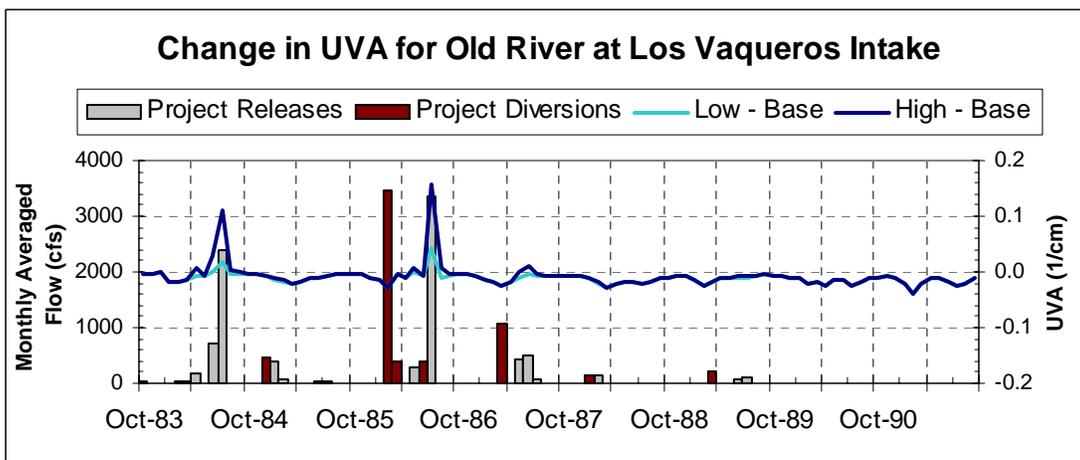


Figure 4.56b: Change in UVA for Old River at Los Vaqueros Intake for 1983-1991.

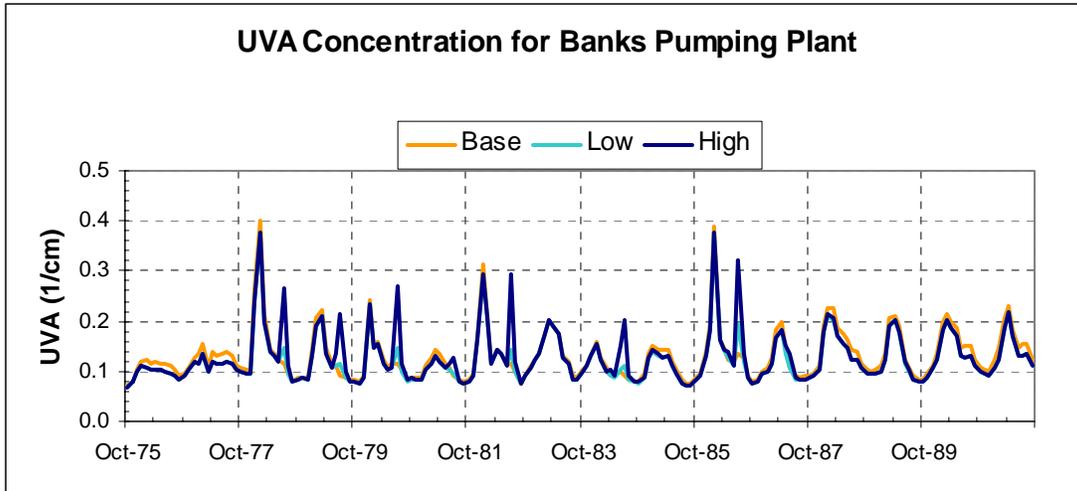


Figure 4.57: UVA Concentration for Banks Pumping Plant.

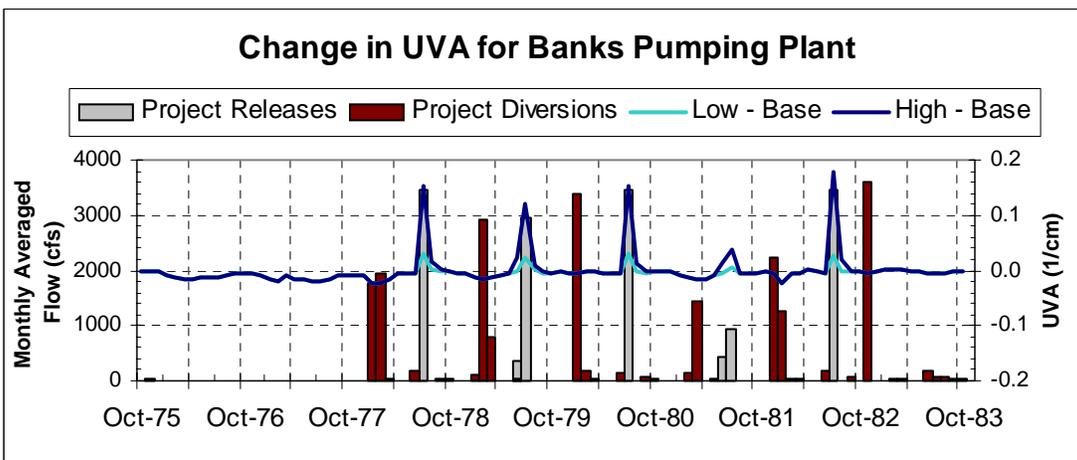


Figure 4.58a: Change in UVA for Banks Pumping Plant for 1975-1983.

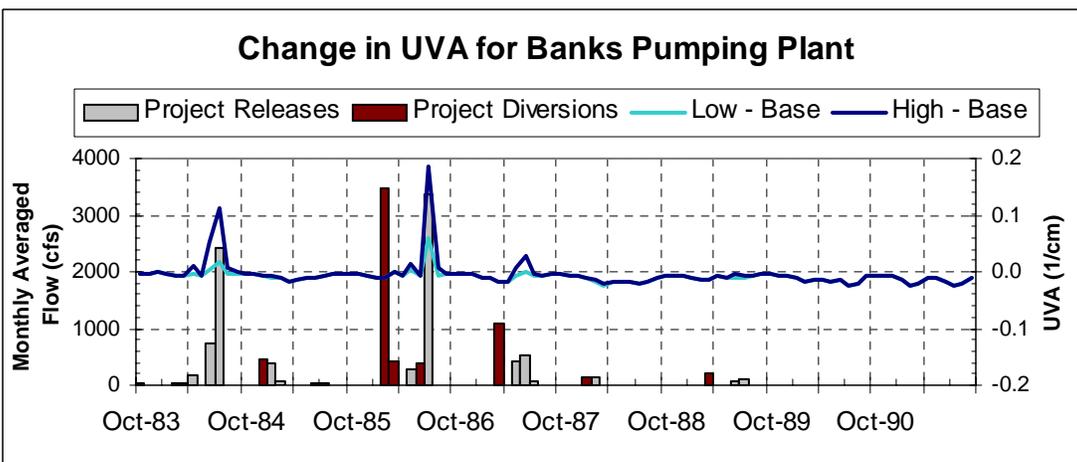


Figure 4.58b: Change in UVA for Banks Pumping Plant for 1983-1991.

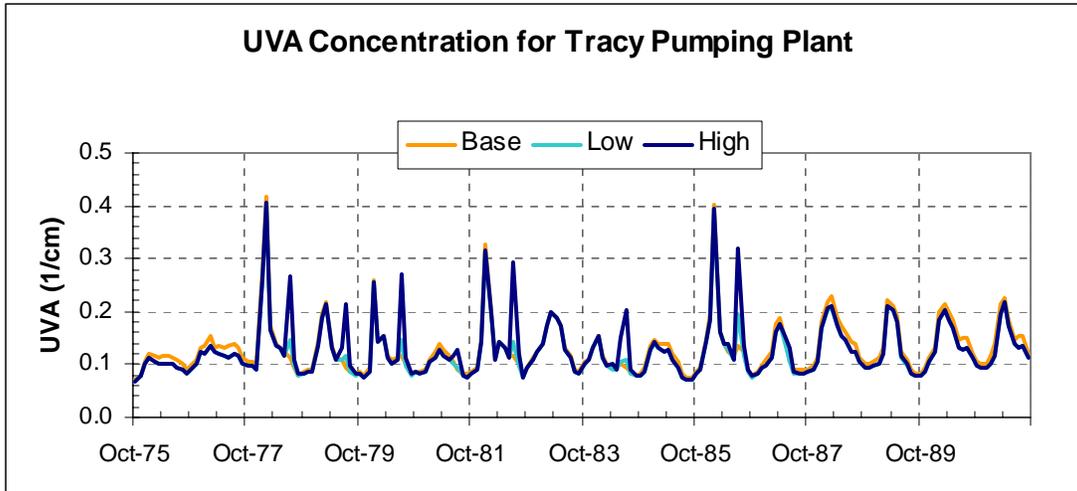


Figure 4.59: UVA Concentration for Tracy Pumping Plant.

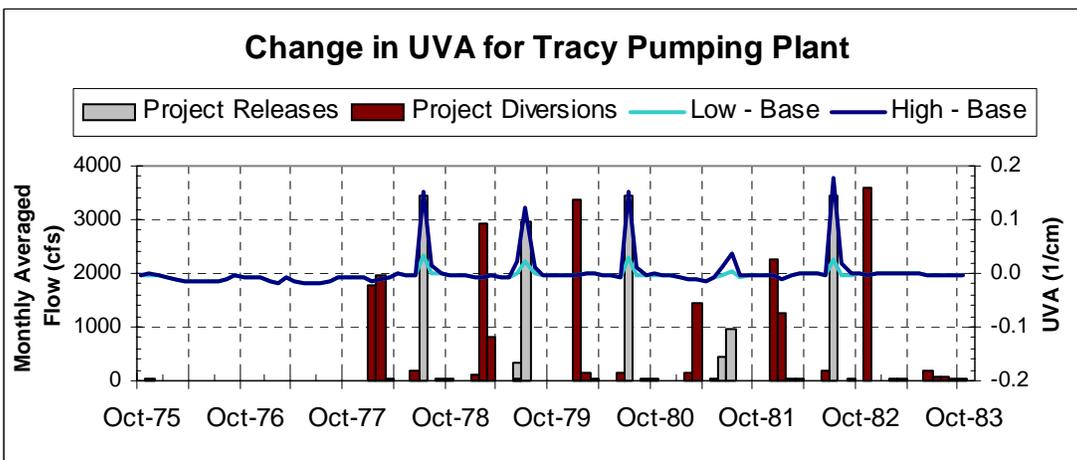


Figure 4.60a: Change in UVA for Tracy Pumping Plant for 1975-1983.

