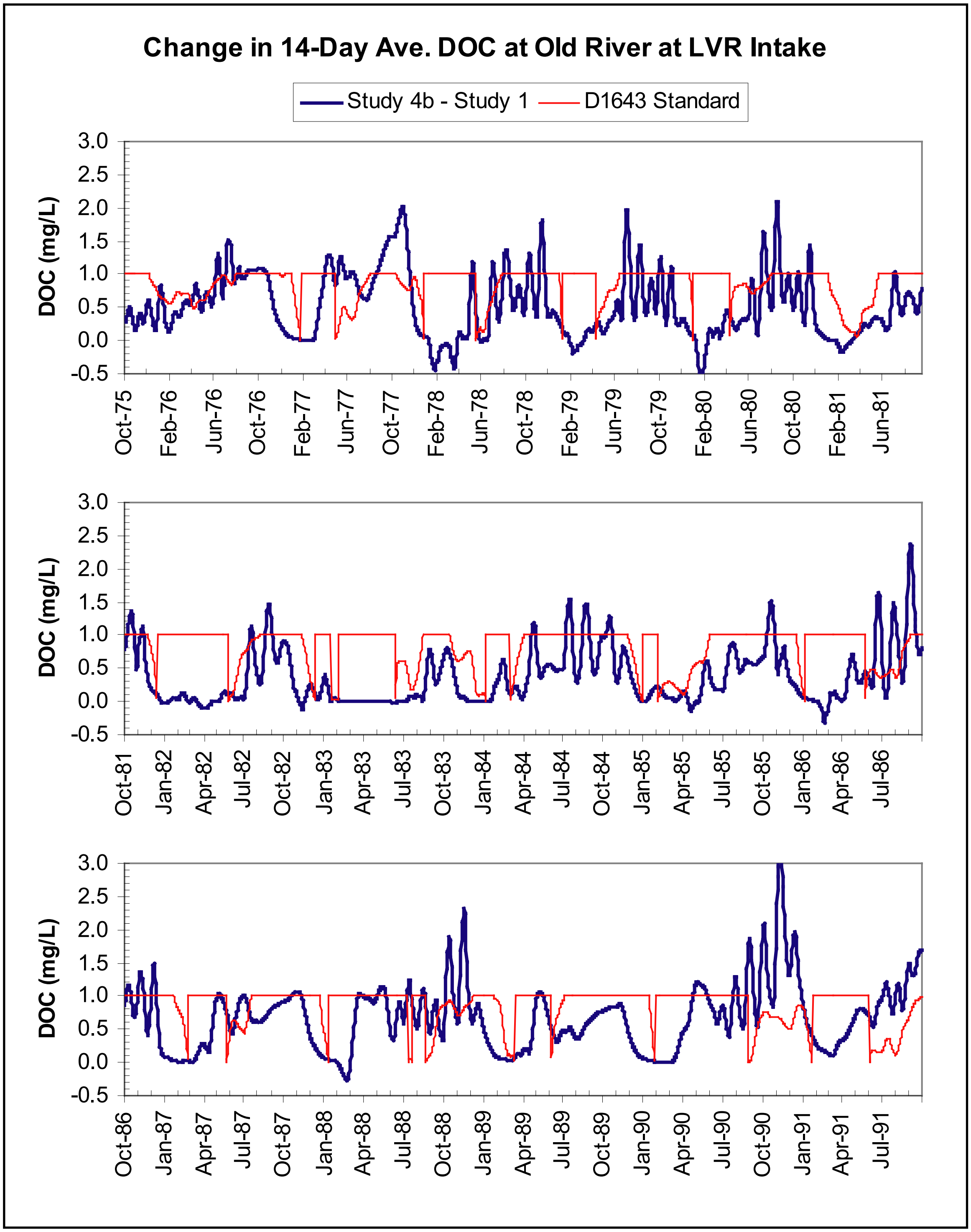

Figure 2.5.22: Change in 14-Day Average DOC (mg/L) at Old River at LVR Intake (LVR).

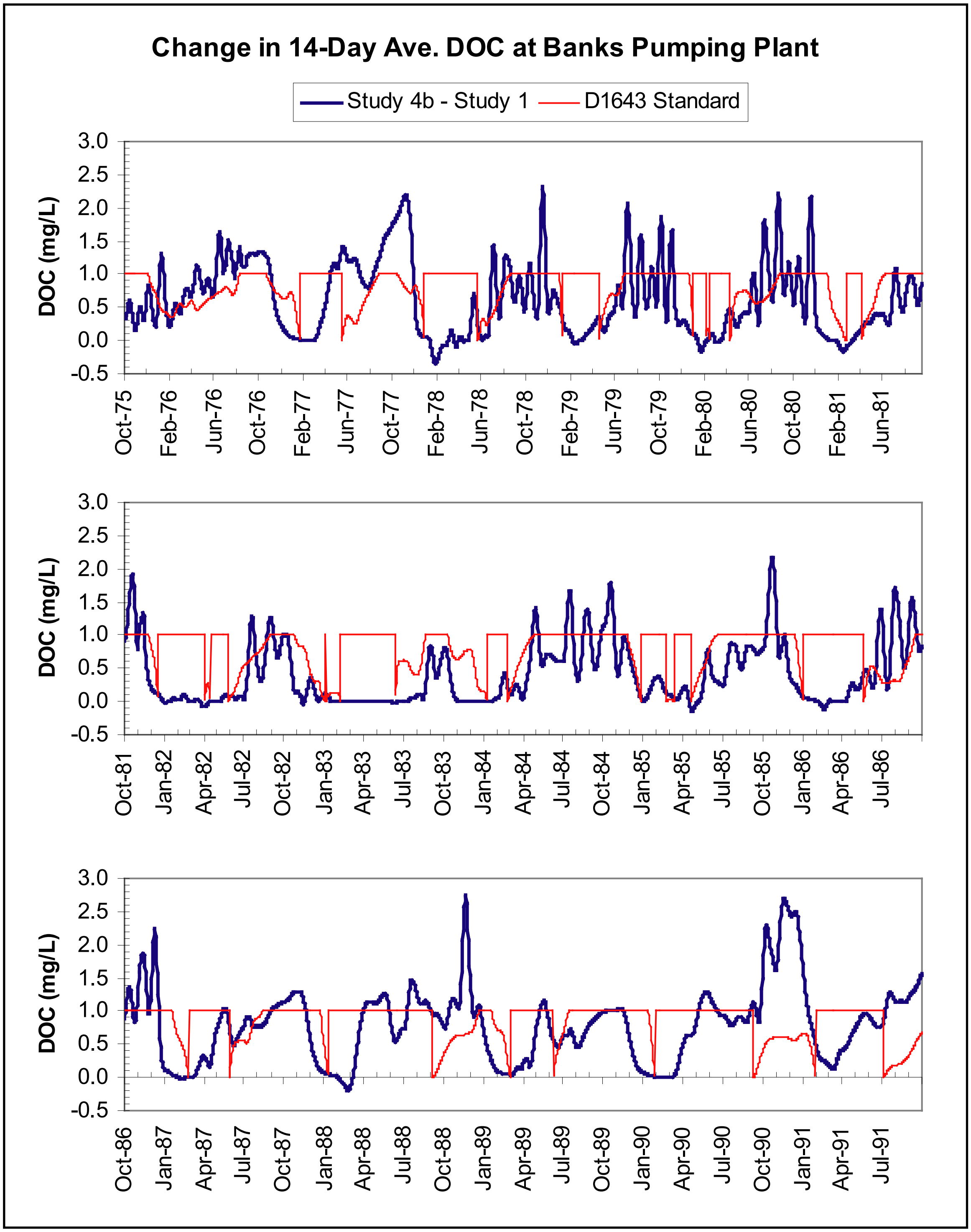

Figure 2.5.23: Change in 14-Day Average DOC (mg/L) at Banks Pumping Plant (SWP).

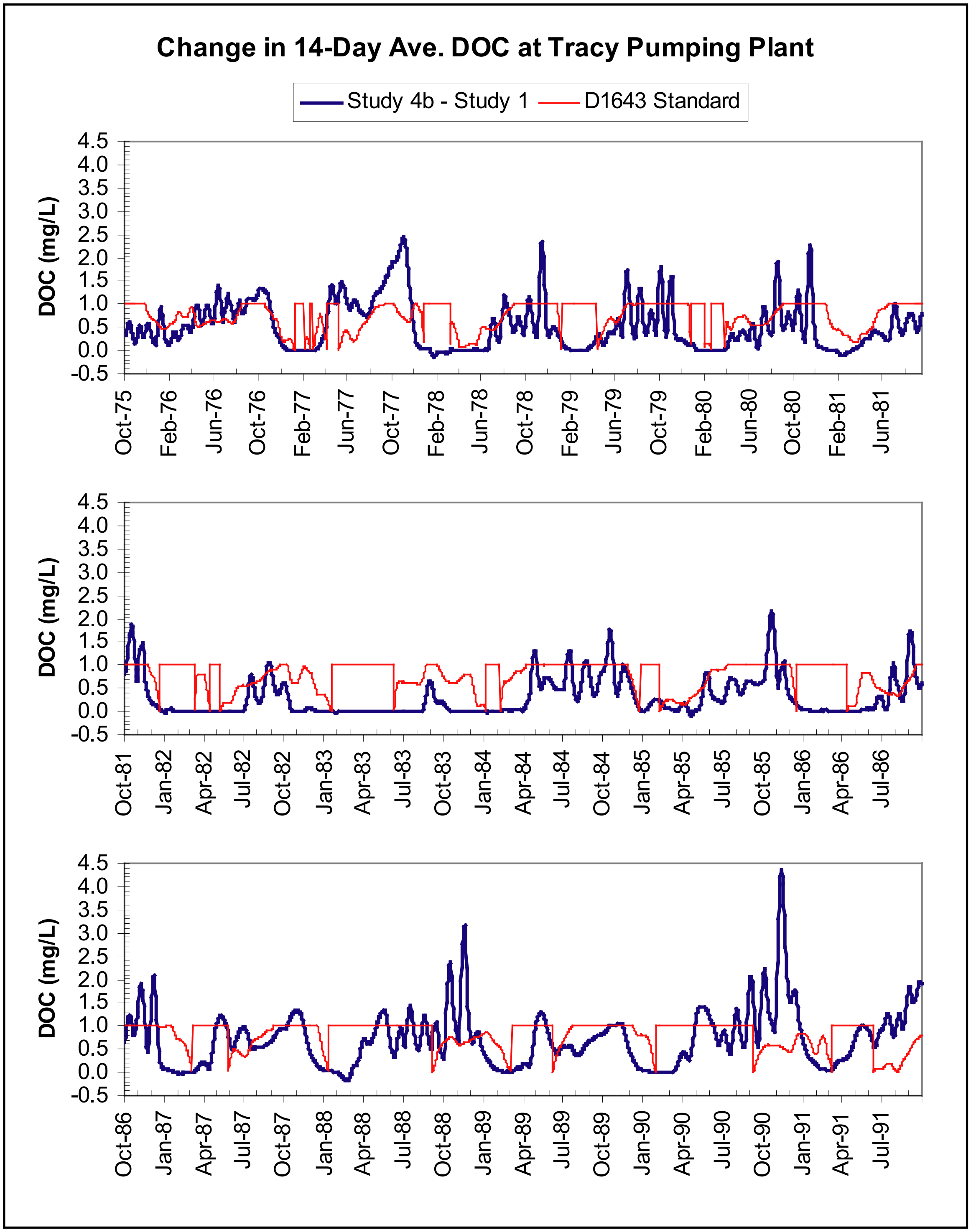

Figure 2.5.24: Change in 14-Day Average DOC (mg/L) at Tracy Pumping Plant (CVP).

2.5.4 TTHM at Urban Intakes

Like the chloride and DOC constraints, the impact of total trihalomethane (TTHM) formation is measured by increases in the project alternative when compared to the modeled base case concentration. TTHM is not directly modeled in DSM2. The WQMP established an incremental standard (described below) and agreed upon the basic modeling approach to be used to calculate TTHM. TTHM is calculated as a function of EC, DOC, and water temperature using the following formulas (Hutton, 2001):

$$TTHM = C_1 \times DOC^{0.228} \times UVA^{0.534} \times (Br+1)^{2.01} \times T^{0.48} \qquad \text{Eqn. 5.12}$$

where

TTHM = total trihalomethane concentration (ug/L),
C_1 = 14.5 when DOC < 4 mg/L,
C_1 = 12.5 when DOC ≥ 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) from EC, and
T = raw water temperature (C).

