7 SOURCE ASSESSMENT – TOTAL MERCURY & SUSPENDED SEDIMENT

Sources and losses of total mercury and suspended sediment are described in this chapter. The Delta mercury TMDL program addresses total mercury in addition to methylmercury because:

- Methylmercury production has been found to be a function of the total mercury content of the sediment (Chapter 3) and decreasing total mercury loads may be an option for controlling methylmercury;
- The mercury control program for the Delta must maintain compliance with the USEPA's CTR criterion of 50 ng/l for total recoverable mercury for freshwater sources of drinking water developed for human protection; and
- The mercury TMDL for San Francisco Bay assigns a total mercury load reduction to the Central Valley watershed to protect human and wildlife health in the San Francisco Bay (Johnson & Looker, 2004). The San Francisco Bay Basin Plan requires the attainment of the total mercury load allocation to be demonstrated by a net 110 kg/yr decrease in five-year average annual total mercury loads entering the Delta or fluxing past Mallard Island. Meeting the San Francisco Bay goal will require an understanding of total mercury and sediment discharge to the Delta.

Sections 7.1 and 7.2 describe the total mercury and suspended sediment concentrations (measured as total suspended solids, or TSS) for Delta sources and losses and identify major data gaps and uncertainties. The water volume calculations upon which the load calculations are based are described in Section 6.1 and Appendix E. Input and loss loads were evaluated for the WY2000-2003 period, a relatively dry period that encompasses the available methylmercury concentration data for the major Delta inputs and exports. In addition, the WY1984-2003 period was evaluated to illustrate the importance of wet years, particularly for loading from the Yolo Bypass. This 20-year period includes a mix of wet and dry years that is statistically similar to what has occurred in the Sacramento Basin over the last 100 years. An assessment of a typical distribution of wet and dry water years is critical to the understanding of mercury and sediment sources because, as illustrated in the daily total mercury load graphs in Appendix J, the load for several high flow days may be equivalent to the annual load of the system during a dry year.

All the mass load calculations were developed using Equation 6.1. Section 7.3 presents the total mercury and suspended sediment mass budgets based on the input and export loads described in Sections 7.1 and 7.2. Section 7.4 reviews the mercury-to-TSS ratio (TotHg:TSS) for each input and export to identify areas that may be the focus of future remediation efforts to reduce total mercury loading. As described in Chapter 8 of this report and Chapter 4 of the Proposed Basin plan Amendment draft staff report, the total mercury limits and implementation plans for total mercury reduction will focus on sources that have both relatively large mercury loadings and high TotHg:TSS ratios.

7.1 Total Mercury and Suspended Sediment Sources

The following were identified as sources of total mercury and suspended sediment to the Delta: tributary inflows from upstream watersheds, municipal wastewater, atmospheric deposition, and urban runoff. Table 7.1 lists the estimated loads associated with these sources for the WY2000-2003 and WY1984-2003

Table 7.1: Average Annual Total Mercury and TSS Source Loads and Confidence Intervals for WY2000-2003 and WY1984-2003. (a)

	WY2000-2003				**WY1984-2003**			
	TotHg		**TSS**		**TotHg**		**TSS**	
	(kg/yr)	% of All Inputs	(Mkg/yr)	% of All Inputs	(kg/yr)	% of All Inputs	(Mkg/yr)	% of All Inputs
Tributary Inputs (b)								
Sacramento River	149 ±#	67%	689 ±#	63%	183 ±#	46%	865 ±#	40%
Prospect Slough	36 ±#	16%	195 ±#	18%	161 ±#	41%	984 ±#	46%
San Joaquin River	19 ±#	8.5%	146 ±#	13.4%	30 ±#	7.6%	235 ±#	11.0%
Calaveras River	3.6 ±#	1.6%	14 ±#	1.3%	3.8 ±#	1.0%	15 ±#	0.7%
Mokelumne-Cosumnes River	3.1 ±#	1.4%	8.6 ±#	0.8%	4.2 ±#	1.1%	11 ±#	0.5%
Ulatis Creek	2.0 ±#	0.9%	15.2 ±#	1.4%	2.1 ±#	0.5%	16 ±#	0.7%
French Camp Slough	1.6 ±#	0.72%	2.3 ±#	0.21%	1.7 ±#	0.43%	2.4 ±#	0.11%
Morrison Creek	0.80 ±#	0.36%	3.4 ±#	0.31%	0.86 ±#	0.22%	4.7 ±#	0.22%
Marsh Creek	0.54 ±#	0.24%	1.1 ±#	0.11%	0.54 ±#	0.14%	1.1 ±#	0.05%
Bear/Mosher Creeks	0.28 ±#	0.13%	2.2 ±#	0.21%	0.29 ±#	0.07%	2.3 ±#	0.11%
Sum of Tributary Sources:	**215** ±#	**96.8%**	**1,077** ±#	**99.3%**	**387 ±#**	**98.1%**	**2,137 ±#**	**99.6%**
Within-Delta Sources (c)								
Wastewater (Municipal & Industrial)	2.4 ±#	1.1%			2.4 ±#	0.61%		
Urban	2.5 ±#	1.1%	8.0 ±#	0.74%	2.6 ±#	0.66%	8.3 ±#	0.39%
Atmospheric (Indirect) (d)	1.4 ±#	0.63%			1.5 ±#	0.38%		
Atmospheric (Direct) (d)	0.9 ±#	0.38%			0.89 ±#	0.23%		
Sum of Within-Delta Sources:	**7.4 ±#**	**3.2%**	**8.0 ±#**	**0.7%**	**7.7 ±#**	**1.9%**	**8.3 ±#**	**0.4%**
TOTAL INPUTS:	**223 ±#**	**100%**	**1,085 ±#**	**100%**	**395 ±#**	**100%**	**2,145** ±#	**100%**

(a) The 95% confidence limits will be calculated using a method developed in consultation with UC Davis that will be described in Appendix J once completed.
(b) Total mercury and TSS concentration data are not available for other small drainages to the Delta, including the following areas shown on Figure 6.1: Dixon, Upper Lindsay/Cache Slough, Manteca-Escalon, Bethany Reservoir, Antioch, and Montezuma Hills areas.
(c) Total mercury and sediment loading data for any erosion of Delta soils are not available.
(d) The uncertainty of the atmospheric deposition load estimates was not evaluated.

periods. Tributary sources account for almost all the total mercury and TSS fluxing though the Delta, with more than 80% of the loading coming from the Sacramento Basin. The following sections describe the available concentration data and identify some of the data gaps and uncertainties associated with the load estimates.

7.1.1 Tributary Inputs

During WY2000-2003, tributaries to the Delta contributed approximately 97% of the total mercury and 99% of the suspended sediment (Table 7.1). The Sacramento Basin alone (Sacramento River at Freeport + Yolo Bypass) contributed more than 80% of all mercury and TSS loading to the Delta. The load estimates illustrated in Table 7.1 are based on the water volumes described in Section 6.1 and Appendix E, and concentration data collected by several agencies.

Central Valley Water Board staff began evaluating mercury loading from the Sacramento River watershed and Yolo Bypass to the Delta in 1994 (Foe & Croyle, 1998). From March 2000 to September 2001, staff conducted monthly sampling at the Delta's four major tributary input sites (Foe, 2003): Sacramento River; San Joaquin River; Mokelumne River (downstream of the Mokelumne/Cosumnes Rivers confluence); and Prospect Slough at Toe Drain in the Yolo Bypass. In addition, other programs conducted periodic aqueous sampling between 1993 and 2003 on the Sacramento River (SRWP, 2004; CMP, 2004; Stephenson *et al.*, 2002). Central Valley Water Board staff resumed sampling in April 2003. Figure 6.2 shows the tributary monitoring locations. Table 7.2 and Figures J.1 through J.3 in Appendix J summarize the available total mercury and TSS concentration data for the Delta's tributary inputs.

Sections 7.1.1.1 through 7.1.1.3 describe the methods used to estimate the loads for the Delta's tributary watersheds and identify uncertainties. Because the Sacramento Basin is the primary source of mercury to the Delta, Section 7.1.1.3 provides an analysis of loading from the tributaries that contribute to the Sacramento Basin exports to the Delta. In addition, Section 7.1.1.4 evaluates compliance of Delta and Sacramento Basin tributary waters with the CTR. The Sacramento Basin tributary evaluation is needed to develop the total mercury limits and implementation strategies described in Chapter 8 in this TMDL report and Chapter 4 in the Proposed Basin Plan Amendment draft staff report. Specific sources of total mercury within the Sacramento Basin tributary watersheds upstream of the legal Delta boundary – for example, historic mining operations and erosion of naturally mercury-enriched soils – will be evaluated in the implementation phase of this TMDL (see Chapter 4 in the Proposed Basin Plan Amendment draft staff report) and in the TMDL programs for those watersheds.

7.1.1.1 Sacramento Basin Inputs to the Delta

Sacramento Basin total mercury and TSS discharges to the Delta were evaluated at the Sacramento River at Freeport and the Yolo Bypass at Prospect Slough. Total mercury and TSS concentrations for the Sacramento River at Freeport were regressed against Freeport flow data to determine if correlations existed. Both regressions were statistically significant at $P< 0.01$. The statistically significant correlations indicate that it is possible to predict Sacramento River mercury and TSS concentrations from flow. Therefore, the mercury/flow and TSS/flow equations were used to predict average annual loads

Table 7.2: Total Mercury and TSS Concentrations for Tributary Inputs

Site (a)	**# of Samples**	**Sampling Begin Date**	**Sampling End Date**	**Min. Conc.** (ng/l)	**Ave. Conc.** (ng/l)	**Median Conc.** (ng/l)	**Max. Conc.** (ng/l)
TOTAL MERCURY CONCENTRATIONS							
Bear/Mosher Creeks (b)	4	03/15/03	02/26/04	3.55	8.15	8.84	11.36
Calaveras River @ RR u/s West Lane (b)	4	03/15/03	02/26/04	13.23	20.53	21.34	26.22
French Camp Slough near Airport Way	7 [4]	01/28/02	02/26/04	1.73 [3.32]	12.9 [20.5]	3.40 [11.63]	55.42 [55.42]
Marsh Creek @ Hwy 4	19 [3]	11/05/01	02/02/04	0.93	7.31	4.36	30.18
Mokelumne River @ I-5	21	03/28/00	09/30/03	0.26	5.34	5.19	12.28
Morrison Creek (c)	47 [15]	04/09/97	01/28/02	1.62 [3.9]	7.96 [10.46]	7.23 [9.12]	19.75 [19.75]
Prospect Slough (Yolo Bypass) (d)	28 (26)	01/10/95	09/30/03	7.18	73.10 (30.67)	26.70 (25.73)	695.6 (92.2)
Sacramento River @ Freeport	155	02/15/94	11/06/02	1.20	8.28	6.31	36.19
San Joaquin River @ Vernalis	35	10/29/93	02/26/04	3.12	8.18	7.22	23.54
Ulatis Creek near Main Prairie Rd	6 [4]	01/28/02	02/26/04	1.34 [24.21]	36.06 [53.24]	28.68 [52.51]	83.74 [83.74]
TSS CONCENTRATIONS							
Bear/Mosher Creeks (b)	4	03/15/03	02/26/04	15.8	65.8	24.1	199.1
Calaveras River @ RR u/s West Lane (b)	4	03/15/03	02/26/04	32.4	82.7	55.4	187.5
French Camp Slough near Airport Way	5 (4)	01/28/02	02/26/04	12.0 [16.7]	26.0 [29.5]	26.4 [27.5]	46.5 [46.5]
Marsh Creek @ Hwy 4	7 (2)	04/28/02	02/02/04	17.9 [36.9]	69.1 [155.0]	36.9 [155.0]	273.2 [273.2]
Mokelumne River @ I-5	23	3/28/00	9/30/03	5.8	14.5	12.0	31.0
Morrison Creek (c)	44 (15)	04/09/97	01/28/02	6.0 [7.0]	39.9 [57.0]	27.0 [40.5]	140 [140]
Prospect Slough (Yolo Bypass) (d)	46 (24)	1/10/95	9/30/03	36.6	301.4 [170.0]	143.2 [139.9]	2300.7 [512.7]
Sacramento River @ Freeport	186	12/15/92	1/20/04	2.0	38.2	26.0	368.0
San Joaquin River @ Vernalis	34	3/28/00	2/26/04	20.0	64.4	58.6	175.0
Ulatis Creek near Main Prairie Rd	6 (4)	01/28/02	02/26/04	2.5 [140.2]	276.5 [411.6]	217.8 [338.4]	829.6 [829.6]

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. Therefore, wet weather concentration data (noted in brackets), and estimated wet weather runoff (Section E.2.3 in Appendix E), were used to develop load estimates.

(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek data to estimate loads for both creeks (Appendix J).

(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to develop load estimates creeks (Appendix J).

(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. The above values do not include data collected when there was no net outflow. The values in parentheses are from calculations without the two very high values shown in Figure J.1. The regression is between total mercury concentrations observed at Prospect Slough (not including the two very high values shown in Figure J.1) and total export flows for the previous day estimated for Lisbon Weir, approximately 15 miles north of the Prospect Slough sampling station. The previous day's flow values were used to address the approximate residence time of the water as it travels through the Yolo Bypass to the export location where samples were collected.

Table 7.3: Comparison of Loading Estimates for Sacramento Basin Discharges to the Delta

Study	Sampling Location	Period	Average Sacramento Valley Water Year Hydrologic Index (a)	Average Annual TotHg Load [Upper & Lower Limits] (kg) (d)	Average Annual TSS Load [Upper & Lower Limits] (Mkg) (d)
Sacramento River					
Delta Mercury TMDL	Freeport	WY2000-2003	7.3	149 [#, #]	689 [#, #]
		WY1984-2003	7.8	183 [#, #]	865 [#, #]
Foe and Croyle (1998)	Greene's Landing	May 1994- April 1995	12.9	426	1,400
Foe (2002)	Greene's Landing	WY2001 (b)	5.8	91	526
LWA (2002)	Freeport	WY1980-1999	8.5	188.9 [187.0,190.7]	na
Wright & Schoellhamer (2005)	Freeport	WY1999-2002	7.7	na	1,100 [930, 1270]
Yolo Bypass					
Delta Mercury TMDL	Prospect Slough	WY2000-2003	7.3	36 [#, #]	195 [#, #]
		WY1984-2003	7.8	161 [#, #]	984 [#, #]
Foe and Croyle (1998)	Prospect Slough	May 1994- April 1995	12.9	375	2,500
Foe (2002)	Prospect Slough	WY2001 (d)	5.8	3.8	42
LWA (2002)	Woodland	WY1980-1999	8.5	117.5 [125.5, 134.1]	na
Wright & Schoellhamer (2005)	Woodland	WY1999-2002	7.7	na	310 [180, 440]
Sacramento Basin Total (Sacramento River + Yolo Bypass)					
Delta Mercury TMDL		WY2000-2003	7.3	185 [#, #]	884 [#, #]
		WY1984-2003	7.8	344 [#, #]	1,849 [#, #]
Foe and Croyle (1998)		May 1994- April 1995	12.9	801	3,900
Foe (2002)		WY2001 (d)	5.8	94.8	568
LWA (2002)		WY1980-1999	8.5	306	na
Wright & Schoellhamer (2005)		WY1999-2002	7.7	na	1,410 [1110, 1710]
Domagalski (2001) (c) 3 winter seasons, 20 December to 20 March		WY1997	10.8	487	na
		WY1998	13.3	506	na
		WY1999	9.8	169	na

(a) Source: DWR, http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST. DWR calculated a hydrologic index for the Sacramento Valley (Section E.2.1 in Appendix E). "Normal" hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, "wet" is ≥9.2, "dry" is between 5.4 and 6.5, and "critical dry" is ≤5.4. Figure E.1 in Appendix E illustrates the indices for each water year for the period of record.