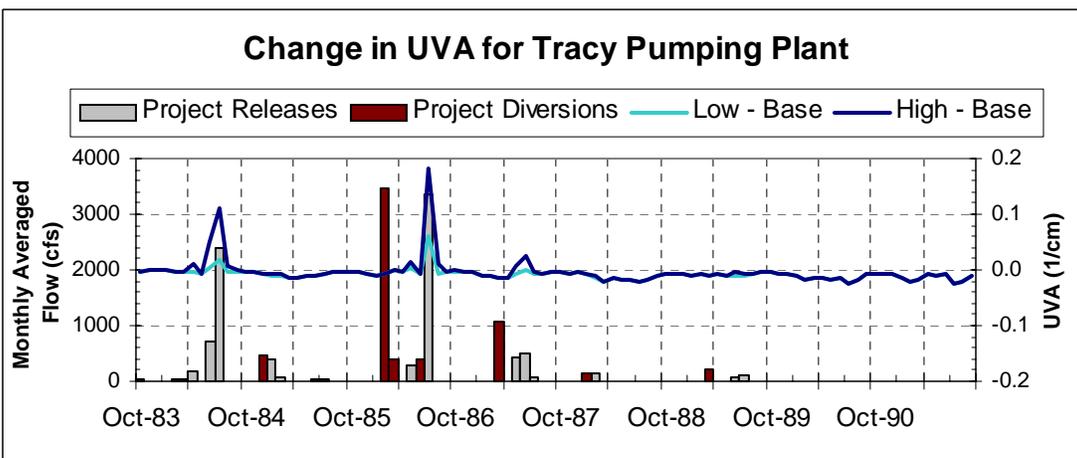


Figure 4.60b: Change in UVA for Tracy Pumping Plant for 1983-1991.

4.6 TTHM

According to the WQMP total trihalomethane (TTHM) formation is limited to 64 ug/l. For periods when the modeled base case exceeds this 64 ug/l standard, the WQMP permitted a 5% increase above the standard (3.2 ug/l) due to operation of the Delta Wetlands project.

Using the EC and DOC low and high bookend results from QUAL, two TTHM bookend values for Old River at Rock Slough were calculated using (Hutton, 2001):

$$TTHM = C_1 \times DOC^{0.228} \times UVA^{0.534} \times (Br + 1)^{2.01} \times T^{0.48} \quad [\text{Eqn. 8}]$$

where

TTHM = total trihalomethane concentration (ug/l),

$C_1 = 14.5$ when $DOC < 4$ mg/l,

$C_1 = 12.5$ when $DOC \geq 4$ mg/l,

DOC = raw water dissolved organic carbon (mg/l) from DSM2,

UVA = raw water ultraviolet absorbance at 254 nm (1/cm) from DOC,

Br = raw water bromide concentration (mg/l) as converted from DSM2, and

T = raw water temperature (°C).

The bromide concentration at Rock Slough was developed by Bob Suits (2001b) from regressions of observed (1) Contra Costa Canal Pumping Plant #1 chloride data to Contra Costa Canal Pumping Plant #1 Bromide data, and (2) Contra Costa Canal Pumping Plant #1 chloride data to Rock Slough EC. The bromide relationship used in Equation 8 for Rock Slough is:

$$Br_{Rock\ Slough} = \frac{EC_{Rock\ Slough} - 118.7}{1040.3} \quad [\text{Eqn. 9}]$$

The bromide relationship for the remaining urban intake locations used in Equation 8 is:

$$Br = \frac{EC - 189.2}{1020.77} \quad [\text{Eqn. 10}]$$

However, during a few periods QUAL's EC concentrations were so low that using these field conversions the resulting bromide concentrations were too low. A minimum bromide concentration of 0.01 ug/l was assumed during these periods.

The monthly average water temperatures used in Equation 8 are shown below in Figure 4.61. These temperature data came from Contra Costa water treatment plant averages, as provided by K.T. Shum of Contra Costa Water District (Forkel, 2001).

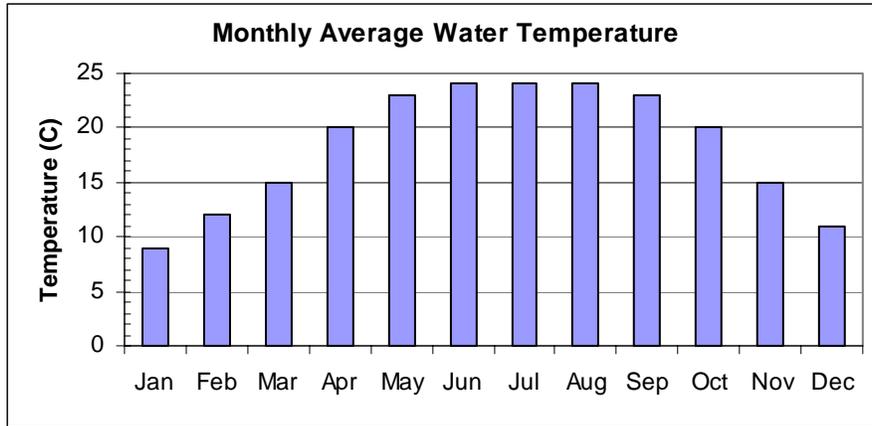


Figure 4.61: Monthly Average Water Temperature.

Using Equations 8, 9, and 10, the TTHM for all the urban intakes was calculated for the entire 16-year simulation period. The sensitivity to DOC and bromide release from the project islands is shown in Figures 4.63, 4.66, 4.69, and 4.72. The 64 ug/l WQMP constraint was exceeded only a few times. The base case exceeded this standard in February 1991 at Old River at Rock Slough. At the Old River at Los Vaqueros Intake, Banks, and Tracy, the only time the base case exceeded the TTHM constraint was in March 1977. Both the bromide and DOC were fairly high during this month. Releases from the projects in both alternatives resulted in increases in TTHM, however, the operation of the project also resulted in some slight reductions in the simulated TTHM concentration. For example, though the base case exceeded the 64 ug/l standard in March 1977 at Banks, both the low- and high-bookend simulations were slightly below this constraint.

The maximum monthly TTHM concentrations for each of the simulations are displayed in Table 4.17. The largest maximum monthly averaged TTHM concentrations for the base case and low- and high-bookend simulations occurred at Tracy in March 1977. Though the maximum monthly TTHM concentration was the same for the low- and high-bookend simulations at Old River at Rock Slough, the Old River at Los Vaqueros Intake, and the Tracy, as was shown in Figures 4.63, 4.66, 4.69, and 4.72, TTHM was different at other times. The high-bookend maximum monthly averaged TTHM concentration for Banks corresponded with a project release month in July 1986.

Table 4.17: Maximum Monthly Averaged TTHM (ug/l).

| <i>Location</i> | <i>Base</i> | <i>Low Bookend</i> | <i>High Bookend</i> |
|----------------------------------|-------------|--------------------|---------------------|
| Old River at Rock Slough | 66.8 | 57.5 | 57.5 |
| Old River at Los Vaqueros Intake | 79.5 | 68.3 | 68.3 |
| Banks Pumping Plant (SWP) | 67.0 | 63.9 | 64.4 |
| Tracy Pumping Plant (CVP) | 84.4 | 82.0 | 82.0 |

Time series plots (see Figures 4.64, 4.67, 4.70, 4.73) illustrating the change between each alternative scenario and the base case provide a more useful tool to assess the impact of the project operation on TTHM formation. Although these plots show the change due to the project

operation over the entire simulation period, the intermittent 3.2 ug/l maximum increase in TTHM constraint applies only at the times when the regular 64 ug/l constraint was exceeded by the base case as shown in Figures 4.63, 4.66, 4.69, and 4.72. This maximum increase constraint is only shown on these figures when it applies.

The WQMP constrained the operation of the project such that TTHM concentrations should not exceed 64 ug/l, unless the modeled base case TTHM already exceeds 64 ug/l (Hutton, 2001). When the base TTHM concentration exceeded the 64 ug/l constraint, a fixed allowable increase of 3.2 ug/l applies. When the base TTHM concentration was less than 64 ug/l, the incremental increase was set-up such that the alternative TTHM concentration would not exceed the 64 ug/l constraint. At these times, the incremental constraint is the difference between 64 ug/l and the modeled base case, as is shown in Figure 4.62.

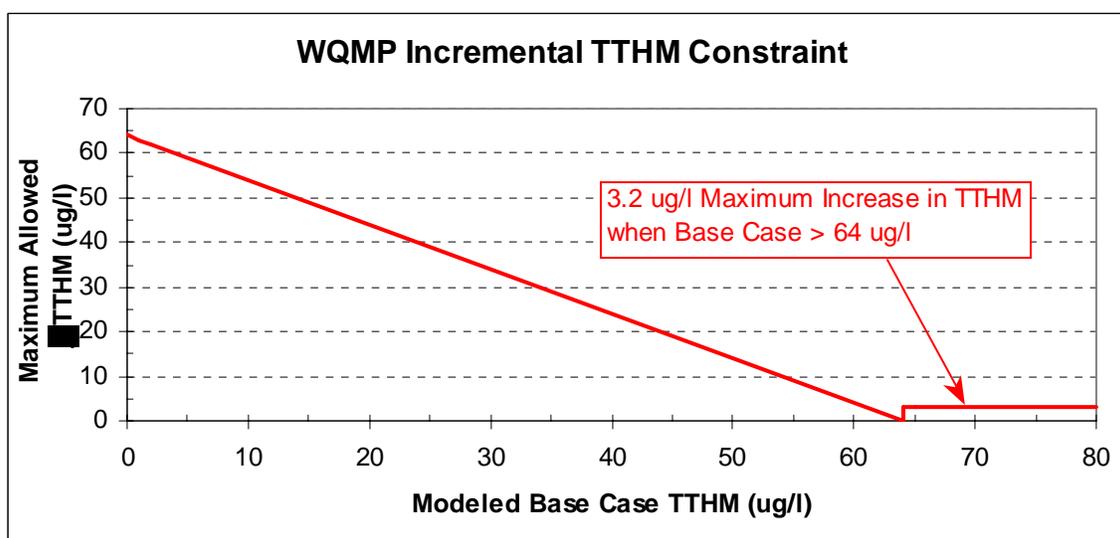


Figure 4.62: WQMP Incremental TTHM Constraint.