Although UVA boundary conditions have been developed for DSM2, due to time constraints UVA was not simulated in DSM2-QUAL. Instead, relationships between UVA and DOC were developed for each of the four urban intakes based on MWQI grab sample data (Wilde, 2003). Based on the grab sample data the following regressions were used to convert modeled DOC into UVA:

$$UVA_{RS} = 0.0374 DOC_{RS} - 0.0152 \qquad \text{Eqn. 5.13}$$

$$UVA_{LVR} = 0.0401 DOC_{LVR} - 0.021 \qquad \text{Eqn. 5.14}$$

$$UVA_{SWP} = 0.0366 DOC_{SWP} - 0.0121 \qquad \text{Eqn. 5.15}$$

$$UVA_{CVP} = 0.037 DOC_{CVP} - 0.0209 \qquad \text{Eqn. 5.16}$$

The bromide concentration at Rock Slough was developed from regressions of (1) Contra Costa Canal Pumping Plant #1 chloride data to Contra Costa Canal Pumping Plant #1 data, and (2) Contra Costa Canal Pumping Plant #1 chloride data to Rock Slough EC (Suits, 2001). The bromide relationship used in Equation 5.12 for Rock Slough is:

$$Br_{RS} = \frac{EC_{RS} - 118.7}{1040.3} \qquad \text{Eqn. 5.17}$$

The bromide relationship used for the remaining urban intake locations was developed based on Delta wide relationships (Suits, 2001):

$$Br = \frac{EC - 189.2}{1020.77} \qquad \text{Eqn. 5.18}$$

During a few periods DSM2-QUAL's EC concentrations were so low that using these field conversions would have resulted in negative bromide concentrations. A mimimum bromide concentration of 0.05 ug/L was assumed during these periods.

The monthly average water temperatures used in Equation 5.12 are shown below in Figure 2.5.25. These temperature data originally came CCWD water treatment plant averages (Hutton, 2001).

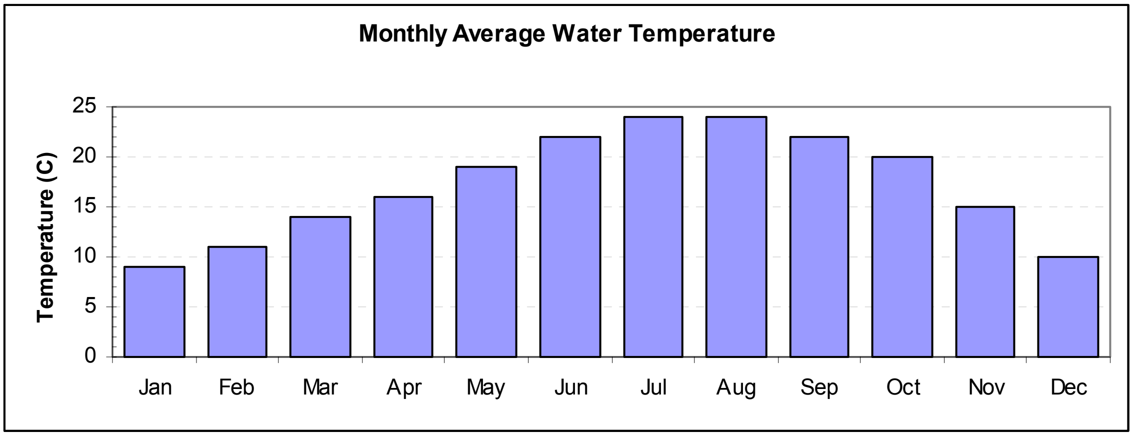

Figure 2.5.25: Monthly Average Water Temperature Used to Calculate TTHM.

The 16-year minimum, average, and maximum daily averaged TTHM concentration at the four urban intakes for study 1 (base case) and study 4b is shown below in Table 2.5.11. The TTHM concentration associated with the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile at each location is also shown. These percentiles were calculated in the same manner as the chloride percentiles (see *Section 2.5.2*). Although the 50^{th} percentile (median) TTHM concentrations for all locations are similar to the 16-year average concentrations, the 90^{th} percentile concentrations are much lower than the 16-year maximums.

Table 2.5.11: Summary of Daily Averaged TTHM (ug/L) at Urban Intakes.

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10^{th}	25^{th}	50^{th}	75^{th}	90^{th}
RS	Study 1	18	37	88	25	29	35	43	52
	Study 4b	18	42	115	27	31	38	49	60
LVR	Study 1	17	36	77	25	29	35	42	50
	Study 4b	17	41	131	27	32	38	48	57
SWP	Study 1	19	35	63	25	29	35	40	47
	Study 4b	19	40	82	27	32	38	47	53
CVP	Study 1	17	37	102	26	30	37	43	49
	Study 4b	17	41	113	26	32	40	49	57

The 14-day average TTHM constraints called for by the Delta Wetlands WQMP were calculated every day as the average of the 14 previous days (WQMP, 2000). This was done not only to remain consistent with CALSIM, but also under the assumption that forecasting and operations would make use of the previous 14 days worth of field and modeling data. A summary of the 14-day average TTHM constraints is shown in Table 2.5.12.

Table 2.5.12: Summary of 14-Day Average TTHM (ug/L) at Urban Intakes.

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	19	37	85	26	29	35	43	51
	Study 4b	20	41	104	27	32	38	49	59
LVR	Study 1	20	36	73	25	29	35	42	50
	Study 4b	20	41	108	28	32	39	48	57
SWP	Study 1	20	35	61	26	29	35	40	47
	Study 4b	20	40	75	27	32	38	47	52
CVP	Study 1	18	37	89	26	30	37	43	49
	Study 4b	18	41	103	26	32	40	49	56

Time series plots of the 14-day running average TTHM at all four urban intakes are shown below in Figures 2.5.26 – 2.5.29.

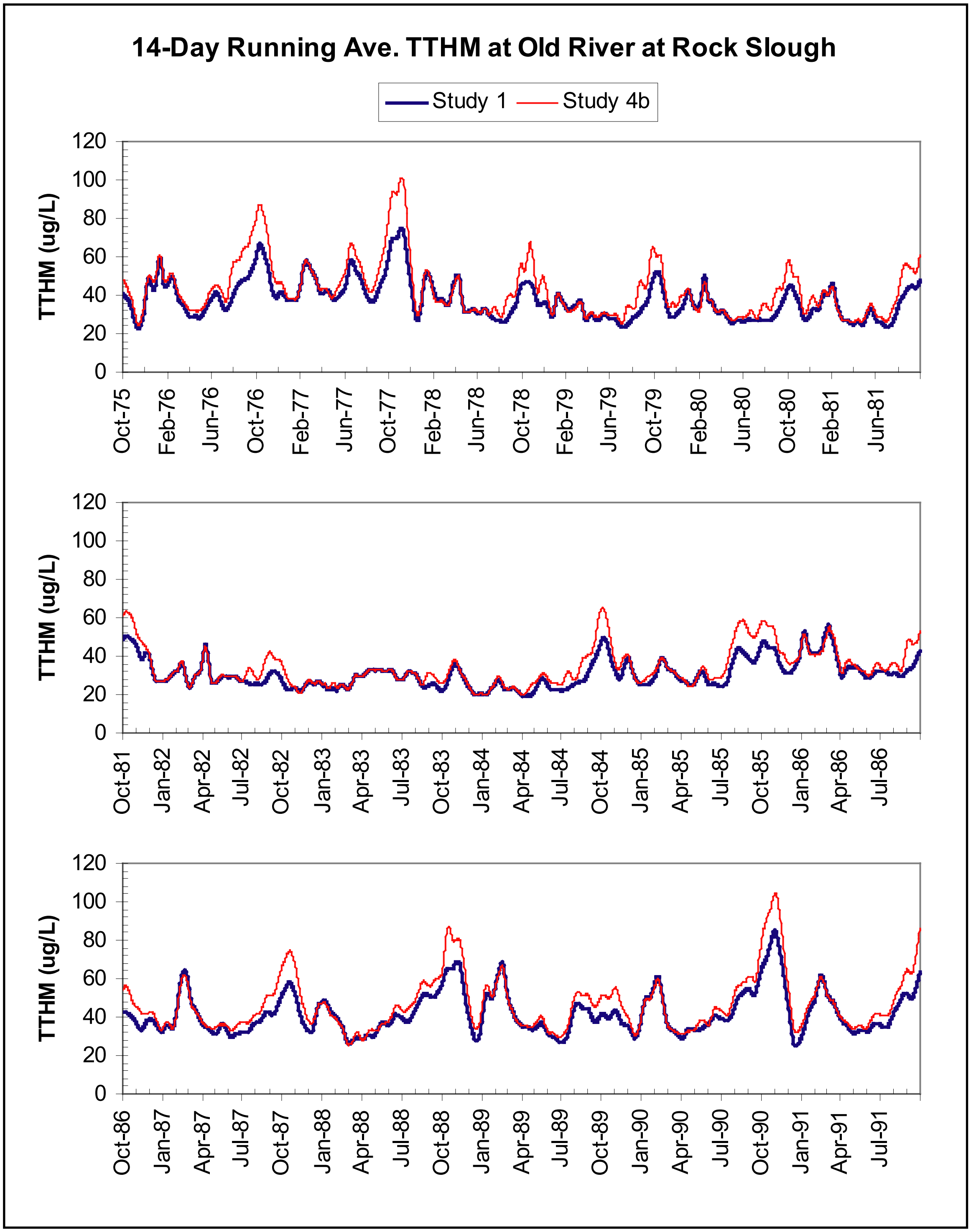

Figure 2.5.26: 14-Day Average TTHM (ug/L) at Old River at Rock Slough (RS).

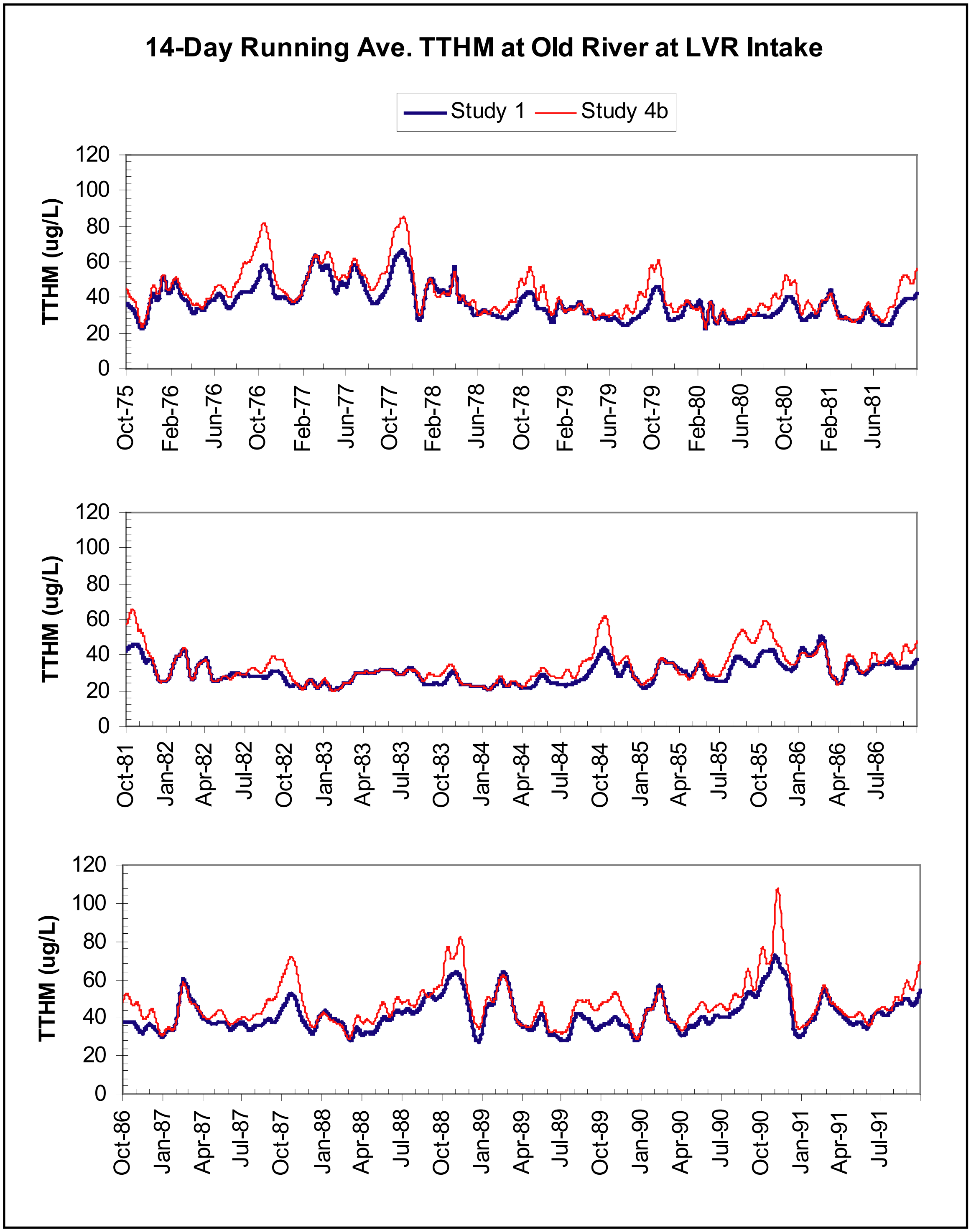

Figure 2.5.27: 14-Day Average TTHM (ug/L) at Old River at LVR Intake (LVR).