(b) Foe's 2002 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

(c) Domagalski (2001) reported winter mercury loads from the Sacramento Basin for WY1997 through 1999 based on data collected at Sacramento River at Freeport and Yolo Bypass at Interstate 80 (upstream of Putah Creek inputs), but did not report individual loads for the Sacramento River and Yolo Bypass.

(d) The 95% confidence limits will be calculated for the TMDL loads using the method developed in consultation with UC Davis and will be described in Appendix J once completed.

from the Sacramento River watershed entering the Delta,[36,37] resulting in estimated average annual loads of 149 kg mercury and 689 Mkg TSS for WY2000-2003, and 183 kg mercury and 865 Mkg TSS for WY1984-2003 (Tables 7.1 and 7.3). Regression uncertainty will be evaluated by calculating the 95% confidence intervals for the mean response (in progress; Helsel and Hirsch, 2002),[38] which will be presented as the lower and upper load limits in Tables 7.1 and 7.3.

Prospect Slough is the main channel draining the Yolo Bypass. Total mercury and TSS samples were collected in Prospect Slough during outgoing tides. Total mercury and TSS concentrations observed on dates when there appeared to be net outflow from Lisbon Weir were regressed against estimated daily Yolo Bypass outflows at Lisbon Weir lagged by one day[39] to determine if statistically significant correlations might exist (Section E.2.2 in Appendix E & Appendix J, Figure J.1). Extremely high total mercury and TSS concentrations were measured on 10 and 11 January 1995 (Figure J.1). These values were not included in the regressions because, as described in Section E.2.2, the hydrologic conditions that probably caused these events appear to have occurred only once during the WY1984-2003 study period. The TotHg/flow and TSS/flow regressions were significant at $P < 0.01$ (Figure J.1), indicating that the concentrations of both constituents could be predicted from flow. The regressions were used to estimate annual average loads of 36 kg mercury and 195 Mkg TSS for WY2000-2003 (Table 7.1), and 161 kg mercury and 984 Mkg TSS for WY1984-2003 (Table 7.3). The estimated mercury and TSS loads for the WY1984-2003 period illustrate the importance of wet years on loading from the Yolo Bypass.

Several studies have evaluated total mercury and suspended sediment loading from the Sacramento Basin for a variety of wet and dry years (Table 7.3). These studies are summarized below. The results of these studies will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations once the 95% confidence limits have been completed.

Foe and Croyle (1998) reported loading estimates of approximately 426 kg total mercury and 1,400 Mkg TSS for the Sacramento River at Greene's Landing, and 375 kg mercury and 2,500 Mkg TSS for the Yolo Bypass at Prospect Slough for May 1994 through April 1995, a very wet period. In contrast, Foe (2002) reported loading estimates of about 91 kg mercury and 526 Mkg TSS for Greene's Landing, and 3.8 kg

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[36] For all tributaries with statistically significant TotHg/flow or TSS/flow relationships, the predicted concentrations were multiplied by daily flow volumes to estimate daily loads. The estimated daily loads were summed and then divided by the number of years in the study period to estimate the average annual loads for WY2000-2003. If a flow record had dates with missing values, the data were normalized to estimate annual loads. For example, a 20-year record would be normalized by dividing 7305 (the number of days in the 20-year period) by the number of days with a recorded value in the flow record and then multiplying the resulting quotient by the calculated sum of loads; the result was then divided by 20 to obtain the average annual load.

[37] The Delta area that drains to the 13-mile reach of the Sacramento River between Freeport (near river mile 46) and the I Street Bridge (the northernmost legal Delta boundary, near river mile 59) is predominantly urban and is encompassed by the urban load estimate described in Section 5.2.5. No attempt was made to subtract this area from the Sacramento River watershed load estimate. Therefore, the Sacramento River load noted in Table 7.1 incorporates a small portion of the within-Delta urban runoff loading.

[38] Appendix J will describe the method used to calculate the intervals.

[39] The estimated daily flows from Lisbon Weir on Toe Drain were lagged one day to address the approximate residence time of water along the ~15 miles between Lisbon Weir and Prospect Slough. There is generally no net outflow from the Yolo Bypass's Toe Drain downstream of Lisbon Weir between April and November. (See Appendix E for a description of Yolo Bypass hydrology.) Therefore, although sampling of Prospect Slough took place during outgoing tides with the intent of sampling outflows from the Yolo Bypass, during the summer months this sampling most likely represents waters tidally-pumped northward from Cache Slough, rather than outflows from the Yolo Bypass north of Lisbon Weir.

mercury and 42 Mkg TSS for the Yolo Bypass, during WY2001,[40] a dry period with limited outflows from the Yolo Bypass (Figure E-2).

LWA (2002) reported average annual mercury loading estimates of 189 kg/yr for the Sacramento River at Freeport and 126 kg/yr for the Yolo Bypass (Table 7.3). This study used flow data for 1980-1999, a period that was wetter than the TMDL periods, and concentration data collected during 1993-2000, an exceptionally wet period. LWA (2002) estimated an average annual total mercury load from the Yolo Bypass of using 1980-1999 flow data from the USGS gage, Yolo Bypass at Woodland, and concentration data collected during 1993-2000.

Wright and Schoellhamer (2005) estimated an average annual suspended sediment load of approximately 1,100 Mkg/yr for the Sacramento River at Freeport for WY1999-2002 (a wetter period, Table 7.3). The authors also estimated an average annual water flux of 1.7 x 10^9 m^3 (1.4 M acre-feet) and a suspended sediment flux of approximately 310 Mkg/yr for the Yolo Bypass for WY1999-2002. Their suspended sediment load estimate is based on flow estimates from the Dayflow model and daily suspended-sediment flux records for the Yolo Bypass developed using a rating curve based on data collected at the Woodland flow gage.[41]

Domagalski (2001) estimated the amount of total mercury transported out of the Sacramento Basin during three winters: 487 kg for WY1997, 506 kg for WY1998, and 169 kg for WY1999. All three of the periods correspond to relatively wet periods in the Sacramento Valley (Table 7.3). WY1998 was exceptionally wet. Domagalski noted that precipitation in the Sacramento Valley during this period was lower than average while the precipitation in the Sierra Nevada was higher than average, such that much less water was transported out of the basin through the Yolo Bypass, which may account for its relatively low loading compared to Foe & Croyle's estimate for a similar wet year, WY1995.

7.1.1.2 Other Tributary Inputs to the Delta

The TotHg/flow and TSS/flow regressions for the Mokelumne and San Joaquin Rivers were not significant ($P > 0.05$). Therefore, the average mercury and TSS concentrations (Table 7.2) for these locations were multiplied by average annual flow volumes for WY2000-2003 and WY1984-2003 (Table 6.1) to estimate average annual loads. The Mokelumne River has estimated average annual loads of 3.1 kg mercury and 8.6 Mkg TSS for WY2000-2003, and 4.2 kg mercury and 11 Mkg TSS for WY1984-2003 (Table 7.1). The San Joaquin River has estimated average annual loads of 19 kg mercury and 146 Mkg TSS for WY2000-2003, and 30 kg mercury and 235 Mkg TSS for WY1984-2003.

Several other studies have evaluated total mercury and suspended sediment loading from the Delta's tributaries for a variety of wet and dry years (Table 7.4). LWA (2002) estimated Mokelumne and San Joaquin Rivers average annual total mercury loadings for 1980-1999 at 3 kg/yr and 26 kg/year, respectively. Foe (2002) estimated Mokelumne River total mercury and TSS loadings of approximately 1.5 kg and 5.2 Mkg, and San Joaquin River total mercury and TSS loadings of approximately 16 kg and

[40] Foe's 2002 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.

[41] Wright and Schoellhamer's Yolo Bypass sediment data includes 45 sediment flux measurements between 1957 and 1961 and three measurements in 1980.

110 Mkg, for WY2001, a drier water year. Wright and Schoellhamer (2005) estimated an average annual suspended sediment load of approximately 210 Mkg/yr for the San Joaquin River for WY1999-2002 (a wetter period). The results of these studies will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations for the Mokelumne and San Joaquin Rivers once their 95% confidence limits have been completed. Nonetheless, it is obvious that both mercury and sediment discharges from the San Joaquin River and Mokelumne River are much less than discharges from the Sacramento Basin.

Table 7.4: Comparison of Loading Estimates for Other Major Delta Tributaries

Study	**Period**	**Average San Joaquin Valley Water Year Hydrologic Index** (a)	**Average Annual TotHg Load** [Upper & Lower Limits] (kg) (c)	**Average Annual TSS Load** [Upper & Lower Limits] (Mkg) (c)
San Joaquin River @ Vernalis				
Delta Mercury TMDL	WY2000-2003	2.7	19 [#, #]	146 [#, #]
	WY1984-2003	3.1	30 [#, #]	235 [#, #]
Foe (2002)	WY2001 (b)	2.2	16	110
LWA (2002)	WY1980-1999	3.5	26	na
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	210 [231, 189]
Mokelumne River downstream of Cosumnes River Confluence				
Delta Mercury TMDL	WY2000-2003	2.7	3.1 [#, #]	8.6 [#, #]
	WY1984-2003	3.1	4.2 [#, #]	11 [#, #]
Foe (2002)	WY2001 (b)	2.2	1.5	5.2
LWA (2002)	WY1980-1999	3.5	3	na
Eastside Tributaries (Cosumnes, Mokelumne & Calaveras Rivers & French Camp Slough)				
Delta Mercury TMDL	WY2000-2003	2.7	8.3 [#, #]	25 [#, #]
	WY1984-2003	3.1	9.7 [#, #]	28 [#, #]
Wright & Schoellhamer (2005)	WY1999-2002	2.9	na	36 [28, 44]

(a) Source: DWR, http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST. DWR calculated a hydrologic index for the San Joaquin Valley (Section E.1 in Appendix E). "Normal" hydrologic conditions for the San Joaquin Valley are represented by an index value of 3.1, "wet" is ≥3.8, "dry" is 2.1 to 2.5, and "critical dry" is ≤2.1.
(b) Foe's 2002 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.
(c) The 95% confidence limits will be calculated for the TMDL loads using the method developed in consultation with UC Davis and will be described in Appendix J once completed.

The regression between total mercury concentration and flow for Marsh Creek was statistically significant, but the TSS/flow regression was not. The resulting regression equation for total mercury was used to estimate daily total mercury concentrations. The predicted total mercury concentrations were multiplied by daily flow volume at the Brentwood gage to estimate daily loads, which were summed and then divided by the number of years in the flow gage record to estimate the average annual loads. The Marsh Creek total mercury and TSS loads shown in Table 7.1 represent the average annual loads for WY2001-2003 because the Brentwood flow gage was not operational during WY2000. Because the TSS/flow regression was not significant at $P < 0.05$, the average wet weather TSS concentration was multiplied by average annual flow volume to estimate WY2001-2003 average annual loads.

There were no flow gages available for watershed outflow sampling locations on several small eastside and westside tributaries: Morrison Creek, Bear Creek, Mosher Creek, French Camp Slough, and Ulatis Creek. The average wet season total mercury and TSS concentrations (Table 7.4) were multiplied by estimated average annual rainfall runoff volumes (Table 6.1 and Section E.2.2 in Appendix E) to estimate average annual loads.

Wright and Schoellhamer (2005) estimated an average annual suspended sediment load of approximately 36 Mkg/yr for WY1999-2002 for the eastside tributaries, which include the Cosumnes and Mokelumne Rivers (the primary sources) as well as the Calaveras River and French Camp Slough. Their suspended sediment estimate is based on flow estimates from the Dayflow model, which provided an estimated annual water flux of about 0.81 M acre-feet, and daily suspended-sediment flux records for the Cosumnes and Mokelumne Rivers developed using rating curves. The Cosumnes River rating curve is based on data collected from the USGS gage near Michigan Bar (about 36 river miles upstream of the statutory Delta boundary), which include 80 flux measurements between 1965 and 1974 and 13 measurements during WY2002. The Mokelumne River rating curve is based on data from the USGS gage at Woodbridge (about 15 river miles upstream of the statutory Delta boundary), which include 125 flux measurements between 1974 and 1994. The sum of the WY2000-2003 average annual water volumes provided in Table 6.1 for the Mokelumne-Cosumnes, Calaveras, and French Camp Slough outflows to the Delta is 0.64 M acre-feet. The sum of WY2000-2003 average annual TSS loads provided in Table 7.1 for these watersheds is 25 Mkg, a load estimate that is similar to Wright and Schoellhamer's load estimate for eastside tributaries.

7.1.1.3 Sacramento Basin Tributary Watersheds Loads

Because Sacramento Basin outflows account for about 80% of all mercury and TSS loading to the Delta, evaluation of the loading from its tributary watersheds is needed to develop total mercury limits and implementation strategies for mercury reductions in Delta biota and outflows to the San Francisco Bay. During low flow conditions, water in the Sacramento River at Freeport primarily originates from Shasta and Oroville Dams in the upper Sacramento and Feather River basins, respectively (Figure 7.1). In contrast, during large storms the Sacramento River at Freeport may be dominated by flows from the American and Feather Rivers. Storm overflow from the upper Sacramento River, Feather River and Colusa Basin are routed down the Yolo Bypass. The Yolo Bypass also receives flows from Putah Creek and Cache Creek *via* the Cache Creek Settling Basin. The Settling Basin is located at the base of the Cache Creek watershed and currently captures about half of the sediment and mercury transported by Cache Creek (Foe and Croyle, 1998; CDM, 2004; Cooke *et al.*, 2004); untrapped sediment is flushed into the Yolo Bypass.