The maximum monthly averaged increases at the urban intakes are listed below in Table 4.18. Though the majority of these increases were less than the incremental TTHM constraint illustrated in Figure 4.62, there was one time (at Banks in July 1986) when the base case TTHM concentration was below 64 ug/l and the high-bookend TTHM concentration was greater than 64 ug/l. Otherwise, there were no violations of the incremental TTHM constraint during the course of the 16-year study.

Table 4.18: Maximum Monthly Averaged Increase in TTHM (ug/l).

| <i>Location</i> | <i>Low - Base</i> | <i>High - Base</i> |
|----------------------------------|-------------------|--------------------|
| Old River at Rock Slough | 5.65 | 18.14 |
| Old River at Los Vaqueros Intake | 5.10 | 19.07 |
| Banks Pumping Plant (SWP) | 5.27 | 22.58 |
| Tracy Pumping Plant (CVP) | 5.25 | 22.15 |

Frequency histograms of the percent increase in TTHM for the entire simulation period were used to create cumulative distribution functions (cdfs). These cdfs are shown in Figures 4.65, 4.68, 4.72, and 4.74. Although a change in TTHM concentration of 3.2 is shown on each figure,

the WQMP change in TTHM constraint frequently is much higher than this amount. However, this value, 3.2 ug/l, represents 5% of the 64 ug/l standard and thus is used to illustrate how frequently the change in TTHM is equal to or greater than a 5% change. The percent of time that the change in TTHM concentration is greater than 3.2 ug/l is shown for each location in Table 4.19.

Table 4.19: Percent of Time that the Change in TTHM is Greater Than 3.2 ug/l.

| <i>Location</i> | <i>%Exceedance Low - Base</i> | <i>%Exceedance High - Base</i> |
|----------------------------------|-----------------------------------|------------------------------------|
| Old River at Rock Slough | 5.3 | 7.7 |
| Old River at Los Vaqueros Intake | 3.6 | 8.0 |
| Banks Pumping Plant (SWP) | 2.3 | 8.5 |
| Tracy Pumping Plant (CVP) | 4.1 | 10.1 |

The number of months, out of the 192 months simulated, exceeding the WQMP TTHM constraints for both bookend simulations are shown below in Table 4.20. Though times when the simulated TTHM concentrations exceed 64 ug/l are listed, it is the change in TTHM constraint that measures the total number of violations of the WQMP. As discussed above, the only violation occurred at Banks for the high-bookend simulation in July 1986, because the high-bookend TTHM concentration exceeded 64 ug/l when the modeled base case TTHM was less than 64 ug/l.

Table 4.20: Number of Months of Exceedance of the WQMP TTHM Constraint.

| <i>Location</i> | 64 ug/l TTHM Constraint | | | Change in TTHM Constraint | |
|-------------------------------------|--------------------------------|------------|-------------|----------------------------------|-------------|
| | <i>Base</i> | <i>Low</i> | <i>High</i> | <i>Low</i> | <i>High</i> |
| Old River at Rock Slough | 0 | 0 | 0 | 0 | 0 |
| Old River at Los Vaqueros Reservoir | 1 | 1 | 1 | 0 | 0 |
| Banks Pumping Plant (SWP) | 2 | 0 | 1 | 0 | 1 |
| Tracy Pumping Plant (CVP) | 2 | 1 | 1 | 0 | 0 |

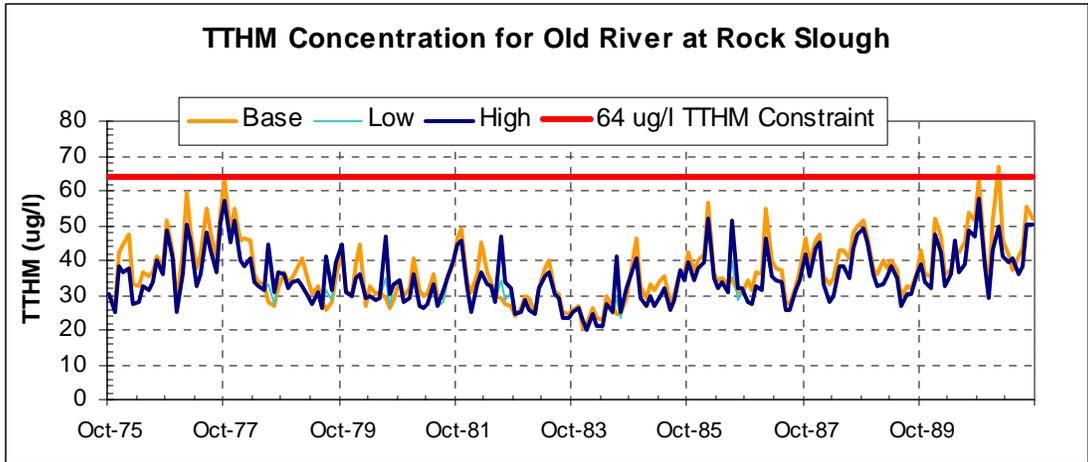


Figure 4.63: TTHM Concentration for Old River at Rock Slough.

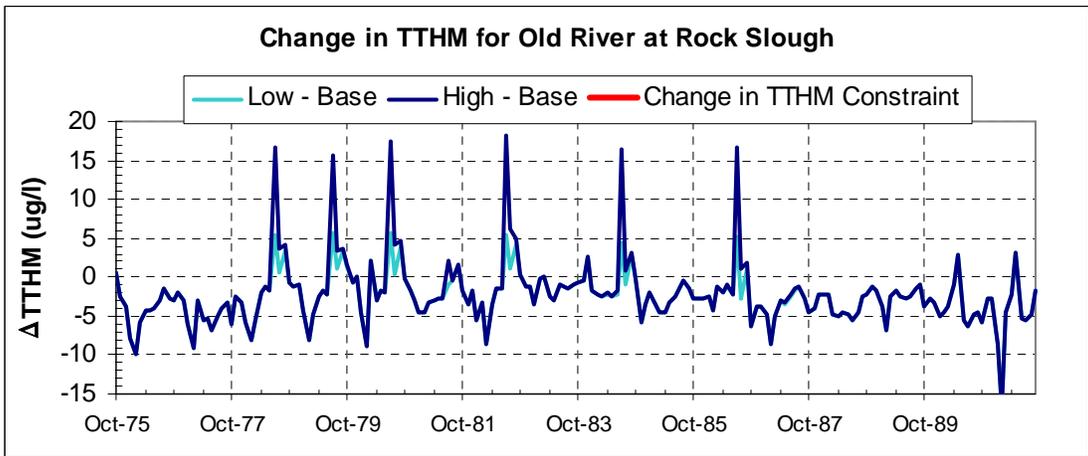


Figure 4.64: Change in TTHM for Old River at Rock Slough.

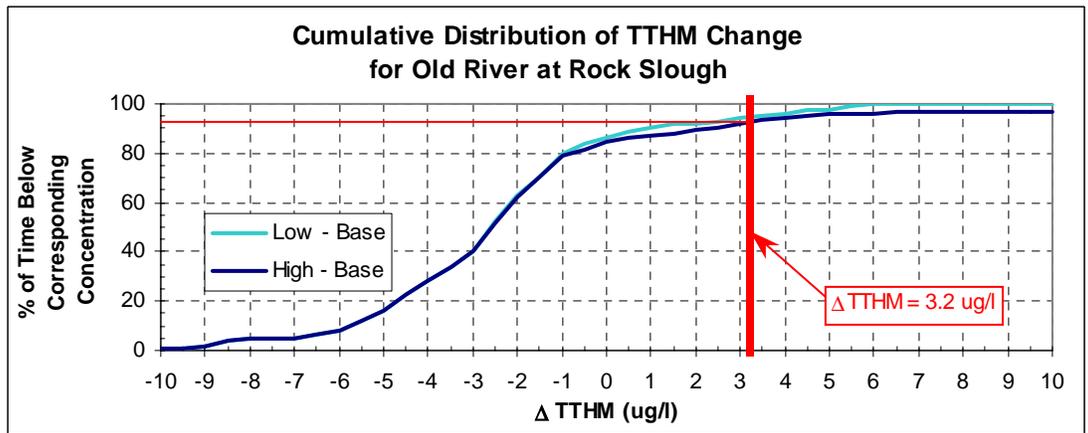


Figure 4.65: Cumulative Distribution of TTHM Change for Old River at Rock Slough.

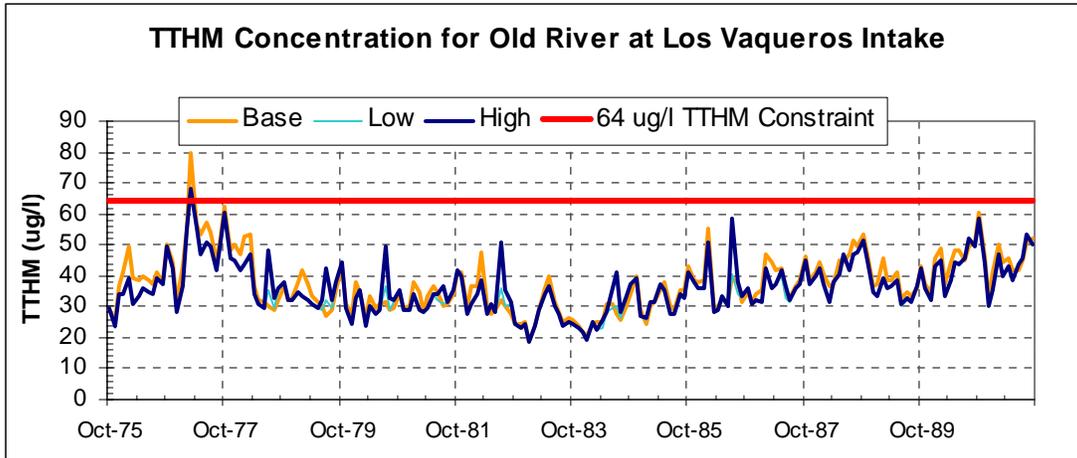


Figure 4.66: TTHM Concentration for Old River at Los Vaqueros Intake.