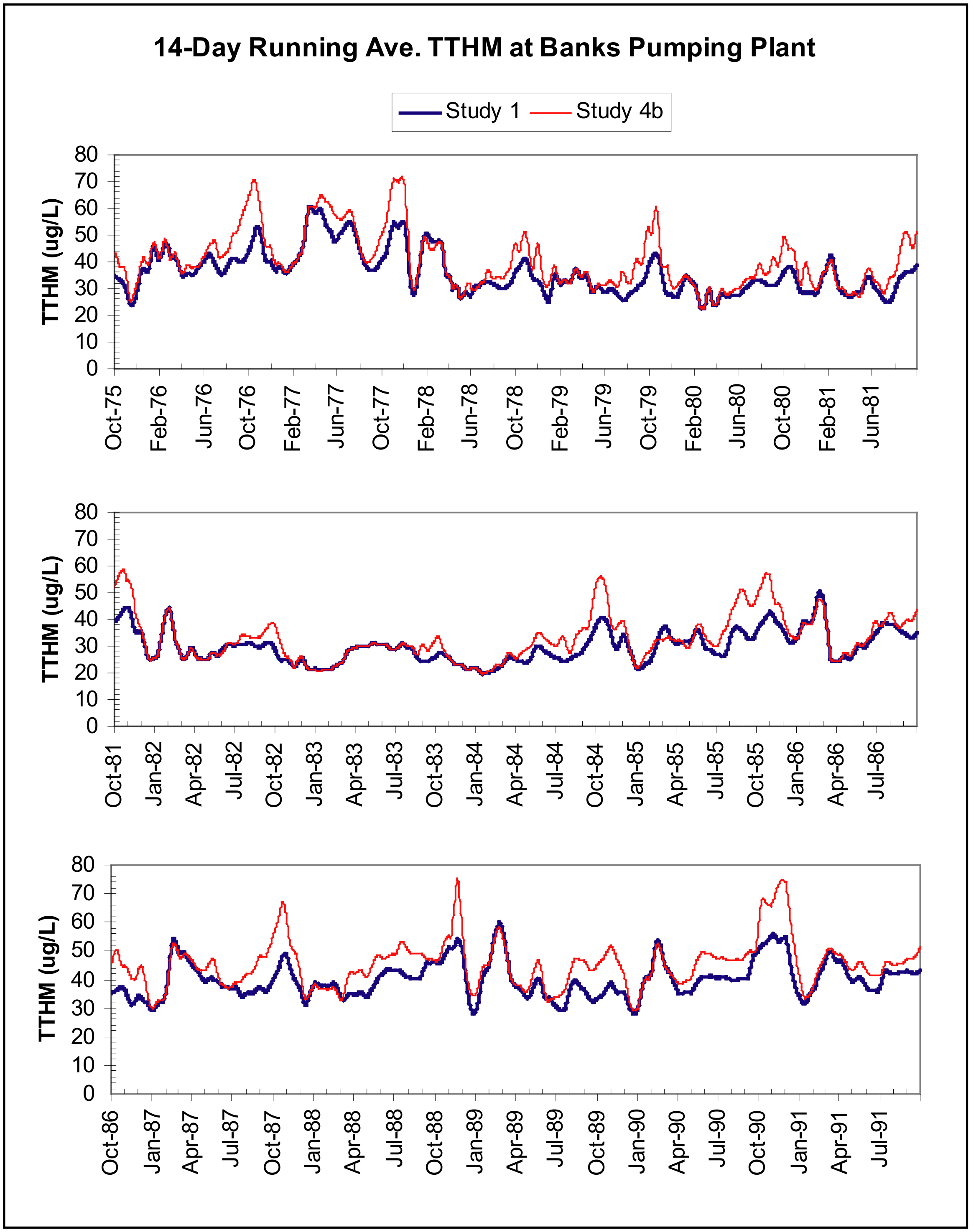

Figure 2.5.28: 14-Day Average TTHM (ug/L) at Banks Pumping Plant (SWP).

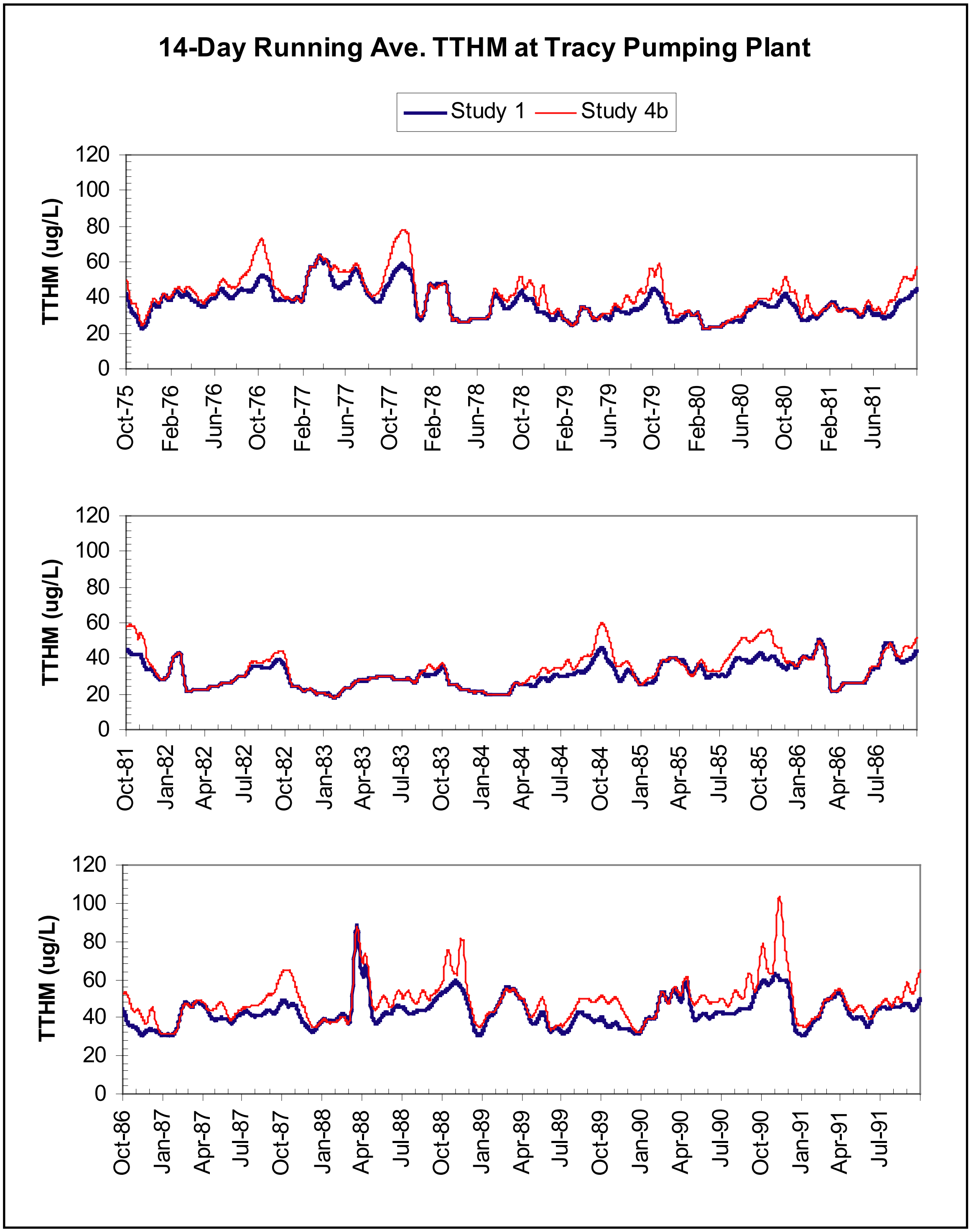

Figure 2.5.29: 14-Day Average TTHM (ug/L) at Tracy Pumping Plant (CVP).

Violations of the Water Quality Management Plan (WQMP) TTHM standard are not based on the 14-day averages, but instead on the difference between the new IDS operation and the modeled base case (WQMP, 2000). According to the WQMP, when the modeled base case TTHM is less than or equal to 64 ug/L, the modeled project (alternative) TTHM can not exceed 64 ug/L. When the base case TTHM already exceeds

64 ug/L, the 14-day average increase in TTHM concentration at any urban intake can not exceed 3.2 ug/L. The incremental WQMP constraint is illustrated below in Figure 2.5.30.

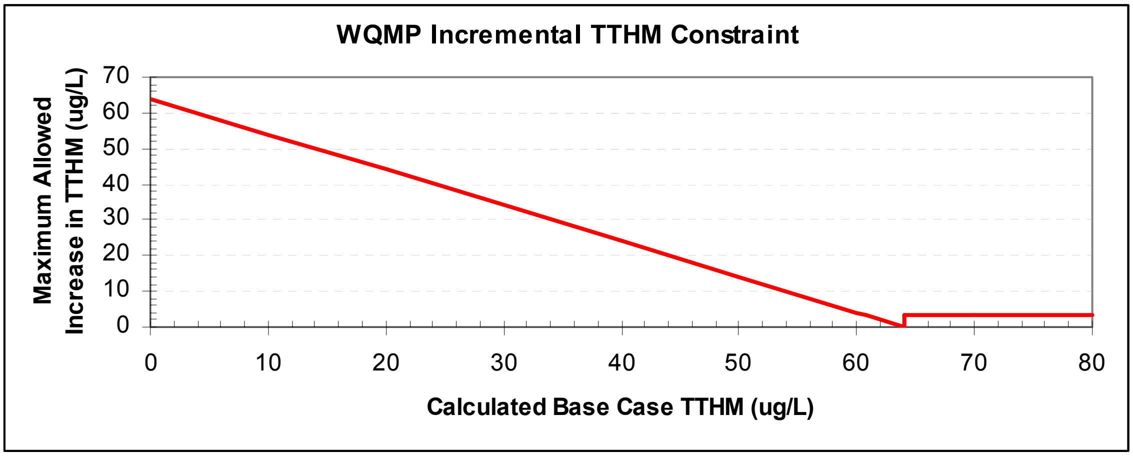

Figure 2.5.30: WQMP Incremental TTHM Constraint.

The 16-year minimum, average, and maximum change (study 4b - study 1) in the 14-day average TTHM at the urban intakes is shown in Table 2.5.13. The 10^{th} percentile results so a slight improvement (decrease) in TTHM concentrations, while the 25^{th} percentile results show an equivalent increase in TTHM concentrations.

Table 2.5.13: Summary of Change in 14-Day TTHM (ug/L) at Urban Intakes.