Four-year (WY2000-2003) and 20-year (WY1984-2003) average annual loading values were calculated for the tributary watersheds that contribute to loads discharged from the Sacramento Basin to the Delta. Table 7.5 summarizes the total mercury and TSS concentration data available for the Sacramento Basin tributaries. Table 7.6 presents the watershed acreages, water volumes and estimated total mercury and

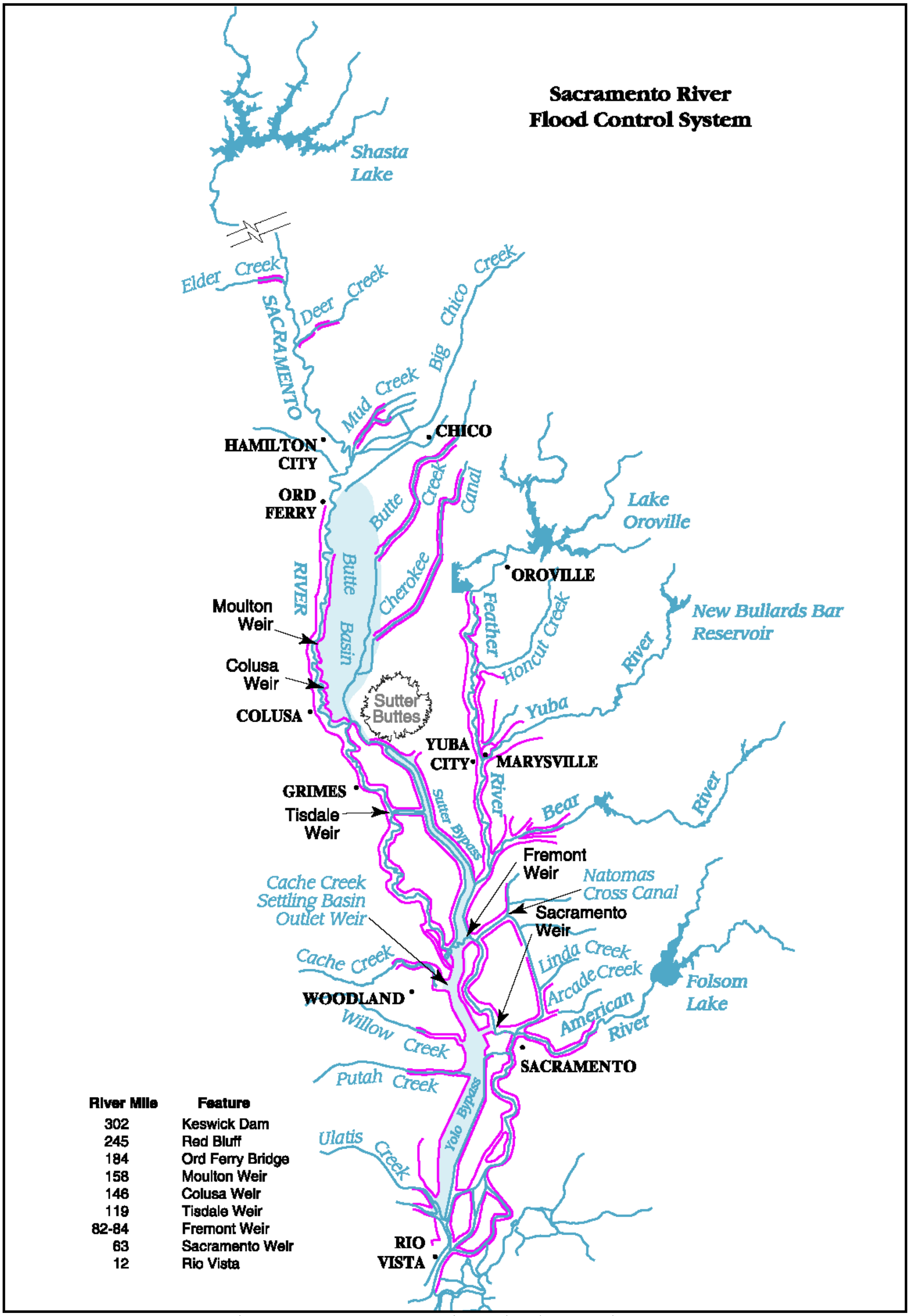

Figure 7.1: Sacramento River Flood Control System.
Pink lines represent levees. (Tetra Tech, 2005; DWR, 2003a)

Table 7.5: Total Mercury & TSS Concentrations for Sacramento Basin Tributaries.

Site	# of Samples	Sampling Begin Date	Sampling End Date	Min. Conc. (ng/l)	Average (ng/l)	Median Conc. (ng/l)	Max. Conc. (ng/l)
Total Mercury Concentrations							
American River @ Discovery Park	155	2/01/94	2/19/04	0.46	2.97	2.14	18.51
Cache Creek Settling Basin	26	12/23/96	2/17/04	4.07	185.73	63.04	984.60
Colusa Basin Drain	63	1/31/95	2/18/04	1.59	11.58	6.90	75.10
Feather River near Nicolaus	77	1/31/95	2/18/04	1.49	6.76	4.31	46.19
Natomas East Main Drain (a)	56 (12)	3/5/96	12/12/02	1.06 (9.52)	10.87 (27.78)	6.88 (20.84)	82.99 (82.99)
Putah Creek @ Mace Blvd.	36	1/31/95	3/09/04	1.25	33.10	9.29	485.00
Sacramento River above Colusa	68	3/10/95	2/17/04	0.60	12.18	4.08	105.16
Sacramento Slough near Karnak (b)	56	2/12/96	9/15/03	0.69	8.81	7.67	30.8
TSS Concentrations							
American River @ Discovery Park	191	12/15/92	2/19/04	0.5	6.23	3.0	116.0
Cache Creek d/s Settling Basin	24	12/23/96	2/17/04	41.0	452.7	187.5	1,900
Colusa Basin Drain	59	2/07/96	2/18/04	21.0	128.0	101.0	487.7
Feather River near Nicolaus	72	2/23/96	2/18/04	2.0	23.5	14.5	123.0
Natomas East Main Drain (a)	30 (8)	3/5/96	3/8/02	5.0 (16.6)	31.3 (43.0)	66.0 (34.5)	122.0 (96.0)
Putah Creek @ Mace Blvd.	27	3/28/00	2/29/04	1.6	53.4	30.0	417.8
Sacramento River above Colusa	51	3/10/95	2/17/04	10.0	101.6	36.0	662.2
Sacramento Slough near Karnak (b)	54	2/12/96	9/15/03	14.8	62.6	53.0	182.0

(a) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected total mercury and TSS concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. Wet weather concentration data for Arcade Creek and Dry Creek (noted in parentheses), and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Table 6.1 in Chapter 6 and Section E.2.2 in Appendix E), were used to develop preliminary load estimates. Note, Natomas East Main Drain was recently renamed “Steelhead Creek”.

(b) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

Table 7.6a: Sacramento Basin Tributaries – Acreage & Water Volumes.

	Acreage	% All Acreage	WY2000-2003 Water Volume (M acre-feet/yr)	WY2000-2003 % All Water	WY1984-2003 Water Volume (M acre-feet/yr)	WY1984-2003 % All Water
Upstream Tributary Inputs						
American River	1,253,740	7.5%	1.88	11%	2.5	12%
Cache Creek	724,526	4.3%	0.22	1.3%	0.38	1.9%
Colusa Basin Drain	1,577,307	9.4%	0.571	3.4%	0.574	2.8%
Coon Creek/Cross Canal	287,914	1.7%	0.089	0.5%	0.094	0.5%
Feather River	3,793,179	23%	3.7	22%	5.5	27%
Natomas East Main Drain	231,598	1.4%	0.064	0.4%	0.067	0.3%
Putah Creek	652,762	3.9%	0.24	1.5%	0.32	1.6%
Sacramento River above Colusa	7,562,525	45%	8.2	49%	8.1	40%
Sutter Bypass (a)	682,071	4.1%	1.8	11%	2.8	14%
Sum of Upstream Inputs:	**16,765,622**	**100%**	**16.8**	**100%**	**20.3**	**100%**
Exports to Delta						
Yolo Bypass (Prospect Slough)	- - -		1.0	6%	2.7	14%
Sacramento River (Freeport)	- - -		15.1	94%	16	86%
Sum of Exports to Delta:	- - -		**16.1**	**100%**	**18.8**	**100%**
Tributary Inputs – Exports to Delta:			**0.6**		**1.5**	
Exports to Delta / Tributary Inputs			**96%**		**93%**	

Table 7.6b: Sacramento Basin Tributaries – Total Mercury Loads.

	WY2000-2003			WY1984-2003			% of TotHg Inputs (Average)	
	Lower Limit	Average	Upper Limit	Lower Limit	Average	Upper Limit	WY2000-2003	WY1984-2003
Upstream Tributary Inputs								
American River	5.5	**6.5**	7.4	12	**14**	17	2.6%	3.4%
Cache Creek Settling Basin	15	**30**	45	95	**125**	154	12%	29%
Colusa Basin Drain	8.8	**8.9**	9.1	11	**11**	11	3.6%	2.7%
Feather River	18	**30**	35	36	**77**	96	12%	18%
Natomas East Main Drain	1.2	**2.2**	3.2	1.3	**2.3**	3.4	0.9%	0.5%
Putah Creek	1.3	**10**	19	1.7	**13**	24.7	4.1%	3.1%
Sacramento River above Colusa	95	**139**	184	105	**151**	197	57%	36%
Sutter Bypass (a)	16	**19**	22	26	**30**	35	7.8%	7.1%
Sum of Upstream Inputs:	161	**246**	324	288	**424**	538	100%	100%
Exports to Delta								
Prospect Slough	27	**36**	45	104	**161**	218	20%	47%
Sacramento River @ Freeport	131	**149**	166	162	**183**	204	80%	53%
Sum of Exports to Delta:	157	**185**	212	266	**344**	422	100%	100%
Trib Inputs - Exports to Delta		**61**			**80**			
Exports to Delta / Trib Inputs		**75%**			**81%**			

Table 7.6c: Sacramento Basin Tributaries – TSS Loads (Mkg/yr).

	WY2000-2003			WY1984-2003			% of TSS Inputs (Best Estimate)	
	Lower	Best Estimate	Upper	Lower	Best Estimate	Upper	WY2000-2003	WY1984-2003
Upstream Tributary Inputs								
American River	11	**14**	17	44	**53**	62	0.75%	2.2%
Cache Creek Settling Basin	40	**72**	105	205	**269**	333	3.8%	11%
Colusa Basin Drain	82	**103**	124	96	**129**	162	5.4%	5.2%
Feather River	77	**103**	130	179	**256**	332	5.5%	10%
Natomas East Main Drain	2	**3**	5	2	**4**	5	0.18%	0.14%
Putah Creek		**8**	17	7	**21**	34	0.4%	0.8%
Sacramento River above Colusa	1,153	**1,446**	1,738	1,223	**1,522**	1,821	77%	62%
Sutter Bypass (a)	115	**136**	156	182	**215**	248	7.2%	8.7%
Sum of Upstream Inputs:	1,479	**1,885**	2,291	1,940	**2,468**	2,996	100%	100%
Exports to Delta								
Prospect Slough	125	**195**	265	536	**984**	1,431	22%	53%
Sacramento River @ Freeport	575	**689**	803	729	**865**	1,002	78%	47%
Sum of Exports to Delta:	700	**884**	1,068	1,265	**1,849**	2,433	100%	100%
Trib Inputs - Exports to Delta		**1,001**			**619**			
Exports to Delta / Trib Inputs		**46.9%**			**75%**			

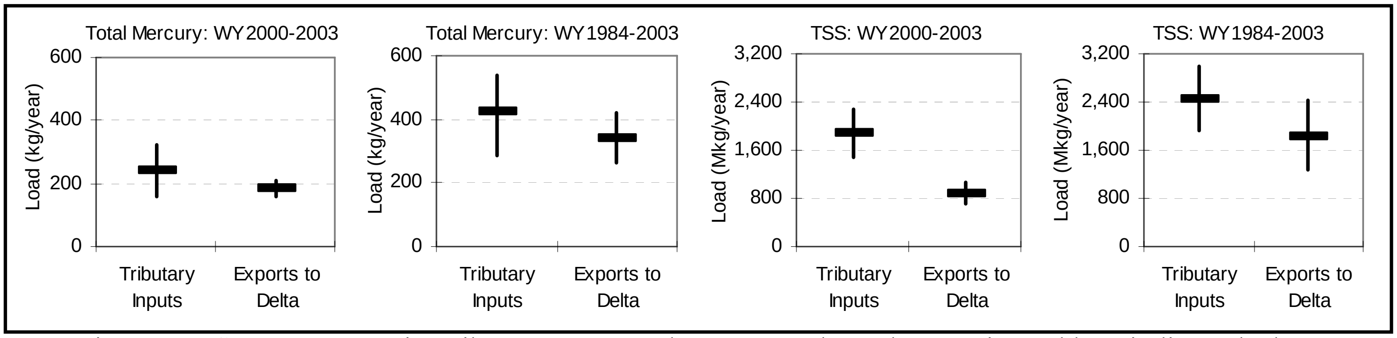

Figure 7.2: Sacramento Basin Tributary Inputs and Exports to the Delta. Horizontal bars indicate the best estimates of average annual mercury and TSS loads for each study period. Vertical bars indicate the possible range of load estimates. [This figure will be updated with corrected confidence intervals.]

TSS loads that characterize each of the watersheds. Concentration data were collected by the SRWP, DWR, USGS, CMP, and Central Valley Water Board staff (Appendix M). The water volume calculations upon which the load calculations are based are described in Appendix E. Appendix J provides graphs that illustrate time series of the available total mercury and TSS concentration data and the total mercury/flow and TSS/flow regressions described in the following pages.

Four watersheds provide more than 90% of the annual average water volume to the Sacramento River and Yolo Bypass during WY2000-2003 and WY1984-2003: Sacramento River above Colusa, Feather River, Sutter Bypass and American River. A different combination of four watersheds contributes about 90% of the annual mercury load: Sacramento River above Colusa, Cache Creek Settling Basin, Feather River, and Sutter Bypass. These same four watersheds also contribute more than 90% of the TSS load. Although the same four watersheds contribute the most mercury and TSS load, their relative ranking is different for each constituent during the different study periods. The Cache Creek Settling Basin, with a 20-year average annual mercury load of 125 kg, contributes almost as much as the upper Sacramento River watershed, while draining one of the smallest, driest watersheds in the Sacramento Basin.

Tables 7.6a and 7.6b and Figure 7.2 show the draft mass budgets for tributary inputs to the Sacramento Basin and exports from the Sacramento Basin to the Delta. The water budget balances within 4 to 7%, which indicates that all major water inputs and exports have been identified. The mass budgets will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations once the 95% confidence limits have been completed. The following pages describe how the total mercury and TSS loads were estimated for the Sacramento Basin tributary watersheds and the uncertainties inherent in the estimates, particularly for Sutter Bypass. For the purpose of the proposed total mercury limits (Section 8.2), it is assumed that over long periods, reductions in mercury loads in the Sacramento Basin inputs will result in equal reductions in Sacramento Basin exports to the Delta. This assumption will be reevaluated as more information becomes available.

Several studies have evaluated total mercury and suspended sediment loading in the Sacramento Basin for a variety of wet and dry years. These studies are summarized below along with the total mercury and TSS loads estimated for the Sacramento Basin tributary watersheds for this TMDL program. The results of these studies will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations once the 95% confidence limits have been calculated.

Total mercury and TSS concentrations for each tributary were regressed against flow to determine if correlations existed (Appendix J). The TotHg/flow and TSS/flow regressions for the American River, Cache Creek, Colusa Basin Drain, Feather River, and Sacramento River at Colusa were all statistically significant at $P<0.01$. The TotHg/flow and TSS/flow equations were used to predict the average annual loads from the tributary watersheds for WY2000-2003 and WY1984-2003 shown in Table 7.6.
LWA (2002) reported 1980-1999 annual average total mercury loads from the American River, Feather River and Sacramento River above Colusa of 15.4 kg, 55.4 kg, and 88.1 kg, respectively.

The TSS/flow regression for Putah Creek was statistically significant, but the TotHg/flow regression was not. The resulting regression equation for TSS was used to predict daily TSS concentrations. The predicted TSS concentrations were used to predict the average annual TSS loads for WY2000-2003 and WY1984-2003. Because the TotHg/flow regression was not significant at $P < 0.05$, the average total mercury concentration (Table 7.5) was multiplied by average annual flow volume to estimate WY2001-2003 and WY1984-2003 average annual mercury loads.

Daily flow data were not available for Natomas East Main Drain (NEMD) and Coon Creek watershed outflows to the Sacramento River. Average annual rainfall runoff volumes were estimated to approximate their watershed outflows (Appendix E). In addition, no concentration data were available for the outflows from these watersheds. Concentration data collected by the SRWP, USGS and City of Roseville were available for Arcade Creek near Norwood and Del Paso Heights and Dry Creek, within the NEMD watershed. Wet weather concentration data for Arcade and Dry Creeks (noted in parentheses in Table 7.5) and estimated wet weather runoff for the entire Natomas East Main Drain watershed (Appendix E) were used to develop preliminary load estimates for NEMD outflows. No total mercury or TSS concentration data were available to estimate loads in Coon Creek outflows.