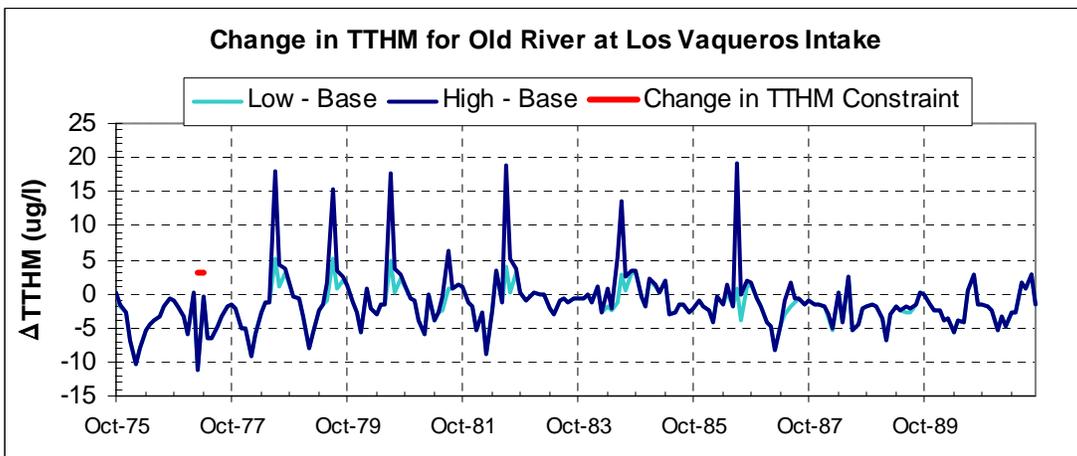


Figure 4.67: Change in TTHM for Old River at Los Vaqueros Intake.

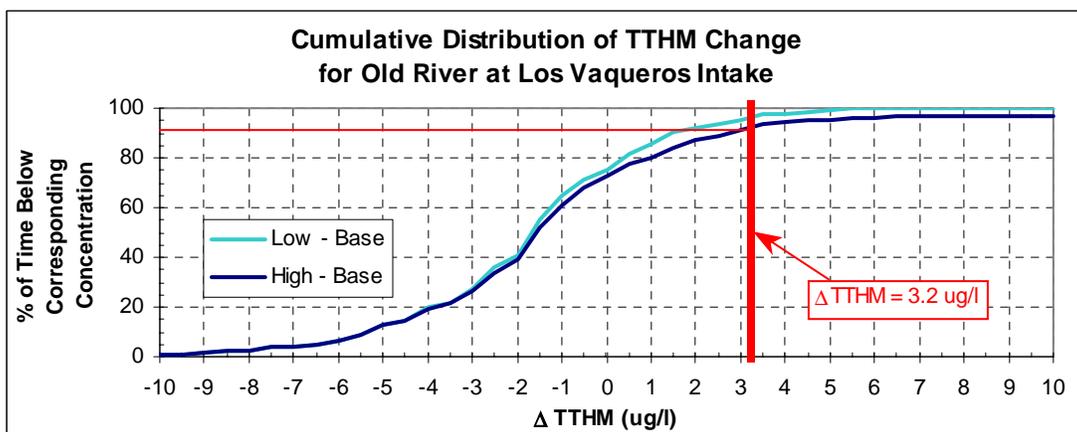


Figure 4.68: Cumulative Distribution of TTHM Change for Old River at Los Vaqueros Intake.

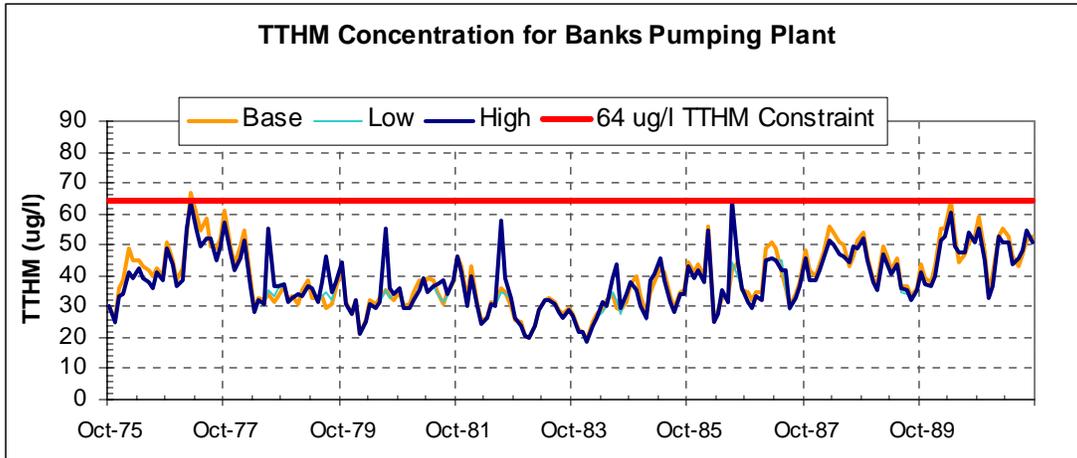


Figure 4.69: TTHM Concentration for Banks Pumping Plant.

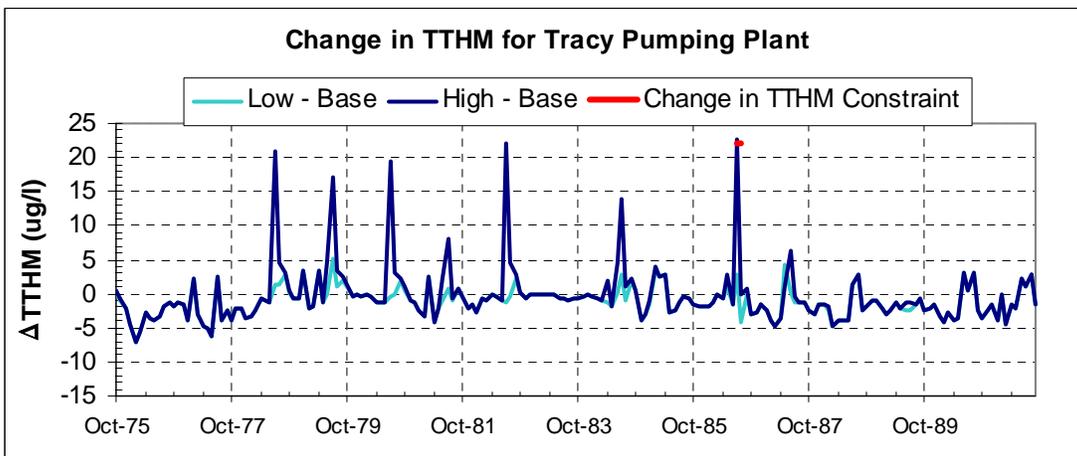


Figure 4.70: Change in TTHM for Banks Pumping Plant.

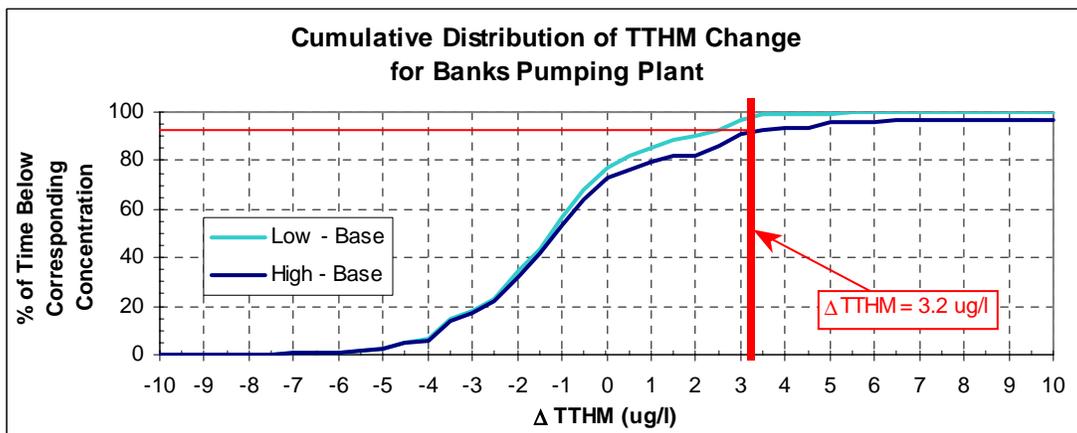


Figure 4.71: Cumulative Distribution of TTHM Change for Banks Pumping Plant.

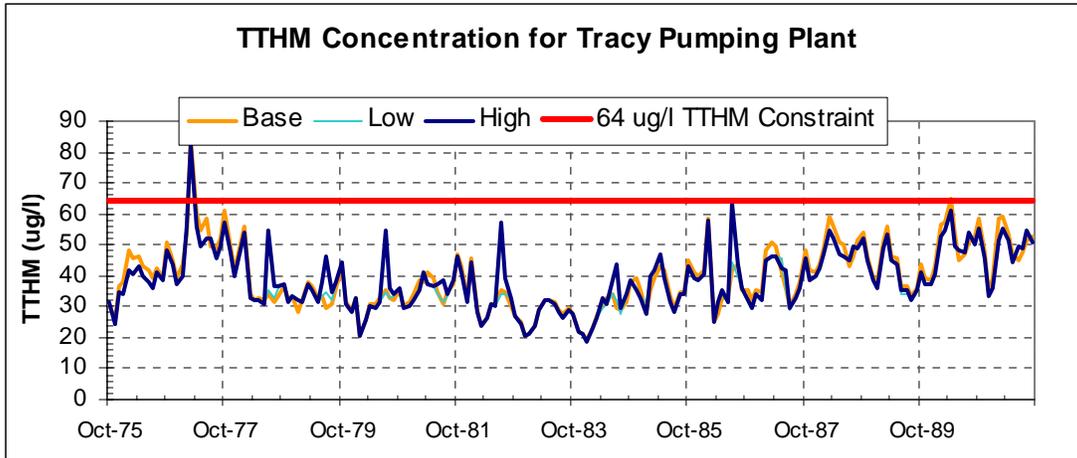


Figure 4.72: TTHM Concentration for Tracy Pumping Plant.