Urban Intake	Min	Ave	Max	Percentiles				
				10^{th}	25^{th}	50^{th}	75^{th}	90^{th}
RS	-3.5	4.5	26.7	-0.4	0.3	2.9	7.1	12.1
LVR	-4.5	4.6	37.7	-0.5	0.5	3.2	7.1	12.0
SWP	-4.8	4.3	22.1	-0.2	0.4	3.0	6.9	11.0
CVP	-3.1	4.1	42.5	-0.1	0.1	2.6	6.5	10.9

The number and frequency of days out of the 5,844 day simulation when the variable WQMP TTHM constraint was exceeded were calculated using the modeled base case (study 1) to find the WQMP standard and the change in 14-day average TTHM (Table 2.5.14).

Table 2.5.14: Number and Frequency of Days the WQMP TTHM Constraint is Exceeded.

Urban Intake	# Days > Standard	% Days > Standard
RS	355	6%
LVR	290	5%
SWP	175	3%
CVP	229	4%

Time series plots of the change (study 4b – study1) in 14-day running average TTHM at all four urban intakes are shown below in Figures 2.5.31 – 2.5.34. The WQMP D1643 change in TTHM standard is also shown.

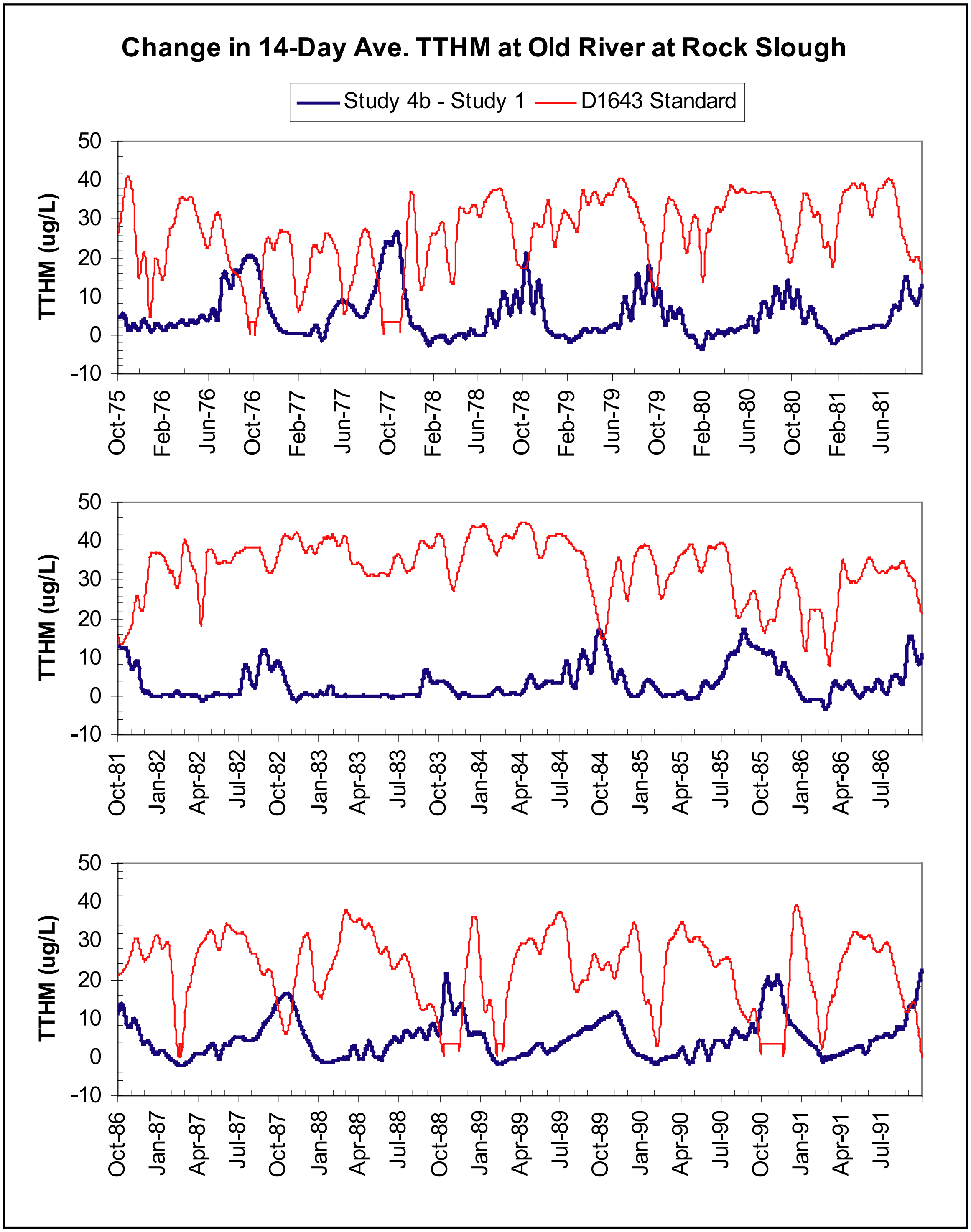

Figure 2.5.31: Change in 14-Day Average TTHM (ug/L) at Old River at Rock Slough (RS).

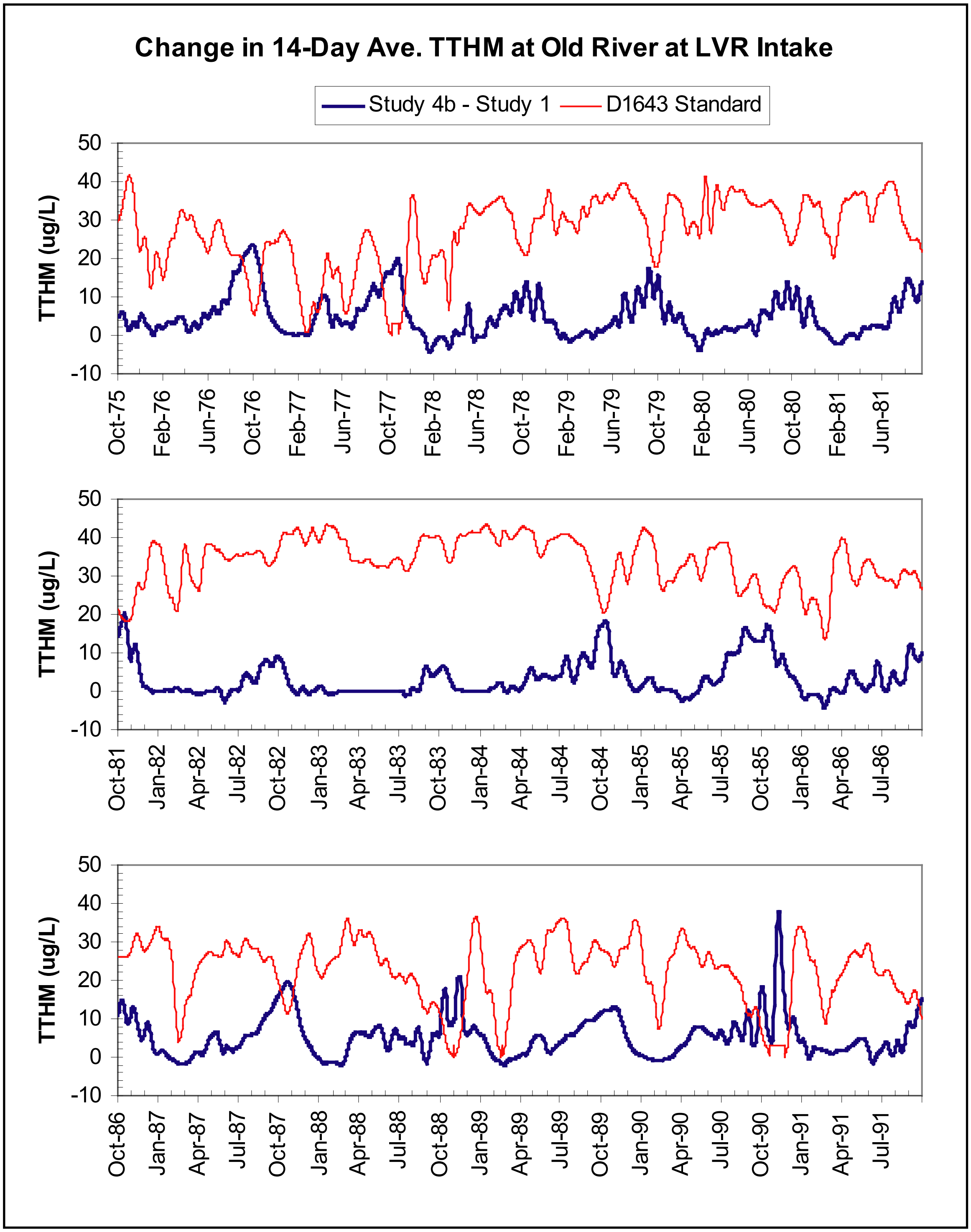

Figure 2.5.32: Change in 14-Day Average TTHM (ug/L) at Old River at LVR Intake (LVR).

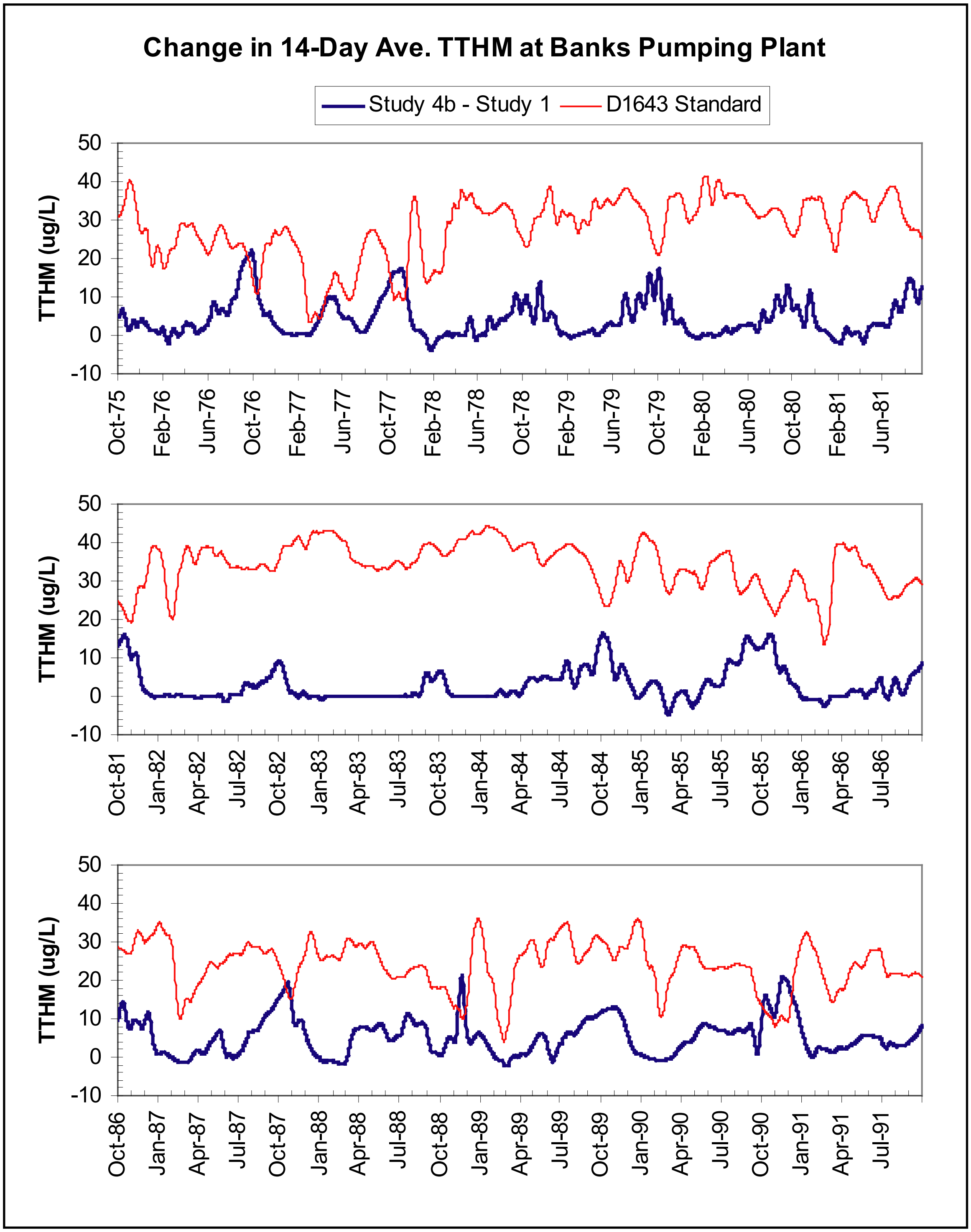

Figure 2.5.33: Change in 14-Day Average TTHM (ug/L) at Banks Pumping Plant (SWP).