The Sutter Bypass watershed includes the areas that drain into Butte Creek south of Chico and areas that drain into the Sutter Bypass between the Sacramento and Feather Rivers and south of the Sutter Buttes (Figure 7.1). In addition, flood flows from the Sacramento River upstream of Colusa are diverted into Sutter Bypass through the Moulton and Colusa bypasses; flood flows from the Sacramento River downstream of Colusa are diverted into the Sutter Bypass through the Tisdale bypass. Floodwaters from the Sacramento River also spill at several locations into the Butte Creek basin and Butte Sink, which drain to Sutter Bypass. During low flow conditions, the Sutter Bypass drains through Sacramento Slough near Karnak into the Sacramento River less than a mile upstream of the Feather River confluence. During high flow conditions, the Sacramento Slough channel is submerged and the Sutter Bypass has unchannelized flow directly into the Sacramento River. Sacramento Slough flows also are affected by Sacramento River conditions; Central Valley Water Board and DWR staff has witnessed backwater conditions on Sacramento Slough near Karnak, where the slough's flow reverses direction during high stages on the Sacramento River.

The Sutter Bypass average annual water volumes and loads illustrated in Table 7.6 were estimated using flows recorded by the DWR gage on Butte Slough near Meridian. The bypass at this location includes flows from Butte Creek and diversions from the Sacramento River made by Moulton and Colusa Weirs, which are upstream of the "Sacramento River above Colusa" sampling station, but not from Tisdale Weir or other sources that discharge to the bypass downstream of Meridian. Because only flows for WY1998-2003 are available for the gage at Meridian, the WY1998-2003 flows were used to estimate long-term average mercury and TSS loads from Sutter Bypass. WY1998-2003 represent a relatively wetter period than the WY1984-2003, hence these load estimates may overestimate the Sutter Bypass contribution to the Delta.

Total mercury and TSS concentration data were available for the Sutter Bypass at Sacramento Slough near Karnak, about 30 miles downstream of the Meridian flow gage. The data were collected between February 1996 and September 2003 during a range of flow conditions, including when Sacramento Slough was submerged. There is a flow gage located nearby; however, it was operational only during the WY1996-1998 period. In addition, it was not rated for flows above 5,200 cfs (Figure 7.3); flows exceeded the 5,200 cfs rating for the gage for extended periods during each year of the record. Therefore, the TotHg/flow and TSS/flow regressions for Sacramento Slough shown in Appendix J are based only on the samples collected when the Karnak gage recorded flows within its rating curve, most of which are low flow events. Not surprisingly, the TotHg/flow and TSS/flow regressions for Sacramento Slough were not statistically significant. Therefore, a preliminary estimate of Sutter Bypass loading was developed by multiplying water volumes recorded by the Meridian gage by the average total mercury and TSS concentrations observed at Karnak. The uncertainty of the load values was estimated by calculating the

95% confidence interval for the mean of the concentration data. This calculation does not address any uncertainty associated with using concentration data collected 30 miles downstream of the flow gage.

Tetra Tech, Inc., under contract by the USEPA, recently completed a hydrologic model for the Sacramento River watershed that Central Valley Water Board staff will use to improve flow estimates for Sutter Bypass exports. The Central Valley Water Board, SRWP, CMP and USGS all have ongoing mercury monitoring programs for locations throughout the Sacramento Basin. Results from these programs will be used to update the Sacramento Basin loading assessment as they become available.

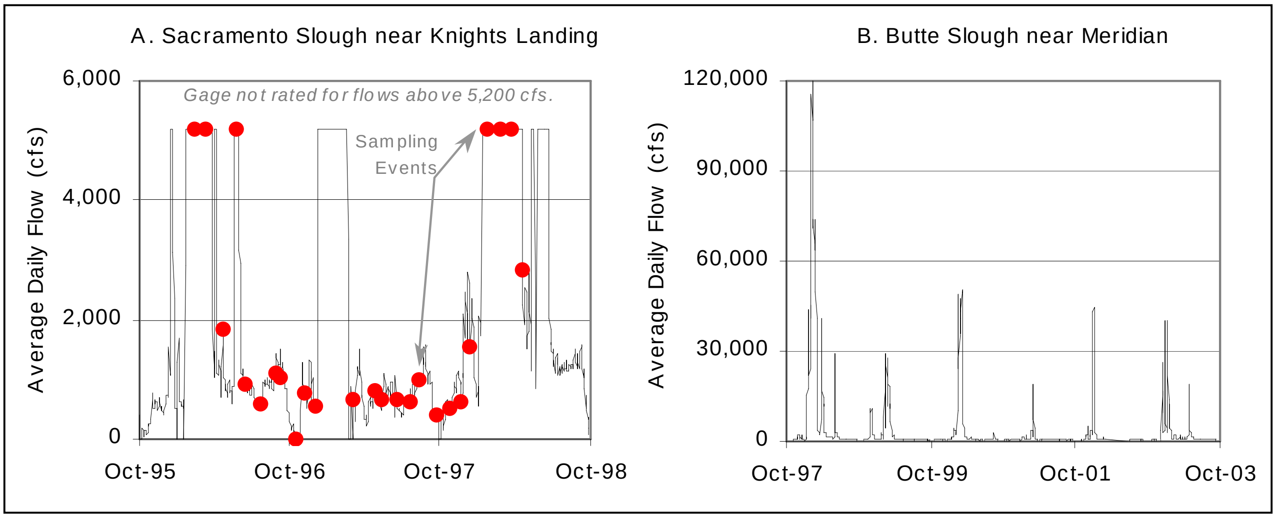

Figure 7.3: Flow Data Evaluated for Sutter Bypass.

7.1.2 Municipal & Industrial Sources

There are 20 NPDES-permitted municipal and industrial discharges to surface water in the Delta[42] (Figure 6.5). Of the 20 facilities in the Delta, five are heating/cooling and power facilities; discharges from these facilities are not considered mercury inputs to the Delta because the available information indicates that the facilities do not add notable amounts of total mercury to the water that they withdraw from Delta waterways. Information on the facilities is from the State Water Resources Control Board's Surface Water Information (SWIM) database.

Information on average flows rates for each facility was obtained from the Central Valley Water Board's discharger project files and permits. Effluent total mercury concentration data were obtained from project files and dischargers' SIP monitoring efforts.[43] Table 6.5 in Chapter 6 and Table G.1 in Appendix G

[42] It is assumed that facility discharges contain negligible amounts of suspended solids.

[43] In September 2002, the Central Valley Water Board issued a California Water Code Section 13267 order to all NPDES dischargers (except municipal stormwater dischargers) requiring the dischargers to collect effluent and receiving water samples and to have the samples analyzed for priority pollutants contained in the U.S Environmental Protection Agency's California Toxics Rule and portions of the USEPA's National Toxics Rule. This action was directed by Section 1.2 of the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, also known as the State Implementation Policy (SIP), which was adopted by the State Water Resources Control Board on 2 March 2000. The SIP monitoring requires that the dischargers' mercury monitoring utilize "ultra-clean" sampling and analytical methods including Method 1669 (Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels, US EPA)

provide additional information about the facilities. Table G.1 lists the estimated annual mercury loads from each facility, which were obtained from the facility-specific average effluent concentration and average daily discharge volume multiplied by 365. It was assumed that total mercury loading from the facilities does not vary substantially between wet and dry years. This consideration will be re-evaluated as additional information becomes available. The sum of facility loads is approximately 2.4 kg/yr, about 1% of all Delta sources.

7.1.3 Urban Runoff

Approximately 60,000 acres in the Delta are urban, most of which are regulated by NPDES waste discharge requirements. Table 6.10 in Chapter 6 lists the permits that regulate urban runoff and their corresponding acreage. Figure 6.7 shows their locations. Urban areas not encompassed by a MS4 service area were grouped into a "nonpoint source" category.

Total mercury and TSS concentration data were collected by Central Valley Water Board staff and the City and County of Sacramento from several urban waterways within or adjacent to the Delta. Figure 6.8 shows the urban areas and sampling locations and Figure I.1 in Appendix I illustrates the wet and dry weather concentrations by location. Data generation by analytical methods with detection limits less than 1 ng/l began in 1996. The total mercury concentrations ranged from a dry weather low of 1.06 ng/l (Arcade Creek) to a wet weather high of 1,138 ng/l (Strong Ranch Slough). The TSS concentrations ranged from a dry weather low of less than 3 mg/l (City of Sacramento Sump 111) to a wet weather high of 1,300 mg/l (Strong Ranch Slough). A visual inspection of the total mercury and TSS data suggests that the differences between the urban watersheds are not directly related to land use. Therefore, the data were averaged by wet and dry weather for each location (Table 7.7). The averages of these location-based wet and dry weather averages are assumed to represent runoff from all urban areas in or adjacent to the Delta.

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and Method 1631 (Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence, US EPA). The SIP monitoring requires major industrial and municipal NPDES dischargers to collect monthly samples for metals/mercury analysis, and minor industrial and municipal NPDES dischargers to collect quarterly samples. All dischargers were required to submit their effluent and receiving water data by 1 March 2003. Staff evaluated discharge data contributed prior to March 2003 to develop preliminary mercury load estimates. Staff will update this evaluation using the recently received data.

Table 7.7: Summary of Urban Runoff Total Mercury and TSS Concentrations

Urban Watershed	# of Samples	Minimum Conc. (ng/l)	Average Conc. (ng/l)	Maximum Conc. (ng/l)
TOTAL MERCURY				
DRY WEATHER				
Arcade Creek	37	1.06	8.07	34.80
City of Sacramento Strong Ranch Slough	7	3.63	18.43	84.00
City of Sacramento Sump 104	7	1.61	7.78	24.30
City of Sacramento Sump 111	7	2.16	9.59	28.96
Tracy Lateral to Sugar Cut Slough	1	7.92	7.92	7.92
Average of Location Dry Weather TotHg Averages:			**10.36**	
WET WEATHER				
Arcade Creek	14	1.73	20.90	54.30
City of Sacramento Strong Ranch Slough	13	20.10	188.32	1137.90
City of Sacramento Sump 104	14	9.94	36.72	118.42
City of Sacramento Sump 111	13	10.68	28.56	65.23
Stockton Calaveras River Pump Station	5	14.18	26.07	49.71
Stockton Duck Creek Pump Station	1	13.57	13.57	13.57
Stockton Mosher Slough Pump Station	5	9.67	14.16	17.29
Stockton Smith Canal Pump Station	4	23.17	40.97	65.87
Tracy Drainage Basin 10 Outflow	3	8.78	12.13	16.12
Tracy Drainage Basin 5 Outflow	3	7.02	12.59	20.67
Tracy Lateral to Sugar Cut Slough	3	5.44	18.10	28.45
Average of Location Wet Weather TotHg Averages:			**37.46**	
TSS				
DRY WEATHER				
Arcade Creek	28	5.0	31.7	122.0
City of Sac'to Strong Ranch Slough	6	5.0	9.3	15.0
City of Sac'to Sump 104	7	4.0	7.6	12.0
City of Sac'to Sump 111	7	1.5	6.2	11.0
Tracy Lateral to Sugar Cut Slough	1	26.5	26.5	26.5
Average of Location Dry Weather TSS Averages:			**16.26**	
WET WEATHER				
Arcade Creek	12	7.0	99.5	320.0
City of Sac'to Strong Ranch Slough	13	23.0	208.7	1300.0
City of Sac'to Sump 104	14	31.0	104.3	270.0
City of Sac'to Sump 111	11	15.7	92.4	340.0
Stockton Calaveras River Pump Station	5	26.0	94.3	264.6
Stockton Duck Creek Pump Station	1	281.3	281.3	281.3
Stockton Mosher Slough Pump Station	5	6.0	19.6	34.0
Stockton Smith Canal Pump Station	4	76.0	125.8	184.6
Tracy Drainage Basin 10 Outflow	3	81.1	136.9	236.0
Tracy Drainage Basin 5 Outflow	3	26.1	77.5	148.1
Tracy Lateral to Sugar Cut Slough	3	6.3	153.7	342.9
Average of Location Wet Weather TSS Averages:			**126.7**	

To estimate wet weather mercury and TSS loads, the average wet weather concentrations were multiplied by the runoff volumes estimated for WY2000-2003 and WY1984-2003 for each MS4 area within the Delta. To estimate dry weather mercury and TSS loads, the dry weather concentrations were multiplied by the estimated dry weather urban runoff volume. Appendix E describes the methods used to estimate wet and dry weather urban runoff from urban areas within the Delta. Wet and dry weather mercury and TSS loads were summed to estimate the WY2000-2003 average annual loadings of 2.5 kg mercury and 8.0 Mkg/yr suspended sediment, and WY1984-2003 average annual loadings of 2.6 kg mercury and 8.3 Mkg/yr TSS (Table 7.8). Uncertainty was evaluated by calculating the 95% confidence intervals for the wet and dry weather average concentrations (Table 7.1, Appendix J). Additional uncertainty may be present in the 20-year load estimates because it is unknown whether the concentration data collected between 1996 and 2003 is representative of earlier years; this uncertainty is not quantified at this time.

Urban land uses comprise a small portion of the Delta and contribute about 1% of the mercury load (Table 7.1). In contrast, approximately 320,000 acres of urban land – about 42% of all urban area within the Delta source region – are within 20 miles of the Delta boundary, about one day water travel time upstream. In addition, some of the urban watersheds outside the Delta discharge via sumps into Delta waterways. These discharges were not included in the Delta urban load estimate. As a result, the urban contribution to the Delta mercury load may be underestimated. To evaluate the potential contributions from upstream urban lands, the total mercury loadings from the two MS4 service areas with the greatest urban acreage immediately outside the Delta were estimated for the WY2000-2003 period. The sum of mercury loads from the Sacramento and Stockton MS4 areas may contribute more than 3% of loading to the Delta (Table 7.9). These loads are expected to increase as urbanization continues around the Delta.

Table 7.8: Average Annual Total Mercury and TSS Loadings from Urban Areas within the Delta

MS4 Permittee	WY2000-2003		WY1984-2003	
	TotHg Load (kg/yr)	**TSS Load** (Mkg/yr)	**TotHg Load** (kg/yr)	**TSS Load** (Mkg/yr)
City of Lathrop	0.03	0.10	0.03	0.11
City of Lodi	0.006	0.021	0.007	0.022
City of Rio Vista	0.002	0.005	0.002	0.006
City of Tracy	0.21	0.69	0.22	0.72
City of West Sacramento	0.21	0.69	0.21	0.70
County of Contra Costa	0.60	1.94	0.62	2.01
County of San Joaquin	0.41	1.33	0.42	1.38
County of Solano	0.02	0.06	0.02	0.07
County of Yolo	0.02	0.08	0.02	0.08
Port of Stockton MS4	0.05	0.15	0.05	0.16
Sacramento Area MS4	0.35	1.15	0.36	1.19
Stockton Area MS4	0.47	1.52	0.49	1.58
Urban Nonpoint Source (a)	0.31	0.99	0.10	0.33
Grand Total	**2.5**	**8.0**	**2.6**	**8.3**

(a) Urban areas not encompassed by a MS4 service area were grouped into a "nonpoint source" category within each Delta subarea.