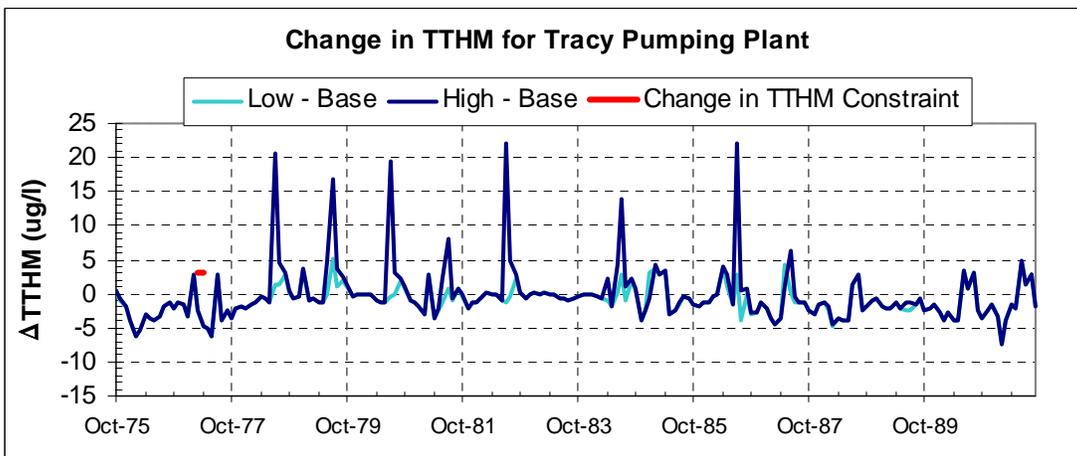


Figure 4.73: Change in TTHM for Tracy Pumping Plant.

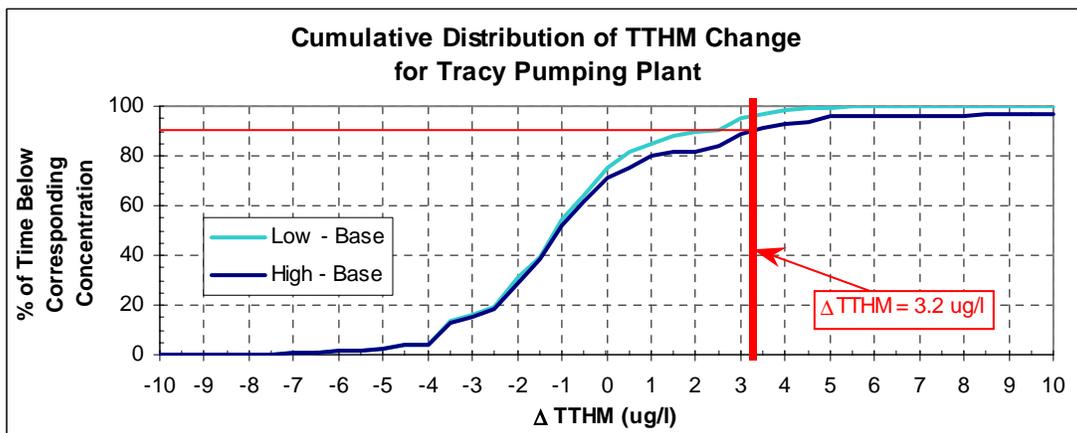


Figure 4.74: Cumulative Distribution of TTHM Change for Tracy Pumping Plant.

4.7 Bromate

According to the WQMP bromate formation is limited to 8 ug/l. For periods when the modeled base case exceeds this 8 ug/l constraint, the WQMP permitted a 5% increase above the constraint (0.4 ug/l) due to operation of the project.

Using EC and DOC discussed in Sections 4.1 and 4.3 above, bromate for all four urban intakes was calculated using (Hutton, 2001):

$$BRM = C_2 \times DOC^{0.31} \times Br^{0.73} \quad [\text{Eqn. 11}]$$

where

BRM = bromate (ug/l),

$C_2 = 9.6$ when $DOC < 4$ mg/l,

$C_2 = 9.2$ when $DOC \geq 4$ mg/l,

DOC = raw water dissolved organic carbon (mg/l) from DSM2, and

Br = raw water bromide (mg/l) from Equations 8 and 9.

The sensitivity of bromate formation potential to project operations is shown in Figures 4.76 - 4.87. Bromate formation is a function of both DOC and bromide concentration. The bromide concentration was calculated based on the EC results discussed in Section 4.1 using Equations 8, 9, and 10 (see Section 4.6). The two DOC bookends modeled were used to calculate two different bromate bookends. Time series plots of the monthly average bromate formation potential at the four intake locations are shown in Figures 4.76, 4.79, 4.82, and 4.85. The base case and alternative simulation bromate formation potentials frequently exceed the 8 ug/l level.

The maximum monthly average bromate concentrations for each of the bookend simulations is displayed in Table 4.21. The base case maximum monthly averaged bromate concentrations were higher than both alternative simulation concentrations for all four locations. Tracy had the highest maximum monthly bromate concentration for all three simulations.

Table 4.21: Maximum Monthly Averaged Bromate (ug/l).

| <i>Location</i> | <i>Base</i> | <i>Low Bookend</i> | <i>High Bookend</i> |
|----------------------------------|-------------|--------------------|---------------------|
| Old River at Rock Slough | 11.67 | 11.51 | 11.51 |
| Old River at Los Vaqueros Intake | 10.50 | 10.10 | 10.10 |
| Banks Pumping Plant (SWP) | 11.47 | 11.30 | 11.30 |
| Tracy Pumping Plant (CVP) | 12.96 | 12.86 | 12.86 |

The WQMP constrained the operation of the project such that bromate concentrations should not exceed 8 ug/l, unless the modeled base case bromate already exceeds 8 ug/l (Hutton, 2001). When the base bromate concentration exceeded this constraint, an incremental constraint of 0.4 ug/l applies. When the base bromate concentration was less than 8 ug/l, the incremental increase was set-up such that the alternative bromate concentration would not exceed the 8 ug/l

constraint. At these times the incremental constraint is simply the difference between 8 ug/l and the modeled base case, as is shown in Figure 4.75.

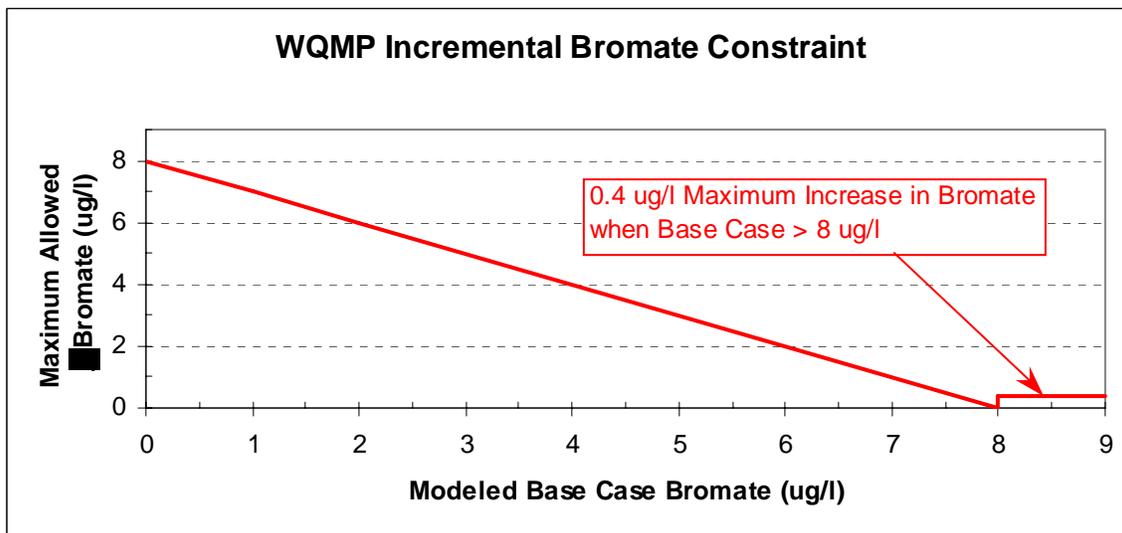


Figure 4.75: WQMP Incremental Bromate Constraint.

Time series plots illustrating the change in bromate formation (alternative - base) are shown in Figures 4.77, 4.80, 4.83, and 4.86. The incremental constraint discussed above is shown on each plot when it applies. The alternative simulation is in violation of this standard only when the change in bromate formation exceeds the constraint. Both the low- and high-bookend simulations violated the change in bromate formation constraint at Old River at Rock Slough and Old River at Los Vaqueros Intake in Oct. 1979. Both the low- and high-bookend simulations violated the change in bromate formation constraint two months, Oct. 1981 and Dec. 1988, at Banks and Tracy. The maximum difference between the alternative simulations and the base case generally decreased the further the output location was from the ocean boundary.

The maximum change in monthly averaged bromate formation for the two bookend simulations is displayed in Table 4.22. The largest increase in the monthly averaged bromate formation was at the Old River at Rock Slough location for both the low- and high-bookend simulations.

Table 4.22: Maximum Monthly Averaged Increase in Bromate (ug/l).

| <i>Location</i> | <i>Low - Base</i> | <i>High - Base</i> |
|----------------------------------|-------------------|--------------------|
| Old River at Rock Slough | 1.35 | 1.39 |
| Old River at Los Vaqueros Intake | 1.16 | 1.19 |
| Banks Pumping Plant (SWP) | 0.84 | 0.86 |
| Tracy Pumping Plant (CVP) | 0.85 | 0.87 |

Typically the maximum monthly bromate concentrations occur in the high salinity periods (winter). Changes in land use made using the DICU model coupled with the winter time diversion of water from Delta channels to the island reservoirs resulted in lower maximum monthly averaged bromate concentrations at the urban intake locations when compared to the

base case (see Table 4.21). However, the summer releases from the project islands resulted in increases in the monthly averaged bromate concentrations at the urban intakes (see Table 4.22).

Frequency histograms of the percent increase in bromate for the entire simulation period were used to create cumulative distribution functions (cdfs). These cdfs are shown in Figures 4.7.3, 4.7.6, 4.7.9, and 4.7.12. Although a change in bromate concentration of 0.4 ug/l is shown on each figure, the WQMP change in bromate formation constraint frequently is much higher than this amount. However, this value, 0.4 ug/l, represents 5% of the 8 ug/l standard and thus is used to illustrate how frequently the change in the bromate formation is equal to or greater than a 5% change. The percent of time that the change in bromate (alternative - base) is greater than this level is shown for each location in Table 4.23.