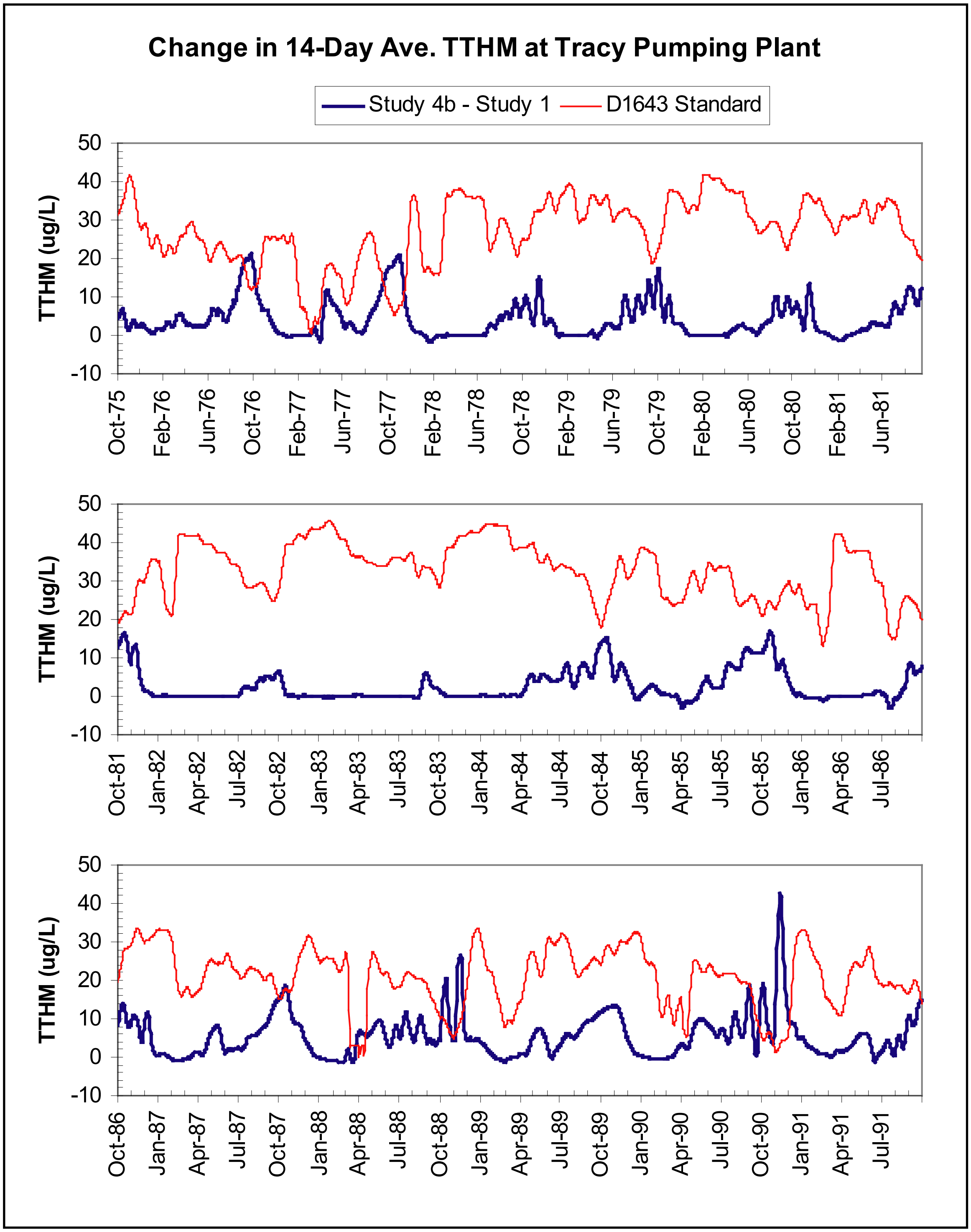

Figure 2.5.34: Change in 14-Day Average TTHM (ug/L) at Tracy Pumping Plant (CVP).

2.5.5 Bromate at Urban Intakes

Like the other water quality constraints, the impact of bromate (TTHM) formation is measured by increases in the project alternative when compared to the modeled base case concentration. Like TTHM, bromate is not directly modeled in DSM2. The WQMP established an incremental standard (described below) and agreed upon the basic modeling approach to be used to calculate bromate. Bromate is calculated as a function of EC, and DOC using the following formulas (Hutton, 2001):

$$BRM = C_2 \times DOC^{0.31} \times Br^{0.73} \qquad \text{Eqn. 5.19}$$

where

BRM = bromate concentration (ug/L),
C_2 = 9.6 when DOC < 4 mg/L,
C_2 = 9.2 when DOC ≥ 4 mg/L,
DOC = raw water dissolved organic carbon (mg/L) from DSM2, and
Br = raw water bromide concentration (mg/L) from EC.

The bromide concentration used in Equation 5.19 was calculated from EC based on its location using the same equations used when calculating TTHM (see *Section 2.5.4*).

The 16-year minimum, average, and maximum daily averaged bromate concentration at the four urban intakes for study 1 (base case) and study 4b is shown below in Table 2.5.15. The bromate concentration associated with the 10th, 25th, 50th, 75th, and 90th percentile at each location is also shown. These percentiles were calculated in the same manner as the chloride percentiles (see *Section 2.5.2*).

Table 2.5.15: Summary of Daily Averaged Bromate (ug/L) at Urban Intakes.

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	0.1	5.7	14.3	2.3	3.0	5.2	7.9	10.0
	Study 4b	0.2	6.0	14.9	2.4	3.2	5.5	8.5	10.4
LVR	Study 1	0.2	7.3	18.9	2.4	3.5	6.8	10.3	13.0
	Study 4b	0.1	7.5	19.1	2.4	3.7	6.9	11.0	13.3
SWP	Study 1	0.1	6.9	17.4	2.4	3.7	6.5	9.7	11.8
	Study 4b	0.1	7.1	17.1	2.4	3.8	6.8	10.1	11.9
CVP	Study 1	0.1	7.9	18.4	2.4	5.3	8.0	10.6	12.6
	Study 4b	0.1	8.0	18.4	2.4	5.4	8.1	10.9	12.8

The 14-day average bromate constraints called for by the Delta Wetlands WQMP were calculated every day as the average of the 14 previous days (WQMP, 2000). This was done not only to remain consistent with CALSIM, but also under the assumption that forecasting and operations would make use of the previous 14 days worth of field and modeling data. A summary of the 14-day average bromate constraints is shown in Table 2.5.16.

Table 2.5.16: Summary of 14-Day Average Bromate (ug/L) at Urban Intakes.

Urban Intake	Study	Min	Ave	Max	Percentiles				
					10th	25th	50th	75th	90th
RS	Study 1	0.6	5.7	13.6	2.3	3.0	5.2	7.9	9.9
	Study 4b	0.7	6.0	14.6	2.4	3.2	5.5	8.5	10.2
LVR	Study 1	0.8	7.3	18.5	2.4	3.5	6.7	10.3	12.9
	Study 4b	0.6	7.5	18.1	2.4	3.8	6.9	11.0	13.2
SWP	Study 1	0.7	6.9	17.1	2.4	3.7	6.5	9.7	11.8
	Study 4b	0.7	7.1	16.8	2.4	3.8	6.8	10.1	11.9
CVP	Study 1	0.3	7.9	16.9	2.4	5.2	8.0	10.5	12.5
	Study 4b	0.3	8.0	17.5	2.4	5.4	8.1	10.9	12.7

Time series plots of the 14-day running average bromate at all four urban intakes are shown below in Figures 2.5.35 – 2.5.38.

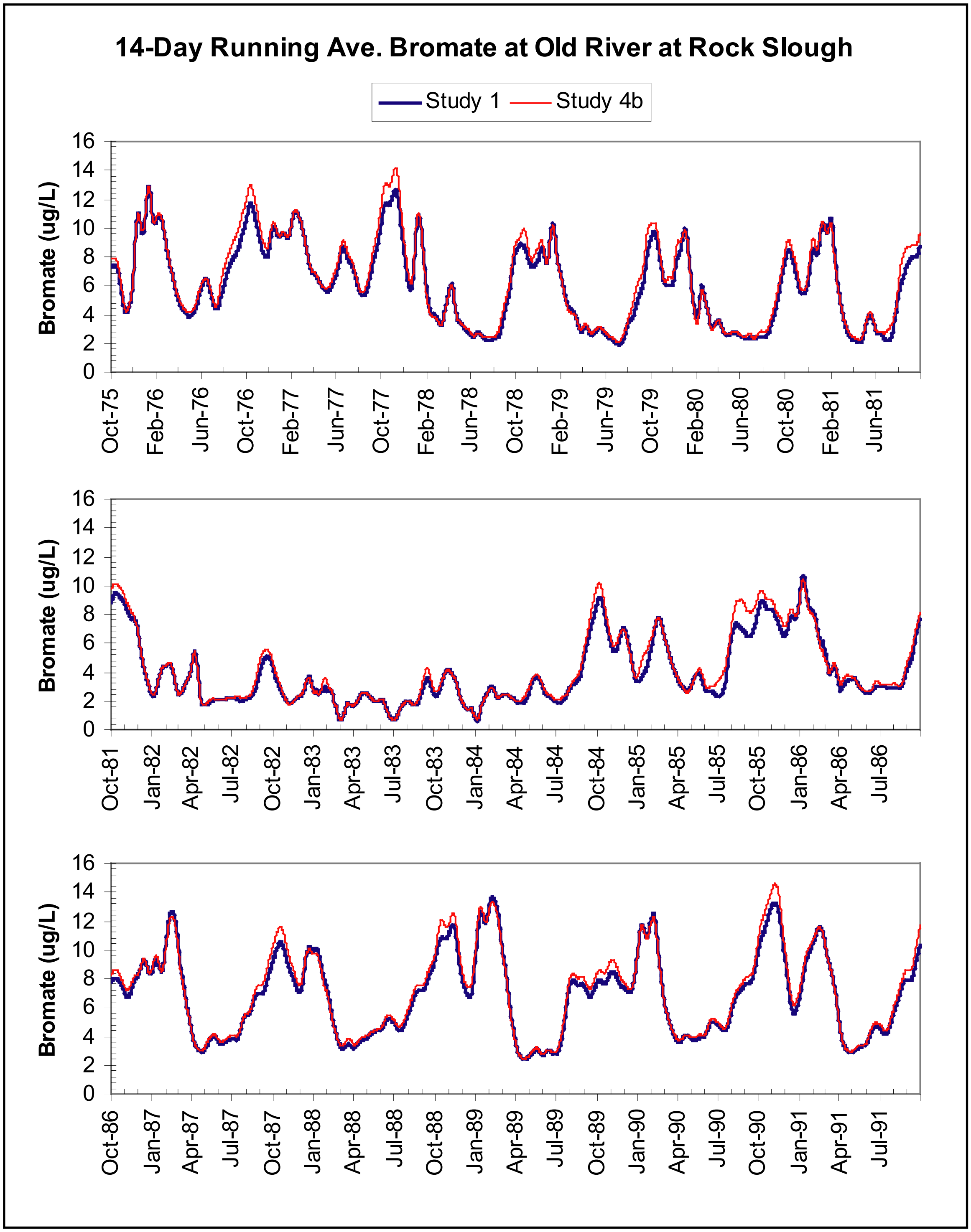

Figure 2.5.35: 14-Day Average Bromate (ug/L) at Old River at Rock Slough (RS).