Table 7.9: Comparison of WY2000-2003 Annual Delta Mercury and TSS Loads to Sacramento & Stockton Area MS4 Loads (a)

MS4 Service Area (Urban Acreage)	**Water Volume** (acre-feet) (b)	**TotHg Load** (kg/year)	**TSS Load** (Mkg/yr)
Sacramento MS4 Urban Total	174,593	6.85	22.31
Stockton MS4 Urban Total	25,304	0.97	2.05
Total Delta Inputs (c)	19,425,472	222	1,085
Stockton & Sacramento Urban Runoff as % of Total Delta Inputs	**1.0%**	**3.5%**	**2.2%**

(a) The Sacramento and Stockton Area MS4s are the two MS4 service areas with the greatest urban acreage immediately outside the Delta, with urban land use areas of 154,050 and 24,901acres, respectively.
(b) Refer to Appendix E for urban runoff volume estimates for wet and dry weather, which were summed to estimate the annual average water volumes shown above.
(c) These values represent the sum of all tributary and within-Delta total mercury and TSS sources shown in Table 7.1.

7.1.4 Atmospheric Deposition

Atmospheric deposition of mercury has not yet been measured within the Delta. Table 7.10 and Figure 7.4 illustrate the wet deposition data available for northern and central California. Volume-weighted average total mercury concentrations ranged from 4.1 ng/l at Covelo to 13 ng/l at Sequoia National Park. To estimate wet deposition, the volume-weighted average concentration observed at the North Bay/Martinez station (7.4 ng/l) was used because the station is closest to, and typically upwind of, the Delta. The other stations are separated from the Delta by mountainous watershed divides and may not be as representative of conditions in the Delta.

Total mercury loading from precipitation on surface water in the Delta (direct deposition) was estimated by multiplying the average mercury concentration in North Bay/Martinez rainwater (Table 7.10) by the average rainfall volume to fall on Delta water surfaces during WY2000-2003. Loading from runoff of mercury-contaminated rain falling on land (indirect deposition) was estimated by multiplying the average mercury concentration in rainwater by the estimated runoff volume for WY2000-2003. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3. Appendix E describes the method used to estimate rainfall runoff volumes for the Delta. Table 7.11 lists the estimated mercury loads from direct and indirect wet deposition. Wet deposition contributes approximately 1% of all mercury entering the Delta (Table 7.1).

There are several uncertainties inherent in the estimates of atmospheric deposition of mercury in the Delta, including but not limited to: (a) the concentration of mercury in rainfall and dry deposition loading in the Delta and its tributary watersheds; (b) the appropriate runoff coefficient to use; and (c) the amount of mercury deposited from local air emissions. These uncertainties do not have a substantial impact on the Delta total mercury budget described in Tables 7.1 because even a tenfold increase in loading from atmospheric deposition would be insubstantial when compared to the loading to the Delta from the

Table 7.10: Summary of Available Data Describing Mercury Concentrations in Wet Deposition in Northern and Central California.

Study (a)	**Station**	**Volume-Weighted Average TotHg Conc.** (ng/l)	**# of Samples**	**Collection Period**
San Francisco Bay Atmospheric Deposition Pilot Study (SFBADPS) (b)	North Bay	7.4	14	Aug. 1999 – Jul. 2000
	Central Bay	6.6	16	
	South Bay (c)	9.7	29	
National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN)	San Jose (c)	10	86	Jan. 2000 – Dec. 2003
	Sequoia National Park (d)	13	5	Jul. 2003 – Dec. 2003
	Covelo (e)	4.1	60	Dec. 1997 – Sep. 2000

(a) Sources: NADP MDN – Sweet, 2000; NADP, 2004. SFBADPS – SFEI, 2001.
(b) The North Bay, Central Bay, and South Bay sites are located at Martinez, Treasure Island and Moffett Federal Airfield/NASA Ames Research Center near San Jose, respectively.
(c) In addition to being part of the SFBADPS, the South Bay site also became one of the NADP MDN stations. Co-location of mercury wet deposition sampling under the MDN/NADP with the Pilot Study at the South Bay site began in January 2000 and resulted in ten replicate field precipitation samples.
(d) Sequoia National Park is in the Sierra Nevada Mountains to the southeast of Fresno in the Tulare Basin, which is south of the San Joaquin Basin.
(e) Covelo is ~150 miles north of San Francisco Bay in the Coast Range.

Table 7.11: Average Annual Total Mercury Loads from Wet Deposition for WY2000-2003 (a)

Period/Deposition Type (b)	**Water Volume** (acre-feet) (c)	**TotHg** (kg/year)
Direct Deposition	93,498	0.85
Indirect Deposition	154,100	1.41
TOTAL	247,598	2.26

(a) The volume-weighted average concentration observed in the North Bay/Martinez (7.4 ng/l, Table 7.10) was used to estimate total mercury loading to the Delta.
(b) Direct deposition results from mercury-contaminated rain falling on Delta surface waters. Indirect deposition results from runoff of mercury-contaminated rain falling on land surfaces in the Delta. Runoff from urban areas was not included because it is inherently incorporated in the estimates for loading from urban runoff described in Section 7.1.3.
(c) Refer to Appendix E for a description of the methods used to estimate rainfall runoff volumes.

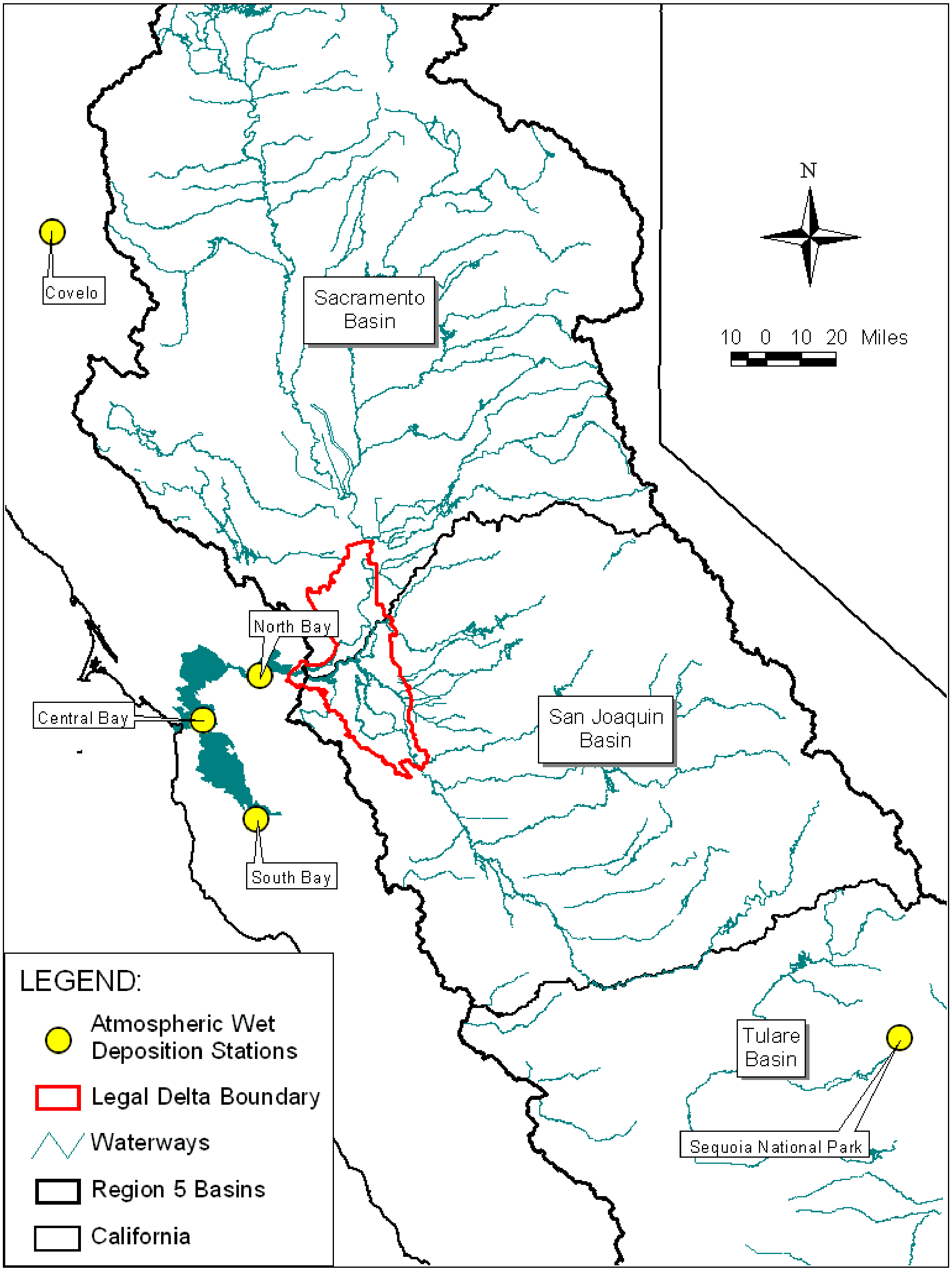

Figure 7.4: Wet Deposition Total Mercury Sampling Locations in Northern and Central California

Sacramento River and Yolo Bypass. However, these uncertainties have important implications for determining future mass budgets for the tributary watersheds because of their immense acreage.

Mercury loading from dry deposition was not estimated because of the level of uncertainty with respect to the amount of dry deposition that is entrained in runoff. SFEI (2001b) estimated that about 4.5 times more mercury is deposited on an annual basis in dry deposition than in wet deposition in San Francisco Bay. In addition, it was assumed for the wet deposition load estimates listed in Table 7.11 that total mercury in atmospheric deposition has a similar runoff coefficient as water. However, mercury may be more or less easily transported than water once it comes in contact with land surfaces. Runoff coefficients are a function of meteorology, land use characteristics, slope, size and soil characteristics of the watershed (Tsiros, 1999). Dolan and others (1993) estimated that roughly 10% of the mercury falling in the Lake Superior watershed entered the lake. Quemerais and others (1999) determined that about 12% of the atmospheric mercury deposited in the St. Lawrence River watershed ran off. Mason and others (1994) estimated that about 30% of atmospheric deposition was reaching Swedish and mid continental American lakes in overland flow. SFEI (2001b) used a runoff coefficient of 32% for San Francisco Bay. The Delta TMDL analyses employed a range of runoff coefficients based on land uses that ranged from 13% for forested upland areas to 70% for industrial/commercial areas. Dr. Gill and other researchers from Texas A&M University are currently conducting a study as part of the ongoing CALFED-funded project (ERP-02-C06-B) to measure total mercury in atmospheric deposition at sites in the Sierra Nevada Mountain Range, Coastal Range, and the Delta. The study should be completed and a report prepared by the fall of 2006.

In an attempt to identify local – and therefore potentially controllable – sources of mercury in atmospheric deposition in the Delta and its tributary watersheds, mercury loads emitted by facilities that report emissions to the California Air Resources Board (ARB) were reviewed. The ARB Emission Inventory Branch tracks mercury loading in air emissions in its California Emission Inventory Development and Reporting System database. ARB staff provided a database describing facilities that reported mercury emissions in 2002. Appendix K provides a summary of the types of facilities in each watershed and their estimated loads. The data indicate that almost 10 kg of mercury were released in the Delta by sugar beet facilities, electric services, paper mills, feed preparation, and rice milling. Cement and concrete manufacturing facilities and crematories in the Delta's tributary watersheds appear to have relatively high mercury emissions. These loads are not incorporated in the mass budgets because their deposition rates are not known. Local air emissions of mercury warrant additional research.

7.1.5 Other Potential Sources

Loading from Delta soils has not been evaluated. More than 70% of Delta lands have agricultural land uses and many of the urban areas in the Delta were once agricultural. Farming began in the Delta in 1849, about the same time that gold mining began in the Sierra Nevada Mountains (DWR, 1995). In 1861, the California legislature authorized the Reclamation District Act, which allowed drainage of Delta swampland and construction of levees; the extensive Delta levee system was mostly built between 1869 and 1880 (DWR, 1995). By 1852, hydraulic mining was the most common method for mining the placer gold deposits in the Sierra Nevada (Hunerlach *et al*., 1999) and continued until the Sawyer Decision outlawed the practice in 1884. Hydraulic gold mining resulted in the deposition of large amounts of silt and sand in Delta channels and upstream rivers (DWR, 1995). Much of these deposits may be contaminated with mercury used to amalgamate the gold. Therefore, some levees and Delta islands may have been constructed with mercury-contaminated sediment.

Barley and other grains have historically been common rotational crops in the Delta (Weir, 1952), and the seeds were treated with mercury-based fungicides before sowing (LWA, 2002). It is not known how much mercury was used in the Delta, but up to 38,000 kg of mercury may have been added in fungicides in the Sacramento Valley between 1921 and 1971 (LWA, 2002). Mercury is no longer used as an active ingredient in any pesticides (DPR, 2002).

Mercury has been measured in 26 soil samples in the Delta source region, mostly from agricultural fields (Bradford *et al.*, 1996). One sample was collected in the eastern Delta near White Slough north of Stockton (0.27 mg/kg) and five samples were collected within 10 miles of the Delta boundary (0.25, 0.34, and three results <0.2 mg/kg). There was no relationship between soil mercury levels and location and soil type. Some of the mercury concentrations were elevated and may warrant additional monitoring.

7.2 Total Mercury and TSS Losses

The following were identified as total mercury losses from the Delta: flow to San Francisco Bay, water diversions to south of the Delta, removal of dredged sediments, and evasion. Table 7.12 lists the total mercury and TSS load estimates for these losses. The following sections describe the total mercury and TSS concentration data available for the losses and identify some of the data gaps and uncertainties associated with the load estimates.

Table 7.12: Average Annual Total Mercury and TSS Losses for WY2000-2003 and WY1984-2003. (c)

	WY2000-2003				WY1984-2003			
	TotHg		TSS		TotHg		TSS	
	(kg/yr)	% of All Inputs	(Mkg/yr)	% of All Inputs	(kg/yr)	% of All Inputs	(Mkg/yr)	% of All Inputs
Outflow to San Francisco Bay [X2] (a)	83 ±28	43%	450 ±##	52.1%	201 ±68	65%	1,202 ±381	75
Dredging (b)	57 ±##	30%	304 ±##	35.2%	57 ±##	19%	304 ±##	19
Evasion	30 ±##	16%	*not applicable*		30 ±##	10%	*not applicable*	
State Water Project	12 ±##	6.2%	47 ±##	5.4%	9.6 ±##	3.1%	38 ±##	2.4
Delta Mendota Canal	11 ±##	5.7%	62 ±##	7.2%	10.3 ±##	3.3%	60 ±##	3.7
Sum of Losses	**193 ±##**	**100%**	**863 ±##**	**100%**	**308 ±##**		**1,604 ±##**	

(a) Source: Leatherbarrow & others, 2005. The X2 TotHg and TSS loads listed for WY1984-2003 are based on the average annual load calculations for WY1995-2003.
(b) The confidence intervals for the evasion mercury and dredging sediment load estimates were not evaluated.
(c) The 95% confidence limits will be calculated using a method developed in consultation with UC Davis that will be described in Appendix J once completed.

7.2.1 Outflow to San Francisco Bay

Estimates of total mercury and sediment loading from the Delta to San Francisco Bay are critical components of the Delta mercury TMDL for two reasons. First, outflow to San Francisco Bay is the primary export from the Delta and must be accurately measured to determine whether the Delta is a net source or sink for mercury and sediment. Second, the San Francisco Bay mercury TMDL assigned the Central Valley a mercury load allocation of 330 kg/yr that must be met either at Mallard Island or by a 110 kg reduction in mercury sources to the Delta (Section 2.4.2.3). Four studies have evaluated sediment and mercury loading rates to the San Francisco Bay (Table 7.13). These studies are summarized below. The results of these studies will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations once the 95% confidence limits have been completed. Comparison of the results is complicated by the fact that all estimates were done by different methods and for different groups of water year types. Greater flux rates are thought to occur in wet years.