Table 4.23: Percent of Time that the Change in Bromate is Greater Than 0.4 ug/l.

| <i>Location</i> | <i>%Exceedance Low - Base</i> | <i>%Exceedance High - Base</i> |
|----------------------------------|-----------------------------------|------------------------------------|
| Old River at Rock Slough | 6.3 | 9.4 |
| Old River at Los Vaqueros Intake | 5.7 | 7.8 |
| Banks Pumping Plant (SWP) | 3.6 | 4.7 |
| Tracy Pumping Plant (CVP) | 3.6 | 4.7 |

The number of months, out of the 192 months simulated, exceeding the WQMP bromate constraints for both bookend simulations are shown below in Table 4.24. Though the simulated bromate concentration frequently exceeded 8 ug/l, it is the change in bromate constraint that measures the total number of violations of the WQMP. At the two locations closest to the ocean boundary, Old River at Rock Slough and Old River at Los Vaqueros Reservoir, the only violation of the change in bromate constraint occurred in Oct. 1979. Further south, the two violations occurred in Oct. 1981 and Dec. 1988.

Table 4.24: Number of Months of Exceedance of the WQMP Bromate Constraints.

| <i>Location</i> | 8 ug/l Bromate Constraint | | | Change in Bromate Constraint | |
|-------------------------------------|----------------------------------|------------|-------------|-------------------------------------|-------------|
| | <i>Base</i> | <i>Low</i> | <i>High</i> | <i>Low</i> | <i>High</i> |
| Old River at Rock Slough | 46 | 39 | 39 | 1 | 1 |
| Old River at Los Vaqueros Reservoir | 28 | 25 | 25 | 1 | 1 |
| Banks Pumping Plant (SWP) | 24 | 21 | 21 | 2 | 2 |
| Tracy Pumping Plant (CVP) | 26 | 23 | 23 | 2 | 2 |

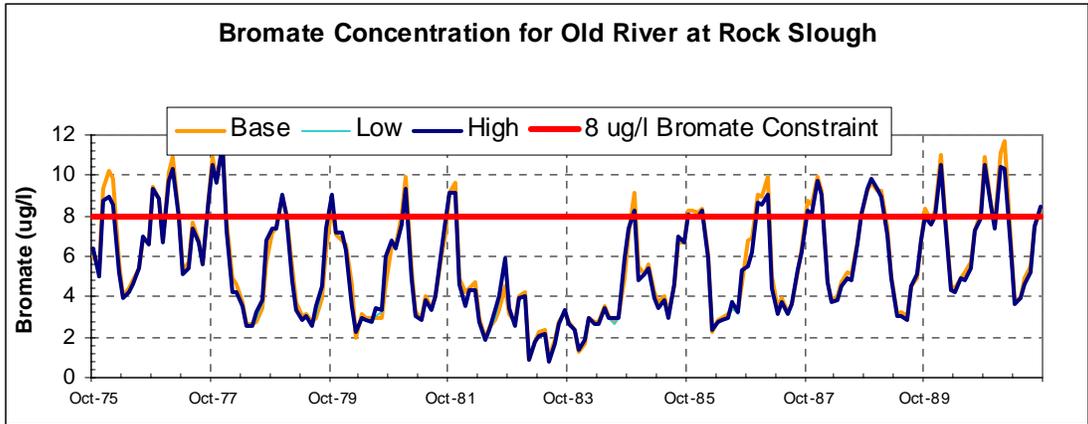


Figure 4.76: Bromate Concentration for Old River at Rock Slough.

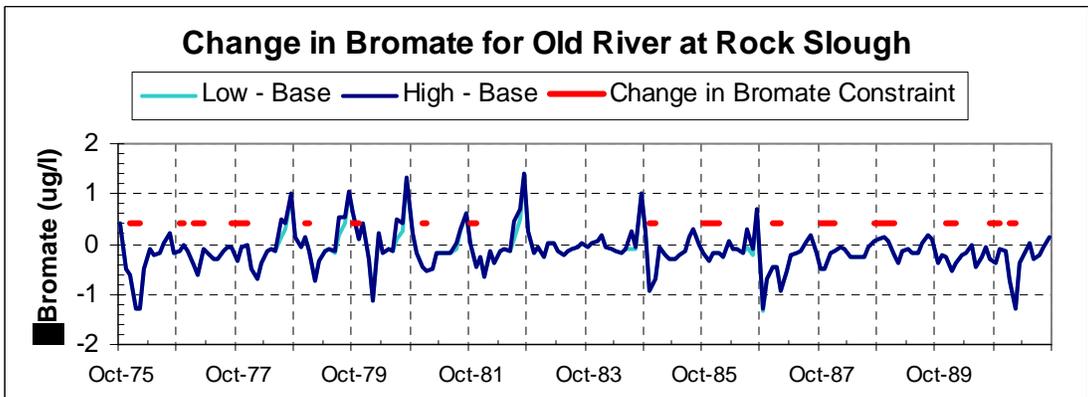


Figure 4.77: Change in Bromate for Old River at Rock Slough.

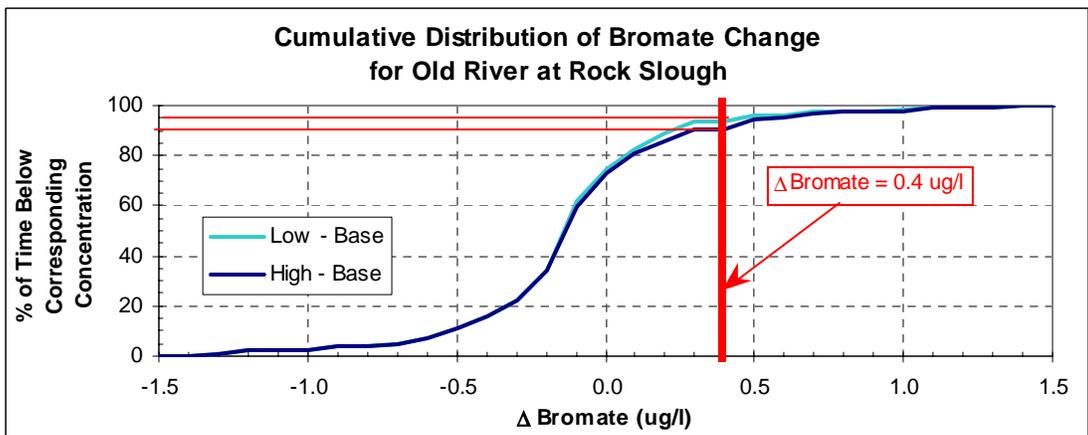


Figure 4.78: Cumulative Distribution of Bromate Change for Old River at Rock Slough.

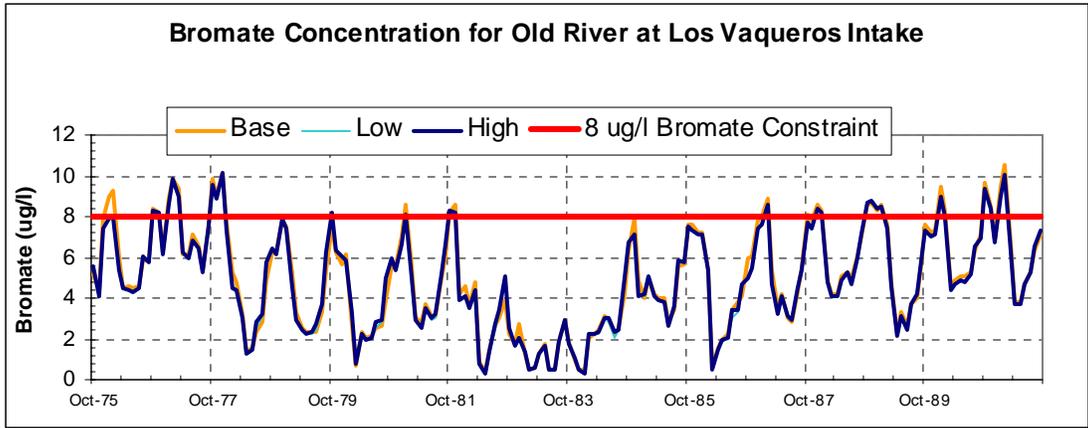


Figure 4.79: Bromate Concentration for Old River at Los Vaqueros Intake.

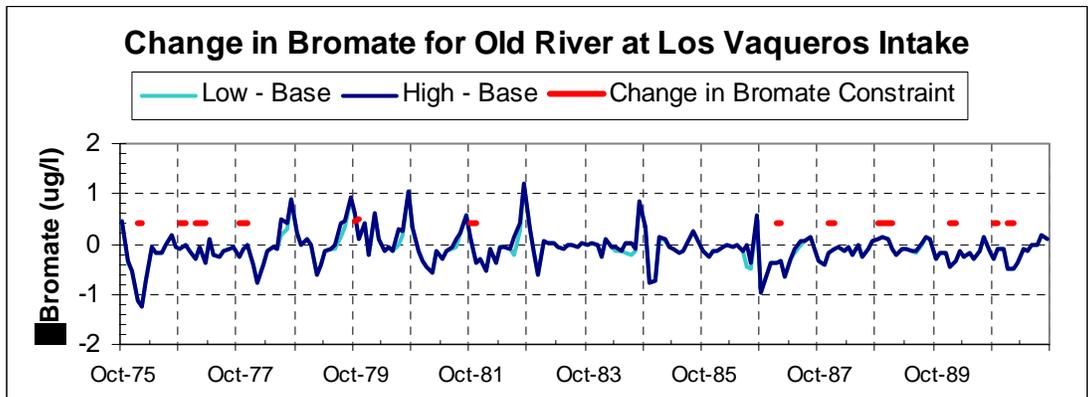


Figure 4.80: Change in Bromate for Old River at Los Vaqueros Intake.

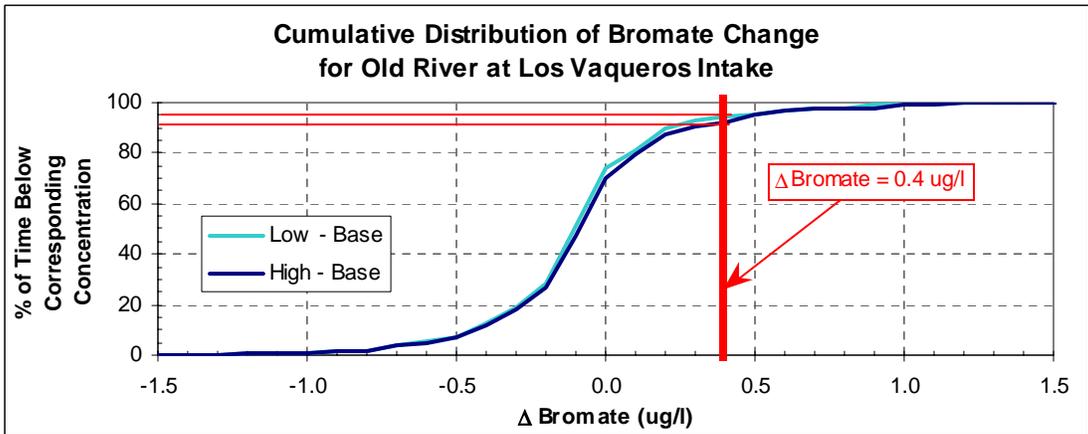


Figure 4.81: Cumulative Distribution of Bromate Change for Old River at Los Vaqueros Intake.