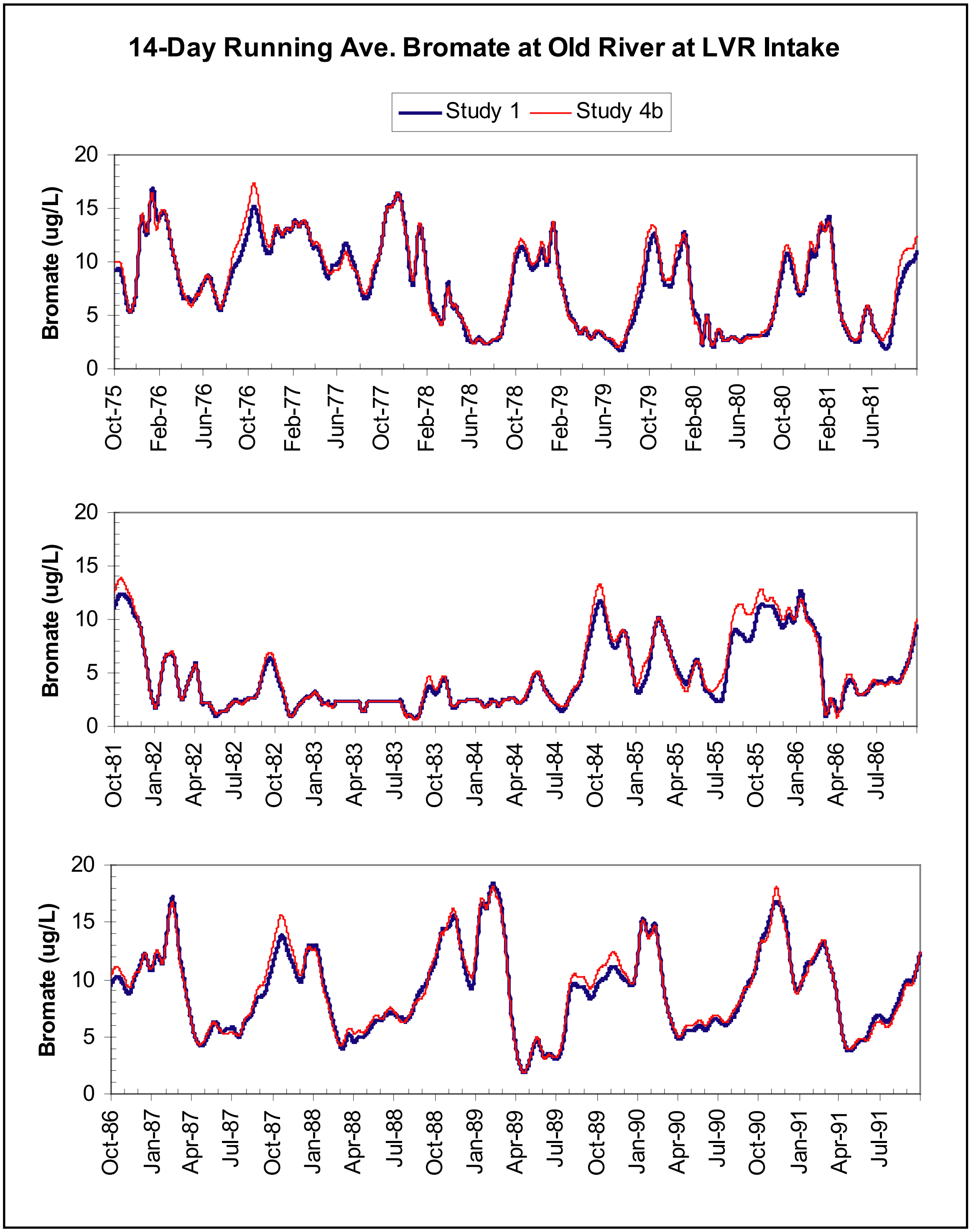

Figure 2.5.36: 14-Day Average Bromate (ug/L) at Old River at LVR Intake (LVR).

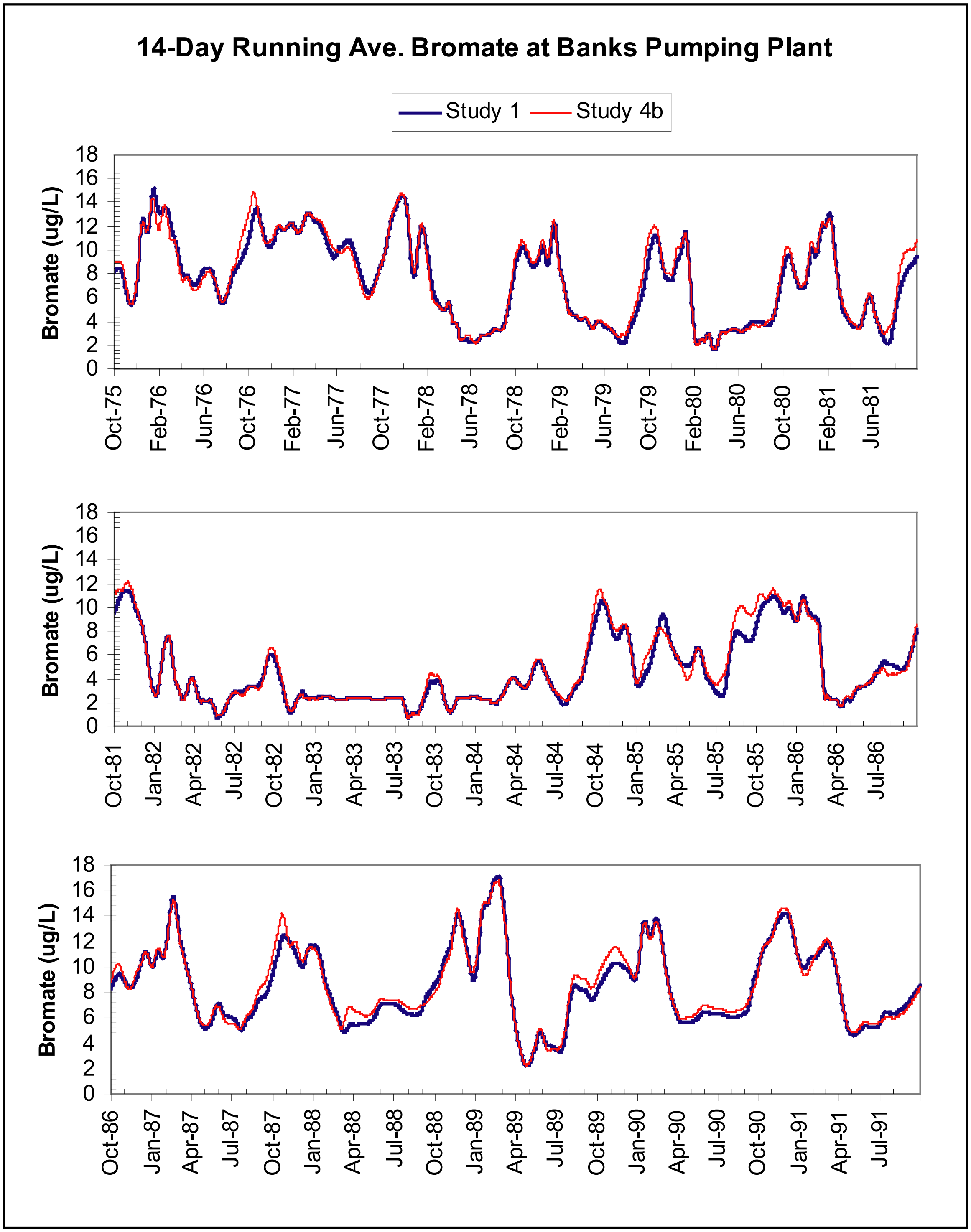

Figure 2.5.37: 14-Day Average Bromate (ug/L) at Banks Pumping Plant (SWP).

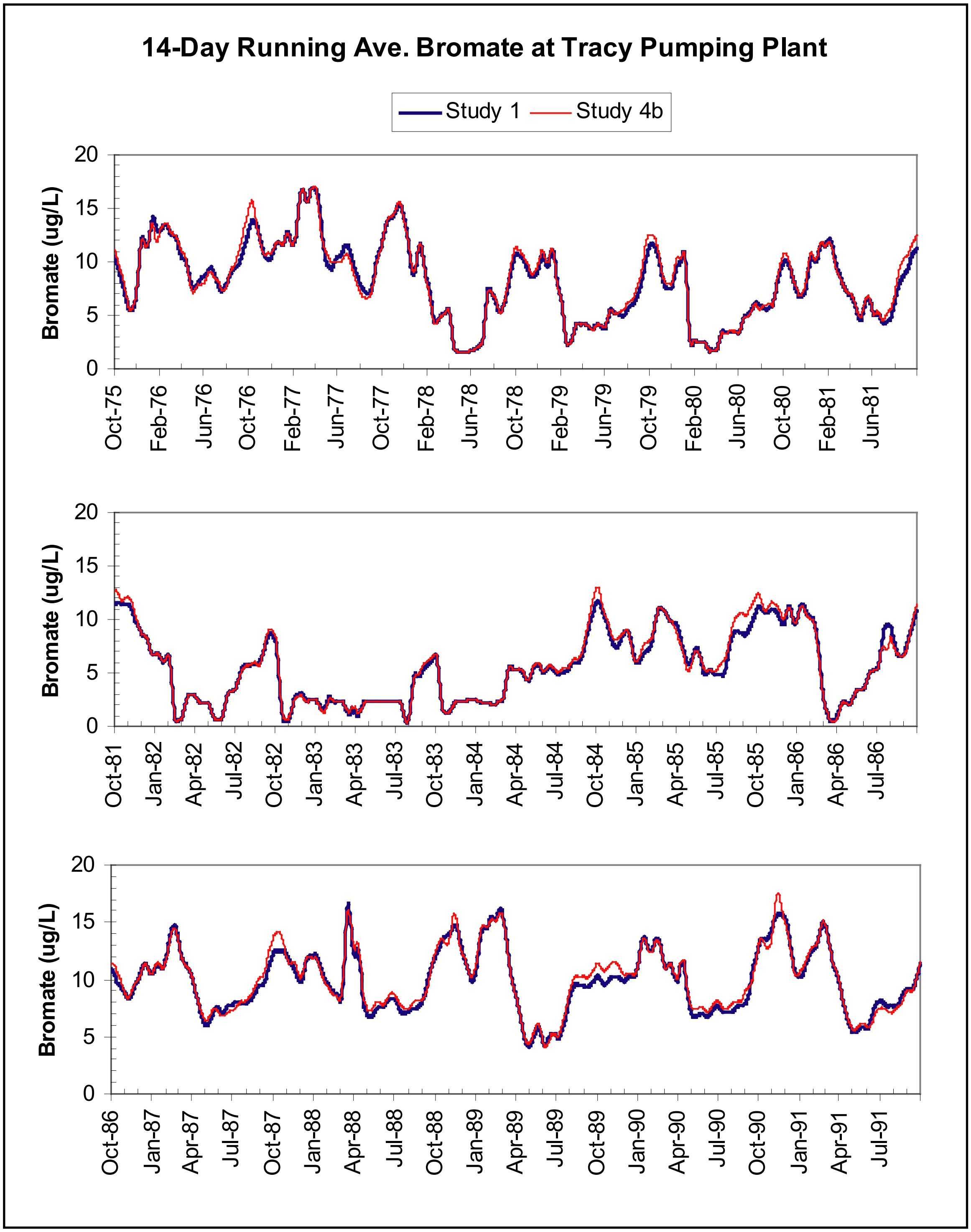

Figure 2.5.38: 14-Day Average Bromate (ug/L) at Tracy Pumping Plant (CVP).

Violations of the Water Quality Management Plan (WQMP) bromate standard are not based on the 14-day averages, but instead on the difference between the new IDS operation and the modeled base case (WQMP, 2000). According to the WQMP, when the modeled base case bromate is less than or equal to 8 ug/L, the modeled project (alternative) bromate can not exceed 8 ug/L. When the base case bromate already exceeds 8 ug/L, the 14-day average increase in bromate concentration at any urban intake can not exceed 0.4 ug/L. The incremental WQMP constraint is illustrated below in Figure 2.5.39.