Central Valley Water Board staff evaluated TSS and mercury levels in Central Valley outflows to San Francisco Bay by collecting samples at X2. Figure 6.9 in Chapter 6 illustrates a typical location of X2. Central Valley Water Board staff conducted monthly aqueous total mercury and TSS sampling at X2 from March 2000 to September 2001 (Foe, 2003) and from April 2003 to September 2003. Table 7.14 and Figures J.1 through J.8 summarize the available total mercury and TSS concentration data for the Delta's major exports. Total mercury concentrations at X2 averaged 17.3 ng/l and ranged from 3.9 ng/l to 49.2 ng/l. The TSS concentrations at X2 averaged 60 mg/l and ranged from 27 mg/l to 168 mg/l. Net daily Delta outflow was obtained from the Dayflow model (Appendix E). Total mercury and TSS concentrations at X2 were regressed against Delta outflow to determine whether either could be predicted from flow (Appendix J). Neither regression was significant. Therefore, average mercury and TSS concentrations were multiplied by average annual flow volumes for WY2000-2003, WY1984-2003 and WY1995-2005 to estimate annual loads (Table 7.13). Foe (2002) used a similar method to estimate monthly loads between March 2000 and September 2001, a relatively dry period. He estimated annual sediment and mercury loads for WY2001 of 473 Mkg and 122 kg, respectively (Table 7.13).

The average Central Valley total mercury load cited in the San Francisco Bay TMDL (Johnson & Looker, 2004) was based on research available at the time of its development (McKee & Foe, 2002; McKee *et al.*, 2001; Foe, 2003). The average annual total mercury load (440 kg) was estimated by multiplying suspended sediment flux measured at Mallard Island using an optical back scatter meter (OBS)[44] during WY1995-2000 (McKee & Foe, 2002; McKee *et al.*, 2001) by the mercury concentrations in suspended sediment measured at X2 during March 2000 through September 2001 (Foe, 2003). The sediment flux value was corrected for tidal dispersion (McKee & Foe, 2002; McKee *et al.*, 2001).

Leatherbarrow, McKee and others (2005) updated the mercury load estimates cited in the San Francisco Bay mercury TMDL report using mercury concentration data collected at Mallard Island between January 2002 and May 2003, an effort that focused on high flows and the influence of tide and salinity on mercury. The updated mercury load for WY1995-2000 (270 kg) is a 40% decrease from the earlier TMDL estimate (440 kg). The authors found that the origin of water – predominantly from upstream during floods or a mixture of water from the Delta and Suisun Bay during low flows – influenced the particulate mercury concentration in the water column. The increased concentrations on incoming tide may result from erosion of sediment and associated mercury from Suisun and Grizzly Bays. Because the updated load estimate is based on mercury data collected during a relatively low flow period that did not experience substantial flood inputs from the Yolo Bypass, the authors expect the long-term estimates to change as more information for larger flood events becomes available.

[44] The Mallard Island OBS instrument was calibrated with water samples collected at the same point and analyzed in a laboratory for suspended sediment concentration.

Table 7.13: Estimates of Delta Loading to San Francisco Bay

Study (a)	**Sampling Location**	**Period**	**Average Water Year Hydrologic Index** (b)	**Average Annual Water Volume** (M acre-feet) (c)	**Average Annual TotHg Load** (kg)	**Average Annual TSS Load** (Mkg)	**TotHg:TSS** (mg/kg)
Delta Mercury TMDL Program X2 Calculations	X2 (f)	WY2000-2003	7.3	12	258 ±##	893 ±##	0.30
		WY1984-2003	7.8	17	363 ±##	1,257 ±##	
		WY1995-2000	11.0	31	660 ±##	2,289 ±##	
Foe (2002)	X2 (d)	WY2001 (d)	5.8	7.2	122	473	0.25
S.F. Bay Mercury TMDL (2004)	Mallard Island	WY1995-2000	11.0	31	440 ±100	1,600 ±300	0.26 ±0.075
Leatherbarrow & others (2005) (e)	Mallard Island	WY1999-2003	7.8	18	97 ±33	524 ±166	0.11 / 0.29 (e)
		WY2000-2003	7.3	12	83 ±28	450 ±140	
		WY1995-2000	11.0	31	270 ±91	1,600 ±510	
		WY1995-2003	9.6	24	201 ±68	1,202 ±381	

(a) Sources: this report; Leatherbarrow & others, 2005; Johnson & Looker, 2004; Foe (CALFED), 2002.
(b) DWR calculated a hydrologic index for the Sacramento Valley (Appendix E). “Normal” hydrologic conditions for the Sacramento Valley are represented by an index value of 7.8, “wet” is ≥9.2, “dry” is between 5.4 and 6.5, and “critical dry” is ≤5.4.
(c) All average annual water volumes are from the Dayflow model results for Delta outflows to San Francisco Bay.
(d) Foe’s 2002 CALFED study estimated monthly total mercury and TSS loads for March 2000 through September 2001, but did not include load estimates for November 2000. November total mercury and TSS loads for WY2001 were estimated by averaging the loads for October and December 2000.
(e) Leatherbarrow and others (2005) extrapolated total mercury loads from suspended sediment flux and suspended sediment mercury levels by adjusting for tidal dispersion and salinity, where for conductivity < 2 mS/cm, TotHg:TSS is 0.11 mg/kg, and conductivity > 2 mS/cm, TotHg:TSS is 0.29 mg/kg. Central Valley Water Board staff averaged the annual load estimates provided by Leatherbarrow and others (2005) for WY1995 through 2003 to estimate average annual loads for the periods that correspond to the San Francisco Bay mercury TMDL study period (WY1995-2000) and the Delta mercury TMDL WY2000-2003 study period.
(f) The 95% confidence limits will be calculated using a method developed in consultation with UC Davis that will be described in Appendix J once completed. Caution should be used in the comparison of the WY1995-2000 and WY1984-2003 load estimates to other studies because

Table 7.14: Summary of Total Mercury and TSS Concentration Data for X2

	# of Samples (a)	**Min. Conc.**	**Ave. Conc.**	**Median Conc.**	**Max. Conc.**
TotHg (ng/l)	21	3.95	17.29	11.00	49.20
TSS (mg/l)	22	27.0	60.0	42.0	168.0

(a) Sampling at X2 took place between March 2000 and September 2003.

7.2.2 Exports South of Delta

Water diversions to the southern Central Valley and southern California account for approximately 12% of the total mercury and TSS exports from the Delta. Delta Mendota Canal (DMC) and State Water Project (SWP) exports were evaluated by collecting water samples from the DMC canal off Byron highway (County Road J4) and from the input canal to Bethany Reservoir, respectively. Bethany is the first lift station on the State Water Project canal system and is about one mile south of Clifton Court Forebay in the Delta (Figure 6.9).

Central Valley Water Board staff collected monthly total mercury and TSS samples from the DMC and SWP between March 2000 and September 2001 (Foe, 2003) and between April 2003 and 2004. Table 7.15 and Appendix J summarize the data. DMC and SWP exported water volumes were obtained from the Dayflow model (Appendix E). Total mercury and TSS concentrations were regressed against daily flow at both sites to determine whether concentrations could be predicted from flow (Appendix J). The regressions were not significant. Therefore, average mercury and TSS concentrations were multiplied by the WY2000-2003 average annual water volumes to estimate loads (Table 7.12). Central Valley Water Board staff is continuing to collect additional information at both locations. The data should be available in the fall of 2006.

Table 7.15: Summary of Total Mercury and TSS Concentration Data for Exports South of the Delta

Site	# of Samples (a)	Min. Conc.	Ave. Conc.	Median Conc.	Max. Conc.
Delta Mendota Canal					
TotHg (ng/l)	21	1.85	3.48	3.41	5.96
TSS (mg/l)	22	9.2	20.1	18.9	36.0
State Water Project					
TotHg (ng/l)	19	0.99	3.02	2.23	7.17
TSS (mg/l)	21	4.4	12.0	8.2	59.0

(a) Sampling of these exports took place between March 2000 and September 2003.

7.2.3 Dredging

Sediment is dredged from the Delta to maintain the design depth of ship channels and marinas. Dredge material is typically pumped to either disposal ponds on Delta islands or upland areas with monitored return-flow. Table 6.18 provides details on recent dredge projects in the Delta and Figure 6.9 shows their approximate location. The Sacramento and Stockton deep water channels have annual dredging programs; the locations dredged each year vary. Dredging occurs at other Delta locations when needed, when funds are available, or when special projects take place. Approximately 533,000 cubic yards of sediment are removed annually with about 200,000 cubic yards from the Sacramento Deep Water Ship Channel and about 270,000 cubic yards from the Stockton Deep Water Channel. Other minor dredging projects, mostly at marinas, remove an additional 64,000 cubic yards per year.

The amount of mercury removed annually by dredging was estimated by multiplying dredge volume at each project site by its average mercury concentration. Average mercury concentrations in the sediment for the project sites range from 0.04 to 0.44 mg/kg (dry weight). Two critical assumptions were made to calculate the total mercury removed from the Delta by dredging projects:

- Water content of the dredged material is 100% (50% water and 50% sediment by weight) (USACE, 2002); and
- There are about 570 kilograms of dry sediment per cubic yard of wet dredged material based on relative densities of water and sediment (Weast, 1981; Elert, 2002).

The following uses the Stockton Deep Water Channel dredging project information to illustrate how mercury loads in dredge materials were estimated.

Equation 7.1:

TotHg Removed by Dredging Project	=	Volume * Concentration
23 kg/year	=	[(270,000 cy/year) * (570 kg)] * (0.15 mg/kg)

Where:	Volume	=	Volume of wet dredge material (cubic yards) * 570 kg/cy (to convert to dry sediment volume)
	Concentration	=	Dry sediment total mercury concentration

The uncertainty of the mercury load values associated with each project was estimated by calculating the 95% confidence interval for the mean of the mercury concentration data for each project. As indicated in Table 6.18, the uncertainty associated with the amount of mercury removed by dredging in the Sacramento Deep Water Ship Channel is particularly substantial (±446 kg), as a consequence of its calculation being based on only two sample results (0.68 and 0.061 mg/kg mercury) that have a tenfold range.

Central Valley Water Board waste discharge requirements regulate sediment disposal and effluent from the disposal sites. The effluent limit for total mercury is 50 ng/l. For sites that have discharges to surface waters within the Delta, the total mass of mercury returned to the Delta is approximately 0.01 kg/year (Table 6.18).

The calculations indicate that annual dredging in the Delta removes about 57 ±451 kg of total mercury and 349 Mkg of sediment. This accounts for approximately 30% of the total mercury and 35% of sediment exports (Table 7.12). Central Valley Water Board staff will continue evaluation of the uncertainty in this estimate as more data becomes available.

7.2.4 Evasion

The loss of elemental mercury from water surfaces can be estimated on the basis of measured dissolved gaseous elemental mercury concentrations, atmospheric mercury concentrations, and estimated wind speeds (Conaway *et al.*, 2003). Conaway and others (2003) estimated summer and winter evaporation rates for San Francisco Bay. The Bay has a surface area of approximately 1.24×10^9 square meters (~306,400 acres) and is estimated to lose about 190 kg/yr of mercury to the atmosphere (Johnson & Looker, 2004). Similar estimates are not available for the Delta. However, an ongoing CALFED-funded project (ERP-02-C06-B) is attempting to measure evasion in the Delta. The results should become available in the winter of 2006. To obtain a preliminary estimate of evasion in the Delta, it was assumed that the loss rate would be proportional to that of San Francisco Bay. The mercury lost from the Bay's surface (190 kg/year) was multiplied by the ratio of the water surface area of the Delta to that of the Bay (0.16). The result is an evasion rate for the Delta of about 30 kg/yr, about 16% of all Delta mercury losses.

Dr. Gill and other researchers are currently conducting a study as part of an ongoing CALFED-funded project (Proposal ERP-02-C06-B) to measure atmospheric flux of dissolved gaseous mercury from the Delta. Once the results of their study are available, the evasion load will be re-calculated.

7.2.5 Other Loss Pathways

Wright and Schoellhamer (2005) indicated that a substantial portion (~67%) of annual sediment inflow to the Delta between 1999 and 2002 may have been deposited in the Delta. The amount of sediment removed by regular dredging operations in ship channels and marinas (see Section 7.2.3) indicates that substantial deposition takes place in some areas of the Delta. Annual deposition in channel point bars and banks and in flooded wetlands was not estimated. Insufficient information presently exists to determine whether the Delta experiences net erosion or deposition over a longer period.

7.3 Total Mercury & Suspended Sediment Budgets

Delta mercury and suspended sediment assessments rely on a box model approach to approximate mass balances. Mass balances are useful because the difference between the sum of known inputs and exports is a measure of the uncertainty of the load estimates and of the importance of other unknown processes. Table 7.16 and Figure 7.5 show the Delta's average annual water, total mercury and TSS budgets for WY2000-2003, based on the values presented in Tables 6.1, 7.1, and 7.12.

Table 7.16: Water, Total Mercury & TSS Budgets for the Delta for WY2000-2003.

	Water Volume (M acre-feet/yr)	**Total Mercury** (kg/yr)			**TSS** (Mkg/yr)		
		Lower	**Average**	Upper	Lower	**Average**	Upper
Inputs	19.38	*tbd*	222	*tbd*	*tbd*	1,085	*tbd*
Exports	19.04	*tbd*	191	*tbd*	*tbd*	863	*tbd*
Inputs - Exports	**0.34**		**31**			**222**	
Exports ÷ Inputs	**98%**		**86%**			**80%**	

The sum of WY2000-2003 water inputs and exports balance within 2%, indicating that all the major water inputs and losses have been identified. In contrast, the mercury and TSS budgets do not balance. The best estimates of mercury and TSS loads indicate exports are about 80% of inputs. The mass budgets will be evaluated in the context of the confidence limits of the TMDL total mercury and suspended sediment load calculations once the 95% confidence limits have been completed to determine whether uncertainty in the load calculations may result in the deficit balance.

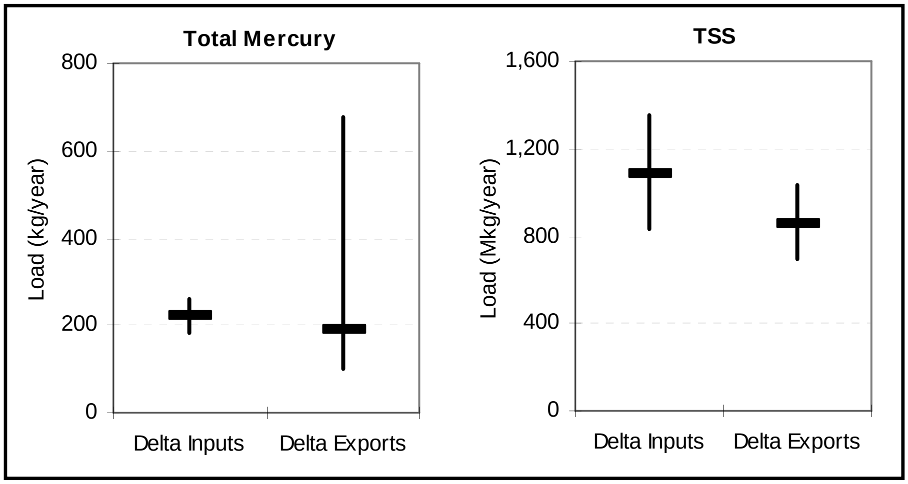

Figure 7.5: Total Mercury & TSS Inputs to and Exports from the Delta.
Horizontal bars indicate the best estimates of average annual mercury and TSS loads for WY2000-2003.
Vertical bars indicate the possible range of load estimates.
[This figure will be updated with corrected confidence intervals.]