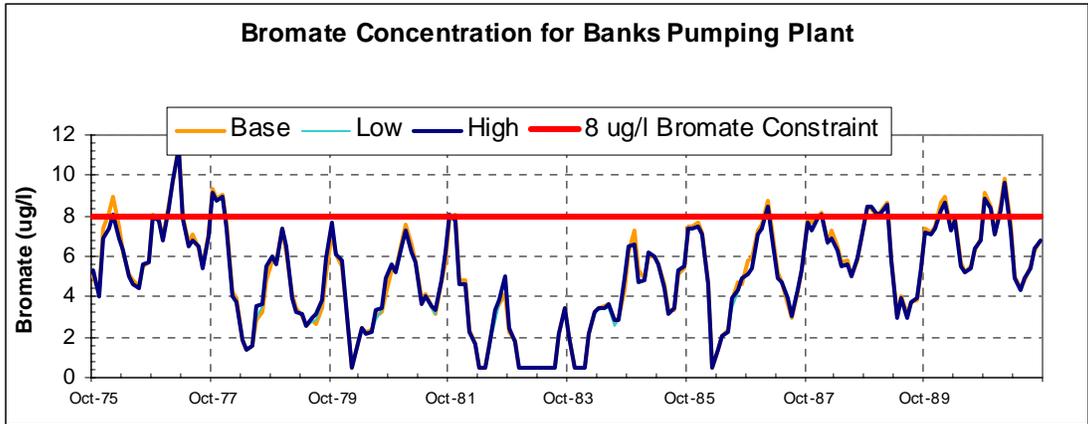


Figure 4.82: Bromate Concentration for Banks Pumping Plant.

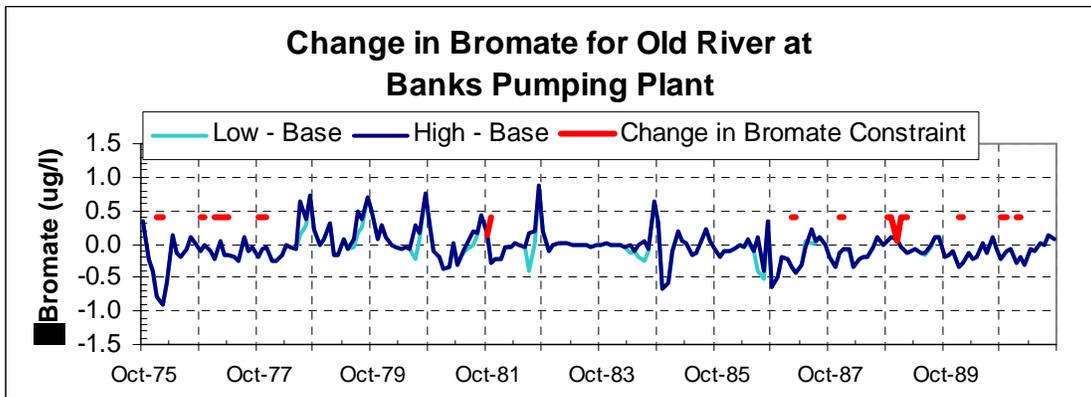


Figure 4.83: Change in Bromate for Banks Pumping Plant.

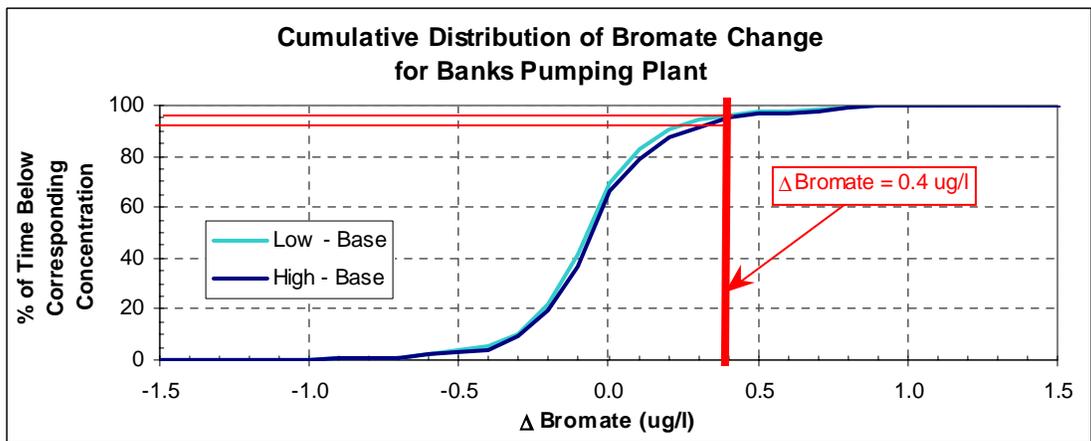


Figure 4.84: Cumulative Distribution of Bromate Change for Banks Pumping Plant.

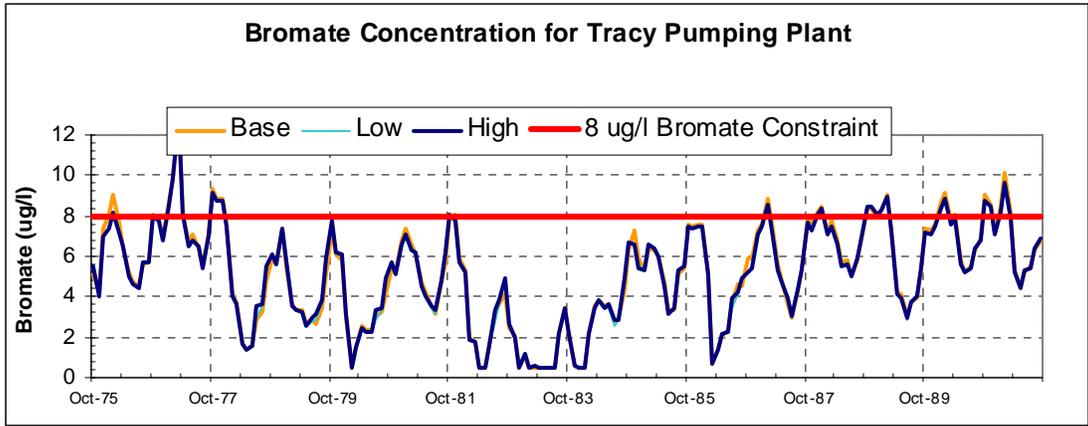


Figure 4.85: Bromate Concentration for Tracy Pumping Plant.

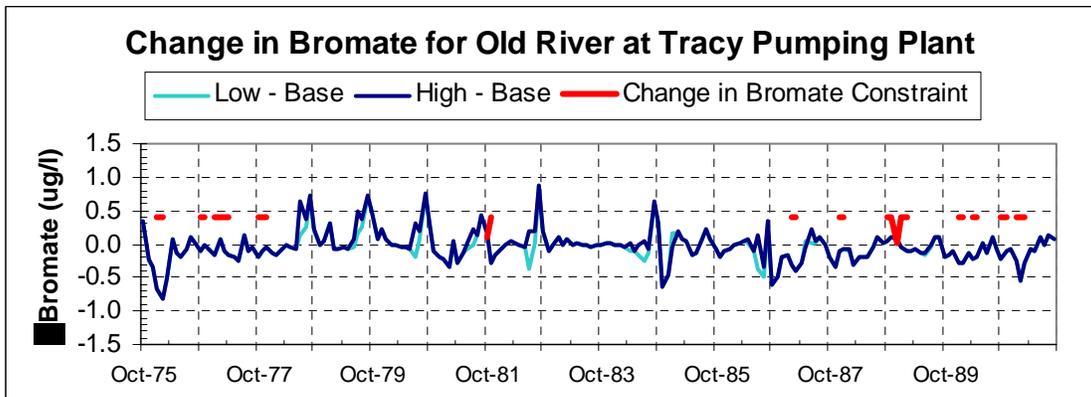


Figure 4.86: Change in Bromate for Tracy Pumping Plant.

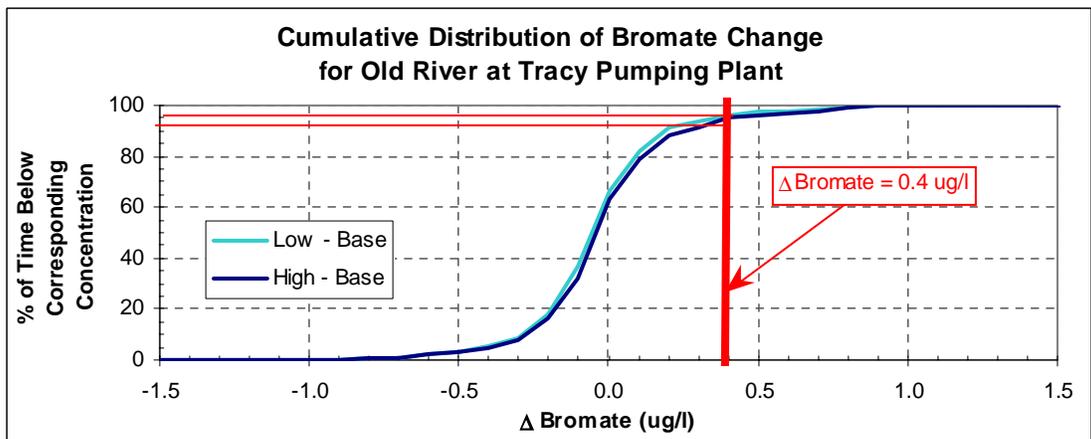


Figure 4.87: Cumulative Distribution of Bromate Change for Tracy Pumping Plant.