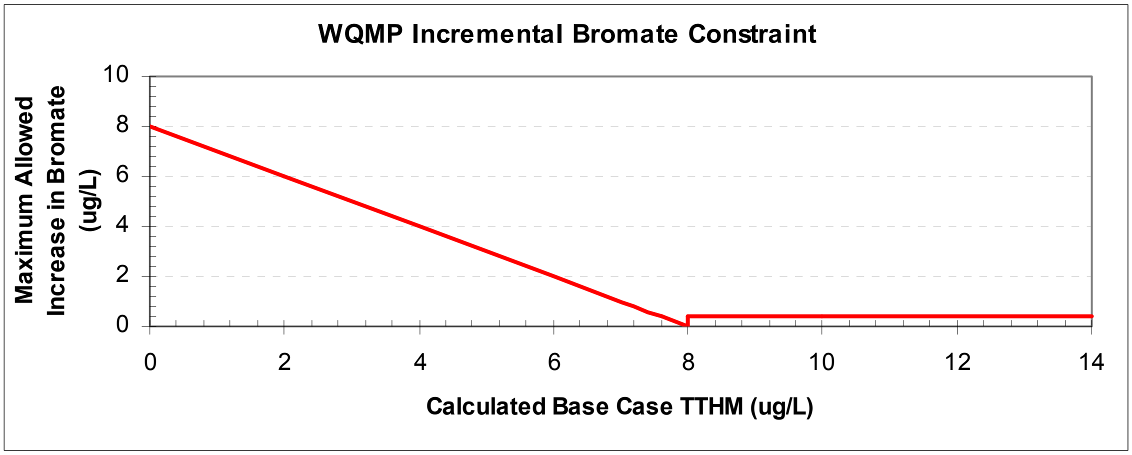

Figure 2.5.39: WQMP Incremental Bromate Constraint.

The 16-year minimum, average, and maximum change (study 4b - study 1) in the 14-day average bromate at the urban intakes is shown in Table 2.5.17.

Table 2.5.17: Summary of Change in 14-Day Bromate (ug/L) at Urban Intakes.

Urban Intake	Min	Ave	Max	Percentiles				
				10th	25th	50th	75th	90th
RS	-0.6	0.3	2.0	-0.1	0.0	0.2	0.5	0.9
LVR	-1.6	0.2	2.8	-0.4	-0.1	0.1	0.5	1.0
SWP	-1.7	0.2	2.5	-0.4	-0.1	0.1	0.4	0.8
CVP	-2.2	0.2	2.0	-0.3	-0.1	0.1	0.4	0.7

The number and frequency of days out of the 5,844 day simulation when the variable WQMP bromate constraint was exceeded were calculated using the modeled base case (study 1) to find the WQMP standard and the change in 14-day average bromate (Table 2.5.18).

Table 2.5.18: Number and Frequency of Days the WQMP Bromate Constraint is Exceeded.

Urban Intake	# Days > Standard	% Days > Standard
RS	1,098	19%
LVR	1,248	22%
SWP	966	17%
CVP	1,161	20%

Time series plots of the change (study 4b – study1) in 14-day running average bromate at all four urban intakes are shown below in Figures 2.5.40 – 2.5.43. The WQMP D1643 change in TTHM standard is also shown.

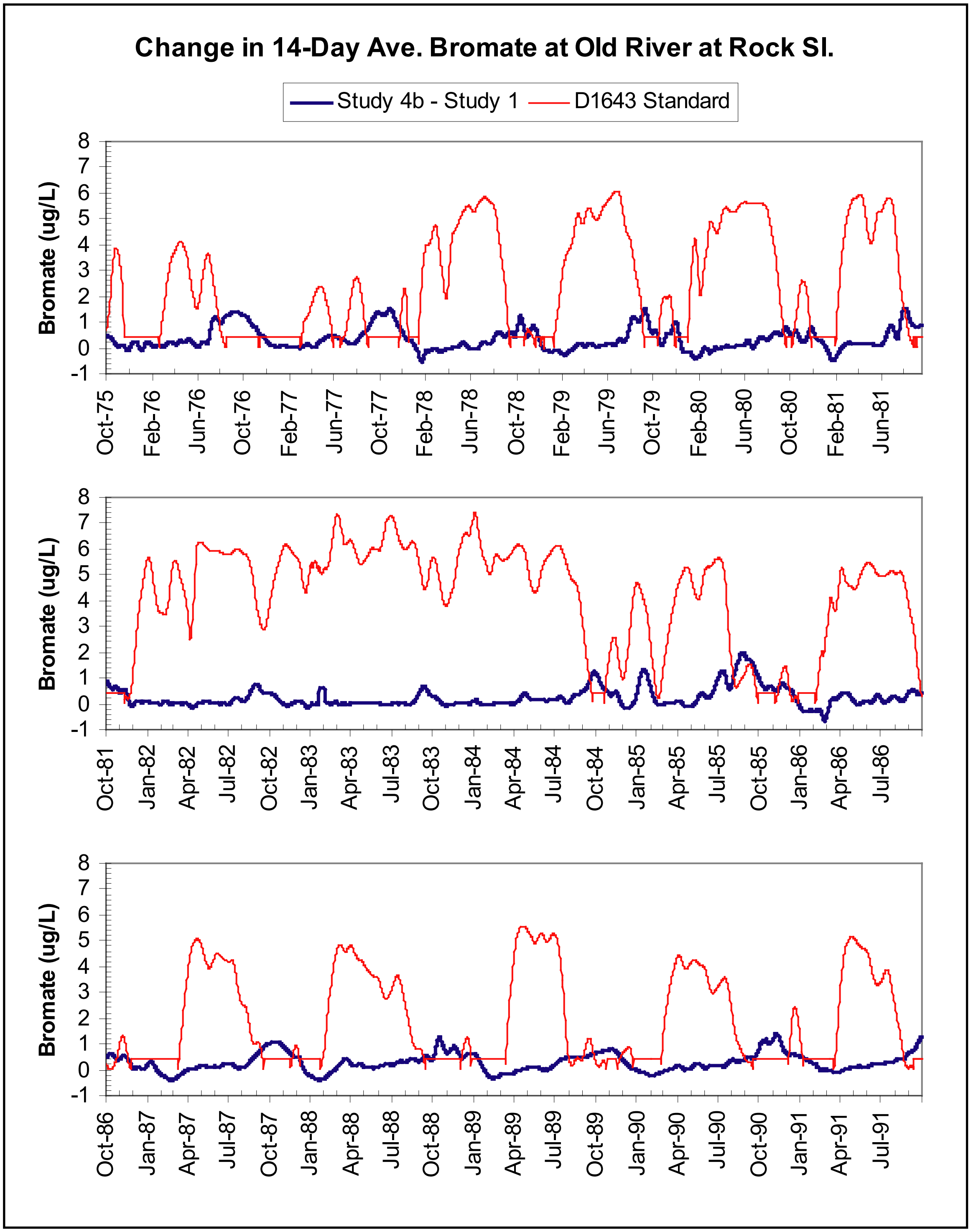

Figure 2.5.40: Change in 14-Day Average Bromate (ug/L) at Old River at Rock Slough (RS).

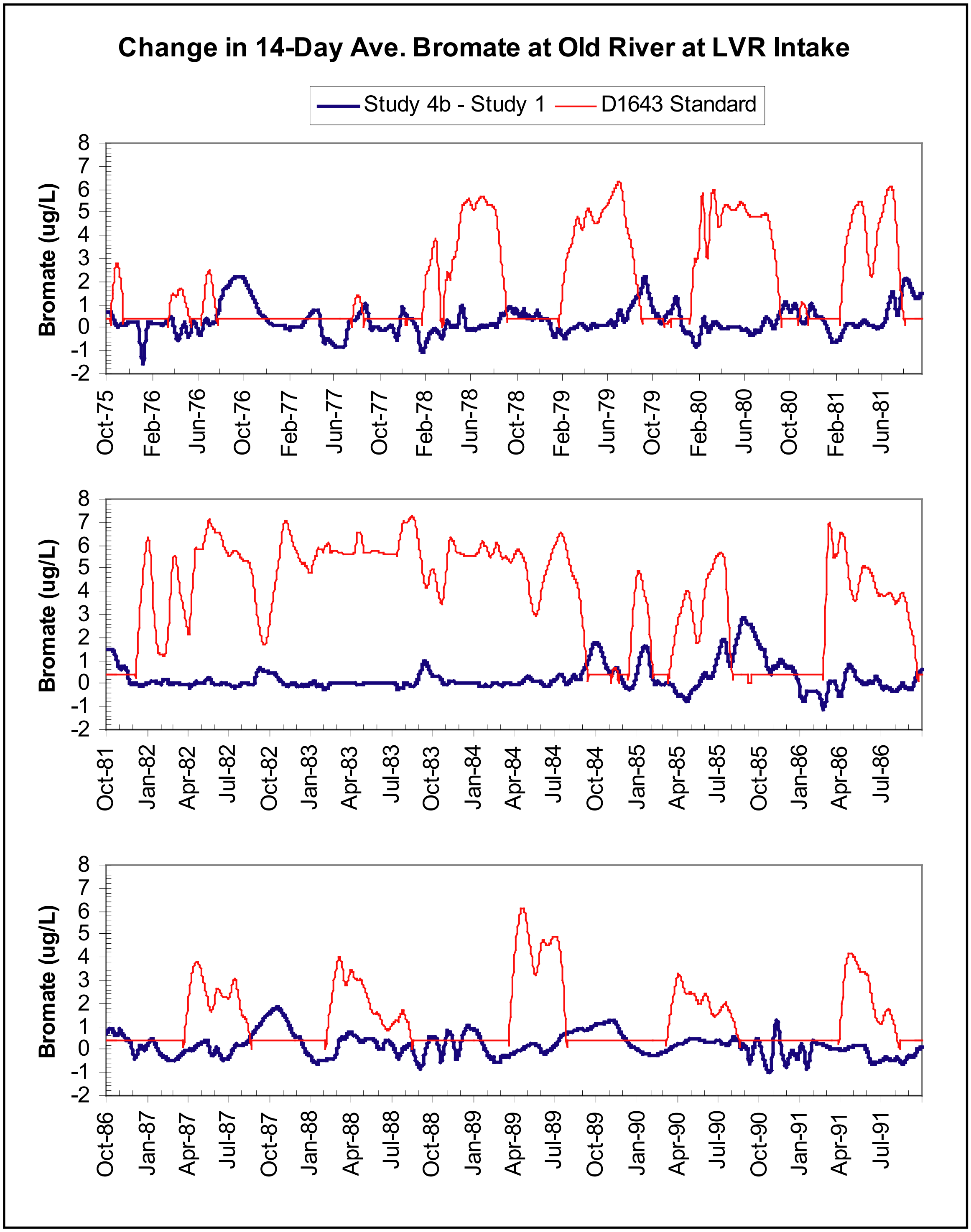

Figure 2.5.41: Change in 14-Day Ave. Bromate (ug/L) at Old River at LVR Intake (LVR).