Quantifying loading from the Central Valley to the San Francisco Bay and understanding whether the Delta is erosional or depositional is critical for developing a strategy to (1) efficiently reduce the stock of new mercury to be methylated in the Delta and (2) to meet San Francisco Water Board staff's proposed total mercury allocation for the Central Valley. Quantifying the uncertainty in the load estimates (e.g., the 95% confidence limits) is critical to the assessment of the effectiveness of control actions taken to reduce total mercury loading to the Delta and of compliance with San Francisco Water Board's allocation.

The TMDL for San Francisco Bay assigned the Central Valley a five-year average total mercury load allocation of 330 kg/yr at Mallard Island or a decrease of 110 kg/yr in mercury sources to the Delta (Section 2.4.2.3). The variety of study results for total mercury loading from the Central Valley to San Francisco Bay illustrated in Table 7.13 demonstrate the importance of both the method used to estimate loads and the water year type for which they are made. It may be more accurate to assess compliance with the San Francisco TMDL by focusing on loads entering the Delta because of the difficulty in measuring loads removed by Delta outflow, dredging, and deposition. As described in Section 7.2.1, the Sacramento Basin is the primary source of mercury in Delta outflows to San Francisco Bay. This TMDL estimated average annual Sacramento Basin loads to the Delta for WY1984-2003 of approximately 344 kg mercury and 1,849 Mkg sediment. The WY1984-2003 period had a mix of wet and dry water years similar to the 98-year water record for the Sacramento Basin. Mercury loads entering the Delta from the Sacramento Basin during this 20-year period were about 22% less than Delta outflows estimated by the San Francisco Bay TMDL for WY1995-2000[45] while sediment loads were about 16% higher. The Sacramento Basin and Delta total mercury outflows will be further evaluated against the San Francisco

[45] The San Francisco Bay TMDL sediment target applies to particulate not total mercury. Particulate mercury is defined as total minus filter-passing mercury. Filter-passing mercury concentrations at X2 in the Delta average 4% of the total concentration, demonstrating that most of the mercury exiting the Delta is attached to particles (Foe, 2003). Therefore, the WY1984-2003 loads may slightly overestimate particulate loads.

Bay allocation in the context of their 95% confidence limits once the confidence limits have been completed.

7.4 Evaluation of Suspended Sediment Mercury Concentrations & CTR Compliance

The evaluation of mercury contamination on suspended sediment particles for each Delta input and export site – in tandem with the source load analyses described in Sections 7.1 and 7.2 – is used to identify locations for possible remediation. The recommended total mercury control strategy described in Chapter 8 focuses on sources that have large mercury loadings and suspended sediment with high mercury concentrations, the premise being that it will be more cost effective to focus cleanup efforts on watersheds that export large amounts of mercury-contaminated sediment. In addition, the strategy incorporates source reductions needed to meet and maintain compliance with the CTR throughout the Delta.

7.4.1 Suspended Sediment Mercury Concentrations

Table 7.17 lists mercury to TSS ratios for Delta sources and export sites calculated using three different methods. The three approaches provide a range of particulate mercury contamination fluxing past a site. First, the ratios (in mg/kg) were estimated by dividing average annual mercury load (kg) by average annual TSS load (Mkg). This relationship is the preferred approach for stations with statistically-significant total mercury to flow and TSS to flow relationships because it provides a flow-weighted estimate. The ratio was also estimated from the slope of the regression between mercury and TSS using paired samples. The least acceptable method is to take the median of the mercury to TSS ratios computed from individual paired samples. The median value tends to overemphasize low and moderate flows (the flows sampled most often) and not high flow events, which transport the majority of the suspended sediment and mercury. All three methods slightly overestimate particulate mercury (the focus of the San Francisco Bay sediment goal of 0.2 mg/kg) because none subtract the dissolved fraction from the total mercury concentration.

7.4.1.1 Mercury to TSS Ratios for Delta Outflows to San Francisco Bay

The San Francisco TMDL for mercury adopted a sediment objective of 0.2 mg/kg (Johnson & Looker, 2004). Mercury contamination on sediment in Delta outflow to San Francisco Bay averaged between 0.18 mg/kg and 0.30 mg/kg (Table 7.17). The low value is from Leatherbarrow and others' (2005) estimate for total mercury and suspended sediment loads at Mallard Island. The ratio of 0.18 may underestimate the average concentration on suspended particles because it is less than all values presently being measured by Central Valley Water Board staff in midchannel off Mallard Island (Foe, personal communication). In contrast, the ratio of 0.3 mg/kg is from measurements taken in mid channel at X2 (Foe, 2003). The 0.3 ratio may overestimate the degree of mercury contamination being exported from the Central Valley to San Francisco Bay. The 0.3 ratio is similar to suspended sediment concentrations of 0.33 mg/kg in San Pablo Bay (Schoellhamer, 1996) and bulk surficial sediment concentrations in Suisun Bay of 0.3 to 0.35 ppm (Slotton *et al.*, 2003; Heim *et al.*, 2003) but higher than most suspended sediment values for the lower Sacramento River (0.17 to 0.23 mg/kg) or Yolo Bypass (0.16 to 0.19 mg/kg at Prospect Slough, Table 7.17). Hornberger and others (1999) report that the mercury concentration of sieved surficial sediment (<0.64 µm) in a core from Suisun Bay was 0.3 mg/kg but increased to 0.95

mg/kg at a depth of 30 cm. The mercury enriched zone persisted to a depth of about 80 cm before declining to a baseline concentration of 0.06 ±0.01 mg/kg. The increased mercury concentration at 30-cm was ascribed to deposition of mercury contaminated gold tailings. The suspended sediment values for the Delta in Table 7.17 are also consistent with bulk surficial sediment concentrations (0.15 to 0.2 mg/kg) reported for the Delta by Slotton and others (2003) and Heim and others (2003).

No current information is available on erosion rates in Suisun and Grizzly Bays but both embayments were eroding at the rate of 528 Mkg per year between 1942 and 1990 (Cappiella *et al.*, 2001). Therefore, a hypothesis is that the elevated mercury contamination on particles at X2 and at Mallard is the result of continuing erosion from Suisun Bay and possibly San Pablo Bay. Both embayments are within the legal jurisdiction of the San Francisco Water Board and are part of their recently adopted TMDL for mercury. Central Valley Water Board staff recommends that compliance with the San Francisco Bay mercury allocation for the Central Valley be assessed upstream of Mallard Island to avoid problems with possible contamination from continuing erosion of Suisun Bay.

7.4.1.2 Mercury to TSS Ratios for Delta Inputs

Urban runoff and almost all Delta inputs have mercury to TSS ratios greater than 0.2 mg/kg (Table 7.17). Exceptions are the San Joaquin River, Ulatis Creek, and Yolo Bypass. An evaluation of the tributary sources to the Sacramento River and Yolo Bypass indicates that all but the Sacramento River above Colusa, Sacramento Slough and Colusa Basin Drain have ratios greater than 0.2 mg/kg. A comparison of Table 7.5 and Table 7.17 indicates that several tributaries in the Sacramento Basin have high mercury to TSS ratios and large loads of total mercury. Cache Creek and Feather River have high ratios and high average annual total mercury loads. This makes both attractive candidates for mercury control programs. The American River and Putah Creek also have high ratios but comparatively smaller mercury loads. In contrast, the Sacramento River above Colusa and Sacramento Slough (which receives most of its annual flows when upper Sacramento River flood waters are diverted to Sutter Bypass) have ratios comparable to background levels (0.10 and 0.14 mg/kg, respectively) but high mercury loads. This is because both are transporting large amounts of sediment.

The 2002 LWA report noted a similar pattern in its evaluation of median mercury to TSS ratios for the Sacramento Basin. Suspended sediment mercury concentrations between 0.03 and 0.19 mg/kg may result from a combination of erosion of background soils and atmospheric deposition from regional and global mercury sources. Therefore, the low mercury to TSS ratios for the upper Sacramento River watershed may indicate, unless site-specific hot spots are found, that very little total mercury could be removed by means other than erosion control. This has important implications for the implementation plans for total mercury reduction described in Chapter 8 in this TMDL report and Chapter 4 in the Proposed Basin Plan Amendment draft staff report.

Table 7.17: Suspended Sediment to Mercury Ratios for Delta Inputs and Exports (a)

	# of TotHg/TSS Paired Samples	Method A. TotHg Load ÷ TSS Load		Method B. Linear Regression Slope for Paired TotHg/TSS (b)	Method C. Median of TotHg/TSS Paired Sample Results
		WY2000-2003	WY1984-2003		
DELTA INPUTS					
Bear/Mosher Creeks	5	0.12		0.07	0.24
Calaveras River	4	0.25		0.17	0.41
French Camp Slough (c)	5	0.69		0.62 (0.32)	0.20
Marsh Creek	7	0.47		0.12	0.19
Mokelumne-Cosumnes Rivers	21	0.37		0.35	0.41
Morrison Creek (d)	44	0.24		0.16	0.24
Prospect Slough (Yolo Bypass)	24	0.18	0.16	0.16	0.19
Sacramento River (Freeport)	150	0.22	0.21	0.17	0.23
San Joaquin River	30	0.13		0.13	0.14
Ulatis Creek	6	0.13		0.11	0.19
Urban Runoff (e)	128 (123)	0.31		0.18 (0.22)	0.35
DELTA EXPORTS					
Outflows to San Francisco Bay (X2)	21	0.18		0.30	0.28
State Water Project	19	0.25		0.17	0.29
Delta Mendota Canal	21	0.15		0.16	0.18
Dredging (f)	*8 projects*	0.19		- - -	04 to 0.44
TRIBUTARIES TO THE SACRAMENTO BASIN [Sacramento River + Yolo Bypass]					
American River	117	0.46	0.27	0.20	0.41
Cache Creek Settling Basin	22	0.42	0.46	0.47	0.36
Colusa Basin Drain	56	0.09	0.09	0.09	0.07
Feather River	61	0.29	0.30	0.26	0.32
Natomas East Main Drain (Arcade Ck.)	30	0.65		0.22	0.32
Putah Creek	28	1.25	0.64	0.26	0.31
Sacramento River above Colusa	50	0.10	0.10	0.12	0.11
Sutter Bypass (Sacramento Slough)	52	0.14		0.13	0.13

(a) The preferred method for each monitoring location is highlighted in gray. If total mercury concentrations and TSS concentrations both correlated well with daily flow at a given monitoring location, Method A was the preferred method for estimating suspended sediment mercury concentrations. If the available concentration data for a location were too variable and/or sparse to reliably estimate annual average suspended sediment concentrations, none of the values were highlighted. The WY1984-2003 period was evaluated only for Sacramento Basin (Sacramento River and Yolo Bypass) tributaries.

(b) Regressions between total mercury and TSS concentrations are illustrated in Appendix J.

(c) Alternate value noted in parentheses for French Camp Slough does not include one unusually high total mercury result (Appendix J).

(d) Appendix J provides the regressions for each Morrison Creek sampling location. The values noted in this table were generated from the compilation of data from all the sites.

(e) Urban runoff samples were collected at eleven locations. Methods B and C were performed between the urban runoff total mercury and TSS concentration data with and without five dramatically different sample TotHg:TSS ratios observed for Strong Ranch Slough (Appendix J).

(f) Sediment mercury concentrations in dredged material varied substantially across the Delta. The range of project-specific average concentrations was 0.02 to 0.77 mg/kg. The volume-weighted average mercury concentration of all the dredged material was approximately 0.19 mg/kg.

7.4.2 Compliance with the USEPA's CTR

The USEPA's California Toxic Rule mercury objective is 0.05 µg/L (50 ng/l) total recoverable mercury for freshwater sources of drinking water. The CTR criterion was developed to protect humans from exposure to mercury in drinking water and in contaminated fish. It is enforceable for all waters with a municipal and domestic water supply or aquatic beneficial use designation. This includes all subareas of the Delta. The CTR does not specify duration or frequency. As noted in Chapter 2, the Central Valley Water Board has previously employed a 30-day averaging interval with an allowable exceedance frequency of once every three years for protection of human health.

Samples for total mercury analysis were not collected at a frequency to support 30-day averaging. Data therefore do not exist to show whether the CTR has actually been exceeded. To evaluate compliance with the CTR, regression analyses of flow and concentration were used to estimate 30-day running averages. As described in Sections 7.1.1.1 through 7.1.1.3, total mercury concentrations measured in instantaneous grab samples at Delta and Sacramento Basin tributary locations near flow gages were regressed against daily flow to determine if total mercury concentrations for days with no concentration data could be predicted. Figures 7.6 and 7.7 illustrate the regression-based 30-day running averages for locations with statistically significant ($P<0.01$) TotHg/flow correlations. Appendix J provides the TotHg/flow regressions upon which the 30-day averages are based. Table 7.18 provides a summary of the CTR compliance evaluation.

A waterway location was considered to be in compliance if its regression-based 30-day average total mercury exceeded 50 ng/l no more than once in any three-year period. Some locations had total mercury/flow regressions that were not statistically significant; also, some locations with concentration data were not near a flow gage. Such locations on larger waterways (e.g., Mokelumne River and San Joaquin River) were considered likely to be in compliance if none of the grab samples had mercury concentrations that exceeded 50 ng/l. Locations on small tributaries that typically experience short-duration, storm-related high flow events (e.g., French Camp Slough and Ulatis Creek) were considered likely to be in compliance if none of the water samples had mercury concentrations exceeding 50 ng/l, or if the exceedances occurred only during peak storm flows.

The evaluation of regression-based 30-day running average total mercury concentrations and available grab sample total mercury results indicates that all sampled locations within the Delta – except possibly Prospect Slough and Marsh Creek – are in compliance with the CTR criterion for total mercury. Although none of the grab samples collected from Marsh Creek near Highway 4 exceeded 50 ng/l total mercury, the regression-based 30-day running averages indicated that the CTR criterion may have been exceeded during one period. However, only about three years of flow data were available for the Marsh Creek location; therefore, compliance with the CTR criterion cannot be adequately determined with available data. Marsh Creek is already identified on the 303(d) List as impaired by mercury. The future mercury TMDL monitoring program for Marsh Creek will conduct another evaluation of CTR compliance as more data become available.