5 Conclusions

The results presented in this study focused primarily on comparing DSM2-QUAL results to the WQMP standards for chloride, DOC, TTHM, and bromate. DSM2-QUAL was modified to account for increases in DOC due to storage. There was no standard for UVA, but the results were shown above since they are used to calculate TTHM. The WQMP constraints apply at any of the urban water supply intakes, thus results were presented for the following locations: Old River at Rock Slough, Old River at the Los Vaqueros Reservoir, the Banks Pumping Plant (SWP), and the Tracy Pumping Plant (CVP) intakes.

A summary of the results for each constituent is presented below:

Chloride

- ❑ WQMP Constraints:
Change in Chloride ≤ 10 mg/l, and
Chloride (w/ Project) ≤ 225 mg/l.
- ❑ The base and alternative simulations exceeded 225 mg/l at the Old River at Rock Slough and Central Valley Project intakes. This constraint was not exceeded at the Old River at Los Vaqueros Reservoir intake and Banks Pumping Plant.
- ❑ The change in chloride due to operation of the project exceeded 10 mg/l at all four intake locations with the largest violation occurring at Rock Slough 5.7% of the time.
- ❑ The percent of time that change in chloride exceeded 10 mg/l ranged between 4 to 6% for the different intake locations.

Long-Term Chloride

- ❑ WQMP Constraint:
Change in Long-Term Chloride Mass Loading $\leq 5\%$.
- ❑ The operation of the project exceeded the WQMP 5% long-term increase constraint between 0 to 9% of the time for the three urban intakes.²⁰ The greatest violation occurred at Rock Slough with 14 months exceeding 5%.
- ❑ The long-term chloride mass loading ranged between 0.7 to 2 thousand metric-tons/month at Rock Slough, 15 to 28 thousand metric tons/month at Banks, and 11 to 23 thousand metric tons/month at Tracy for both the base and alternative simulations.

²⁰ Old River at Los Vaqueros Reservoir was not calculated because the operations provided by CALSIM II do not separate the CCWD diversions between Rock Slough and Los Vaqueros.

DOC

- ❑ WQMP Constraint:
Change in DOC ≤ 1 mg/l.²¹
- ❑ The low-bookend island release DOC quality ranged from 6 to 10 mg/l. The high-bookend island releases ranged from 13 to 22 mg/l.
- ❑ The base and both bookend alternative simulations exceeded 4 mg/l at all four intake locations.
- ❑ The change in DOC was greater than 1 mg/l at all four intake locations for high-bookend simulations. The change in DOC was greater than 1 mg/l at Banks and Tracy for the low-bookend simulations.
- ❑ The percent of time that change in DOC exceeded 1 mg/l ranged between 0 to 4% for the different intake locations.

Long-Term DOC

- ❑ WQMP Constraint:
Change in Long-Term DOC Mass Loading $\leq 5\%$.
- ❑ The Banks Pumping Plant exceeded the WQMP 5% long-term increase constraint 0 months for the low-bookend and 78 months for the high-bookend. The Old River at Rock Slough intake exceeded this constraint for only 12 months for the high-bookend simulation.
- ❑ The operation of the project exceeded the WQMP 5% long-term increase constraint 0% of the time for the three urban intakes for the low-bookend simulation.²² The WQMP 5% long-term increase constraint was exceeded 8 to 50% of the time for the high-bookend simulation.
- ❑ The long-term DOC mass loading ranged between 0.04 to 0.065 thousand metric-tons/month at Rock Slough, 0.5 to 1.9 thousand metric tons/month at Banks, and 0.7 to 1.2 thousand metric tons/month at Tracy for both the base and both bookend simulations.

²¹ The Δ DOC constraint was between 0 and 1 mg/l depending on the modeled base case DOC concentration (see Hutton, 2001).

²² Old River at Los Vaqueros Reservoir was not calculated because the hydrodynamics provided by CALSIM II do not separate the CCWD diversions between Rock Slough and Los Vaqueros.

TTHM

- ❑ WQMP Constraint:
Change in TTHM ≤ 3.2 ug/l.²³
- ❑ The base and both bookend alternative simulations exceeded 64 ug/l at the Old River at Los Vaqueros Reservoir Intake and Tracy. The Banks and Tracy Pumping Plants exceeded the 64 ug/l concentration level for the base case and high-bookend, however, the high-bookend simulation did not increase the TTHM concentration at this time. Old River at Rock Slough did not exceed this concentration for any of the simulations.
- ❑ The percent of time that the change in TTHM was greater than 3.2 ug/l due to operation of the project ranged between 2 to 5% of the time for the different intake locations for the low-bookend simulation. Similarly, TTHM increased 7.7 to 10% of the time for the high-bookend simulation.
- ❑ The change in TTHM constraint was violated only once for the high-bookend simulation at Banks. The rest of the time that the change in TTHM was greater than 3.2 ug/l, the base case was less than 64 ug/l and the alternative did not exceed 64 ug/l.

Bromate

- ❑ WQMP Constraint:
Change in Bromate ≤ 0.4 ug/l.²⁴
- ❑ The base and both bookend alternative simulations exceeded 8 ug/l at all four intake locations. Rock Slough exceeded this concentration 39 months for both the low- and high-bookend simulations; compared to the 46 months the base case exceeded 8 ug/l at Rock Slough.
- ❑ The percent of time that the change in bromate was greater than 0.4 ug/l ranged around 6% at Old River at Rock Slough and Old River at Los Vaqueros for the low-bookend. This percentage increased to range between 8 and 9% for the same locations for the high-bookend. However, only one month did these increases result in a violation of the WQMP constraint. The rest of the time that the change in bromate was greater than 0.4 ug/l, the base case was less than 8 ug/l and the alternative did not exceed 8 ug/l.
- ❑ The percent of time that the change in bromate was greater than 0.4 ug/l at Banks and Tracy was less for both bookend simulations than for the other two locations, however, a total of two months these increases resulted in violations of the WQMP constraint.

²³ The Δ TTHM constraint permitted any increase in TTHM when the base case was less than 64 ug/l, otherwise it limited the Δ TTHM to 5% of 64 ug/l (Hutton, 2001).

²⁴ The Δ Bromate constraint permitted any increase in Bromate when the base case was less than 8 ug/l, otherwise it limited the Δ Bromate to 5% of 8 ug/l (Hutton, 2001).

Over the course of the 16-year study, there was a violation of each water quality constraint at least one of the locations for the high-bookend simulations. The low-bookend simulations met the long-term DOC and TTHM constraints at all four locations, however there were violations at some of the locations for all of the other water quality constraints. The most significant violations of the WQMP constraints involved DOC. The Old River at Rock Slough was the only location that did not have a violation in the low-bookend. Out of the eight major release periods, the two Old River locations violated the high-bookend WQMP constraints 6 times, and then the Banks Pumping Plant (SWP) and Tracy Pumping Plant (CVP) violated the WQMP constraints 7 times.

There are chloride and bromate violations in the alternative simulations. Although these violations are not directly related to the releases or diversions (meaning they do not always occur during a project release or diversion), they represent a cumulative impact resulting from the re-operation of the entire system in CALSIM.

It is important to note that all of the results presented in this report were based on monthly averages. The WQMP actually applies to 14-day running averages. However, the process of averaging water quality results on a monthly basis tended to smooth out peaks in the results.

The modifications to QUAL did not account for increases in stored DOC due to primary productivity or due to seepage into the reservoirs from the neighboring channels. Robert Duvall of DWR-ISI is conducting work to study the impact of primary productivity.

The violations of the WQMP incremental standards could be minimized by implementing changes in the operation of the project (such as by designing additional operating constraints for CALSIM II to use while modeling the project diversions and releases). Previous DSM2-CALSIM II Delta wetlands studies have shown larger numbers (and magnitudes) of WQMP violations (Mierzwa, 2001). The principle differences between this and previous DSM2 studies are in the CALSIM II operations. One suggested approach to implementing changes in the operation of the project would be to decrease the magnitude of releases from the project islands, but extend the duration of these releases such that a similar volume of water is released.

6 References

- Anderson, J. (2001). *DOC-UVA Correlations*. Draft Memo, December 7, 2001. California Department of Water Resources. Sacramento, CA.
- Ateljevich, E. (2001a). "Chapter 11: Improving Estimates of Salinity at the Martinez Boundary." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 21st Annual Progress Report to the State Water Resources Control Board*. California Department of Water Resources. Sacramento, CA.
- Ateljevich, E. (2001b). "Chapter 10: Planning Tide at the Martinez Boundary." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*.

- 21st Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.
- Delta Wetlands Water Quality Management Plan. (2000). *Exhibit B from the Protest Dismissal Agreement Between Contra Costa Water District and Delta Wetlands Properties.*
- Easton, D. (2001). *CALSIM Model Runs; In-Delta Storage Facilities.* Draft Memo, December, 2001. California Department of Water Resources. Sacramento, CA.
- Forkel, D. (2001). Correspondence about Delta in channel water temperatures for use in calculating TTHM formation.
- Hutton, P. (2001). *ISI In-Delta Storage: CALSIM Water Quality Constraints to Meet Delta Wetlands WQMP.* Draft Memo, May 29, 2001. California Department of Water Resources. Sacramento, CA.
- Jung, M. (2000). *Revision of Representative Delta Island Return Flow Quality for DSM2 and DICU Model Runs, Municipal Water Quality Investigation Program.* California Department of Water Resources – Division of Planning and Local Assistance, Sacramento, CA.
- Jung, M. (2001a). *Reservoir Island Organic Carbon Model: Executive Summary.* Draft Report, November 2001. California Department of Water Resources. Sacramento, CA.
- Jung, M. (2001b). E-mail correspondence about recommended wetland return water quality concentrations.
- Mierzwa, M. (2001). *Delta Wetlands Preliminary DSM2 Studies.* Memo, August 26, 2001. California Department of Water Resources. Sacramento, CA.
- Pandey, G. (2001). Implementation of DOC Growth Module in DSM2-QUAL. Draft Memo, November 28. California Department of Water Resources. Sacramento, CA.
- Suits, B. (2001a). *Boundary DOC and UVA for DSM2 Planning Studies.* Memo, November 19, 2001. California Department of Water Resources. Sacramento, CA.
- Suits, B. (2001b). *Relationships Between EC, Chloride, and Bromide at Delta Export Locations.* Memo, May 29, 2001. California Department of Water Resources. Sacramento, CA.