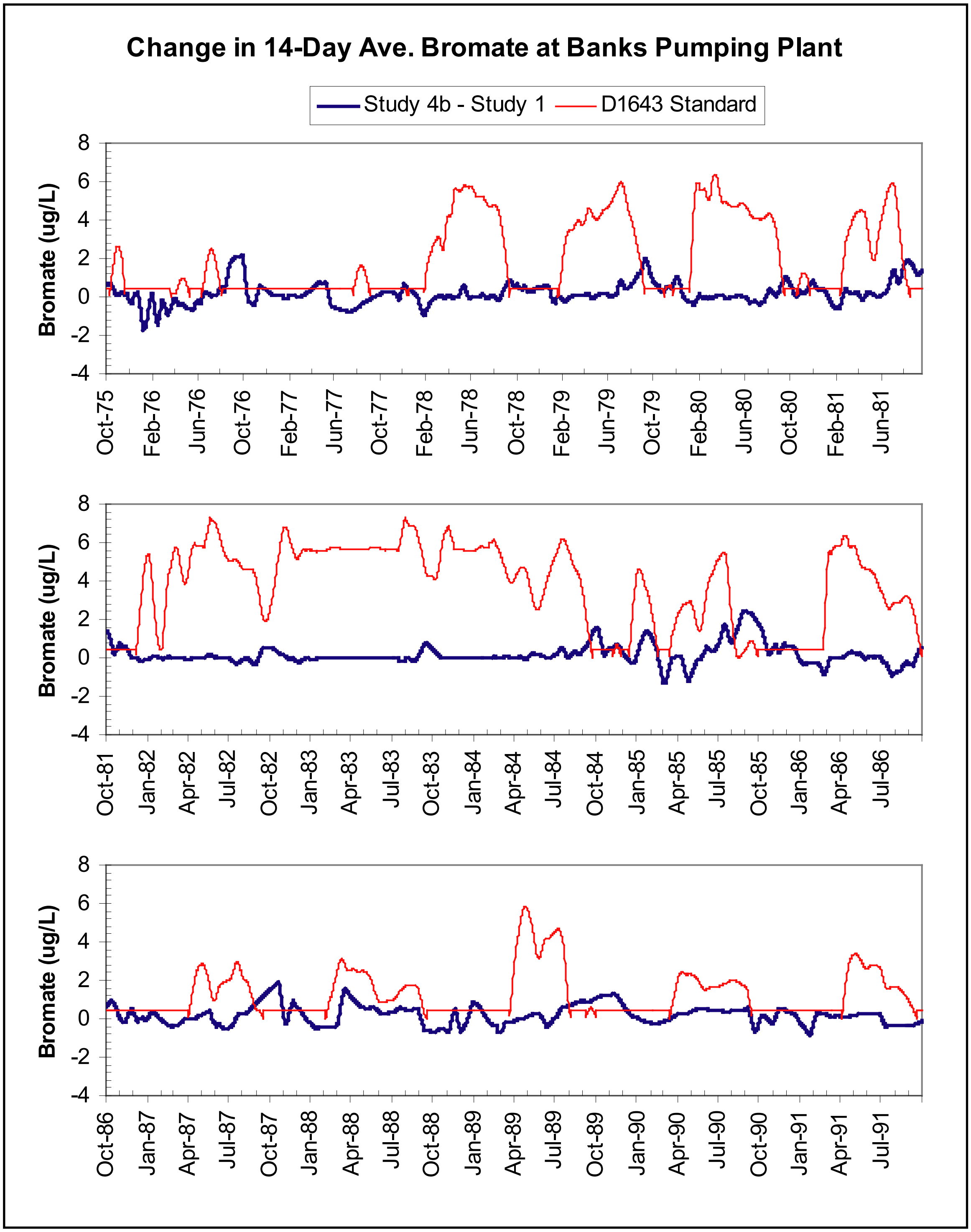

Figure 2.5.42: Change in 14-Day Average Bromate (ug/L) at Banks Pumping Plant (SWP).

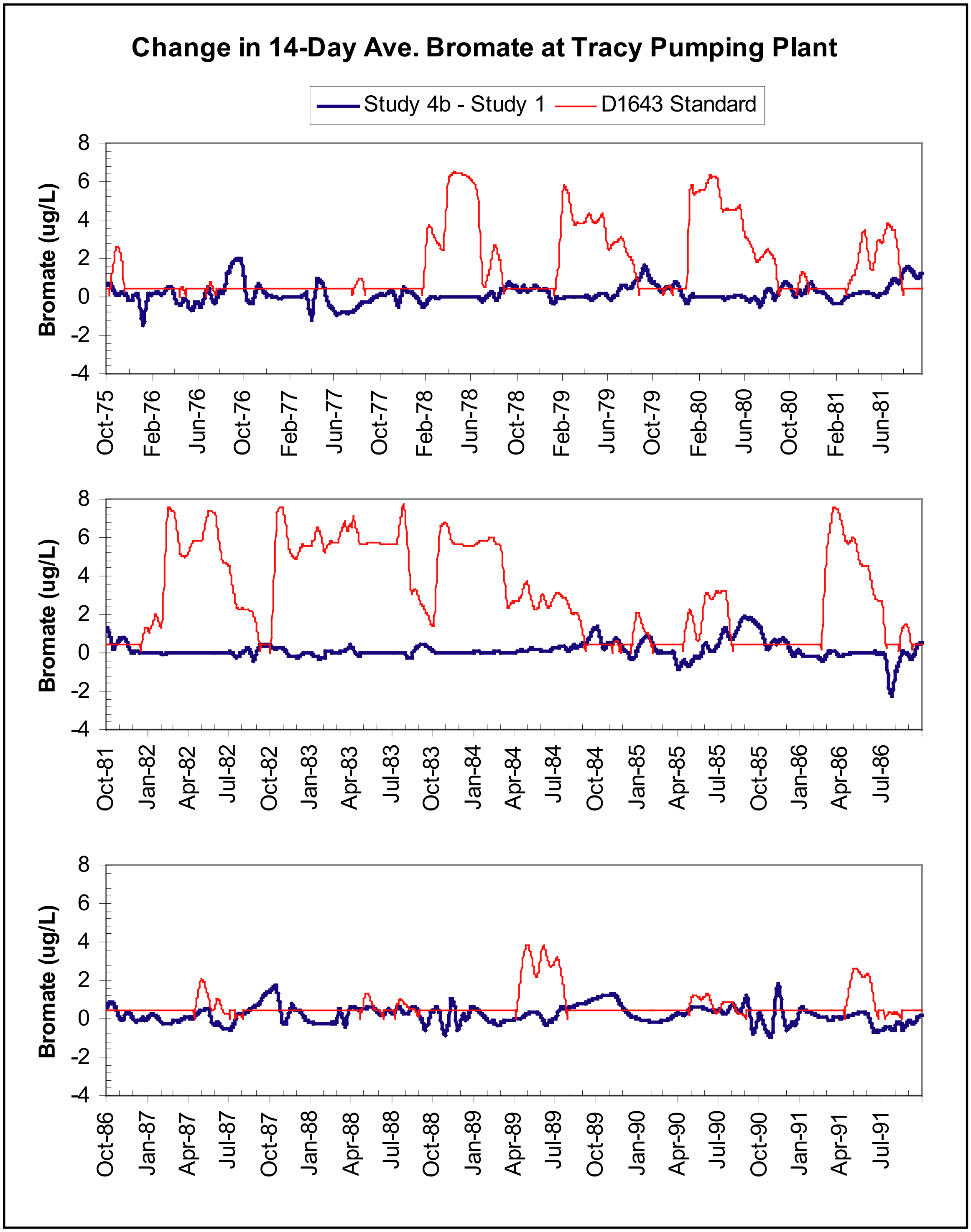

Figure 2.5.43: Change in 14-Day Average Bromate (ug/L) at Tracy Pumping Plant (CVP).

2.6 Conclusions

In general, the DSM2-QUAL results not only reflect changes to Delta water quality due to operation of the project, but should be viewed as responding to larger system wide changes made within CALSIM II due to not just the immediate short-term operations of the project, but also the long-term presence of the IDS project. In other words, DSM2 will show a water quality response when the CALSIM II inflows and exports are changed regardless of the immediate diversions or releases. Although CALSIM II simulated a 72-year period, DSM2 planning studies are still limited to a standard 16-year period. This 16-year period (water years 1976 – 1991) was chosen because a mix of critical, wet, and normal years exist in the historical (and hence CALSIM) hydrology. Though it would be interesting to extend to the DSM2 water quality simulation to the full length of the CALSIM II operations, two constraints still exist:

- Extending the downstream ocean stage boundary condition; and
- Developing practical data storage and processing system to handle 72 years work of hourly tidal data throughout the Delta.

The 16-year minimum, average, and maximum daily average values are presented for most of the DSM2 inputs and all of the water quality constituents: chloride, DOC, TTHM, and bromate. However, the usefulness of these three time-series statistics is extremely limited when analyzing as complex a system as the Sacramento - San Joaquin Delta. Though cumulative frequency distributions have proved useful in prior IDS DSM2 reports, time constraints prevented the generation of these statistics and plots distributions. Instead, 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile states are provided for many of the flow and water quality parameters related to the operation of the IDS project. These percentile values can be used to fill in the general shape of the missing cumulative frequency distributions, and provide valuable insight into change in frequency of events.

Another useful statistic is the change in daily average concentrations (measured as the difference of study 1, the no action base case, from study 4b, the alternative with circulation). Since the differences are calculated before the percentiles are calculated, they preserve the temporal character of the CALSIM operations. In other words, not all of the decreases or increases in water quality parameters are directly related to an immediate operation of the IDS islands. The only changes made within DSM2's description of the Sacramento – San Joaquin Delta were the addition of the project islands and the spatial characterization of the island operations (via the simulation of two integrated facilities per island). In fact, global Delta wide processes such as consumptive or the operation of the South Delta permanent barriers use were not changed, thus the primary possible sources for differences (alternative – base) in water quality are related to:

- Differences in CALSIM II's alternative and base flows and exports;
- Local effects due to circulation and the physical placement of the integrated facilities;
- Temporal effects due to differences in how CALSIM II and DSM2 treat the long-term sinks of organic carbon in the Delta; and
- The amount of organic carbon produced (via the wetted surface area) in each island.

A general summary of the range (16-year min and max), median (50th percentile), and percent time that the WQMP constraints were exceeded (regardless of the magnitude of the difference) for all four urban intakes combined is shown in Table 2.6.1 for the following water quality parameters. The lowest and highest values for all four urban intakes are shown for each of these three statistics. The lowest and highest values frequently come from different locations.

Table 2.6.1: Summary of Change in Water Quality Constituents for all Urban Intakes.

Water Quality Constituent	Range	Median	% Days > WQMP Standard
Chloride	-21.8 – 40.7 mg/L	0.1 – 0.4 mg/L	1 – 8%
DOC	-0.6 – 4.4 mg/L	0.3 – 0.5 mg/L	9 – 33%
TTHM	-4.8 – 42.5 ug/L	2.6 – 3.2 ug/L	3 – 6%
Bromate	-2.2 – 2.8 ug/L	0.1 – 0.2 ug/L	17% - 22%

Again, it is important to not focus on generalized statistics covering all of the locations for the entire simulation period, but rather to spend time reviewing the percentile results for both the change in water quality and absolute results for each individual location. However, though the range of values shows a highly varied response to the various water quality parameters, the median values show a very slight increase in all four water quality parameters covered in this study. The estimate of the percent days that the WQMP standards adopted in D1643 were exceeded does not take into account the magnitude of each exceedence of the standards. At times, the differences between D1643 compliance and a violation are minor. The time series plots for each water quality parameter provide a crude estimate of the magnitude of these differences.

2.7 Recommendations

Though the current study was designed to accommodate a fairly complete simulation of several of the key physical processes (see Figure 2.4.2) unique to the operation of the IDS project, the magnitudes and details associated with some of these processes are not completely understood. Often types of scaling or sensitivity analysis have been used to bookend or justify assumptions made when developing boundary conditions or mechanisms to represent these processes. In most cases, the DSM2 simulations were designed such that these assumptions can be easily repeated and/or tested in future studies. The following are suggestions for improvements to future DSM2 simulations:

- Either remove seepage flows if the reasoning for assigning a fixed concentration to the seepage return flows is insignificant or make use of the current DSM2 setup and conduct an actual sensitivity test on the seepage return flow concentrations;
- Estimate the long-term mass flux of the various water quality constituents passing through the urban intakes;
- Improve the project island volume – flow relationships used in the CALSIM II DOC constraints by rerunning the DSM2-QUAL fingerprinting simulation for conditions similar to the proposed circulation operations;
- Conduct and present a formal scale analysis of the project island volume – flow relationships;
- Develop and apply flow – organic carbon relationships for the flow boundaries;
- Develop and apply a daily ANN or other EC / chloride constraint in CALSIM II to better match the current DSM2 salinity simulations;
- Quantify the difference in organic carbon produced by the project islands in DSM2 to the amount of organic carbon produced in CALSIM II, and if the values are significantly different, rethink the way DSM2 is representing DOC in the project islands; and
- Extend the DSM2 analysis (post-processing) time frame such that cumulative frequency distributions and closer analysis between the CALSIM and DSM2 results may be conducted.

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