Evaluation of Yolo Bypass compliance with the CTR is complicated by the variety of watersheds that contribute water to it during varying hydrologic regimes. During low flow conditions, the Yolo Bypass receives flows from coastal mountain watersheds, particularly Cache Creek and Putah Creek, and other agricultural and native areas that drain directly to the bypass (Figure 7.1). During high flow conditions

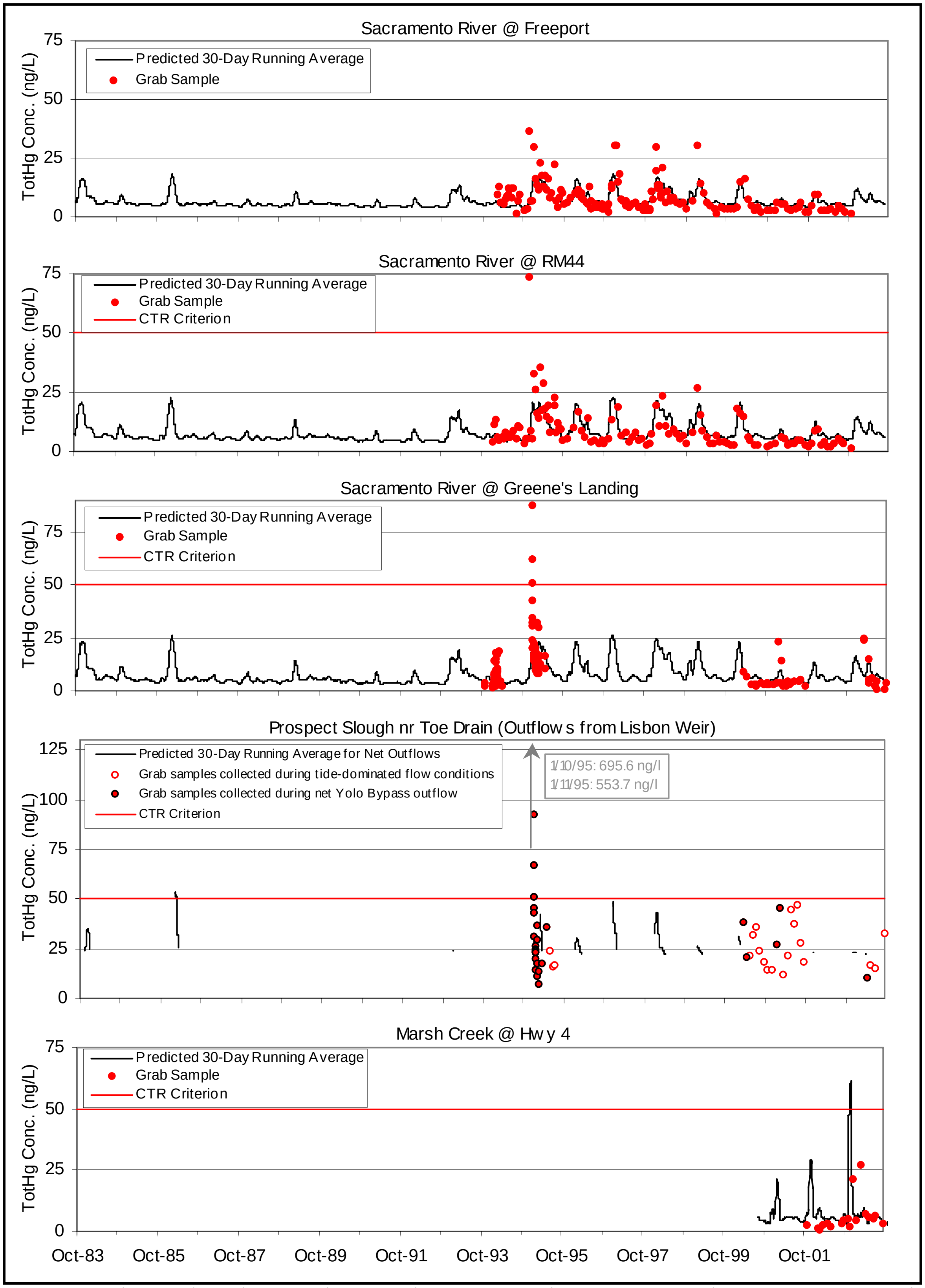

Figure 7.6: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Delta Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

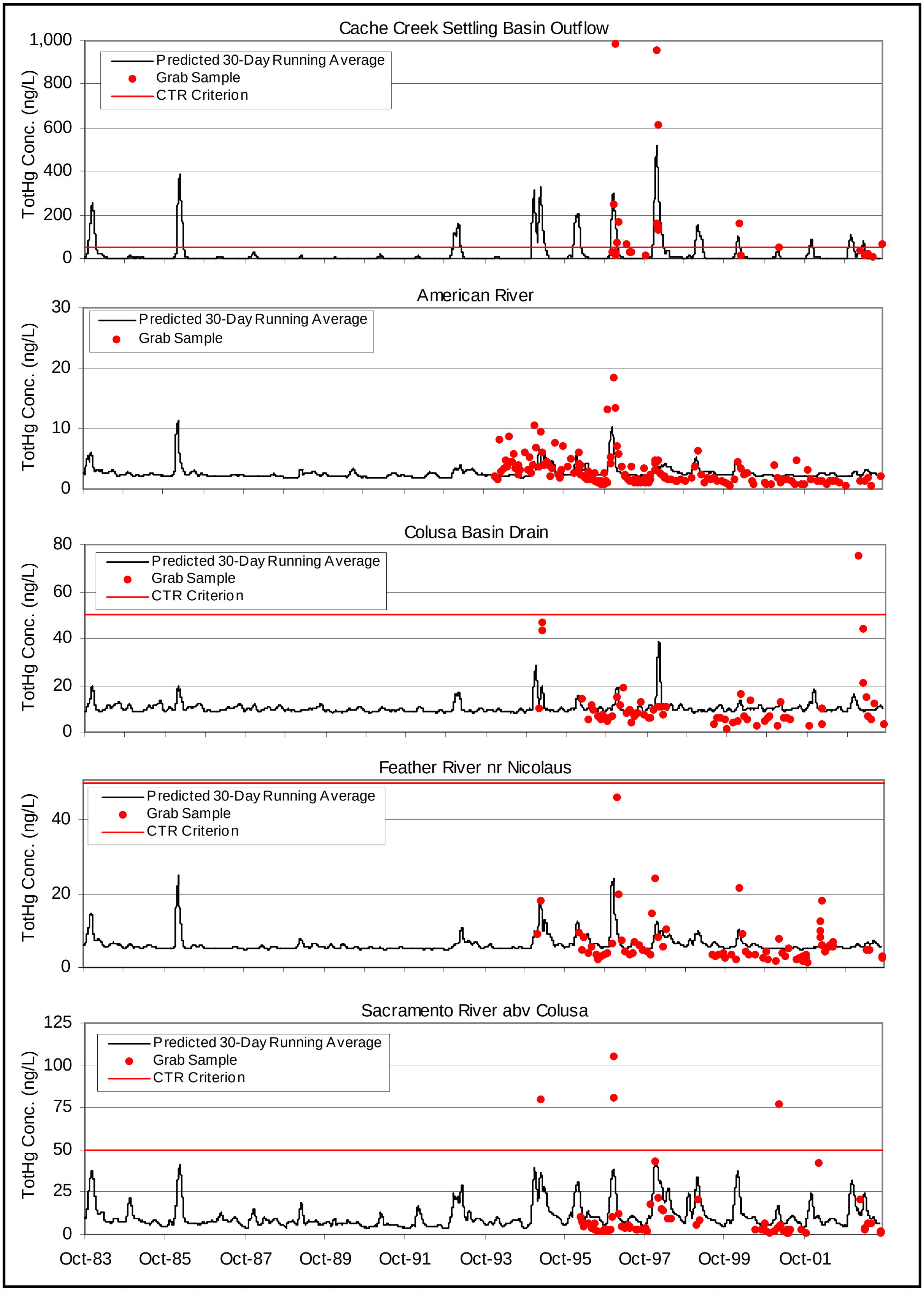

Figure 7.7: Grab Sample and Regression-Based 30-Day Running Average Total Mercury Concentrations for Sacramento Basin Tributary Locations with Statistically Significant (P<0.05) Aqueous TotHg/Flow Correlations

Table 7.18: Evaluation of CTR Compliance at Delta and Sacramento Basin Tributary Locations

Site	Is TotHg/Flow Regression Significant? (a)	Does Predicted 30-Day Average TotHg Ever Exceed CTR's 50 ng/l? (a)	# of Grab Samples > 50 ng/l	Is the Site in Compliance with CTR?
DELTA LOCATIONS				
Bear/Mosher Creeks (b)	- - -	- - -	0	Likely Yes
Calaveras River @ RR u/s West Lane (b)	- - -	- - -	0	Likely Yes
Delta Mendota Canal	No	- - -	0	Likely Yes
French Camp Slough near Airport Way	- - -	- - -	1	Likely Yes
Marsh Creek @ Hwy 4	Yes	Once in 3 year record.	0	***Possibly Not***
Mokelumne River @ I-5	No	- - -	0	Likely Yes
Morrison Creek (c)	- - -	- - -	0	Likely Yes
Outflow to San Francisco Bay	No	- - -	0	Likely Yes
Prospect Slough (Yolo Bypass) (d)	Yes	Once (d).	5	***Possibly Not***
Sacramento River @ Freeport (e)	Yes	No.	0	Yes
Sacramento River @ Greene's Landing (e)	Yes	No.	4	Yes
Sacramento River @ RM44 (e)	Yes	No.	1	Yes
San Joaquin River @ Vernalis	No	- - -	0	Likely Yes
State Water Project	No	- - -	0	Likely Yes
Ulatis Creek near Main Prairie Rd	- - -	- - -	2	Likely Yes
SACRAMENTO BASIN TRIBUTARIES (f)				
American River @ Discovery Park	Yes	No.	0	Yes
Cache Creek d/s Settling Basin	Yes	In 11 of 20 years.	15	***No***
Colusa Basin Drain	Yes	No.	2	Yes
Feather River near Nicolaus	Yes	No.	0	Yes
Natomas East Main Drain (g)	- - -	- - -	1	Unknown
Putah Creek @ Mace Blvd.	No	- - -	4	***Possibly Not***
Sacramento River above Colusa	Yes	No.	4	Yes
Sacramento Slough near Karnak (h)	No	- - -	0	Likely Yes

(a) Flow gage data were not available for most of the small tributary outflows to the Delta. All of the regressions for sampling locations near a flow gage were based on 20-year flow datasets except for Marsh Creek, for which only a 3-year dataset was available. Regressions were considered statistically significant for R^2 values with $P < 0.05$. Appendix J provides the regression plots.
(b) Only wet weather events were sampled on the Calaveras River and Bear and Mosher Creeks in Stockton. The one wet weather Mosher Creek sample result was combined with the Bear Creek dataset to evaluate compliance for both creeks.
(c) Concentration data collected at multiple sites on lower Morrison Creek were compiled to evaluate compliance.
(d) Sampling took place at Prospect Slough (export location of the Yolo Bypass) both when there were net outflows from tributaries to the Yolo Bypass and when there was no net outflow (i.e., the slough's water was dominated by tidal waters from the south). The regression analysis focuses only on the conditions when there was net outflow from the Yolo Bypass. Available flow information (Appendix E) indicates that during many years, the Yolo Bypass does not have a net outflow that lasts for 30 days or more.
(e) The Sacramento River sampling locations at Freeport and River Mile 44 (RM44) are upstream and downstream, respectively, of the outfall for the Sacramento Regional County Sanitation District's Sacramento River Wastewater Treatment Plant. Greene's Landing is about nine miles downstream of the RM44 sampling location. Concentration data collected at all three sites were regressed against the flow data recorded at the Freeport gage, as no other gages are operational in this river reach. Appendix M provides the total mercury concentration data available for all three Sacramento River locations.
(f) Flows from the listed tributary watersheds may be diverted to the Yolo Bypass during high flow conditions via Knights Landing Ridge Cut, Fremont Weir and Sacramento Weir. The Coon Creek/Cross Canal watershed also contributes to the Sacramento River downstream of the Feather River but no aqueous total mercury data are available for its discharges.
(g) No concentration or flow data gage data were available for Natomas East Main Drain outflows. The SRWP, USGS and City of Roseville collected total mercury concentration data on Arcade Creek near Norwood and Del Paso Heights and Dry Creek. It was assumed that this dataset characterizes NEMD outflows.
(h) Sacramento Slough near Karnak is the low flow channel for Sutter Bypass.

on the Sacramento River, excess flows from the upper Sacramento River, Sutter Bypass, Feather River, Colusa Basin, and American River watersheds may be routed down the Yolo Bypass at Fremont Weir, Sacramento Bypass and Knights Landing Ridge Cut. In a typical storm event, flows from the Cache Creek Settling Basin (northwest and outside of the legal Delta boundary) and other local sources reach the Yolo Bypass first, to be followed by lower concentration inputs from the Colusa Basin, Sacramento River and Feather River.

As indicated in Figure 7.7 and described in detail in Appendix E (Section E.2.2 and Figure E.2), the Yolo Bypass may not experience 30 days of continuous net outflow from Lisbon Weir upstream of Prospect Slough during dry years. In addition, storm data collected in 1995 indicate that total mercury concentrations in Prospect Slough (the primary outflow from the Bypass to the Delta) peak for a very short time. To evaluate conditions within the Bypass, the total mercury levels in tributary inputs to the Bypass were evaluated (Figure 7.7). The regression-based 30-day averages of predicted total mercury concentrations in the Sacramento River upstream of Colusa and the Feather River indicate that their flows are in compliance with the CTR criterion. However, the regression-based 30-day running average total mercury concentrations in Cache Creek Settling Basin outflows indicate that Cache Creek flows into the Yolo Bypass are not in compliance with the CTR criterion. The TotHg/flow regression for Putah Creek was not statistically significant; therefore, compliance with the CTR criterion cannot be adequately determined with available data. However, four grab samples collected from two separate storm events (one in March 1995, the other in March 2004) on Putah Creek had mercury levels between 52 and 485 ng/l, indicating that inputs from Putah Creek to the Yolo Bypass also may not be in compliance with the CTR criterion. This implies that when the Bypass is dominated by flows from Cache and Putah Creeks, it may not be in compliance with the CTR criterion. Therefore, Yolo Bypass areas downstream of the Cache Creek Settling Basin and Putah Creek outflows probably do not meet the CTR criterion.

The Basin Plan Amendment for control of mercury in Cache Creek was adopted by the Central Valley Water Board in October 2005. As outlined in the Basin Plan Amendment report (Cooke & Morris, 2005), implementation actions would enable CTR compliance in outflows from Cache Creek. Continued monitoring of Putah Creek outflows to the Yolo Bypass as part of implementation activities for the Delta mercury TMDL could enable better evaluation of CTR compliance. In order to meet the mercury loading allocation proposed for the Central Valley by San Francisco Water Board staff, the total mercury reduction strategy described in Chapter 8 assigns a 37% load reduction to mercury exports from the Feather River, American River and Putah Creek. In addition, Putah Creek is already identified on the 303(d) List as impaired by mercury. If future monitoring indicates that Putah Creek and Cache Creek Settling Basin outflows to the Yolo Bypass do not comply with the CTR even after proposed total mercury reductions described are achieved, and other reductions designed to accomplish safe fish tissue methylmercury levels in Cache Creek and Putah Creek are achieved, additional reductions will be required.

Key Points

- The primary sources of total mercury in the Delta include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, and municipal and industrial wastewater. Losses include flow to San Francisco Bay, water exports to southern California, removal of dredged sediments and evasion.
- More than 96% of identified total mercury loading to the Delta comes from tributary inputs; within-Delta sources are a very small component of overall loading.
- The Sacramento Basin (Sacramento River + Yolo Bypass) contributed approximately 80% or more of total mercury fluxing through the Delta, most of which was transported during winter storms.
- Outflow to San Francisco Bay accounted for approximately 50% or more of total mercury exported from the Delta.
- The Cache Creek, Feather River, American River and Putah Creek watersheds in the Sacramento Basin had both relatively large mercury loadings and high mercury to TSS ratios, making them attractive candidates for remediation.